The Institute for Strategic Studies

Ninth Annual Conference, Elsinore 28sett./1ott. 1967

"The Implications of Military Technology in the 1970"

1 - Programma e lista dei partecipanti

2 - H.De l'Estoile: Strategic implications of technological innovation. A european point of view.

3 - A.Hockaday: The economic implications of technology.

4 - J.J.Holst: Some perspective on BMD.

5 - C.Hartley: The future of Manned Aircraft.

6 - J.P.Craven: Oceanmtechnology and submarine warfare.

7 - E.C.Cornford: Technology and the Blattlefield.

8 - L.L.Johnson: Some implications of new communications technologies for national security in the 1970's.

9 - J.Prawitz: Technology and arms control.

10 - R.B.Fisher: Developments in chemical and biological warfare.

11 - J.Maddox: The diffusion of nuclear technology and capabilities.

12 - J.H.Hoagland: The diffusion of conventional weapons.

13 - K.Subrahmanyam: Defence technology in a major developing country: India.

14 - F.Cooper: The effect of military technology on civil and military planning

15 - R.L.Lesher: The economic and technological impact of the U.S. space programme.

16 - A.Buchan: A european arms production system?

1)

The Institute for Strategic Studies

NINTH ANNUAL CONFERENCE

Hotel Marienlyst, Elsinore

September 28th — October 1st, 1967

"The Implications of Military Technology in the 1970s"

Members of the Conference

Chairman: His Royal Highness Prince Bernhard of the Netherlands

Vice-Chairman: Mr. Erik Seidenfaden

Guest Speakers

Ingénieur Militaire-en-Chef de l'Air H. DE L'ESTOILE
Directeur, Centre de Prospective et d'Evaluations,
Ministère des Armées, Paris

Mr. Arthur HOCKADAY,
Assistant Secretary-General for
Defence Planning & Policy, NATO, Paris

Prof. Albert J. WOHLSTETTER
University Professor,
University of Chicago

Capt. Carl H. AMME	Senior Operations Analyst, Stanford Research Institute, California
Prof. E. C. BAUGHAN	Royal Military College of Science, Shrivenham
Dr. Erwin BAUMGARTEN	Director, Insitute of Naval Studies, Franklin Institute, Washington
Prof. Ernst D. BERGMANN	Professor of Organic Chemistry, Hebrew University, Jerusalem
Prof. E. BJØL	Professor of International Relations, University of Aarhus
Niels BOEL	Head of Department, Ministry of Foreign Affairs, Copenhagen
Leif BOHN	Military Correspondent, *Aftenposten*, Oslo
Charles BOLTÉ	Vice-President, Carnegie Endowment for International Peace, New York
Vice-Adm. H. BOS	Office of the Prime Minister, The Hague
Robert R. BOWIE	The Counselor, The State Department, Washington
Dr. Dean O. BOWMAN	Vice-President, Autonetics, California
Ambassador Jens BOYESEN	Associate of Norwegian Defence Research Establishment, Oslo
Maj.-Gen. Dr. M. J. W. BROEKMEIJER	Chairman, Netherlands Defence Study Centre, The Hague

Arne O. BRUNDTLAND	Research Associate, Norwegian Insitute of International Affairs, Oslo
Alastair BUCHAN	Director, ISS, London
P. L. BURCKHARDT	Managing Director, Contraves Ltd., Zurich
Col. Donald S. BUSSEY	Senior Specialist in National Defense, Legislative Reference Services, Library of Congress, Washington
P. J. A. CALVOCORESSI	Reader in International Relations, University of Sussex
Air Vice-Marshal F. S. CARPENTER	Commandant, National Defence College of Canada, Kingston
Suresh CHANDRA	PhD Student in Department of War Studies, King's College, University of London
Robert J. CLARK	Assistant Executive Director, International Operations, N. America Aviation Inc., California
~~Dr. Walter C. CLEMENS, Jr.~~	~~Department of Government, Boston University~~
Prof. Joseph I. COFFEY	Professor of International Affairs, University of Pittsburgh
Gen. C. COMBEAUX	Vice-President, Comité d'Etudes de Défense Nationale, Paris
Melvin CONANT	Government Relations Counselor, Standard Oil Company (New Jersey), New York
Frank COOPER	Assistant Under-Secretary of State (Policy), Ministry of Defence, London
Prof. E. L. COPPIETERS DE TER ZAELE	Director-General, Royal Institute of International Relations, Brussels
E. C. CORNFORD	Deputy Chief Adviser (Studies), Ministry of Defence, London
Dr. Alvin J. COTTRELL	Center for Strategic Studies, Georgetown University, Washington
Dr. John P. CRAVEN	Deep Submergence Systems Project Office, Department of the Navy, Washington
Gordon CREAN	Canadian Ambassador to Italy, Rome
Gen. Baron A. DEL MARMOL	Commandant, L'Ecole de Guerre de Belgique, 1961-63
A. D. DIVINE	Defence Correspondent, *The Sunday Times*, London
Col. T. N. DUPUY	Historical Research and Evaluation Organization, Washington
A. E. M. DUYNSTEE	Member of Parliament, The Hague
Dr. Stephen ENKE	Manager, Economics and Special Projects, GEC Tempo, Santa Barbara
E. J. FEUCHTWANGER	Department of Adult Education, Southampton University
Prof. R. B. FISHER	Professor of Biological Chemistry, University of Edinburgh
P. FOTHERINGHAM	Lecturer, Department of Politics, University of Glasgow
Joseph FROMM	London Correspondent, *US News and World Report*
Dr. Curt GASTEYGER	Director of Programmes, ISS, London
Dr. Hans GERLACH	Political and Military Editor, *Kölner-Stadt-Anzeiger*
Prof. N. H. GIBBS	Chichele Professor of History of War, Oxford
Col. W. W. GILBERT	USAF: Senior Research Associate, ISS, London, 1967-8
R. Rockingham GILL	Radio Free Europe, Munich
Lord GLADWYN	President, Atlantic Treaty Association, London
R. J. M. GOOLD-ADAMS	Chairman of the Council, ISS, London
Henning V. GOTTLIEB	Foreign Affairs Adviser to the Prime Minister, Copenhagen
D. E. GREENWOOD	Lecturer in Political Economy, University of Aberdeen
Brig.-Gen. Samuel B. GRIFFITH	Council on Foreign Relations, New York
A. J. R. GROOM	Lecturer, University College, University of London
Niels J. HAAGERUP	Paris Correspondent, *Berlingske Tidende*, Copenhagen
Prof. Louis J. HALLE	Graduate Institute of International Studies, Geneva
Morton H. HALPERIN	Deputy Assistant Secretary of State for International Security Affairs (Arms Control), Washington
Air Marshal Sir Christopher HARTLEY	Controller of Aircraft, Ministry of Technology, London

Pierre HASSNER	Centre d'Etudes des Relations Internationales, Paris
Brig.-Gen. Frederick P. HENDERSON	RCA Advanced Military Systems, New Jersey
Dr. Charles M. HERZFELD	Director, Advanced Research Projects Agency, Department of Defense, Washington
Vice-Adm. Sir Arthur HEZLET	Royal Navy (ret.)
John H. HOAGLAND	Executive Vice-President, Browne & Shaw Research Corporation, Waltham, Mass.
P. W. HODGENS	Principal Administrator, Council of Europe, Strasbourg
~~John W. HOLMES~~	~~Director-General, Canadian Institute of International Affairs, Toronto~~
J. J. HOLST	Norwegian Defence Research Establishment, Oslo
Brig.-Gen. Henry C. HUGLIN	Senior Military Scientist, GEC Tempo, Santa Barbara
Col. Donald H. HUMPHRIES	Director for Arms Control, Office of Assistant Secretary of Defense (ISA), Washington
Brig. Kenneth HUNT	Deputy Director, ISS, London
Wynn JAMES	Office of Assistant Secretary of Defense (ISA), Washington
Leland L. JOHNSON	RAND Corporation, Santa Monica
Maj.-Gen. I. C. KATOCH	Military Adviser to Indian High Commissioner, London
M. H. KEENS-SOPER	Graduate Institute of International Studies, Geneva
Air Vice-Marshal E. J. KINGSTON-McCLOUGHRY	RAF (ret.)
Dr. William R. KINTNER	Deputy Director, Foreign Policy Research Institute, Philadelphia
Prof. Klaus KNORR	Director, Princeton Center of International Studies
James E. KNOTT	Director, International Information Center on Peace-Keeping Operations, Paris
Prof. H. KOEPPLER	Warden, Wilton Park, Sussex
Dr. O. M. KOFOED-HANSEN	Professor of Reactor Physics, AEC, Copenhagen
Prof. H. KOTANI	Kyoto Industrial University
Maj.-Gen. Erik KRAGH	Member of Parliament, Copenhagen
Lt.-Col. W. KUNTNER	Commander, National Defence Department, Austrian Staff Academy, Vienna
Jerome LANDAY	London Bureau Chief, Westinghouse Broadcasting Co.
Wg.-Cdr. Asher LEE	British Broadcasting Corporation, London
Dr. Richard LESHER	National Aeronautics and Space Administration, Washington
Franklin A. LINDSAY	President, ITEK Corporation, Lexington, Mass.
Dr. G. R. LINDSEY	Defence Research Board, Ottawa
M. G. S. MACDONALD	International Security Affairs, Department of Defense, Washington
E. C. McCABE	Delegacy for Extra-Mural Studies, Oxford
John MADDOX	Editor, *Nature*, London
Andrew W. MARSHALL	RAND Corporation, Santa Monica
Wg.-Cdr. W. C. MILNE	Serving Officer, RAF
Robert P. MILTON	Director, Strategic Environment (Planning), Douglas Aircraft Co., Santa Monica
Col. D. N. MOIR	GSO1, Royal Military College of Science, Shrivenham
Kjeld MORTENSEN	Head of Secretariat, Ministry of Foreign Affairs, Copenhagen
Robert NEILD (n. who are people)	Director, International Institute for Peace and Conflict Research, Stockholm
Uwe NERLICH	Foundation for Science and Politics, Munich
John NEWHOUSE	Associate Director, The Tocqueville Series, Paris
Rear-Adm. Perucca ORFEI	Centro di Alti Studi Militari, Rome
Dr. Nils ØRVIK	Professor of Political Science, Oslo University
A. M. PALLISER	Private Secretary to the Prime Minister, London
Jan PRAWITZ	Swedish Delegation, 18 Nation Disarmament Conference, Geneva
B. T. PRICE	Director, Defence Operational Analysis Establishment, West Byfleet

PROGRAMME

Thursday, September 28th

1.00 p.m. – 4.30 p.m.	Conference Assembles, Hotel Marienlyst
4.30 p.m.	Opening of the Conference by H.R.H. Prince Bernhard and Mr. Victor Gram, Danish Minister of Defence
5.00 p.m. – 7.00 p.m.	*Technology: Capabilities and Interests in the 1970s*—Prof. Albert J. Wohlstetter
7.00 p.m. – 8.00 p.m.	Reception at Hotel Marienlyst
8.00 p.m.	Dinner

Friday, September 29th

9.30 a.m. – Noon	Committee Discussions: see details below (Coffee at 10.45 a.m.)
1.00 p.m.	Lunch
2.30 p.m. – 5.00 p.m.	Committee Discussions: see details below (Tea at 3.45 p.m.)
5.30 p.m. – 7.00 p.m.	Reception given by the Royal Danish Ministry of Foreign Affairs on the Minelayer "Falster"
7.30 p.m.	Dinner
8.30 p.m. – 10.00 p.m.	*Technological Innovation and International Politics*—Ing. Mil. Chef de l'Air de l'Estoile

Saturday, September 30th

9.00 a.m. – 11.00 a.m.	Committee Discussions: see details below
11.00 a.m.	Coffee
11.30 a.m. – 1.00 p.m.	Panel Discussion
1.00 p.m.	Lunch
Afternoon	Free
7.30 p.m.	Dinner

Sunday, October 1st

9.30 a.m. – 11.30 a.m.	*Economic Implications of Military Technology*—Mr. Arthur Hockaday
11.30 a.m. – Noon	Final Plenary Session
Noon	Conference closes
1.00 p.m.	Lunch

Committee Discussions

	1	2	3
	Friday		*Saturday*
	9.30 a.m. – Noon	2.30 p.m. – 5.00 p.m.	9.00 a.m. – 11.00 a.m.
Committee I *Chairman:* Mr. Henry Rowen	*During this session, Members of Committee I will be divided among the remaining four Committees*	*Anti-Ballistic Missile Systems*— Mr. J. J. Holst	*The Future of Manned Aircraft*— Air Marshal Sir Christopher Hartley
Committee II *Chairman:* Maj.-Gen. E. Kragh	*Ocean Technology and Submarine Warfare*— Dr. John P. Craven	*Developments in Strategic Mobility*— Prof. Joseph I. Coffey	*Technology and the Battlefield*— Mr. E. C. Cornford
Committee III *Chairman:* Dr. Urs Schwarz	*Implications of New Communications Technologies for National Security*— Mr. Leland L. Johnson	*Technology and Arms Control*— Mr. Jan Prawitz	*Developments in Chemical and Biological Warfare*— Prof. R. B. Fisher
Committee IV *Chairman:* Prof. Norman Gibbs	*The Diffusion of Nuclear Technology and Capabilities*— Mr. John Maddox	*The Diffusion of Conventional Weapons*— Mr. John H. Hoagland	*Military Technology in a Major Developing Country*— Mr. K. Subrahmanyam
Committee V *Chairman:* Dr. T. G. Sommer	*The Effect of Military Technology on Civil and Military Planning*— Mr. Frank Cooper	*The Economic and Technological Impact of the US Space Programme*— Dr. Richard Lesher	*A European Arms Production System?*— Mr. Alastair Buchan

Dr. George H. QUESTER	Harvard Center for International Affairs
Peter RAMSBOTHAM	Foreign Office, London; Senior Research Associate, ISS, London, 1967-8
Maj. D. G. RASCHEN	Serving Officer, British Army
J. A. REDEKER	Assistant Foreign Editor, *Algemeen Dagblad*, Rotterdam
Cdre. L. J. J. ROBINS	Director, Philips, Belgium
Maj.-Gen. L. C. ROLSTAD	Formerly Commandant, Norwegian National Defence College, Oslo
George L. ROUNDS	Director of Systems Analysis and Aerospace Group, Boeing Co., Seattle
Henry S. ROWEN	President, RAND Corporation, Santa Monica
G. M. RUTHERFORD	Diplomatic Correspondent, *The Financial Times*, London
Kiichi SAEKI	Executive Director, Nomura Research Institute of Technology and Economics, Tokyo
Dr. J. C. M. SANNESS	Director, Norwegian Institute of International Affairs, Oslo
Dr. Urs SCHWARZ	Formerly Foreign Editor, *Neue Zürcher Zeitung*, Zurich
Erik SEIDENFADEN	Warden of the Danish College, Cité de l'Université de Paris
Gunnar SEIDENFADEN	Assistant Under-Secretary of State, ~~Ministry of Foreign Affairs, Copenhagen~~
~~Gustave H. SHUBERT~~	~~Associate Head, Economics Department,~~ RAND Corporation, Santa Monica
J. SIMPSON	Assistant Lecturer, Department of Politics, Southampton University
Dr. T. G. SOMMER	Foreign Editor, *Die Zeit*, Hamburg
Helmut SONNENFELDT	Department of State, Washington
Åke SPARRING	Swedish Institute for International Affairs, Stockholm
Ronald I. SPIERS	Counselor, Politico-Military Affairs, US Embassy, London
Dr. Altiero SPINELLI	Director, Italian Institute of International Affairs, Rome
Jerome H. SPINGARN	US Arms Control and Disarmament Agency, Washington
Col. John F. SPLAIN	Foreign Service Institute, Washington
Gp.-Capt. M. M. STEPHENS	Executive, Rolls-Royce (France) Ltd., Paris
Brig. J. STEPHENSON	Director, Royal United Service Institution, London
K. SUBRAHMANYAM	Deputy Secretary, Ministry of Defence, New Delhi
Gen. Ichiji SUGITA	Adviser, Mitsubushi Heavy Co. Ltd., Tokyo
Col. John L. SUTTON	Serving Officer, USAF
Brig. W. F. K. THOMPSON	Military Correspondent, *The Daily Telegraph*, London
J. A. THOMSON	Planning Staff, Foreign Office, London
J. H. W. TROTMAN	Department of National Defence, Ottawa
William R. VAN CLEAVE	Political Scientist, Stanford Research Institute, California
Prof. Jacques VERNANT	Director, Centre d'Etudes de Politique Etrangère, Paris
Dr. W. WAGNER	Acting Director, Research Institute, German Society for Foreign Affairs, Bonn
C. N. WAIN	Television Journalist, Salisbury
Leonard WAINSTEIN	Weapons System Evaluation Group, Washington
Wg.-Cdr. J. WALSH	RAF College, Cranwell
John T. WHITMAN	Attaché, US Embassy, London
J. WILHJELM	Secretary-General, Foreign Policy Society, Copenhagen
Dr. F. WILLE	Schweizer Monatshefte, Zurich
Andrew WILSON	Defence Correspondent, *The Observer*, London
Mrs. Roberta WOHLSTETTER	Historian, Chicago
David WOODWARD	Producer, Features Department (Sound), BBC, London
L. C. WREFORD-BROWN	Senior Lecturer, Royal Naval College, Dartmouth
Mrs. Elizabeth YOUNG	Writer, London
G. K. YOUNG	European Representative, Kleinwort, Benson Ltd., London
M. ZVEGINTZOV	National Research Development Corporation, London

INSTITUTE FOR STRATEGIC STUDIES

NINTH ANNUAL CONFERENCE

ELSINORE, September 28th - October 1st, 1967

NOTES ON SPEAKERS

Hugues de l'Estoile (France)

Ingénieur Militaire-en-Chef de l'Air, Directeur, Centre de Prospective et d'Evaluations, Ministère des Armées, Paris.

Educated at the Ecole Polytechnique and the Ecole Nationale Supérieure de l'Aéronautique, Paris. Professor at the latter school and at the Ecole Supérieure d'Electricité:

Arthur P. Hockaday (Britain)

Assistant Secretary General for Defence Planning and Policy, NATO.

Graduated from Oxford University (1949); United Kingdom Home Civil Service (1949); various appointments in Admiralty (1949-1962); Private Secretary to successive Defence Secretaries, Ministry of Defence (1962-65), Special Adviser on Defence, NATO (1965 until his recent appointment)

Albert J. Wohlstetter (USA)

University Professor of Political Science, University of Chicago.

Formerly Associate Director of Projects, the RAND Corporation; Professor at Berkely University; Consultant to State Department.

Author of "Delicate Balance of Terror" (in Foreign Affairs") and other publications.

*** *** *** *** *** *** *** ***

Dr. Joseph I. Coffey (USA)

Professor of International Affairs, University of Pittsburgh.

Educated at West Point and Georgetown University (Ph.D.). Held various planning, analysis and research posts in the White House staff, the Department of State, and the Institute for Defense analysis.

Before his present University appointment he was Chief of the Office of National Security Studies of the Bendix Systems Division.

Frank Cooper (Britain)

Assistant Under-Secretary of State (Policy), Ministry of Defence, London.

Private Secretary to Chief of the Air Staff (1950-53); Head of Air Staff Secretariat (1955-60); Director of Accounts (1960-62); Assistant Under Secretary (General and Finance; Air Staff)

Edward C. Cornford (Britain)

Deputy Chief Adviser (Studies), Ministry of Defence.

Educated at Jesus College, Cambridge (BA); Graduated Joint Services Staff College (1951); Chairman, Defence Research Policy Staff (1961-63), Assistant Chief Scientific Adviser (1963-64) Ministry of Defence; Chief Scientist (Army) and Member of Army Board (January 1965 - March 1967).

Dr. John P. Craven (USA)

Project Manager, Deep Submergence Project Office (until 30.9.67); Chief Scientist, Special Projects Office and the Deep Submergence Systems Project Office (from 1.10.67)

Educated at Cornell University (1944-46); California Institute of Technology (1946-47); State University of Iowa (1947-51) (Ph.D.) and George Washington University (1951-58) (UB).

Various positions in private firms and at different Universities (1946-57); Contract Research Administrator, David Taylor Model Basin, Washington (1957-59), Chief Scientist, Special Projects Office, as Advisor on all scientific matters connected with development of FBM System (Polaris) (1959-1966).

R.B. Fisher (Britain)

Professor of Biochemistry, University of Edinburgh (since 1959).

Previously Lecturer in Biochemistry, University of Oxford and Lecturer in Medical Science, Wadham College, Oxford. In World War II he has engaged in Anglo-American operational research.

Sir Christopher Hartley (Britain)

Air Marshall, Controller of Aircraft, Ministry of Technology (since June 1966)

Educated at Balliol College, Oxford, and King's College, Cambridge.

Previously Eastern Sector Commander, Senior Air Staff Officer and Air Officer (1957-1960); Assistant Chief of the Air Staff (Operational Requirements) (1961) and Deputy Chief of the Air Staff (1963).

John H. Hoagland (USA)

Executive Vice President, Browne and Shaw Research Corporation, Waltham (Mass. (since 1961)

Graduated at Yale University. From 1951-1961 Government Service.

Johan J. Holst (Norway)

Senior Analyst, Norwegian Defense Research Establishment; presently working at the Hudson Institute, New York.

Educated at Columbia University and University of Ohio; Research Associate at the Center for International Affairs, Harvard University (1962-63).

Leland B. Johnson (USA)

Research Economist, The RAND Corporation, Santa Monica (since 1957)

Educated at University of Oregon (B.S. 1952; M.A. 1953) and at Yale University (Ph.D. Economics, 1957); Lecturer at Claremont Graduate School (1965-66) and University of California (1962)

Dr. Richard L. Lesher (USA)

Assistant Administrator for Technology Utilization, National Aeronautics and Space Administration (NASA).

Educated at the University of Pittsburgh (B.A.), Pennsylvania State University (M.A.) and Indiana University (Ph.D.). Joined NASA in June 1964 where he served as Director of the Technology Utilization Division, and as Deputy Assistant Administrator until his present appointment.

Franklin A. Lindsay (USA)

President, ITEK Corporation, Lexington, Mass.

U.S. Army (1940-46), Lt. Col.; Member Atomic Energy Commission and UN Disarmament Commission (1946-47), Central Intelligence Agency (1948-52); Consultant, White House; Management Consultant, McKinsey & Co., New York.

John Maddox (Britain)

Editor of Nature.

Educated at Christ Church, Oxford and King's College, London. Assistant Lecturer, then Lecturer in Theoretical Physics at University of Manchester 1949-55. Science Correspondent, Guardian, 1955-64. Affiliate, Rockefeller Institute, New York, 1962-63. Assistant Director of Nuffield Foundation, and Co-Ordinator, Nuffield Foundation Science Teaching Project, 1964-66.

Jan Prawitz (Sweden)

Scientific Adviser, Swedish Delegation to Eighteen Nation Disarmament Conference, Geneva; Associate, Research Institute of National Defence (since 1956).

Educated at Stockholm University (M.A. Science 1956).

K. Subrahmanyam (India)

Deputy Secretary, Ministry of Defence; presently Rockefeller Fellow in Strategic Studies, International Relations Dept., London School of Economics.

Educated at Madras University (M.Sc.), joined the Indian Administrative Service in 1951 and the Ministry of Defence in 1962, where he held various positions connected with weapons procurement, budget, foreign military assistance, planning and coordination in defence production.

INSTITUTE FOR STRATEGIC STUDIES

NINTH ANNUAL CONFERENCE

THE IMPLICATIONS OF MILITARY TECHNOLOGY IN TEH 1970s

Committee List

COMMITTEE I — Chairman: Rowen

Bowman	USA
Broekmeijer	NETH
Combeaux	FRA
Coppieters	BEL
Del Marmol	BEL
Duynstee	NETH
Fotheringham	UK
Gasteyger	ISS
Gladwyn	UK
Goold-Adams	UK
Herzfeld	USA
Keens-Soper	UK
Kintner	USA
Knorr	USA
Kofoed-Hansen	DEN
Lee	UK
Lindsey, G.R.	CAN
Milne	UK
Milton	USA
Mortensen	DEN
Quester	USA
Saeki	JAP
Simpson	UK
Sonnenfeldt	USA
Spiers	USA
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Wilson	UK

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Boel	DEN
Bohn	NOR
Bos	NETH
Bussey	USA
Conant	USA
Divine	UK
Dupuy	USA
Gottlieb	DEN
Henderson	USA
Hezlet	UK
Humphries	USA
Hunt	ISS
Katoch	IND
Kingston	UK
Kotani	JAP
Ørvik	NOR
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Trotman	CAN
Vernant	FRA
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Woodward	UK
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Huglin	USA
James	USA
Moir	UK
Redeker	NETH
Sanness	NOR
Seidenfaden, E.	DEN
Spinelli	IT
Sparring	SWE
Spingarn	USA
Stephenson	UK
Subrahmanyam	IND
Sutton	USA
Thompson, W.F.K.	UK
Walsh	UK
Wohlstetter Mrs	USA

Ring Bernhard

COMMITTEE IV

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Haagerup	DEN
Halle	USA
Halperin	USA
Hodgens	UK
Knott	USA
Landay	USA
Neild	UK
Newhouse	USA
Ramsbotham	ISS
Raschen	UK
Rutherford	UK
Van Cleave	USA
Wagner	GER
Wainstain	USA
Wilhjelm	DEN
Young, Mrs. E.	UK
Young, G. K.	UK

— [illegible] Africa regionalism
(Vol. V. A — regional politics in the existing states

COMMITTEE V

Chairman: Sommer

Baumgarten	USA
Bowie	USA
Brundtland	NOR
Burckhardt	SWI
Buchan	ISS
Greenwood	UK
Hassner	FRA
Koeppler	UK
Kuntner	AUS
Marshall	USA
McCabe	UK
Macdonald	UK
Nerlich	GER
Orfei	IT
Palliser	UK
Robins	BEL
Rolstad	NOR
Rounds	USA
Seidenfaden, G.	DEN
Splain	USA
Stephens	UK
Whitman	USA
~~Zveginzov~~	UK

technological [illegible] - increases
mineral interdependence / proximity cause of
long range [illegible]
~~political~~ distribution of political / conducive to growing
decision-power in the
world to-day gives
a perspective of growing rationality (cont

Wohlstetter -

do you think that the developments of technology ~~will - the~~ as such will contribute to increase or decrease the capability of rational behaviour in international relations? - Perhaps you will answer that ~~the question~~ the question is an indeterminate one ~~or with a basis~~ i.e. having more than one answer - and in this case may ~~I ask you whether~~ It seems to me ~~which should be the political~~ factors ~~of~~ which should be added in order to have an answer concerning the perspective of a more rational future?

conducive towards peace

proximity ~~good~~ important cause of enemity

all world is neighbourhood

chiedergli il testo della conferenza per pubblicare

The impact of the Russian Revolution 1917-1967 with introductory essay by Toynbee Oxford University Press. 1967

NOT FOR PUBLICATION OR QUOTATION

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INSTITUTE FOR STRATEGIC STUDIES

9th ANNUAL CONFERENCE

THE IMPLICATIONS OF MILITARY TECHNOLOGY IN THE 1970s

PLENARY SESSION

Friday 29th September — Evening

Strategic Implications of Technological Innovation
A European Point of View

HUGUES DE L'ESTOILE

I. Introduction and preliminary remarks

1.1. What is meant by a "European view" is not simply an overall survey which happens to be given by a European; I would like to make the point that the reference to Europe relates to the substance of this paper and to the very concept of strategy: strategy exists only because of the contradictions inherent in the plurality of political designs and the continuous interplay between the various decision centres.

It is taken for granted that in the second half of the seventies there will be such a plurality of decision centres; and the tensions that will result from this may be a significant factor for technological progress through the competition that will be generated.

Furthermore, it is also taken for granted that Europe will then constitute one of the decision centres: it is assumed that in the second half ofthe next decade, European countries will have reached a level of interlocked development allowing for common political goals, and, therefore, for a common strategy in the field of defence as well as economic growth. This European strategy is the ultimate implication of the "European point of view" referred to above.

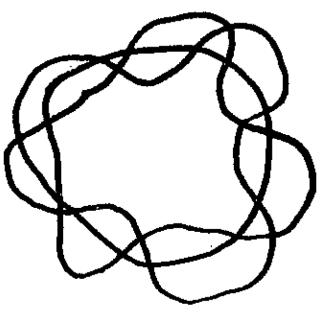
1.2. The classification of powers

The political dynamics specific to each state - or group of states - depends on the importance of its designs, on the ambition and the complexity of its objectives.
The political design appears as a result of some conflictual

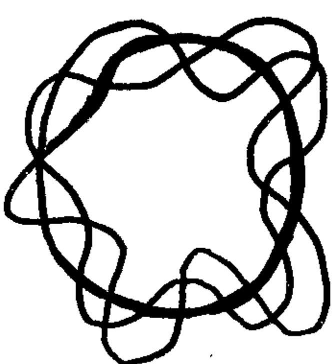
dialectics; one could not possibly imagine suitable designs for Europe without considering its respective position in the international order.

In order to determine this position, one can try to analyze in detail the various elements of power at the eve of the 21st century: demographic and economic rates of growth, stability of institutional structures, intellectual potential, capability of technological innovation, etc. However, this analysis is all the more risky, as it can be put into question by technological progress, the effects of which are precisely the core of our study. One notices, at a more general level, that nations reach their rank in the present and foreseeable hierarchy by bringing all these elements into play. It therefore seems sufficient for our purpose to consider three classes of states which already exist and will continue to do so:

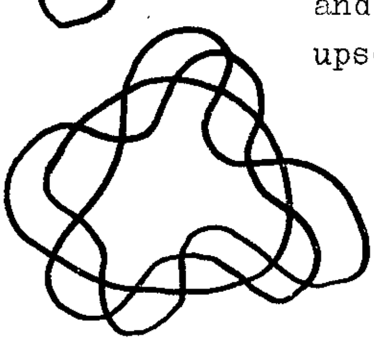
- the super-powers
- the medium powers
- third powers.



a) Super-powers are nations which possess - or will possess from now on to 1975/80 - all the means to enable them to claim world hegemony or to stop any other country from doing so. I do not claim that these super-powers - namely, the USA, URSS and Red China - will necessarily aim at such a political target. But the sheer size of their power enables them, by itself, to compete in most sectors of human activity; to create tensions, which may appear in all areas; to consider, in the context of their conflicts, the other nations as states or instruments to be manipulated. This is of decisive importance for the picture, whatever changes may occur in the balance of power of the other states.



b) Next to the super-powers come medium powers which believe themselves able, by vocation as well as by potentiality, to prove successfully their determination not to be just the stakes, the objects of struggle for hegemony between super-powers. The medium nations intend to conduct their own policy; they have, up to a point at least, all the means enabling them to justify such an ambition. Just because of that claim to conceive and act as subjects, and not as objects, the medium powers will unavoidably upset the strategic game going on between the super-powers;



they prevent the super-powers from enjoying the privilege of doing freely whatever they wish, and also claim to develop positive actions with reference to their particular interest or to what they regard as their vocation.

c) While the nations or groups of nations belonging to both previous types are the haves, the rest of the powers are brought down to the rather ambiguous position of objects in the political designs of the super-powers.

This is an ambiguous position indeed: they are able to supersede some medium powers in a few sectors of activity, but their inability to display in their relationship with the super-powers, the necessary resistance compels them to be stakes and instruments. They may, of course, cherish illusions of self-government, they may speculate on super-powers' rivalry, and exercise blackmail: they then escape a temporary or even limited subordination only to fall under another one.

1.3. Outline of the lecture

In a first part, dedicated to the study of the military component of European strategy, we will begin by showing that a technological innovation belonging to the past - the nuclear weapon - enables Europe to produce - and this with respect to the super-powers - that which is required to take its place among the medium powers (before it becomes, in a more distant future, a super-power). Europe secures the autonomy of decision that its military strategy aims at, by making use of a so-called "absolute dissuasion" strategy; we will point out the fundamental differences which separate it from the nuclear strategies of the super-powers. We will then show that the innovations (present or foreseeable) for the next ten years do not alter such a military strategy: In this connection we will review the influence of ABM systems, space weapons and chemical and biological weapons. But the nuclear stalemate between Europe and the super-powers implies that open-conflict areas will be moved towards regions in an early stage of technological development: the developing countries; the oceans become first-rate theatres of operations, in which the freedom of decision enjoyed by Europe will allow it to play a balancing game, which it will have to use to gain certain concessions from the super-powers (especially in the field of technological innovation taken as one of the keys to economic power).

The military dialectics between Europe and the super-powers being thus frozen, the competition is carried out on the economic plane. This will be covered in the second part. Once the autonomy of decision has become possible in the military sphere, it should not be challenged by an increasing economic domination.

Now, two of the leading elements of economic power are technological innovation and management technique, the latter ensuring the growth of modern methods in data processing.

Considering the limited means of Europe (compared with those of the super-powers), there is no doubt that ensuring economic growth through technological innovation calls for selectivity. Europe has, in fact, to develop a selective strategy of innovation. Seeking the lowest economic dependence, such a strategy of innovation takes into account the requirements of defence; but, because the most advanced techniques have both military and industrial application, there is no serious distortion. The purposes of this strategy should result from applying selective criteria, some of which we will review. Hence we will conclude that trying to close, in all fields, the technological gap which separates it from the super-powers, and especially from the USA, would be a wrong course for Europe. Since it is selective, the European strategy of innovation must make some renunciations; but it must reach in different fields a position of worldwide quasi-monopoly (its military policy of balance between the Third World and the superpowers should enable Europe to get from the latter the few concessions that will need to do so).

If a superp. makes a limited attack and has a limited ABM screen against Europe?

But a strategy of innovation leads only to a development of the "hardware". Now, the management techniques are to economic growth what the "software" is to the extension of the computers: the most important key-element. More than atom, space, oceans, efficient industrial management techniques are, in my opinion, the most important technological innovation for Europe: it is a necessary condition for its economic growth, an essential component for the upholding of its autonomy of decision, which makes it a medium power possibly meant to become a super-power.

We will end with the following two remarks, which will be proposed as a conclusion:

a) If the major technological innovations determining the strategy of Europe for the next ten years are already established facts, all their consequences have not yet been drawn.

b) As far as the economic policy is concerned, the maintenance of Europe at a medium-power level requires a very strict strategy of innovation, leading to the necessity of establishing a satisfactory balance between a fairly strict economic planning system and a free enterprise regime.

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INSTITUTE FOR STRATEGIC STUDIES

9th ANNUAL CONFERENCE

THE IMPLICATIONS OF MILITARY TECHNOLOGY IN THE 1970's

PLENARY SESSION

Sunday 1st October | Morning

The Economic Implications of Technology

ARTHUR HOCKADAY

The title of this presentation, The Economic Implications of Technology, appears extremely far-reaching. I propose, however, to confine my remarks within the overall context of this Conference, namely the implications of military technology in the 1970's, and to talk about the economic implications of technological development as they affect defence planning. I am not a professional economist, but I suppose that I can call myself a defence planner. I shall speak about the special problems of defence planning within an alliance, and the alliance about which I shall have most to say will be that of NATO within which my own day-to-day responsibilities lie. When I speak of defence planning I do not refer primarily to strategic planning of the kind that is properly the responsibility of military experts. I refer to the kind of planning that is concerned with the structure of forces best suited to the execution of the overall politico-military strategy that a country or an alliance adopts, with the resources that a country or an alliance can make available for defence, and with the most rational and effective use of those resources in order to achieve the political and military ends that are in view. I shall, however, also make a few remarks about possible effects of technological developments upon the two-way relationship between military plans and force structures.

NATO, as we are frequently reminded, is an alliance of sovereign states, and within that alliance decisions on force planning and commitments to provide forces are ultimately the responsibility of individual member governments. This remains true even though, since the inception of NATO, various procedures have been devised, adjusted, and we hope improved, over the years for the consideration of force requirements and force plans within the framework of the Alliance in order that the governments may take their decisions in an Alliance-wide context and against the background of an Alliance-wide plan. But both individually and collectively the governments of NATO have found themselves confronted in an increasingly acute form with what I mentioned just now as a basic problem of force planning, namely how to make the most effective use of the available resources so as to achieve the military posture most appropriate for deterrence, and, should deterrence fail, for defence. My last remark, of course, includes words such as "effective" and "appropriate" which in themselves both raise and beg a host of questions. One of the biggest questions of all is that of the balance to be maintained between military desiderata and the constraints imposed by the availability or non-availability of resources. This itself raises the interesting philosophical speculation whether there can exist military desiderata independent of an overall foreign and defence policy which must take into account available resources; but this is going outside the scope of my presentation.

Up to now governments have been able without too much difficulty to make these balancing decisions between the claims of their military advisers and the warnings of their financial watchdogs, and almost all the member countries of NATO have planned to provide a set of balanced national forces with a considerable proportion assigned or earmarked to NATO command. Two exceptions may be remarked to this general principle of the provision of balanced forces by each nation. At one extreme nearly all the other members of NATO have thought it either wise or inevitable to leave to the United States the responsibility for providing the overwhelming preponderance of the strategic nuclear power available to the Alliance, while at the other extreme the contribution of Luxemburg to the forces of NATO has until recently consisted entirely of a battalion of artillery and is at the moment being modified into a different kind of specialisation in the form of a battalion of light infantry. But these exceptions have followed inevitably from disparities in size and wealth and do not really affect the general principle.

The forces provided by the NATO countries have been determined by numerous factors - political, strategic, and economic - but perhaps the most fundamental criterion has been the extent to which the governments have felt that danger was imminent. In the early days of NATO they felt that it was very close indeed, and it was accepted without argument that a substantial effort had to be made to build up the forces of the West, which had been largely disbanded at the close of the Second World War. The famous Lisbon force goals were adopted in 1952 and a very considerable effort was made by the NATO countries, resulting in a very substantial strengthening of their forces even though the Lisbon force goals themselves were never attained.

The influence of technological development and of economic factors upon NATO force planning is not something new. Even at Lisbon in 1952 the principle was affirmed that defence must be built on a sound economic and social basis and that no country should be called on to shoulder a defence burden beyond its capability. Both technology and economics played a part in the changes of emphasis that occurred in the middle of the 1950's. A strategic re-appraisal at the end of 1956 was based on the assumption that a large variety of nuclear weapons would gradually be introduced into the forces both of the NATO countries and of the Soviet bloc. The concept of "massive retaliation" was dominant at this time, but fortunately it did not, as might have been expected, lead to a neglect of the so-called "shield forces" provided on the ground in Western Europe. It was decided in 1957 that stocks of tactical nuclear weapons should be made available to the Armies and Air Forces of the European countries. A fresh set of force goals was devised which called for a smaller number of units than the Lisbon plan but implied high standards of manning, equipment, and training, and provided for the supply of tactical nuclear weapons by the United States under suitable custodial arrangements.

Another example of the impact of technological development upon NATO's military thinking, and consequently upon the problems of resource allocation, can be seen in the strategic debates that have followed the acquisition by the Soviet Union of a nuclear arsenal which, though not equal to that of the United States, has nevertheless conferred upon the Soviet Union a substantial and increasing capability to survive a first nuclear strike and still inflict very severe damage upon the West. This, together with the development of a substantial tactical nuclear weapon capability to the East of the Iron Curtain, has led to the elaboration, in the first instance in the United States, of the strategic concept which has become known as "flexible response". This has been much discussed within NATO and has affected both our strategic thinking and our approach to force planning. It has brought out the need to maintain a balance between the requirement for direct defence on the level at which an aggression is launched and the maintenance of deterrence through the ever-present threat of escalation to a more intense level of combat. It has underlined the importance of preventing the potential aggressor from predicting with confidence NATO's specific response to aggression, and persuading him that an unacceptable degree of risk would be involved regardless of the nature of his attack. It has posed a requirement for conventional and tactical nuclear forces able to meet at an appropriate level any aggression other than a general nuclear attack and either to defeat it or to demonstrate NATO's determination to resist while making clear that the prospect of escalation is very real and gaining time for rational consideration which will, one must hope, cause the aggressor to withdraw rather than embark upon a course that can lead only to mutual destruction. The provision and maintenance of such forces in an era of rapid technological development is likely, as I shall show, to confront force planners with increasingly severe economic problems.

ABM

New procedures have recently been devised within the Alliance for the closer association of national and international military and non-military officials throughout the force planning process, in order that all the essential considerations, military, political, and economic, may be taken into account at all stages. We are now planning for the early 1970's, and the implication of military technology in the 1970's are very relevant to our work. Perhaps the most obvious and most spectacular of the technological considerations with which we are now faced are those that surround the deployment of anti-ballistic missile (ABM) defences in the Soviet Union and have led to so much debate as to the action that should be taken in the West if the Soviets cannot be persuaded to desist from action which can lead only to an intensification of the arms race in one form or another.

The United States are technologically in the position of being able, if they so wish, to install ABM defence systems of various sizes at varying degrees of cost. This capability opens up many questions of importance for planners. Would the installation of ABM defences be the best way of maintaining the deterrent capability on which the peace and security of the West rest? To what degree would it reduce damage and casualties? What collateral measures (either of military or of civil defence) would be required in order to complete a fully effective damage limitation defence system? Can deterrence be maintained more effectively and cheaply by these means or by an increase of offensive power sufficient to counterbalance or surpass the improvements in the potential enemy's defensive capability? Is it considered essential to maintain a given capability for assured destruction, and thus to equip our own offensive armoury with more or better weapons, irrespective of whether we also deploy ABMs? What political effect would a response to ABM deployment, either with similar deployments of our own or with an intensification of our offensive power, have upon our hopes for disarmament? What are the relative military considerations bearing upon ABM deployment in Europe and in America? Would there be political repercussions within the Alliance if the already overwhelming military preponderance of the United States was reinforced by defensive protection of an order different from any available to Europe?

Some of these questions reflect the political and strategic aspects of technological development, with which previous speakers have dealt, and would call for decisions at the highest political level. But the importance of such questions and the resulting decisions lies not only in their political and strategic implications but in the inescapable economic fact that a decision to devote resources to an advanced and expensive military weapon system must involve either an increase in the overall resources assigned to defence or a reduction or adjustment in other defence expenditures. This second alternative, unless there is some administrative "fat" that can be trimmed, means a reduction or adjustment in expenditure on other forces. The force planner is thus confronted with a major decision of force structure and resource allocation, and one whose political, strategic, and economic consequences are so far-reaching that the most searching and comprehensive analyses are required. One can well understand the anxiety of the United States Government to keep the maximum number of options open for as long as possible. And I have not mentioned the implications, for this or for other aspects of force planning, of the rapid technological developments in China which indicate that that country may have an intercontinental ballistic missile capability very early in the 1970's. This might seem a remote threat to NATO until we remember that the Pacific coast of the United States is part of NATO's western flank. It is certainly far from remote for some other countries represented at this conference whose own technological progress may confront them with choices of a most searching character, in which political considerations such as the desirability of curbing the spread of nuclear weapons and economic considerations relating to the allocation of resources for which there are many other social claims will have to be put into the balance with the responsibility of governments to ensure the security of their peoples and protect them against possible nuclear domination or blackmail.

mobilità

Another striking example of the implications of technological development for force planning appears in the field of strategic mobility. It has always been a cardinal principle of strategy to take advantage of the mobility conferred by sea power, and more recently air power also. From the time of the naval war in the Pacific more than twenty years ago there has been an increasing concentration on fleet trains, mobile support, new types of auxiliary ships, and larger and more versatile landing craft. The development of large, fast transport aircraft, of helicopters, and of short take-off and landing techniques has had a significant effect on force planning. There has been a reduced emphasis on fixed bases accompanied by an increased emphasis on carrying one's own logistic support, like the camel or the snail, and on an integrated use of sea, land, and air forces to apply military power in the most effective way at the most sensitive point.

We are already seeing the influence of developments of this kind upon force planning for the 1970's. For the United Kingdom, for example, the increasing range and capability of modern strike and transport aircraft appear to have been among the factors influencing the British Government's recent decisions to run down its extensive base complexes east of Suez. For the United States it seems that developments in strategic transport - in particular the C5A aircraft and the Fast Deployment Logistic Ship - may, with their combination of air-lifted personnel and sea-based prepositioned material, transform the whole approach to the problem of bringing efficient and well-equipped forces to bear in various parts of the world. Present and prospective capabilities in this field have undoubtedly influenced the proposals that the United Kingdom and the United States have put to their NATO allies for the redeployment of certain forces from Germany. I do not go so far as to suggest that these decisions were taken solely on technological grounds, or even that technology was the principal factor; the underlying reasons have almost certainly been political and financial, but equally there is no doubt that the progress of technology has affected the climate in which the decisions were taken and has opened up choices that would not otherwise have been available. Indeed, even a distinction between technological and financial factors may be artificial because technology itself has been a factor in producing the financial climate in which force planning decisions have been taken and will have to be taken in the coming years.

I have made several references in general terms to the way in which technological developments affect and complicate the economic background against which the defence planner has to operate. I am now going to discuss this in more detail, and my remarks will not apply only to developments of the more spectacular type such as those that I have just mentioned. The outstanding economic characteristic of technological progress in the military field is the increasing complexity and capital cost of successive generations of equipment of all kinds - and not only of successive generations, but also the successive marks or modifications of a single generation that are required to offset the rapid obsolescence into which it would otherwise lapse. This is obviously true of missiles and aircraft, or when we compare a nuclear-powered with a conventionally-powered submarine. It is equally true of weapon systems of all kinds - air-to-air, air-to-surface, surface-to-air, and surface-to-surface - where the predominant trend is towards smaller and more mobile weapon systems with greater accuracy and, in many cases, increased ranges. In the later 1970's, indeed, we may well find that the distinction between weapon classes - for example, between guns, mortars and free flight rockets and missiles - will be gradually reduced and that hybrid weapons will be developed such as free rockets or missiles fired from guns or mortars.

It may not be easy to forecast in detail the financial implications of technological developments in terms of cost - let us for the moment concentrate on cost, and consider effectiveness later - but we can be certain that they will be expensive, and probably considerably more expensive than anyone would at present predict. The history of most of the major arms-producing nations is littered with projects which ultimately cost many times more both to develop and to produce than was originally forecast - and with others on which large sums were spent but which did not even reach the production stage.

Some specific examples of the comparative costs of successive generations of equipment were given in the British Defence White Paper of 1965, where it was stated that between 1963 and 1968 the capital cost of equipping an armoured regiment in the British Army of the Rhine would double, of an artillery regiment would triple, and of an infantry battalion would be six times as great. For aircraft, it was stated that the cost of the latest Lightning was about five times that of the latest Hunter and that in the Fleet Air Arm a Sea Vixen cost approximately seven times as much as its predecessor the Sea Venom. And this referred only to the cost in terms of capital investment. The increasing complexity of equipment not only affects investment cost but also frequently calls for more maintenance, which in turn is likely to require more highly qualified personnel. In countries which rely upon volunteer forces this may call for substantial increases in pay to maintain competitive appeal, and even those countries which rely largely on conscript forces may, apart from the question of social justice for conscripts, find themselves compelled to go into the market for a larger proportion of highly qualified volunteer specialist technicians.

The effects of these factors become apparent when we consider the resources that countries are prepared to make available for defence. We are accustomed, at the risk of over-simplification, to adopt as a convenient index the percentage of its Gross National Product (GNP) that a country devotes to defence. Now the capital cost of successive generations of most items of equipment rises considerably faster than the GNP itself, as is evident from the examples that I have just quoted. Likewise, on the manpower side, a recent study within NATO showed that average rates per head of military pay in most NATO countries tended to rise more rapidly than the GNP per head, and that in most NATO countries the share of defence budgets absorbed by the pay and allowances of personnel increased between 1955 and 1965. A number of these increases were substantial, even though in some cases they were accompanied by a decrease in the actual number of personnel. Technology is not necessarily the only factor affecting manpower costs - there may, for example, be political decisions regarding the emphasis to be placed on regular forces - but it undoubtedly plays a part; and increases in the proportion of defence expenditures devoted to manpower imply a smaller proportion for equipment.

It follows that for a given percentage of even an increasing Gross National Product a government can purchase less defence quantitatively in terms either of equipment or of manpower or of both. And in most NATO countries the tendency to-day is towards a reduction, or at most a maintenance at a constant level, of the proportion of GNP devoted to defence. This has been shown very clearly in the surveys of the military balance published each year by this Institute. It appears to be due to a number of reasons, both economic and political. These include the comparative stagnation of a number of national economies, balance of payments difficulties in some cases, and, on the political side, an atmosphere of increasing détente which has modified the calculus of imminent danger which I suggested earlier as one of the determining factors in the attitude of governments to defence planning. One may remark that there is little sign as yet of similar trends in defence planning on the other side of the Iron Curtain, and one may hope that we in the West will not be tempted to forget that one of the causes of increasing détente is the comparative military balance that has been maintained and the continuing evidence of the West's determination not to tolerate aggression from the East.

Economically, technological developments of the kind that we are discussing can produce benefits such as the so-called "spin-off" in research and development or some reduction in the manpower that the armed forces need to draw off from a nation's overall pool of manpower. Militarily, they can bring very notable increases not only in cost but also in effectiveness. The relation between the increased cost and the increased effectiveness in individual cases is a matter for analysis and for judgement, but in general it may be assumed that, for projects which have come or will come to fruition, this relation has been or will be judged to be reasonably satisfactory. One of the first problems for the force planner at any time is to analyse the possible "trade-offs" that can be obtained from various combinations of quantitative and qualitative factors in a force structure. This prblem is intensified by technological developments, but the economic implications of technological development which we have been discussing leave little doubt that the decade of the 1970's will see the evolution of forces smaller in number but with their combat quality enhanced by newer and more effective weapons and equipment and by increased mobility.

We may perhaps see changes in the overall structure of forces - possibly for example a still greater emphasis on command of the air at the expense of surface forces - and we may find that these changes have an effect on military planning. For example, concepts of forward lines of defence may become difficult to implement and our military leaders may have to think more and more in terms of mobility and defence of critical areas. Such thoughts at once raise political problems - even as we sit here in this comfortable hotel we are not very far from the Iron Curtain, and those countries whose territory is a potential battlefield are likely to look with a special concern at notions of defence which imply some initial overrunning of real estate before a retaliatory blow is struck. Nevertheless such notions may prove to be an inevitable corollary of technological development. Indeed on a long view they may perhaps be regarded as little more than an extension of the general trend throughout this century towards more mobile concepts of warfare - a trend which we saw exemplified in the Sinai Desert only a few weeks ago.

I have spoken about some of the economic implications of technology for national force planning. It may also be of interest to consider whether there may be special implications for an alliance such as NATO. I should perhaps stress that I am expressing a personal view and one that should not be taken as necessarily the official view of the Organisation or of the Secretary General. I have mentioned that for the most part each NATO country maintains a balanced set of national forces. I believe, however, that, in addition to the possible effects on force structure and perhaps on military planning to which I have already referred, we may find ourselves moving inevitably towards a new concept of NATO force planning. It is new not in the sense of not having been considered before, for it has been the subject of considerable study in the past; but in the sense that, whereas its previous examination has been somewhat theoretical and has not led to any positive action, the pressure of events may within the next few years bring it sharply within the scope of practical consideration.

NATO force plans up to now have been very largely the sum of balanced national plans, which have certainly been directed towards meeting NATO requirements and carrying out the military plans of NATO's commanders but have been worked out by each of the several governments in the light of national as well as NATO considerations. Work is currently in hand on the production of a NATO force plan of this kind to cover the five-year period 1968-72, and "roll-forward" planning for the period 1969-73 is already in its early stages. As the decade of the 1970's progresses, however, we are likely to be faced in a more and more acute form with the problem of how far nations can continue to provide, maintain, and operate sets of forces of this kind.

One approach towards this problem has been a search for greater co-operation in arms development and production among the members of NATO, as a means of making better use of existing resources, of promoting standardisation or at least operational compatibility of equipment, and of facilitating the provision of logistic support. The Alliance has recently reorganised and revitalised its machinery directed towards these ends. The aim has been to evolve a practical and flexible system to make this co-operation efficient and at the same time attractive to the national authorities with whom the responsibility for its success must rest. New procedures and a new organisation have been devised for the determination of NATO projects and for an adequate sharing of the scientific, technical, and economic benefits resulting from each co-operative programme as a counterpart to the effective contribution of each country. A major source of complications in this last regard is the concentration of research, development, and production capabilities in relatively few countries - and particularly, of course, the sheer size of the effort that the United States can devote to technology and management by comparison with their European allies.

This Institute, too, has been responsible for the publication of some comprehensive and stimulating studies on arms co-operation by Mr. John Calmann, Mr. C.J.E. Harlow, and (with particular reference to NATO) Mr. Robert Rhodes James, with more to come.

But I believe that we may have to go much further than this. I believe that a consequence of the increasing complexity and cost of military equipment is likely to be that some, if not many, NATO countries may have to abandon the attempt to provide balanced national forces and to specialise in forces of high quality designed to discharge a limited number of functions. This idea might be worked out in a number of ways. Countries might become essentially maritime, land, or air powers. Or they might specialise in more diversified functions - one country supplying mainly armoured units and strike aircraft, another anti-submarine forces and fighter aircraft, and so on. Overall balance would be achieved not within the forces of each country but across the board within the forces of the Alliance as a whole.

We may even find in due course that only what is known as a "super-power" can by itself maintain a fully balanced national military capability. We are already seeing some modification in the United Kingdom's world-wide military rôle, and I venture to suggest that it is by no means certain that either the United Kingdom or France will be able to afford a further generation of the strategic nuclear deterrent beyond the ballistic missile submarines already planned. It would be beyond the terms of reference of our present discussion to do more than note, as in my earlier references to anti-ballistic missile developments, the possible political repercussions for the European allies, individually and perhaps also as a group, of what might be regarded as an intensification of the American military and technological preponderance within the Alliance. Such repercussions might take various forms, some of them extremely far-reaching.

If, as I believe likely, a broader approach to force planning, of the kind that I have suggested, comes to be adopted in the 1970's, the need for a flexible and responsive force planning procedure will be accentuated. Long-term planning will be necessary - the time-scale of the development and procurement of most major military equipment is such that decisions have to be taken well in advance of the time at which it will begin to reach the forces. A system of force and financial planning five years ahead, such as we have now adopted, may be insufficient. But equally there will continue to be a need, for which our "rolling" system provides, to review and as necessary re-adjust plans already made for the medium term. Much is said and written nowadays about changes in the political background of NATO and about a possible loosening of the bonds which link the allies. It is not necessary to accept the more pessimistic of these forecasts in order to believe that a more integrated approach to force planning such as I have suggested could increase the cohesion of the Alliance and that this could be a remarkable and perhaps unexpected by-product of the progress of technological development.

I have talked about the implications of technological development for defence planning within NATO, the Alliance which I know. Are similar considerations likely to apply on the other side of the hill in the Warsaw Pact? The grass in other pastures always looks greener, and we tend to assume in a potential opponent maximum efficiency, unlimited resources, and a ruthless devotion to the satisfaction of military requirements. From some points of view this is of course prudent, and the underlying conditions of a dictatorship are bound to be different from those of a democracy. Nevertheless the resource constraints under which we ourselves operate make it important that we should not take an unnecessary burden upon ourselves through over-estimating our potential opponent's capability.

I mentioned earlier that there was no sign of a reduction of defence expenditures on the other side of the Iron Curtain, and indeed the Soviet Union has announced that its defence budget for 1967 is 8.2% higher than that for 1966. It is always difficult to assess the significance of figures such as this; for one thing we can never know how much of what we would call defence expenditure is concealed within other budgets, and for another the prices of particular articles or materials are liable to be distorted not only because of the greater scope open to a totalitarian régime for controlling the market, but also because of the concentration of technological and managerial personnel of high quality in heavy industry and in other sectors of the economy that serve the needs of defence. A reasonable assumption might be that the Soviet Union devotes to defence something up to 10% of its rouble GNP - but because of these distortions it might be unwise to draw a direct comparison with the broadly similar proportion of the much larger American GNP. Nevertheless, there seems no reason to assume that the economic implications of technological developments will not sooner or later be much the same for the Warsaw Pact as for NATO. The extent to which they may be mitigated by the nature of the Communist régime is doubtful. It is true that through its concentration of resources on heavy industry the Soviet bloc is not far behind NATO in military-industrial potential despite the disparity in GNP. We read of conflicts between the heavy industry and light industry schools of thought, between those who favour guns and those who prefer butter. But the pressing need to raise the standard of living by more investment in agriculture and other consumer sectors of the economy will almost certainly have some effect upon the resources available for heavy industry and defence. We may, therefore, very reasonably expect that the Warsaw Pact countries will find themselves faced with force planning problems somewhat similar to those that we have foreseen for NATO, though not necessarily in the same time scale. The Warsaw Pact's search for solutions to these problems might extend similarly to the balance of forces among its non-Soviet members and might even have a similar effect in increasing cohesion and countering centrifugal tendencies such as the Rumanians have displayed. But this is no more than speculation based on what seem to be reasonable probabilities rather than on any definite indictions.

I make no apology if I seem to have spoken too much in terms of NATO and of the balance between East and West. I realise fully that this is not a NATO audience but one which includes a number of distinguished participants from non-NATO countries, who I hope will contribute to our discussion from the wider point of view which they are much better qualified to take than I am. My aim has been not to talk in terms primarily of abstractions but to think about some of the decisions with which force planners will be faced in real life. The conditions with which I have to deal in real life are those of NATO, and this explains, if it does not excuse, any imbalance in my remarks. I have tried to give a general indication of some of the serious problems with which the economic implications of technological developments are likely in the 1970's to confront the force planners of nations and of alliances - almost assuredly those of the Warsaw Pact as well as of NATO. I have also ventured to hint at the possibility, perhaps even the probability, that from the attention that NATO countries will be forced to give to these problems may come a fresh approach to NATO force planning and possibly a new dimension in the reality and the intensity with which member countries participate in the affairs of the Alliance and work together to secure its ends.

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INSTITUTE FOR STRATEGIC STUDIES

9th ANNUAL CONFERENCE

THE IMPLICATIONS OF MILITARY TECHNOLOGY IN THE 1970's

COMMITTEE I-2

Friday 29th September Afternoon

Some Perspectives on BMD

JOHAN J. HOLST

Introduction

The present paper constitutes an attempt at identifying and structuring some of the major policy issues which are connected with ballistic missile defenses (BMD). There can be little doubt that the decisions which are made or not made in this realm will have a major impact on the future shape of the international environment. The many imponderables and uncertainties which are associated with the evaluation of BMD make it impossible to arrive at very exact and high-confidence predictions about the nature of the various BMD ramifications. This state of affairs should, however, not prevent us from making systematic attempts at increasing our understanding of the issues. The analysis which follows is based exclusively on information which is in the public domain.

Some Concepts

The functions which a BMD system would perform may for analytical purposes be divided into four stages: the detection, identification, interception and destruction of the enemy-missile-warheads. In principle we could think of at least three different ways of providing active defenses against ballistic missiles: (1) by erecting a defense "screen" which would close the potential attack routes of ballistic missiles in the higher layers of the atmosphere, and (2) by establishing a "duel" defense based on the principle of firing interceptor missiles at strategic missiles attacking a certain target area and (3) by a space-based ballistic missile boost intercept (BAMBI) system. The perfect defense

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* I am indebted to my friends and colleagues Donald G. Brennan and Jeremy J. Stone for discussing the subject with me and for suggesting perspectives. I remain, of course, responsible for the contents of this paper.

would presumably be of the former kind whilst what is likely to become available in the short run are modifications of duel defense systems. BMD systems can also be classified in relation to the targets they are deployed to protect. By "protect" I shall mean "reduce the probability or degree of damage." Active defenses which are intended to protect only military forces and command centers are known as "point defenses." Such defenses would presumably be most effective for the protection of targets which are hardened to withstand substantial blast overpressure from near hits, which are usually called "hard-point" defense systems. Missiles which are deployed in defense of population centers are usually called "city defenses." An "area defense" system would protect large areas (measured in 10^3 Km^2) including both the cities and strategic forces therein.

Systems, Technology and Cost (1)

The American research effort aimed at providing an active defense against ballistic missiles was started by the U.S. Army in the mid-fifties. It was accelerated in the wake of Sputnik and had by 1959 proceeded to the stage when the Army advocated the procurement of its Nike-Zeus system which grew out of the Nike-Hercules anti-aircraft defense system and which could have been operational by 1963-64 for an estimated cost of $13 to 14 billion. The proposal was rejected and the project limited to continued research and development. The Army's first recommendation for initial production had actually been made as early as in 1958 at which time a general division of responsibilities was established between the U.S. Army and Air Force whose rival BMD system, Wizard, was cancelled. The Air Force was assigned the task of developing a missile warning radar network, and during the period 1960-63 the BMEWS (Ballistic Missile Early Warning System) was installed. The stations were to be supplemented by the MIDAS (Missile Detection and Alarm System) satellites for infra red detection of missile launchings. That project is still in the research and development stage.

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(1) Most of the information in the following has been obtained from the 1967 Posture statement which Mr. McNamara presented to the American Congress 23 January 1967 (reprinted as "McNamara on BMD" in Survival 9 (4) 1967, pp. 108-114, 121) and from the testimonies of Dr. John S. Foster, Director of Defense, Research and Engineering, DoD and the Deputy Secretary of Defense Cyrus R. Vance before the Subcommittee on Disarmament of the Committee on Foreign Relations, United States Senate in February 1967 as released in the printed committee hearings entitled United States Armament and Disarmament Problems, Washington 1967, 181 pp.

During 1962-63 the Army conducted a series of successful single intercepts (10 out of 14 were successful, i.e. a single shot kill probability of 71%). In January of 1963 the decision was made, however, not to procure the Nike-Zeus but to proceed instead with the development of a more advanced system, the Nike-X. The technical reasons for the negative procurement decision in 1963 centered on the system's limited traffic-handling capabilities - it was designed for the interception of single missiles - and its inadequacies for the task of discriminating the real warheads from decoys and chaff which could be developed rather cheaply by an adversary. The defender would have to await atmospheric filtering (slowdown and burnup of the decoys) in which case the Zeus missile was too slow to manage the interception.

In the Nike-X system the mechanical radars of the Nike-Zeus are replaced by phased-array radars providing a capability for simultaneous tracking of many targets and supported by large modular computers. Furthermore the system encompasses a new high-acceleration (~100g+)[1] short range (30-50 km) [1] interceptor, the Sprint. These improvements made feasible atmospheric filtering, which takes place at altitudes of 30-40 km. Other methods of target discrimination based on discernible differences between the radar signals which are returned from the warheads and the penetration aids were presumably also improved (electromagnetic analysis, signal structure analysis, etc). Late interception has however the disadvantage of placing strict limits on the size of the interceptor warhead because of the danger of blast damage to the defended area, and this coupled with the atmosphere's attenuating effect on the energy released by explosion, would mean that the Sprint missile's kill radius is measured only in fractions of a mile. Low altitude interception also makes it necessary to place the defensive missiles close to the protected objects. Hence a system of this kind which was scaled to defend a large area would require a great many missiles and be very expensive. Cheaper versions could only protect selected points and would entail the problems of by-pass attacks.

The most recent improvement in BMD technology is in the area of long-range interception opening up the possibility of area

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(1) These and other performance indicators are taken from Aerospace Technology (formerly Missiles and Rockets and Technology Week).

defense. An area defense system wherein each battery can defend any one of a number of potential targets would serve to deny to the opponent the strategy of attacking undefended targets with minimum force and concentrating his attacks for overcoming the local defenses of the defended targets. Thus the Nike-X system now includes the Spartan missile which would intercept the incoming missile in the ionosphere (up to 450 km) and at long ranges (650 km) from the battery locations. The warheads used for exoatmospheric interception could be high yield - presumably in the megaton range - and designed to maximize the release of energy in the form of radiation (probably chiefly soft X-rays) which could inflict various forms of external and internal damage to the offensive warheads. The kill radii would vary with the altitude and the yield and design of the warhead but available information suggests that it is measurable in miles. The detection sensor would be the perimeter acquisition radar (PAR) which detects the missile at long ranges, tracks and predicts its future path. Both the Spartan and the Sprint missiles are guided by a missile site radar (MSR), a relatively small phased-array radar which would be associated with each battery. The various system components, missiles, radars and computers, constitute a flexible set of building blocks which can be put together in various ways to provide varying levels of defense against different threats. There is also the multi-function array radar (MAR) which is a very powerful phased array radar which is designed to perform all the defense functions involved in countering a large attack. A scaled-down version of this radar is called the TACMAR radar.

The rough costs involved in procuring a BMD system of the kind which is described above have been presented by Mr. McNamara for two alternative deployment configurations, a $10 billion program (Posture A) and a $20 billion program (Posture B). Posture A would consist of an area defense of the entire continental United States providing redundant Spartan coverage of key target areas and a relatively low density Sprint defense of the 25 largest cities. Posture B is a heavier defense including the same area coverage but a higher density Sprint defense for the 50 largest cities.

TABLE I

Two U.S. BMD Deployments

	POSTURE A $ billion	POSTURE B $ billion
RADARS (MAR, TACMAR, PAR, MSR) Invest. Cost	6.5	12.6
MISSILES (Spartan, Sprint) Invest. Cost	2.4	4.8
DoD Invest. Cost	8.9	17.4
AEC Invest. Cost	1.0	2.0
Total Invest. Cost (ex. R&D)	9.0	19.4
Annual Operating Cost	0.38	0.78

We have been cautioned that the estimated costs may be understated by 50 to 100 per cent. It should be noted that the radars account for approximately 2/3 of the investment cost. Unofficial sources have given the following investment costs for the various radars: MAR $400 mill. (+), TACMAR ~ $250 mill., PAR ~$75 mill,MSR ~$125 mill.(1) The investment costs of the Atomic Energy Commission (AEC) presumably refer to warhead costs, and since it is known that nuclear explosives cost on the order of one-half million dollars each, the total number of interceptor missiles would be on the order of 2,000 and 4,000 for the two postures respectively. These figures are also consistent with the unofficial estimate that each Sprint and Spartan missile would cost on the order of $1 million and $1.25 million respectively. (2) Such a number of interceptors is quite large in relation to the number of ICBM's which the Russians are likely to have available in the near term future.

A relatively small number of Spartan batteries could defend the whole of the United States against simple attacks from e.g. smaller nuclear powers. Such a deployment would cost on the order of $4 billion. (Note that we have not addressed ourselves to the expected effectiveness of any of these defense postures.)

The American Joint Chiefs of Staff have recommended procurement of Posture A and they have substantial support in Congress and from the defense industry. About five years would be required to build and install the system. The administration has,

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(1) Missiles and Rockets, 19 (19), 1966, p.14.

(2) Ibid

however, been unwilling to commit itself to procurement. The research and development effort is proceeding at a level of expenditure close to half a billion dollars annually. A reserve fund of $377 million is included in the 1968 Defence Budget for initial procurement in the event that the Moscow discussions about strategic weapons postures should prove unsuccessful and the Administration should decide on deployment. On September 18, 1967 Mr. McNamara announced the American decision to proceed with the deployment of an austere (approx $5 billion) area defense system designed primarily to deal with the expected Chinese missile threat in the early 70's. The implementation of this system may take some 5 years.

Meanwhile we should expect the technology of BMD to proceed. It is known that a very-high-acceleration interceptor (800-1,000 g) is being developed for hard-point defense of strategic forces, HIBEX (High-acceleration Booster Experiment). It will presumably aim at very low altitude interceptions, possibly less than 6 km. A special radar for hard-point defenses is also in the experimental development stage, HAPDAR (Hard-point Demonstration Array Radar). Furthermore, it has been reported that studies are underway to increase the range of the Spartan missile and presumably extend it to cover greater parts of the mid-course trajectory of the offensive missiles. The feasibility of seaborne anti-ballistic missile intercept systems (SABMIS) is reportedly also under study and would seem to point in the same direction. Finally, it has recently been argued by some experts that space based systems designed to intercept ballistic missiles during their vulnerable boost phase, when they are still using their engines and tanks, may become technically and economically feasible in the near-term future.

In the realm of more exotic and long-term solutions, various possible ways of establishing effective defense screens have been suggested consisting of e.g. small pellets, gases or plasma of charged particles, etc. The development of laser technology may have a significant impact on BMD systems should it prove feasible to project the requisite energy radiation levels over substantial distances. Lasers may also become important in range-finding and fire-control systems which might make highly accurate missiles with a range of 300-600 km available some time in the seventies. Such developments might entail the possibility of close-up non-nuclear kill mechanisms. Further advances in computer data processing speed may reduce the problems of target discrimination. It is, of course, impossible to predict how the BMD technology will fare in a race with penetration technology involving such developments as manoeuvreable re-entry vehicles, MIRV's (Multiple Individually Targetable Re-entry Vehicles), active jamming devices, effective warhead shielding, major reductions of the radar cross sections of the re-entry vehicles (RV's), anti-radar weapons, etc. An even larger question is whether prudential policy will predominate in the choice among technological alternatives.

Precise information about the Russian BMD effort is very hard to come by. The Soviet defense establishment has traditionally put a heavy emphasis on active defense systems as witnessed e.g. by their extensive anti-aircraft programs. This tradition is probably reinforced by a doctrinal antagonism to dependence of the kind which is implicit in the concept of deterrence. The following statement by the late Russian strategist, Nikolaj Talenskij is revealing: "The creation of an effective anti-missile system enables the state to make its defenses dependent chiefly on its own possibilities, and not only on mutual deterrence, that is on the goodwill of the other side." (1) During the 1960's several books were published in the Soviet Union on the technical problems of BMD. (2)

In November 1963 The New York Times reported that the Russians were installing an anti-missile system around Leningrad. The system was presumably based on the short range (40-50 km) Griffon (NATO designation) missile which is now being used for anti-aircraft defenses. The system probably ran into technical and operational difficulties in the anti-ICBM role. Films showing ballistic missile intercepts have been shown on Soviet television and since 1963 missiles claimed to be anti-missile missiles have been shown in military parades in Red Square. It was not till November 1966 that Mr. McNamara made a public announcement to the effect that the Russians appeared to be deploying a BMD system around Moscow. That system is believed to be based on the long-range Galosh missile which probably has exoatmospheric range. It was displayed for the first time in November 1964 and in an allegedly improved version

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(1) Nikolaj Talenskij, "Anti-Missile Systems and Disarmament," International Affairs (Moscow) (10) 1964, p.18

(2) Goncharenko, M.N. Rakety i problemy antiraket, 1962. Nikolaev, M.N., Raketa protiv rakety, 1963. Shibayev, N.F., Bor'ba s raketami, 1965. Bragin E.K. and A.G. Kubarev, Protivoraketnaja Oborona, 1966. A.I. Leonov, Radiolokatsia v protivoraketnoj oborone, 1967.

in May 1966. A large phased-array radar which is integrated with smaller tracking radars at several points is reportedly located northwest of Moscow.(1) The first Galosh batteries are not expected to be operational before 1968. There is no known Russian counterpart to the high-acceleration Sprint. (The Griffon is reported to have a speed of Mach 3-5.)(2)

In addition to the Moscow system the Russians are reportedly also installing another system extending along the north-western borders of the Soviet Union, the so-called Tallinn-system. The precise nature of these installations is not publicly known but Mr. McNamara has stated that "the weight of the evidence at this time suggests that this system is not intended primarily for anti-ballistic missile defense." This view has been challenged by the American Joint Chiefs of Staff. It is, of course, possible that the system consists of dual-purpose installations against ballistic missiles as well as against air breathing vehicles. There are also some unconfirmed reports of a great deal of activity elsewhere in the Soviet Union around existing anti-aircraft installations. Mr. McNamara has estimated that a full-scale area defense deployment in the Soviet Union would cost "at least $20 to $25 billion."

The Galosh missile would probably carry a high-yield warhead and there may be some uncertainty as to whether the Russians are in a position to exploit weapon effects which would give them a relative advantage over the Americans. The 1961-62 Russian atmospheric tests are generally thought to have yielded a good deal of information regarding nuclear explosions at high altitudes. The tests were however carried out in an area (off Novaya Zemlya) which is not altogether inaccessible to American observation. Some alarmists have even made the claim that the Russians may be well on the way towards being able to erect a screen defense by large nuclear explosives while others doubt that any extensive radiation belts could be made to persist.

Soviet military statements about their BMD systems have been fairly consistent in making claims of substantial efficiency. Typically the claims are made that the BMD would destroy "many" of an

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(1) Richard J. Whalen, "The Shifting Equation of Nuclear Defense." Fortune, 75 (6) 1967, p.176

(2) Aerospace Technology 21 (3) 1967, p.99

attacker's missiles. There has however been no quantification. It is perhaps significant that the current political leadership in the Soviet Union has not resorted to the kind of dramatic rhetoric which flavored Khrushchev's statement about the ability to hit a fly in space.

THE IMPLICATIONS OF BMD

It has been argued that the introduction of BMD would increase the likelihood of war, accelerate the arms race, destroy the détente and advance the process of nuclear weapons proliferation; others claim that the opposite effects might ensue. Obviously contentions of this kind can never be completely refuted and vindicated only at a time when the relevant decisions have long since been made. There is no such thing as absolute truth in these matters, but that does not make every conclusion equally valid and reasonable. There is no substitute for explicit analysis however inadequate it might be from the perspective of eternal truth.

Towards Pre-emptive Instability? (1)

Let us look at some of the potential effects of BMD. The argument has sometimes been made that BMD would be conducive to pre-emptive instability, i.e. favoring first strike initiatives, by virtue of being more effective against a retaliatory strike from a power whose forces and command centers had been disrupted than against a well-coordinated first strike. In this sense, of course, there would always be a relative advantage associated with the first initiative. The question is whether the advantage be substantial enough to make a difference in the choice between war and peace.

Mr. McNamara has presented some figures which throw light on the question of pre-emptive instability:

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(1) The argument in this section owes much to D.G. Brennan and is developed in greater detail in his forthcoming Adelphi-paper on "Policy Issues in Ballistic Missile Defense."

TABLE 2

Expected BMD Effectiveness if not Offset

	Number of Prompt Fatalities in an All-Out Strategic Exchange (in millions) (Assumes no Soviet Reaction to U.S. ABM Deployment)			
	Russians Strike First, U.S. Retaliation		U.S. First Strike Russian Retaliation	
U.S. Programs	U.S. Fatalities	Russian Fatalities	U.S. Fatalities	Russian Fatalities
Approved	120	120 +	100	70
Posture A	40	120 +	30	70
Posture B	30	120 +	20	70

The figures in the table are based on the projection of both the American and Russian strategic nuclear forces, but assuming no Russian offensive force reaction to the American BMD deployment, to the year when Posture B could be operational (1973-75). The table shows the fatalities which the Russian forces could inflict upon the U.S. (with and without an American BMD) and the fatalities which the American forces could inflict on the Soviet Union (with a Soviet BMD). The calculations are predicated on the assumption that the Russians would be striking both at cities and at military targets in a first strike while an American first strike would be aimed only at military targets. The estimates are based also on the assumption that the BMD systems would actually perform at high levels of effectiveness. If we relax this assumption the fatality figures could be considerably higher. In fact the data are highly sensitive to small changes in the pattern of attack and in force levels.

Bearing in mind these limitations we note that under the assumptions of no Soviet response the number of American casualties could be reduced rather substantially, i.e., from 120 million without BMD to 40 or 30 million for postures A and B respectively in case of a Russian first strike and from 100 million to 30 or 20 million respectively in the event of an American first strike. In the case of a U.S. BMD the difference in American casualties between the case of a U.S. first and second strike is 10 million which is 10 million less than what the difference is in the undefended case!

If we assume the Soviet Union to react with offensive force augmentations up to a point where the ratio of the Russian cost of offsetting the American BMD and the American cost of deploying BMD would equal unity, the difference in American fatalities between the case of a U.S. first and a second strike is 30 million (i.e. 10 million more than in the undefended case) but now the absolute fatality figures are 120 or 90 million respectively. Hence on the basis of these calculations there does not seem to be any evidence for the contention that BMD would produce pre-emptive instabilities. It is perhaps possible that the figures are misleading to the extent that they result from calculations which are based on unrealistic assumptions about the performance of the BMD of the party which is the victim of the first strike. The uncertainties are certainly likely to be quite substantial. It is, however, not altogether clear that the uncertainties concerning the effectiveness of a retaliatory attack (which depends on such factors as the effectiveness of the first counterforce strike, the survival rates of command and control systems, etc.) would work in favor of the first strike. These very uncertainties could be deterring of war initiation too.

It is conceivable in theory that an area defense BMD might tend to make the super-powers less cautious in a crisis on the assumption that the ability to absorb and limit the damage from the nuclear attacks of an adversary would substantially affect their risk calculations. That argument appears to be somewhat tenuous for several reasons: the kind of BMD systems which are likely to become available in the foreseeable future would not be able to provide immunity against nuclear attacks. (There is, of course, a finite chance that some decision-maker would seriously overestimate the protection which BMD may provide.) Actually the existence of BMD might strengthen the capacity for crisis management by providing some insurance against catalytic actions by third powers and against automatic escalation should nuclear weapons be used. The political and psychological inhibitions against <u>any</u> first use of nuclear weapons would probably constitute a dominating factor in any major international crisis, particularly in view of the shared interest in erecting barriers against nuclear proliferation (such barriers are likely to include a tradition of non-use).

An all-out attack is only one, and hardly the most likely, way in which a general war might start. In view of the probable destruction in a general war it is very hard to conceive of its deliberate initiation in a non-tense period. In a crisis the process of escalation may however bring about general war as a result of e.g. demonstration attacks by nuclear weapons. It would seem that reasonably effective BMD systems might serve to lessen the probability of such strategies being pursued because the scale of effort needed to assure demonstration might approach the level of attack which might reasonably be expected to trigger substantial retaliation. BMD might also constitute some insurance against explosive escalation as a result of inadvertent small missile strikes.

Destabilizing effects

This kind of analysis does, of course, raise the whole wide-ranging issue about the expected impact of BMD on the strategies according to which the super-powers would conduct a nuclear campaign should nuclear war occur. It is possible that since one of the tactics for overcoming the effect of a BMD system is to saturate the radar-computer installations and attempt to produce radar blackouts by delivering a heavy attack in a short time, BMD might reduce the chances of controlled and limited war by providing incentives for heavy salvo attacks.

Technological developments might also ensue within the framework of which BMD, particularly hard-point defense systems, might constitute an insurance against pre-emptive instabilities. The development of high-accuracy multiple warheads could come to be perceived as a counterforce threat which might challenge the assured destruction capabilities of the nuclear powers by dramatically raising the exchange ratios for counterforce attacks, i.e. one missile could successfully attack more than one of the adversary's missiles on the ground. Such a state of affairs could ignite pressures for pre-emption in a tense crisis. Hard-point defense systems could presumably constitute a re-stablizing element in such a situation, or even reduce the incentives for the development of improved capability missiles (ICM). It is, of course, possible that a hard-point defense would not constitute the more cost-effective response to a substantial MIRV-counterforce threat compared to e.g. the procurement of mobile land based ICBM's and increased numbers of submarine launched missiles (SLBM's). A hard-point defense might however look less provocative to the adversary, particularly to the Russians given their predilections for active defenses. A U.S. hard-point defense would not add to the American first strike potential as would some of the other choices and would not reduce the assured destruction capabilities of the Russians provided it was not deployed in conjunction with an area defense. We are, of course, up against a chicken-egg problem when evaluating these interactions: were it not for BMD there <u>might</u> not be much incentive for developing MIRV's. However, BMD is now with us and even if it could somehow be limited or halted, it may not be reasonable to expect the parties to have mutual confidence in the non-introduction of penetration systems which might entail significant unilateral strategic advantages. BMD may come to be perceived as a necessary hedge. However, BMD might then also act as a stimulant for more sophisticated penetration technology. Thus the technology itself seems to harbor an inherent instability which adds to the predicament of political decision-making.

The Arms Race and its Management

Some of the arms race implications of BMD may be very serious and should receive careful analysis.

The major reason for the American refusal to initiate BMD procurement so far has been the expectation that such a decision might accelerate both Soviet and American expenditures on strategic forces and not result in greater security for any of the contestants. This expectation is predicated on the assumption that the side which was to increase its damage limitation capability through BMD would trigger an offsetting augmentation in the offensive force posture of the adversary who would want to maintain his capacity for assured destruction. There is also the fear that once BMD became a reality in one of the superpowers it would tend to grow because of vested interests and public pressure for equal protection. It would seem that the United States is much more vulnerable to such expansionary pressures than is the Soviet Union. However, no such pressures seem to have had a major impact on the American anti-aircraft defense system and a public opinion poll of some years back suggested that the majority of Americans thought the U.S. had BMD already. The political pressures may nevertheless be structured differently in the case of BMD deployment, particularly if a procurement decision should be associated with a major political debate.

If we assume the superpowers to be unwilling to accept any reduction in their present assured destruction potential, it is not unreasonable to expect there to be a kind of multiplier effect in the offensive force reactions to BMD. In order to maintain their high capacities for assured destruction, they will be subject to an almost inexorable compulsion to "overreact" by hedging against the possibility that the defenses of the adversary are more effective than they actually are. Thus the party which by BMD deployment had caused its adversary to effectuate offensive force build-ups might, under these assumptions, also have escalated the level of destruction he would suffer should war occur. This potential paradoxical counter-productivity of BMD is associated also with the fact that the contestants are always "responding" to what the adversary might have some five or more years in the future. Because of the contestants' relative ignorance about each other's future capabilities, defense-offense arms race interactions may be propelled in part by a set of "sub-races" which result from the internal competition within the framework of the R & D programs of each of the competing powers. BMD and penetration aids are opposite sides of the same coin. Thus the initial deployment costs may be just the beginning. It has been predicted that the U.S. would have to turn over the whole $20 billion system every few years. (1)

Perhaps one of the most seriously destablizing effects of the uncertainties which are associated with BMD is the opportunity for propagandistic manipulation. Inflated claims could be made about the effectiveness of one's own BMD in the expectation of extracting political concessions from the adversary, or about those of the opponent in order to justify higher defense efforts. There is also the consideration that BMD and penetration technology would substantially complicate the calculations of the damage which the parties expect to suffer and inflict in a war with the resultant possibility that there might develop significant discrepancies between the expectations of the two sides which in turn might cause their diplomatic postures to interact in undesirable ways. The present posture of reciprocal second-strike overkill may be diplomatically more stable largely because of its simplicity and saliency.

In order to assess the potential arms race implications of BMD we should want to obtain some appreciation of the cost-exchange ratio obtaining between defense and offense force build-ups. Some years ago it was widely assumed that the cost exchange ratio was on the order of 10:1 or 100:1, i.e., every $100 spent on defense could be offset by spending from $1 to $10 on increased offensive forces. Under such assumptions BMD was certainly not cost-competitive. Present calculations assume greater BMD efficiency. The figures in the following table have been presented by Mr. McNamara. The fatality figures presume the existence of a substantial U.S. BMD system and a Soviet second strike, which would be the case the Russians would want to examine for purposes of estimating their assured destruction capabilities.

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(1) Dr. John R. Foster, Director of Defense Research and Engineering in United States Armament and Disarmament Problems, op. cit., p.15

TABLE 3

Defense-Offense Cost-Exchange Ratios

Level of U.S. fatalities (millions) which the Russians believe will provide deterrence of an American first strike	Cost-exchange ratio (American BMD cost compared to Soviet offsetting cost)
40	4:1
60	2:1
90	1:1
100	Undefended Case

We see from the table that the lower the level with which the Russians would be satisfied, the more favorable would be the ratio between their expenditure and the cost of American defenses. Mr. McNamara has said that American assured destruction capabilities must be sufficient to guarantee the destruction of one-fifth to one-fourth of the Soviet population and one-half to two-thirds of the industrial capacity of the Soviet Union. According to Mr. McNamara's calculations the Soviet Union is credited with an expected capacity to destroy in excess of one-half of the American population (the American assured destruction capability against the Soviet Union is similarly expected to be able to eliminate one-half of the Soviet population. All fatalities are prompt fatalities from blast and fallout). We should again want to emphasize that the figures given are illustrative only and sensitive to small variations in any of the underlying assumptions. Nevertheless, it is not inevitable that the Russians would feel compelled to react to an American BMD deployment by augmenting their offensive forces to the point where the cost-exchange ratio would equal unity. They might feel that an assured destruction capacity against e.g. one-fourth of the U.S. population (i.e. 45 million) was sufficient. In this case their extra expenditures on offensive forces would be limited to one-fourth of the American BMD expenses. (There is, however, as pointed out above, always the danger of assuming the opponent's BMD to be more effective than it is in order to be on the safe side.) From an American point of view the expected increase in damage limitation (55 million saved) may seem valuable enough to warrant the expenditures. It appears then that the arms race implications of BMD depend *inter alia* on whether it be true that the two superpowers are determined to preserve X million hostages for purposes of deterrence and on whether BMD is expected to reduce the adversary hostages below that level. The magnitude of the arms race would depend on the size of X and on the ability to assess the efficiency of the adversary's BMD. Our analysis also begs the question whether it be possible to envisage stable strategic relationships based on lower levels of assured destruction given reciprocal improvements in damage limitation potentials.

It is logically conceivable that reciprocal BMD deployment might act as a measure of assurance permitting offensive force reductions or a freeze. However, it is legitimate to ask whether such a radical transformation of the strategic postures is politically attainable at the present juncture. In terms of the established theory, vested interests and technological incentives, it seems to the present author very likely that an American BMD deployment would not preclude the prosecution of a vigorous penetration aids program which would be designed to beat a Russian BMD system which was as effective as the American (whose performance is known to those who develop the technology). Such a broad-scale force augmentation might propel the United States in the direction of strategic preponderance, or this may be how some people might come to perceive it. Such perceptions would be strengthened by the observation that many of the strongest advocates of BMD in America are also proponents of strategic superiority. From the point of view of international society it is, I believe, much healthier that power be harnessed by a countervailing balance than by the enlightened prudence of the dominant. Unbalanced power may affect the behaviour and values of those who wield it in ways which would be detrimental to the general good of the citizens of all states, including those of the superior state.

Should BMD become the focus of an intensified arms competition between the superpowers it is possible that the result might entail the breakdown of the present test-ban treaty, e.g. because the parties might perceive needs to increase their knowledge about exo-atmospheric radiation effects. Furthermore, developments which would serve to re-emphasize the strategic adversary relationship of the two superpowers are likely to have a detrimental effect on the efforts to prevent nuclear proliferation. The latter pre-suppose a substantial degree of strategic co-operation between the United States and the Soviet Union. A BMD race would tend to suggest the utility of nuclear weapons for the security of states and the expectation that such weapons might actually be used and thus affect negatively the incentives of the non-nuclear weapons states to commit themselves to long-term abstention.

← test. Ban

← non. prolif

The Soviet-American discussions about strategic force postures do not seem to have gotten off the ground yet. However, perhaps we are entertaining inappropriate expectations. There is little in the post-war disarmament negotiations which suggest a high likelihood of the superpowers concluding an extensive formal agreement on a subject as vital to their security as strategic force postures. Perhaps the Moscow discussions should be viewed more as an instance of a continuous dialogue which would not aim at explicit agreement as much as an informal understanding and discussion which might serve the purposes of reassurance by removing uncertainties regarding intentions. Perhaps through a process of reciprocal education the superpowers might achieve a greater degree of tacit co-ordination in their arms policies and thereby bring the arms race under joint management. There is a precedent for this kind of strategic dialogue in the 1958 surprise attack talks, only this time we ought to have learned about the impossibility and disutility of rigidly separating the political from the technical issues. It may become necessary to face the issue of whether an arms race wherein the economically stronger power established quantitative arms superiority is not bound to become unstable by providing the inferior party with permanent incentives for qualitative innovations. There is, I believe, discernible in Mr. McNamara's annual posture statements, a trend aimed at "educating" the American Congress as well as the Russians' in the mutual dependencies of the arms race. He has come quite close recently towards conceding parity in second strike capacities, even though the United States still have close to three times as many intercontinental delivery vehicles (the Soviet missiles carry larger warheads. Most of the American population is concentrated in a few relatively small areas so that the forces required to inflict any specified level of damage against the U.S. are smaller than what is required to inflict an equivalent level of damage on the Soviet Union. The Soviet Union maintains a substantial ability to strike at American allies in Europe and Asia, etc.). The approximate present strategic balance is described in Table 4.

The Russians are reportedly in the process of building up their force of hardened and dispersed land-based missiles. Two new missiles are entering their inventory, the SS-9 which is roughly comparable to Titan II and the SS-11 which resembles the Minuteman. There are also reports of a major Soviet effort to develop MIRV's for their ICBM's, presumably first of all for the

TABLE 4

American and Russian Strategic Nuclear Forces

	UNITED STATES			SOVIET UNION (1)	
ICBM	Minuteman I	800			
	Minuteman II	200		SS-6, SS-7, SS-8	
	Titan II	54	1.054	SS-9, SS-11	~ 450
SLBM	Polaris A-2	208			
	Polaris A-3	448	656	Sark, Serb (3)	~ 150
	Total		1.710	Total	~ 600
MRBM (2)				Sandal, Shyster	
IRBM				Scrooge, Skean, SS-5	
				Total	~ 700-750
Intercont.	B-52 (4)	555		M-4 (Bison)	
Bombers	B-58	80	635	TU-95 (Bear) --	155
Medium (2)				TU-16 (Badger)	
Bombers				TU-22 (Blinder) (5)--	900

(1) Table uses NATO-designations for Soviet delivery systems.

(2) Capable of hitting Eurasian targets only.

(3) The Soviet Union possesses also submarine-launched cruise-missiles whose primary targets presumably are surface vessels.

(4) The B-52 C-F's and the B-58's will be phased out by 1972, leaving a force of 255 B-52 G-H's and 210 FB-111A's. The latter with SRAM air to surface missiles will enter into service during fiscal year 1969-71.

(5) The Blinder is expected to replace the Badger at the rate of one Blinder for each three Badgers.

SS-9. The big boosters give the Russians a relatively advantageous base for this development. They are, however, thought to be at least five to seven years away from operational multiple warheads. The United States is about to undertake extensive retrofit of both Minuteman and Polaris. MIRV's will presumably be carried by the Poseidon (eventually replacing Polaris in 31 of the 41 submarines at a cost of $3.3 billion) and Minuteman III which will enter the inventory about 1969-70. The American program does not include any increase in the number of delivery vehicles but the number of deliverable warheads is scheduled to increase as a response to the expected Soviet BMD-deployment. It is, of course, possible that the Russians do not intend to, or can be persuaded not to, proceed beyond a token defense around Moscow. This might become dismantled over time as was presumably the Leningrad system. The Russians might also over time become discouraged about the expected performance of BMD against a sophisticated threat. Their defensive weapons tradition would undoubtedly constitute a barrier to this kind of realization.

The Soviet deployment which we are witnessing today is the result of decisions which were reached several years ago, possibly in the aftermath of the Cuban missile crisis. Hence it is possible that the balance of considerations and bargaining power within the Soviet decision-making structure <u>is</u> different today than when the deployment decisions were first made. It may also be more amenable to being influenced by American actions and arguments. (1)

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(1) In this connection it may be important to note that it was around the time when the decision to deploy the Moscow System presumably was made that Marshal Biriuzov was made Chief of the Soviet General Staff (April 1963). Marshal Biriuzov was a former head of the Soviet air defenses (PVO) at the time (1955-62) when most of the current anti-aircraft missiles were emplaced. Marshal Biriuzov was killed in an air crash in October 1964 and succeeded by his predecessor Marshal Zakharov from the Army. It is also possible that the departure of the air defense chief Marshal Sudetz (a strong BMD advocate) from the Central Committee in April 1966 and his replacement as commander the following summer by army General Batitzkij reflected some dissension about the magnitude and priority of the Soviet BMD effort which may have been resolved in favor of a moderate deployment. It was in April 1966 that Malinovskij introduced the formula which has since become the standard assertion, <u>viz</u> that the Soviet Union is able to "shoot down all (sic) enemy aircraft and many enemy missiles.

So far there is however little evidence of any change in the Soviet verbal position. The performance of their SAM's in North Vietnam may cause some to question the utility of investing heavily in technically sophisticated active defenses. The general experience with how they manage or do not manage to make intricate systems perform with high confidence in their economy might also case the political-technocratic leadership to question the advisability of a major BMD-effort. Should, however, the Soviet image of active defenses as desirable and stabilizing elements in the strategic balance prove to be unalterable there may be a good case for exploring with them the possibility of stablizing a strategic balance, which included BMD on both sides, at lower levels of assured destruction. Therein lies another educational challenge which Mr. McNamara and others need to meet in their communication with American and allied audiences as well as with the Russians, viz how to develop sensible force postures in the event that BMD be deployed. The alternative to management of some kind may be a rather extensive escalation of the arms race. "It is now clear that the United States will go ahead with a limited area defense system and that there will be some acceleration of the program to phase in Poseidon and Minuteman III. It is not unlikely that there might also be a decision for some hard-point defense of the Minuteman missiles in the near-term future. These decisions could conceivably constitute a kind of stable compromise posture alleviating the pressure from the strong deployment - now advocates in the U.S. and preserve the option of arriving at some arrangement for arms race management with the Russians who appear to have been unwilling to talk so far. (Vietnam has not prevented them from talking about non-proliferation.)"

Hegemony and Political Mobility (1)

From the point of view of the middle and small powers one of the most important considerations would be the anticipated impact of BMD on the political freedom of action which they enjoy on the international arena. It has been asserted that BMD would tend to re-establish a system of strict bi-polarity based on superpower dominance. Sometimes the argument is carried further by predicting the transformation of a counterpoised hegemony into a Soviet-American condominium aimed at regulating the international system.

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(1) These and other European issues are treated more extensively in my forthcoming Adelphi-paper on "BMD and European Perspectives."

Relatively effective hard-point defenses might, as we have argued above, serve to stabilize the strategic balance. They might thereby also contribute towards de-coupling a wider area of international politics from the influence of the strategic nuclear balance. The fear of inadvertent escalation to nuclear warfare would be less of a dominating factor in international crises. Hence BMD might in fact corrode the hegemonial position of the superpowers to the extent that dominance is associated with their nuclear capabilities.

Area defenses could serve to make the societies of the superpowers less vulnerable to nuclear attacks than those of the other powers in the international system. They would, however, constitute more likely targets. It is possible that the increased protection could erode some of the present restraints on intervention, but it is not very likely. It could also provide incentives for indirect (proxy) deterrence whereby the allies of the adversary are kept as nuclear hostages. There is likely to be a definite asymmetry in this area as it is hard to imagine the United States pursuing such a strategy of deterrence viz-à-vis the Soviet Union via Eastern Europe. It would be incompatible with the policy of peaceful engagement in East Europe and probably cause a lot of internal dissension in the United States. The interest in preventing nuclear proliferation would presumably also militate against such a strategy which would seem bound to stimulate incentives for independent nuclear forces by assigning to nuclear weapons a central role as arbiters of international affairs.

The argument about a Russo-American condominium begs the question what consensus on values would uphold the common endeavor. We can easily imagine a variety of fields where a mutuality of interest would cut across the incompatibility of basic world outlooks. Such areas would include the prevention of nuclear war and nuclear proliferation. However, what would constitute a compatible world from the American value perspective is sufficiently incongruent with Soviet outlooks to make a Russo-American global condominium a very unlikely international constellation. In any case it is difficult to see how BMD could bring it about.

From the point of view of the potential nuclear powers, BMD might look like a means for the re-affirmation of superpower dominance in the sense that it might be perceived as nullifying the threats from the smaller powers against the superpowers. BMD could so to speak raise the entrance fee for great power status and possibly be resented for that reason by certain European countries.

Other European states might consider such impacts as a virtue of the system. Let us look at the impact on the French force.

It is not at all clear that the French force de dissuasion is designed to elevate France to the level of a superpower. The primary motives behind the force are most likely to be found on the political rather than the military level of considerations. The force may be viewed inter alia as a symbol of the restoration of French self-respect, assertiveness, and prestige. As such a symbol, it may have contributed to the reconciliation of a disillusioned army and an embattled political system, in via towards a new sense of national purpose and pride. Whether the force be a necessary adjunct of French diplomacy - it is certainly not a sufficient foundation thereof - is not a question which admits of definitive answers. From a policy perspective which emphasizes the ephemeral nature of political alignments the force may very well be perceived as a necessary hedge against possible transfigurations of the diplomatic arena.

How would a substantial Soviet BMD deployment influence the French calculations concerning the efficacy of the force? The question is not an easy one to answer since it is unclear what the underlying assumptions would be. How effective must the force be in terms of its expected penetration capabilities in order to compete successfully for continued funds in the French decision-making process? The present force consists exclusively of manned bombers (a total of 62 Mirage IV-A's have been ordered) which are confronted with a reasonably impressive (as such things go) Soviet air defense system. The French deterrence calculations are probably based on the residual uncertainties in Soviet calculations, i.e., the force is believed to be large enough and sufficiently sophisticated to present to the Russians an unacceptable risk of unacceptable damage. Given the uncertainties about BMD performance that same calculation may be relevant for the future French missile force confronting a Soviet BMD system. The French force is scheduled to consist of 25-30 SSBS missiles (Sol-Sol Ballistique Strategique) by 1970 with the addition of 48 submarine based MSBS missiles (Mer-Sol Ballistique Strategique) by 1974. It is not likely that a Soviet BMD system could deny with high confidence such a force access to some key urban targets on which it might be concentrated. Whether the residual uncertainty be large enough to deter the Russians would depend inter alia on the stakes of the conflict and the political environment in which it is staged. At present it is rather unlikely that the Russians need to be deterred from attacking France and even if they do, the probability of American intervention is most certainly viewed as unacceptably high in Moscow. The conclusion is much less obvious if we postulate a conflict in which the Soviet Union is confronting France as the protector of Western Europe for high stakes and with high confidence in American abstention. To the extent that the perceived utility of the French force derives from its prospective growth into a credible deterrent in such situations, BMD may be expected to interfere significantly with the realism of the prospects. We may note also that Soviet BMD could generate European interest in the acquisition of e.g. advanced cruise missiles as substitute strategic delivery vehicles.

As I have stated above the kinds of BMD systems which the superpowers might deploy within the foreseeable future would be far from providing absolute invulnerability. The nuclear powers would still be in a position to inflict upon each other damage of a magnitude which reasonable men may be expected to find unacceptable. It is of course possible that there might be technological breakthroughs which could make defense ascendant and, somewhat more likely, that the BMD systems may come to be perceived as much more effective than they actually are. Should the French force thus be widely viewed as impotent vis-à-vis the Soviet Union it might come to look increasingly as a potentially anti-German force or as an instrument for the assurance of French ascendancy in Europe. We need not belabor the politcal conclusions which may be caused by such perspectives. Perceptions of this kind would assume the French and the British to be unable to bear the costs of an adequate penetration aids program for their missiles. That assumption is not necessarily reasonable. Furthermore, the United States would perhaps be motivated to capitalize on her allies' interests in penetration technology to bargain for the kind of strategic coordination which formerly was sacrificed in favor of the MLF-project.

It is furthermore conceivable that BMD might serve as a stimulant for a European deterrent which could constitute a force of a magnitude and quality which would make it a substantial deterrent against any power, including BMD powers. Incidentally such a development might be anti-proliferatory in its impact not only because it would tend to eliminate the participating European countries as potential and actual proliferators but also because it would set a standard concerning the requisite size of a nuclear power which would not admit of widespread emulation.

There remains also the question of whether BMD could be installed in Europe. The question is perhaps somewhat premature and it is impossible to discuss the many ramifications of the problem within the confines of this paper. We could think of an American system deployed in Europe, a joint Euro-American system, or an American-built European system. A European-built system does not belong to the realm of near term prospects. The systems of warhead control which might be designed for such a force would raise issues about their compatibility with non-proliferation. Some kind of dual-key system modelled on the Nike-Hercules arrangements is conceivable. A BMD system in Europe would also raise the issue of alliance integration. There has been some discussion of using BMD as a substitute MLF for purposes of forging cohesion. It is difficult to foresee how the system could serve purposes of such political character without entailing the risk of producing dissension and cleavage as equally likely outcomes. Given the multinational texture of Europe it is easy to see how negotiations about e.g. which cities should be accorded local defenses could have disruptive rather than integrating effects.

The Russian threat against Western-Europe is larger than that against North America measured in numbers of delivery vehicles. Thus a BMD system in Europe would have to be rather tight in order to prevent easy saturation. The relatively small defense area would however generate demands for fewer area-coverage installations than would the areas of the United States and the Soviet Union. The nuclear threat against Western Europe is multi-dimensional in character encompassing e.g. fighter bombers, short range tactical delivery vehicles and submarine-launched missiles as well as intermediate range ballistic missiles and medium bombers. BMD would not close all the gaps. There remains also the issue whether BMD would be the most cost-effective means of damage limitation in Western Europe compared to e.g. civil defense measures and a redesign of the missions and posture of tactical nuclear weapons in Central Europe.

Furthermore, it will be necessary to assess the political implications in Europe of the possible installation of BMD in its Western parts. What would be the impact on the detente and the process of normalization? There is the danger that a BMD in Western Europe might tend to perpetuate a posture and atmosphere of confrontation.

It has been reported that an area defense for Europe (American-built) would cost on the order of $3-12 billion.

American BMD deployment of any of the postures which are up for consideration would not involve requirements for American hardware installations in Europe. Canada may be in a different situation since it may prove useful to deploy the perimeter acquisition radars forward and perhaps a small portion of the area defense system. It is worth noting in this connection that NORAD comes up for renegotiation next year. Close co-operation on missile defense does not admit of dissent in crises, however. The Canadian refusal to go on full alert when NORAD called for it during the Cuban missile crisis is an ominous reminder of the limits and demands of interdependence.

The Problem of China

The Johnson Administration has decided to buy an austere ($3.5 billion) area defense system with some Sprint local defense against a future ballistic missile threat from China. The expected efficiency of such a deployment is shown in the following table.

TABLE 5

U.S. BMD Against Chinese First Strike in the 1970's

U.S. Fatalities (in millions)	Operational Inventory	
	X Missiles	3 X Missiles
Without BMD	5	10
With BMD	0 +	1

Thus Mr. McNamara has argued that such an austere defense could probably preclude damage to the United States in the 1970's almost entirely and, assuming an expansion of the BMD system adjusted to the growth in Chinese offensive capabilities, the expected Chinese assured destruction potentials could alledgedly be limited "to low levels well beyond 1985". It has been argued furthermore that an American decision was not urgent since the U.S. can deploy BMD with shorter lead times than China ICBM's. Intelligence estimation is a very complex business and the lead times may actually be far from comfortable from a point in time where the United States could reckon with having high confidence indicators about the actual time schedule and magnitude of the Chinese ICBM-effort. In fact the Joint Congressional Atomic Energy Committee has predicted in a recent report that China will probably achieve an operational ICBM capability before 1972, and be able to develop a thermonuclear warhead in the ICBM weight class with a yield in the megaton range as early as 1970.

An American BMD could in principle provide extended deterrence against China in the 1970's. There are, however, other considerations. It is conceivable that an American BMD deployment against China could be counter-productive in the sense of magnifying the importance of the Chinese threat rather than degrade it in the eyes of the Indians and the Japanese. The American deployment might in fact influence or be perceived as having influenced the relative priorities of the Chinese MRBM and ICBM programs. The former could be an instrument for proxy deterrence placing e.g. Japanese and Indian cities on the list of hostages. Thus certain American BMD decisions would seem to require some communication with the Asians affected by them.

It is also quite possible that the Chinese demand for nuclear-missile power status is quite inelastic so that any increased price therefore (as would be the result of an American BMD) could tend primarily to reduce the resources which the Chinese could allocate to other purposes such as economic growth and consumer-goods production. Such a diversion of resources is unlikely to produce a less belligerent attitude in Peking and it may hence prolong China's estrangement from the international community. These may be largely intangible considerations but they are part of the matrix of political decision-making.

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THE IMPLICATIONS OF MILITARY TECHNOLOGY IN THE 1970's

COMMITTEE I - 3

Saturday 30th September - Morning

The Future of Manned Aircraft

AIR MARSHAL SIR CHRISTOPHER HARTLEY

INTRODUCTION

The title of this lecture implies that Manned Aircraft have a future and this is the first question which we must examine. It was in fact a problem which confronted Air Force staffs in the late forties, once they had realised the potential impact of the guided missile in all its applications, and to-day it is still a prime question. For how long and in what direction does the manned aircraft have a useful future?

As a starting point I recall my own views of those days and in particular the errors in my first analyses, because they may still be relevant to-day. Broadly, one could see a long future for strategic transport and maritime aircraft, a much shorter life for the free-fall strategic nuclear bomber and a debatable life for tactical air power, with battlefield support probably surviving longest. The main areas for speculation were: the general rate of missile development, the particular solution of the low-level interception problem both for SAMs and for fighters, and the development of ground-to-ground tactical missiles with an accuracy which could match that of the manned strike aircraft. The main gross error was that one consistently underestimated the time-scale of new weapons, that is to say the rate at which what appeared technically feasible could be developed, engineered for service use and placed in the hands of suitably trained troops. The second gross error was that one did not make adequate allowance for the development of manned aircraft systems and tactics which could offset the potentially commanding position of the missile. The compounding of these errors could well have led one to predict a demise of the manned combat aircraft in the tactical role at the latest by the mid-sixties, had one been required to look so far ahead. The third gross error, which was partly a consequence of the first, was that one had no feel for the ultimate cost of new weapons and hence for the rate at which Nations could afford to re-arm their front lines. Finally, the low-level interception problem has proved even more intractable than expected and the manned aircraft is still the only available means of delivering high-explosive warheads with the requisite accuracy outside the range of artillery; no ground-based missile solution has yet emerged.

Twenty years of practical experience have given us a much better feel for these problems, although from time to time we are still apt to underestimate the costs of new systems. We can now see that it is always possible to argue a new development, offensive or defensive, out of court merely by overstressing its own development problems and underestimating the difficulties of the enemy in developing a timely and practical counter to it, even if such a counter can be foreseen in principle. The offensive/defensive situation has been a fluctuating struggle with neither side obtaining an overwhelming and permanent advantage and one foresees this situation continuing. Hence the manned aircraft is still very much with us and new combat types are being developed for all the major air forces. Only the high-level strategic bomber appears to be on the decline, but even here it would be feasible, though not necessarily economic, to prolong its life by giving it a long-range stand-off missile. It was no doubt considerations of cost rather than technical feasibility which led the U.S. to invest in Minuteman and Polaris rather than Skybolt.

COMBAT AIRCRAFT: PRESENT AND FUTURE

The quest for performance, dictated primarily by the fixed gun-armament of the fighter which necessitated attacks from astern, has led us to-day to a generation of aircraft with top speeds from Mach 2 to 2.5, about the maximum achievable with aluminium alloy structures. In parallel, developments to airborne radar and air-to-air guided missiles have produced systems which allow the fighter to attack targets of superior speed and altitude performance with a high expectation of success. Hence the pressure for better fighter performance, which paced airframe development since World War I, has tended to decline and, because of the foreseen potential of both fighters and high-level SAMs, it has not as yet been replaced by a demand for much higher performance in the offensive role. It is now feasible to consider bombers capable of flying at Mach 4 at heights of 85,000 ft. or more, but the development problems and costs would both be formidable and the degree of immunity obtained against contemporary defences probably marginal. Furthermore, the problems of target location and accurate weapon delivery become much more severe. A bomber of the type mentioned would weigh and cost at least twice as much as a Mach 2/60,000 ft. aircraft. It therefore becomes questionable whether this is the best way of investing development money.

One hesitates to be dogmatic since it is highly probable that the hypersonic aircraft will in due course be built though its first roles may well be in the transport and reconnaissance fields, and it is unlikely to be suitable for low-level operation. However, I believe that we have reached something of a plateau in those aspects of performance (top speed and ceiling) so far discussed and that for the next ten years development effort will be focussed on other facets of the combat aircraft. Indeed we are already seeing something of a reverse trend, in the development of relatively cheap and (in the speed sense) unambitious aircraft such as the U.S. F.5 and A.7 and the Anglo/French Jaguar. These aircraft are the direct result of the sophistication of the modern Mach 2.5 strike/fighter. In the forties and fifties the need for close support could be met by adapting current or obsolescent fighters, which were relatively cheap to buy and operate in adequate numbers and could take care of themselves to a large extent in air-to-air combat, should this occur. Sophistication has led to much higher first costs and maintenance costs which make it increasingly hard even for the major powers to pay for a large close-support force. In supporting armies in the field, the number of aircraft available is often of greater importance than the weapon-load per aircraft, since there will be many calls for support which can be better met by a very quick reaction with a modest weapon load rather than by a slower reaction with greater punch and sophistication. There will also be many occasions when it would be uneconomic and unnecessary to expose very expensive aircraft to battle damage from ground defences, if cheaper units are available.

However, these relatively simple aircraft cannot by themselves be wholly adequate. Against an enemy with more sophisticated fighters, they could only gain air superiority by a pre-emptive and highly successful strike against airfields, and although we have recently seen this achieved by the Israeli Air Force we cannot assume that pre-emption would be politically acceptable (or that the conditions which made for its success in this case would always be present). It is more likely that political restraints will lead to a situation where it is not permissable to eliminate enemy power at source, in which case one must be able at least to contain the enemy and preferably to exclude his aircraft from the battle zone and his own rear areas. This task demands a very advanced fighter capability, both for pure air defence and for air-to-air combat.

I would therefore expect the present dual trend of development, the sophisticated strike/fighter and its cheaper complement, to persist into the next generation, although the cheaper element of the force will make relatively more modest demands on advanced technology.

DEVELOPMENT AIMS FOR THE FUTURE

Assuming that we may have reached a plateau in respect of top speed and ceiling of strike/fighter aircraft, there are other performance parameters which will call for close attention in our next generation of aircraft, and which must as far as possible be met within the limits of a light alloy airframe. The most important of these parameters are manoeuvreability, range-payload and take-off and landing requirements. These will vary according to the designated role of the particular development project. We mentioned earlier the need for advanced figher capability. Manoeuvreability, particularly acceleration time and energy manoeuvres, are vital features of this capability. Apart from performance, there are other areas of major importance in producing effective and practical aircraft of the next generation, in particular the ability of the aircraft to penetrate and survive, to locate targets and hit them accurately, to be as reliable as possible in flight, and finally to be readily maintainable at the lowest possible cost and hence to achieve high availability in war. There can also be great attractions in achieving a truly multi-role aircraft, if one can avoid the pitfall of the "compromise" aircraft which can undertake all roles but does not properly meet the needs of any of them.

Even if we accept the relatively modest top speed of Mach 2.5 imposed by light alloys, the design of an aircraft which shows significant improvements in all other aspects over existing types presents a considerable challenge to every branch of Aviation Technology. Clearly, this paper can present only a very broad survey of the possibilities, but the areas of greatest technological importance will emerge if we consider the operational requirement under four main headings: Aircraft Characteristics, Equipment and

Systems, Reliability and Vulnerability. Some of the factors already mentioned, such as survivability, are a product of all four of the above headings; while this complicates the presentation of the subject, it also reflects the complexity of the aircraft designers' task.

AIRCRAFT CHARACTERISTICS

In the airframe field per se the major new technique available to us is Variable Wing Sweep (the term Variable Geometry is more general since it can apply to engine intakes and exhaust systems as well as to wings). Considering the airframe-engine combination, the major advance has been in the development of vertical take-off and landing (VTOL), particularly associated with direct-lift and vectored-thrust (lift-propulsion engines) although there have also been significant advances in rotary-wing techniques, such as the rigid rotor. None of these techniques has, as yet, been fully exploited.

In engines there has been a steady and significant improvement in power/weight ratio and specific fuel consumption, accompanied by occasional discontinuities such as the introduction of the by-pass engine and turbine-blade cooling. We can look for further significant improvements, particularly in power/weight ratio, the extent of the improvement being largely a function of the date on which we need the new engine.

Variable Sweep

Aircraft designers have long been aware of the incompatibility of requirements for high supersonic speed at medium and high altitudes and for range at subsonic speeds in ferry and low altitude strike missions. The result was the design of specialist interceptors, perhaps with a limited strike capability and specialist strike aircraft, perhaps with a limited intercept capability. Variable sweep offers the prospect of designing a multi-role aircraft with consequent reduction of defence costs. However, a variable sweep aircraft can be relatively inefficient under all conditions unless great care is taken in choosing the main design parameters such as hinge-position, wing thickness-to-chord ratio, aspect ratio in swept and unswept states, wing loading, engine thrust and by-pass ratio.

The need to break the wing at some point generally leads to an increase in structure weight since the loads from the outer wing have to be concentrated in the hinge region and to a loss of stowage volume since parts of the outer wing retract into the inner wing. There are other mechanical and weight penalties associated with the sweep mechanism and with sealing the gaps occurring between the two wing sections.

The advantage of variable sweep lies in the fact that the configuration of the aircraft can be adjusted to suit the conditions - high sweep for high Mach number and, since the aspect ratio is then low, for high speed at low altitudes; low sweep/high aspect ratio for take-off and landing and long endurance at high altitude. The high aspect ratio allows the use of efficient leading and trailing edge devices to reduce take-off and landing distances and achieves high lift-to-drag ratios to increase range in subsonic cruise. The low aspect ratio in the swept condition, which is necessary for supersonic flight, also improves flying characteristics in the transonic region and gives the crew a smoother ride at high subsonic speeds at low level.

A low wing loading is required for good field performance and long range subsonic cruise, but a high wing loading is required for high speed at low altitude and rapid acceleration to supersonic speed at high altitude. A relatively high wing loading generally provides the best compromise for a multi-role aircraft. This means that very effective high lift devices are necessary to achieve good field performance.

In positioning the wing hinge, designers have so far preferred a station outboard of the fuselage, but there are indications that a hinge within the fuselage would show overall advantages. In particular, virtually the whole of the wing is then available for high-lift devices to improve take-off and landing performance. This may well be an area in which the potential of variable sweep has not yet been fully exploited.

The choice of engine is critical to the success of the designer and must depend on the relative weighting placed on the various roles which the aircraft is to fulfil. A high by-pass ratio engine is generally to be preferred if the main requirement is for a long range subsonic capability and this type of engine may also be suitable if additionally a high rate of climb is required since a considerable amount of reheat boost can be applied. However, if a long supersonic radius of action or a high speed low altitude capability is required without reheat a low by-pass ratio engine will be preferred because of its high thrust at high subsonic speeds. It is difficult to generalise since the high by-pass ratio engine is generally heavier and requires a larger fuselage for its installation. Probably the most difficult case to meet is that of the interceptor required to patrol for a long time in the combat area and then engage in combat at supersonic speed at high altitude. If a short patrol time is acceptable the low by-pass ratio engine with its associated low drag airframe may be the best choice, but if a long patrol time is required a high by-pass engine will generally show to advantage. The multi-role aircraft thus involves a difficult compromise even when full advantage is taken of variable sweep. There is a clear conflict between the fighter and strike/reconnaissance roles and the long-endurance fighter generally proves the most expensive case, since an aircraft designed to meet this requirement can also have good range/payload in the strike role, but it tends to be larger and more expensive than a variable sweep aircraft designed primarily for the same strike performance. The long-endurance fighter is primarily a Naval requirement for air defence of a Carrier Task Force, but it could also be needed for air defence on land, particularly as a standing patrol against low flying enemy strikes and also for fighter cover to the strikes of the less sophisticated aircraft discussed earlier. The final choice of compromise must rest with the Air Force which orders the aircraft.

VTOL

VTOL is a rather diverse category, since it involves both jet-lift and rotary-wing technology and hence carries us into the field of tactical transport as well as tactical combat aircraft. At this moment we have only one kind of VTOL aircraft in service, the helicopter.

Helicopters provide the only means of landing men and equipment to forward operating positions. They are essentially short range, slow and vulnerable aircraft, relatively expensive to maintain and difficult to move rapidly from the home base to distant combat areas. But despite these disadvantages, we have seen an immense proliferation of military helicopters in the last ten years, which indicates that VTOL in this context is worth its cost. With the development of rigid rotors, we can expect maintenance problems to decrease, range to increase somewhat and top speed and manoeuvreability to improve significantly. This will ease the problems of the helicopter in its present basic role of front-line logistic support and may well lead to the amplification of its more recent role, in providing fire-support for infantry assaults. But the task of delivering men and equipment directly into the operating area and of attacking targets behind the immediate front line may be better met by other methods, and some of these can be applied to combat as well as transport aircraft.

The methods available are deflected engine thrust, light-weight lift engines, tilt wing, stowable rotor, or a combination of two or more of these methods. The preferred solutions will vary according to the role of the aircraft. It may be argued that the main engine should have a thrust sized for the mission flight conditions and that the thrust should be deflected for take-off and landing and be augmented for VTOL operations by light-weight lift engines. This is probably true in the case of transport aircraft, which normally require a thrust-to-weight ratio of about 0.3, but in the case of strike/intercept aircraft, requiring normally a ratio of about 0.6 the situation may be more open, as indicated by the development in the UK of the Harrier strike/reconnaissance aircraft which employs a single deflected thrust engine.

For combat aircraft VTOL offers some obvious and substantial attractions. Because of their independence of prepared airfields, they can be deployed close to the front line, thus improving reaction time both for strike and for tactical reconnaissance; and they can be widely dispersed to increase their chances of surviving a pre-emptive air strike. There is no doubt that the recent task of the Israeli Air Force would have been gravely complicated, had they had to deal not only with airfields, but also with 200 to 300 aircraft of the Harrier category, dispersed and camouflaged over a wide number of unknown locations in the UAR. Given these attractions, why is it that this application of VTOL is not being more actively pursued? At the moment, the UK is the only country in the West which has a VTOL combat aircraft in production. There is no technological barrier; what then are the offsetting penalties?

First and foremost comes cost. A VTOL aircraft will be significantly heavier and more expensive than a conventional aircraft of the same performance in top speed and range-payload, even if this is a VG aircraft capable of operating from airstrips as opposed to long concrete runways. Alternatively, for the same all-up weight, the range/payload of the VTOL aircraft (operating in this mode) will be well below that of its counterpart, though this can be considerably mitigated if a short ground-roll of 300-400 ft. is possible before take-off (the deflected-thrust solution shows up particularly well in these circumstances).

Secondly, there are logistic problems associated with the preparation of VTOL sites which could involve some sort of light-weight platform and subsequent support with fuel and ammunition. Opinions differ on the severity of these problems but the recent trials of the experimental Kestrel squadron in the UK indicate that they can be kept to manageable proportions by a sensible use of the aircraft. Nevertheless, some extra airlift will be needed and this will add to the total cost of the VTOL system.

Thirdly, there are problems of command and control, and of protection against attacks by ground forces. Without secure communications the quick-reaction potential of VTOL will be lost. In a situation like South Vientam, dispersal of aircraft on the ground in penny packets would make them very vulnerable to guerilla attack, a hazard which would outweigh the possible improvement in reaction time. These problems again can be reduced to a minimum when the VTOL aircraft are operating from sites within the Army's area of deployment, although this would not always be consistent with maximum dispersal for protection against a pre-emptive air strike.

It is to-day a matter of opinion whether the advantages outweigh the disadvantages and justify the higher costs of the VTOL combat aircraft. The ground-rules of cost-effectiveness can be framed to show the aircraft in a very good or very bad light, depending on the scenario and the weight given to the pre-emptive strike risk. My own view is that, because of its inherent flexibility, this kind of aircraft will be widely developed, but perhaps in relatively slow time in the hopes that its high cost can be mitigated by further advances in technology.

EQUIPMENT AND SYSTEMS

"Equipment and Systems" is a wide term, covering navigation, target location, weapon aiming, the weapons themselves, flight systems and the presentation of information to the crew. It also embraces the vital but less glamorous parts of the aircraft such as generators, hydraulics and fuel pumps.

Navigation

To the classic navigational aids of ground-based radio and radar beacons and air-to-ground radar mapping, which were developed during World War II, there have now been added airborne doppler radar to measure ground speed, automatic astro-tracking, inertial platforms and electronic computers. Although ground-based aids can provide very accurate fixing, they may be subject to interference and may not always give the coverage needed. The tendency therefore has been to develop a self-sufficient system for strike/reconnaissance aircraft, by improvements to the discrimination of air-to-ground radar, coupled with an inertial system and a computer. This trend will continue. Inertial platforms are already available with errors of less than one mile per hour of flight, and airborne digital computing, with its greater versatility, is beginning to make an impact.

Because of the need to exploit the continuing difficulties of low-level air defence, the strike aircraft of the future must incorporate some form of terrain avoidance system. A fast low-flying attack presents an acute problem for SAM defences, with minimum height paying a greater dividend than maximum speed. Ideally, what is needed is a fully automatic system which will fly the aircraft safely at minimum height in any weather conditions, freeing the crew to attend to other tasks. Needless to say, the system must be highly reliable and must also be designed to feel safe. Systems of this type, comprising a special forward-looking radar coupled through a computer to the auto-pilot, are already in being. The future trend will be towards improving their accuracy and reliability to allow progressive reductions of height without loss of safety.

The ability to fly very low brings its attendant en route navigational problems, particularly in identifying check points, which will appear only briefly and at short range on a forward-looking radar. This difficulty can be reduced by climbing to get a better radar view shortly before the predicted arrival at the check point, but the aircraft then becomes highly vulnerable. There are strong arguments in favour of fitting sideways-looking radar as this can improve coverage and the check point will be kept in view for much longer, even at very low level. Aerials of this type were in fact an integral part of the TSR.2 navigation system, but the TSR.2 had a fixed wing and such aerials may be more difficult to instal in a variable-sweep aircraft.

Target Location and Weapon Aiming

The effectiveness of a strike aircraft depends on the ability of the crew to choose tactics to enhance their chance of finding the target and to degrade the effectiveness of enemy defences, and on the ability to deliver weapons sufficiently accurately to destroy the target. Unfortunately, many tactics, such as the use of low altitude or night attacks, which degrade defence effectiveness, also degrade the chances of finding the target and attacking it with sufficient accuracy, so means have to be found to redress the balance.

A target may be attacked directly or, if the target position is known, by reference to some nearby point, but in either case it is necessary for the aircraft crew to recognise a particular point. If conditions allow visual search, it will be more efficient if the area of search can be reduced. Using an inertial navigation system, the pilot can reasonably expect the target to appear in a small forward zone. But by night or in poor visibility by day, visual search will rarely be effective in a fast aircraft and other means are called for. Radar bombing is a well-established technique and will no doubt be improved by the use of higher frequencies to achieve better target recognition: the use of low light T.V. and image intensifiers may also prove useful. Another technique which might be promising is the use of laser beams to mark the target, the beam being directed by a forward air controller, either on the ground or airborne. This technique may be particularly valuable for aircraft operating in close support of troops, when it is difficult for high performance aircraft to find their targets, and will be useful by day as well as by night.

The accuracy of weapon delivery depends on range to target, speed, height, wind etc., at the instant of release. The inertial navigation system can provide accurate measurements of most parameters, with the exception of range which can be provided by a radar or laser. The release point can be computed continuously and the weapon automatically released when the conditions are right. This degree of automation in the final stages of the attack can also eliminate the crew as a further source of error.

Strike Weapons

The armament hitherto used comprises cannon, rockets, free-fall bombs, usually of 250 lbs. to 1,000 lbs. but occasionally up to 3-4,000 lbs., and napalm. A small proportion of the total weapon load carried is sufficient to destroy targets such as tanks, parked aircraft and personnel (provided a hit is obtained) and in these cases the aiming error is offset to some extent by the spread of weapons such as cannon-fire, rockets and napalm. Other targets such as dams, bridges, bunkers and concrete buildings are so tough that a large amount of explosive is required for their destruction, and in this case the aiming error has to be allowed for by using weapons in a stick or by repeated attacks, both rather crude solutions and wasteful of air effort. Improvements in warhead design including the use of new concepts for focussing and directing explosive effects will give HE warheads more damaging power, especially against "hard" targets. Against the softer targets (and even against armoured vehicles), the effectiveness of attack can be greatly increased by carrying the weapon load in the form of small bomblets which can be scattered over an area, either directly from a dispenser on the aircraft, or by a droppable store which scatters bomblets on impact. The art of dispensing bomblets is in its early stages and the precision with which the bomblets can be distributed over the desired area to match the size and vulnerability of the target can certainly be refined.

Free-fall bombs can only be delivered safely and effectively from medium heights or in a dive. For low-level attacks, the bombs must be retarded to ensure that the aircraft is well clear of the bomb explosion. This can be done aerodynamically by flip-out air brakes, or by retarding rockets. The former means is adequate for a surface-burst, but where the bomb is required to penetrate, e.g. for cratering a concrete runway, we need a combination of rockets to retard the bomb, turn it into a steep trajectory and then accelerate it.

Rocket-propelled weapons can be very accurately guided over short ranges but present guidance systems use line-of-sight aiming which exposes the aircraft itself to close-defence fire. The next stage is to produce a missile which will allow the launching aircraft to remain at low level, well outside the coverage of close defences. This calls for a missile with a better range, with accurate terminal guidance and probably mid-course guidance. Homing techniques will probably use active radar, television, including low-light to extend to night operations, and passive radar for the attack of surface radars. Mid-course navigation may be by cheap inertial navigation or command guidance to radar line-of-sight. Although the emphasis will be towards systems which allow the aircraft to launch its missile and leave the area immediately, the solution of the problem is complex and it seems likely that for many years the crew will have to participate at least in the early phase of weapon flight. The first generation of these weapons is now being developed. The guidance and propulsion systems involve a weight penalty which reduces the warhead weight and hence its effectiveness, compared with a free-fall bomb. On the other hand, its accuracy is greatly increased and, combined with the development of warheads with greater damage potential, it can offer the alternative to the inefficiency of stick-bombing or repeat attacks on "hard" targets.

The Fighter Requirement

So far we have dealt only with the offensive. The multi-role VG aircraft, if fitted with a "coherent" radar and suitable air-to-air missiles, can detect and attack aircraft at any level above or below, while patrolling at medium heights. Such aircraft can have an autonomous air patrol capability, but standing patrols are notoriously wasteful of air-power. The problem could be reduced by developing a specialised aircraft equipped with a high power coherent radar which could give long range detection and early warning of targets flying at any altitude.

We have already considered the difficulties of reconciling strike and fighter performance in one basic aircraft. Coherent radars, essential for interception, are inherently less efficient than pulse radars for air-to-ground work. This is a further area for compromise, or alternatively for further development.

There is one other development area in the fighter field which arises from a combination of recent combat experience and a further consideration of weapon requirements in times of "marginal peace" or "confrontation". In both these situations the fighter pilot may have to identify his target visually and will certainly have to fire at relatively short range. Current systems cannot deal with this situation, because they are designed to meet the more extreme cases discussed earlier. What is wanted is a missile with a very short minimum range, a high lateral acceleration and a large sensor look angle, so that in effect the missile can side-step. This type of missile will also be useful in close combat situations generally, either between fighters or in the melee usually ensuing when fighters get amongst a raid of strike aircraft. Since the missile does not require a long range, it may prove to be relatively small and cheap; at least this should be the aim of future development.

Controls and Displays

The complexity of sensors and system controls has been increasing dramatically and it is now a major problem to ensure that the aircrew can continue to operate them efficiently. In particular, problems arise in the design of automatic flight control equipment, in the display of information to the crew, and in reduction of their work-load.

The development of supersonic aircraft has led to the introduction of powered controls to assist the pilot and most modern aircraft make no provision for reversion to manual control. These controls must include an artificial "feel" effective throughout the flight envelope, which will help to prevent the pilot damaging his aircraft by coarse movement of the controls at high speeds. Generally speaking there has grown around the original mechanical control system a series of ad hoc measures including hydraulic or electric power assistance to achieve auto-stabilisation and the addition of a separate auto-pilot.

This process has probably reached its limit in complexity and efficiency, and the next logical target is the development of a fully integrated flight control system, probably with complete electrical signalling in place of mechanical linkages. The ultimate goal is a fully integrated system able to provide high authority auto-stabilisation and new control characteristics - the so-called maneouvre demand system - with the present cumbersome control column replaced by a finger-tip control to save space in the cockpit. It goes without saying that the very high reliability needed in such a system will demand duplication and a substantial degree of redundancy.

The method of displaying information to the aircrew has tended to grow piece-meal, but human adaptability overcomes many of its weaknesses and as a result there has been a rather slow acceptance of apparently better ways of doing the job. Nevertheless, it is now recognised that a limit has been reached and that something must be done to reduce the crew's work-load. The basic flying and navigation tasks have been greatly reduced, but as a direct result the problems of aircraft systems management have greatly increased. The problem cannot be solved merely by fitting more instruments; it demands a new approach whereby the crew are presented only with that information which is relevant to the job in hand, i.e. the information which they have called down, plus an automatic warning of faults if they develop.

The development of airborne digital computers per se is well advanced, and there is little doubt that they will in future be used for most airborne data processing and management tasks.

However, much detailed systems development remains to be done before we can take full advantages of the potential high reliability, flexibility and low cost in application to the whole avionics system of the aircraft. The best hope probably lies in a building-block approach so that the same basic computer bricks can be used for both simple and complex requirements.

The technical problem of data-handling and presentation is probably not beyond the present state of the art. Already airborne digital computers and electronic displays are capable of such tasks. The major problem is that of assessing the data to be handled, the presentation of data, the facilities available to the aircrew for alternative selection of basic and processed information and finally to prove that the new techniques are reliable and practical. There is every indication that research into the special area of human engineering will grow during the next decade and the efficient use of tomorrow's combat aircraft depends heavily on the success of such work.

RELIABILITY

The effects of unreliability are felt in two ways. An aircraft can sustain defects and failures before, during and after take-off which compromise the success of the mission, and to compensate for this more aircraft have to be deployed. Secondly, maintenance effort (men, spares and test equipment) is needed at operational airfields to trace defects and repair failures. This is an expensive process; over a ten-year life an aircraft might well consume spares about equal in cost to the original production cost, while the cost of maintenance facilities and manpower might come to about the same amount. Improvements in reliability can therefore result in very substantial savings. For example, it has been estimated that an aircraft costing £1m. to produce, with a MTBF of 5 hours could show a saving over ten years of £⅓m. if its MTBF could be reduced to 20 hours - a figure which does not appear to be too difficult to achieve, even at the expense of some increase in R. & D. cost to achieve the improved reliability. The mission success rate would, of course, also be improved.

Somewhat surprisingly perhaps, quite a high percentage of defects and failures arise in the airframe itself and, although most of these do not result in abandonment of flight, they do require maintenance effort and may result in the aircraft being grounded until it has been repaired. Structural defects are largely due to such things as rivets popping, skin-cracking at rivet holes, fractures in castings due to fatigue, bird strikes and debris impact. Many of these will be reduced as better ways are found of casting and forging and the effects of fatigue may be minimised by the increasing use of high damping materials such as carbon fibre composites, which should at least reduce the transmission of vibration through the structure.

The problems of engine maintenance and overhaul strain any supply organisation, not only in the sheer cost of spare engines but in having them in the right place at the right time, and in the disruption caused by taking aircraft out of service for engine change. Great strides are being made in increasing engine overhaul life, largely through the use of materials which will operate at higher temperatures. The search for such material is dictated largely by the demand for higher powers for both military and civil aircraft, but it provides an extremely useful by-product by increasing the reliability of engines designed to run at slightly lower temperatures.

In flying control systems and avionics the problems are largely those of detail design for reliability, and the avoidance of loading every component to work at its limit all the time. This may seem to be retrograde, implying increased weight, but this is often rapidly offset by the adoption of new materials or by the use of new techniques, of which an example is the micro-miniaturisation of electronic components.

Over a number of years the reliability of aircraft has, if anything, been tending to decline. Although component reliability has been improving, this has been more than offset by a big increase in the number of components due to the introduction of extra and complex equipments. The net result is that the defect and failure rate has tended to increase. This does not mean that the expectation of failure per mission has increased, since some equipments may not be needed for a particular flight and some of the extra components are there to provide duplication to improve the flight success rate. Micro-miniaturisation should improve markedly the component and circuit reliability, but the resultant savings in weight and space may tempt designers to increase duplication in order to increase the chance of mission success. The net result could then be no improvement on current defect and failure rates.

Although the flight success will hopefully be improved by these measures, the defect/failure rate may still require a large maintenance effort. It may be possible to reduce this by the use of self-checking equipments and automatic test equipment which will help to locate breakdowns so that the unserviceable item can be extracted quickly and replaced by a new item. This will save a large amount of servicing effort devoted simply to trying to find and isolate defects reported by the aircrew. We must not forget, however, that only 10% to 30% of all defects and failures occur in the avionics equipment. Thus even if we managed to halve the equipment defect rates, we should reduce the overall defect rate by only about 10%.

Lastly, let us not forget that every improvement in reliability and in fault diagnosis will reduce the opportunities for generation of faults by clumsy humans trying to put things right!

VULNERABILITY

Early in World War II it became uncomfortably clear that many aircraft might have been saved by greater attention to vulnerability in the design stage, and the measures which were then applied to new and existing designs included the fitting of armour, inert gas purging, self-sealing tanks, fire-extinguishers and the relocation of vulnerable items. But since 1945, vulnerability has not really been given adequate attention, partly because during the 50's we were designing primarily in the "all or nothing" atmosphere of nuclear war.

However, tactical aircraft will continue to be used in environments where they will be attacked by conventional weapons and one of the Vietnam lessons is that even small arms fire can inflict unacceptable damage on highly sophisticated and expensive aircraft. By paying proper attention to vulnerability throughout the design phases, protection against attack by most types of conventional weapons can be considerably improved.

The protective measures open to us include, besides armour, such measures as duplication and separation of systems, dispersal of key units, and improvements in materials and methods of construction. Where vulnerability is considered only at a late stage in the design, armour is often the only possible answer because of the difficulty of making any basic layout change, but for a given weight increase the other methods offer a greater potential.

Reduced vulnerability can only be obtained at a price which must be balanced against the advantages. An analysis must be made of the probability of a hit and the extent of the damage likely to result from it, taking into account the damaging agent, the direction of attack, the flight condition of the aircraft and the limit of of damage which would be acceptable, i.e. delayed destruction, mission frustrated, aircraft grounded for X days or requiring Y man hours repair before becoming operational again. The extent of the damage will depend on the damaging agent and the area most damaged will be influenced by the direction of attack. The response of the aircraft to damage may be greatly influenced by the flight conditions: for example, the disturbance to the flight path of a low flying high speed aircraft may be disastrous whereas recovery may be possible if the aircraft is flying sufficiently high.

The analysis will generate design proposals to reduce vulnerability, which must then be assessed in relation to their effect on cost, weight, performance and reliability of the aircraft. The process is only likely to pay full dividends if the operational analysts and specialists in maintenance, design and vulnerability work closely together (and with the designers) from the time of the preparation of the operational requirement to the detailed layout stage.

CONCLUSION

We have now reviewed briefly the steps required in order to produce another generation of manned aircraft which are significantly better than current types. I hope you will agree that, while the task is not impossible, it calls for a very considerable technical effort. Should the hypersonic aircraft be developed the problem of systems reliability, for example, will be very much more difficult. Nor will it be a cheap exercise in terms of R. & D.; but it can lead to a real increase in military potential at the same or even lower front-line running costs.

We have spoken mainly of the advanced tactical strike fighter, as this is the most difficult case and you may be wondering what happed in the process to its cheap and simple counterpart. Many of the developments we have discussed will read across into the simpler aircraft, particularly in the fields of reliability and vulnerability and in general engine, airframe and systems technology.

Some of the more sophisticated and advanced equipments are likely to be ruled out on grounds of space and weight alone. For the others, simplicity and cheapness must be balanced against operational effectiveness. It is ultimately for the customers to decide how far they will pursue sophistication, but for an aircraft intended primarily for close support, much can be achieved by making full use of ground-based aids or by working in close conjunction with its more sophisticated brothers. My own vote would go for simplicity.

Committee II 1- 6

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THE IMPLICATIONS OF MILITARY TECHNOLOGY IN THE 1970S

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Ocean Technology and Submarine Warfare

JOHN P. CRAVEN

The effect of modern technology on the use of the sea for strategic purposes and, in particular, its effect on strategic submarine warfare is difficult to assess in an unclassified paper. The minimum requirement, that the paper on its face be subject to critical analyses and rebuttal, can not be met since the vital information relating to the effectiveness or lack of effectiveness of specific technologies are in the domain of classified information. The author, who writes an unclassified paper, but who has access to classified information and is bound by the strictures thereof must, of necessity, appear ignorant, vague or dogmatic in areas vital to his thesis. If this limitation is recognized by the reader, it may then be possible and useful to remain in the unclassified domain and still enumerate problems and trends of developing technology which will force the direction of the evolving strategy of the sea.

NOTE: This paper is in two parts. The first portion is a restatement of the development of the law and strategy of the oceans as it has been affected by the technological constraints of the free surface. It has been restated to provide a basis for examining changes in the law and strategy of the oceans which might result from a developing undersea technology. The reader who is familiar with this restatement may prefer to scan this section and proceed directly to Part II which is devoted to the main theme.

PART I

At the outset, it is necessary to characterize todays opportunities and constraints on the use of sea power as an element of national defense. The single most important element in this consideration is that until 1954, the military use of the sea was by systems confined to, or constrained by the free surface. Until that date, which is recognizable as the operational readiness date of the atomic-powered submarine, USS NAUTILUS, even ships classed as submarines were, in fact, surface craft which were submersible for short periods of opportunity. From a military and strategic standpoint, this tie of all ocean systems to the free surface resulted in the following constraints and opportunities:

(a) Under certain conditions of wind and sea state, the sea system becomes inoperative and in physical peril even with the best technology available today or projected for the future.

(b) Under moderate or modest sea conditions, it is not possible to make a landfall at an arbitrary portion of the coast for transfer of personnel or cargo. The sea system is thereby tied to the existence of a network of friendly, sheltered harbors.

(c) The speed of transit of displacement forms is limited by power considerations.

(d) The system is frequently and unavoidably visible in the optical and electromagnetic spectrum.

(e) The systems are accessable to aircraft which can employ them for attack, surveillance or logistics and are, in turn, vulnerable to surveillance or attack from the air.

(f) Large volumes and tonnages can be easily accommodated, limited in general only by draft and size of harbor.

These characteristics which are peculiar to the free surface have shaped the law of the sea, military tactics, strategy and the maritime supermacy of nations with favored geographic configurations. A brief recapitulation of the effect of the free surface on each of these factors will set the baseline from which changes, due to submarine warfare, can be assessed.

Turning first to commerce, it is noted, even after a brief examination of Admiralty Law that the perils of the free surface have heavily shaped its form and substance. Salvage, jettison, general average, contribution, fire at sea, priority of liens were the major topics of the Rhodian Code and are major topics of Admiralty today. With such a perilous form of commerce, the community solution is soon arrived at and consists of forms of social compact which spread the risk, encourage cooperative action and venture and which place a high premium on keeping ships effectively working at sea. As a result, many anomalies of the law of the sea are created. For example, the right of salvage which permits an intervenor to acquire a vested right by taking under tow an abandoned ship is unknown in land law. In the instance of abandonment at sea, the ship would soon break up and perish were it not for the salvor. A social benefit from intervention thus accrues. On land, the forces of deterioration are sufficiently slow that no benefit results from the intervention of a salvor and, as a consequence, the general land law is that the right of the owner to retain exclusive title is unimpaired Other dissimilarities between sea and land law include the duty to engage in rescue at sea, the partnership between shipper and ship and the inversion of the normal priority of mortage liens. Each can be traced to the forces associated with the air-sea or sea-land interface. These perils of the sea which shape the commercial code have not substantially abated today. Even with modern technological aids to navigation and techniques for safety at sea, from 0.3 of 1% to 0.5 of 1% of the merchant fleet are declared as total losses each year as the result of stranding, foundering, collision, fire or other loss at sea. With a thirty to forty year life on merchant ships, this means that from ten to fifteen percent of the total force will come to an end as peacetime casualties of the perils of the sea.

The military law has been similarly shaped by the effects of the free surface, albeit with a great deal more hot contest than was involved in the development of Admiralty. In this development, certain technological advances can be identified as milestones in the shaping of military law of the sea. These were:

(a) The ability to survive on the open sea and reliably transport troops and military supplies. This ability was developed first for river craft, then for craft capable of navigating the Aegean, then the Mediterranean and finally the open ocean.

(b) The ability to board and capture. This was crucial in the victory of the Romans over the Carthaginians in the battle of Mylae. The technological development employed here was the Corvus, a cantilevered bridge which impaled the deck of the opposition.

(c) The ability to navigate and reliably return from the broad ocean. This was achieved, or perhaps reachieved, at the end of the fifteenth century with the development of geodesy, the sextant and the chronometer.

(d) The ability to arrest and impede flight. This was initially and ineffectively accomplished by the grapple, but was significantly changed as a result of the action over distance afforded by the invention of the cannon.

(e) The ability to retain option of maneuver acquired with steam.

(f) The ability to temporarily achieve optical or near optical invisibility. This capability had the smoke screen as the analog of the grapple and the battery-powered submarine as the analog of the gun.

(g) The ability to launch and retrieve aircraft.

(h) The reacquisition, with nuclear power, of sustained voyage limited only by life support and endurance of the crew. This capability was previously enjoyed with sail.

Prior to the attainment of the capability to arrest and impede flight (i.e., prior to the thirteenth century) combat at sea was rarely possible except by mutual acquiescence and as a consequence, piracy on the high seas or privateering was, at best, a theoretical possibility. Similarly, freedom of the seas was a concomitant of the capability to remain seaworthy and, as a result, sovereignty itself was but a theoretical concept. It is interesting to note that through the development of sea power, the predominant national claim was one of sovereignty with claims made by Tyre, Crete, Rhodes, Persia, Greece, Macedonia, Egypt, Carthage and Rome. These assertions culminated with a division of the World's oceans into two parts assigned to Spain and Portugal by Papal order of Pope Alexander VI in 1494. From this point in history until 1856, a technological-political-legal conflict over the concept of a free ocean or an ocean with emoluments of sovereignty was waged. A primary focus of this struggle was in the development and resolution of the privateering-antiprivateering conflict. The similarities between this ambivalent projection of national power and the dilemma now confronting the submarine-antisubmarine strategists warrants comparison.

Privateering, as unilateral means of keeping the seas free of "trespassers," has roots as early as 1243 when commissions for this purpose were first issued. At that time, the principle technological means for boarding was through use of the grapple, the gun was not yet invented and an effective defense was afforded by flight or the superiority afforded the defense in repelling boarders. It was therefore not until the mid sixteenth century that the conflict began in earnest. The initial challenge to Spain and Portugal came from the English and the Dutch. At that time (1580), Elizabeth I, of England, took the position that "the use of the sea and air is common to all" to justify the voyages of Sir Francis Drake across the "Spanish Main." As England's supremacy was ascendant, James I reversed this position and claimed sovereignty "over our coasts and seas." This position was legally buttressed by the treatise of John Selden "Mare Clausum" written in 1617 and published in 1635. The Dutch, who were less technologically successful in antiprivateering, were reinforced by the competing work of Hugo deGroot or Grotius in his well known work Mare Liberum of 1610.

For the next two centuries, the colonist European nations changed their position on whether or not certain parts or all parts of the sea were free with great frequency. During this period, privateering continued to be a major means of contesting with the ships of competing nations. The initial forms of privateering evolved into the more sophisticated letters of Marque and Reprisal and were codified in legislation such as the 1708 Prize Act of Queen Anne. The downfall of privateering, however, was its technological non-feasibility which in turn resulted in an inability of nations to control their own privateers and an inability to prevent other nations from counter activities at unacceptable levels. The measure of this level was insurance on ships and cargo. Although the Great Britain, United States War of 1812 was perhaps a relatively minor chapter in the decline and disappearance of privateering, it dramatically demonstrated the technological infeasibility of attempting to gain complete control of the seas. In this demonstration, the primary lesson learned was that warships specifically designed for the shielding and protection of ones own merchantmen (antiprivateering) and for the preying on merchantmen of the enemy (privateering) and for destroying the enemys military ships could not fully accomplish this mission without an unacceptable attrition of the military fleet.

In the face of the multi-century empirical demonstration of the technological inability to effectively establish sovereignty on the high seas, the alternative was the introduction of mutual laws of self restraint. One of the first of these was the unilateral declaration of Catherine of Russia, of 1780, enunciating the neutrality doctrine of Free Ships-Free Goods. Shortly thereafter, the Treaty of 1785 between the United States and Russia incorporated the principle of Catherine's declaration of 1780. There remained the last uncontrollable spasm by Britain and France to establish supremacy on the seas. The resulting conflict culminated with the abolition of privateering by the Declaration of Paris of 1856.

The introduction, at this time, of ironclads, steam and superior ordnance had now introduced the necessary sophistication to sweep the seas of independent pirates. Internationally agreed upon legal restraints had eliminated national privateering. Establishment of the jurisdictional concept of territorial waters had further secured the coastlines from indiscriminate attack. The stability of free use of the sea resulting from the new technology and the mutually imposed constraints continued through the latter part of the nineteenth and early part of the twentieth century until rudely shattered by the introduction of the battery-powered submarine. Now this new technology had reintroduced the hope of control of the seas through the uncontrolled attrition of merchant shipping.

The near success of the submarine in achieving this goal in World War I prompted a number of treaties in post war years aimed at minimizing the submersible effects of this destabilizing system. Specifically, Great Britain proposed the abolition of the submarine at the 1921 Washington Nation Conference. Although the parties would not agree to this drastic proposal, the solution was one which rendered the submarine inaffective, in terms of its technological capability. For the World War I submarine, this was simply the ability to limit its optical visibility at moments of opportunity. But, Article (1) of the Treaty imposed restrictions on the use of the submarine which effectively required it to surface, warn, demand, visit, and search prior to initiation of attach. Article (3) provided that "any person in the service of any power who shall violate any of these rules, whether or not such person in under orders of a governmental superior shall be deemed to have violated the laws of war and shall be liable to trial and punishment as if for an act of piracy. . . ."

The manifestly impossible task of legislating against the military attractiveness of the submersible as an attractive weapon of total war was demonstrated in World War II, the Treaties of the London Naval Conference and the Washington Naval Conference becoming thereby documents of historic interest. It is of significance for this paper, however, to note that even in World War II, the submarine was a submersible of opportunity without the attributes of today's nuclear submarine. We should not anticipate therefore that experience with the World War I and II submarine to be indicative of its effect on strategy, tactics or the social order of the oceans.

The effect of the characteristics of free surface operation in shaping the civil and military law of the sea has thus been profound. It has been even more profound as determinative of the maritime supremacy conferred on nations with favored geography. The forces associated with the free surface and the land-sea interface have limited access from the sea to natural or nearly natural ports and harbors. In addition, the volume of commerce which can be handled is a function of the extent of calm waters in terms of deep rivers, estuaries, quiescent bays, lakes, and other waterways connected to the ocean. A cost-effective commercial advantage thus accrues to those nations who can receive raw materials, reduce and refine, manufacture and disseminate to world markets utilizing throughout a singly connected waterway for the transport of low-cost per-unit cube items involved in the commercial product. This advantage will remain as long as the bulk tonnages capable of transport in a marine vehicle are substantially in excess of those capable of transport on a land or air vehicle.

Of those nations having such a favored coastline, a further benefit results, if the coastline can be efficiently defended by sea-based military power. Thus, island domains (Great Britain, Japan, Formosa and Cuba) which can be defended by the mobility of a single fleet are more efficient militarily than countries having multiple widely separated coasts.

The total effect of the social order which resulted from the nature of the free surface, the kindliness of the sea to large volumes and the resistance of the sea limiting transit speeds to at best 30 knots is such that nations having even modest coastlines and harbors can develop navies which can credibly project large elements of their national and political power to the territorial limits of other nations having borders on the sea. The obsolescence of this form of projection of national power has been predicted on almost a daily basis since it was first formally stated by Mahan. Its viability has been demonstrated on almost a daily basis and will be so demonstrated until and unless these major constraints on sea power are altered. The latest demonstration was in the messages communicated by the deployments of United States and Soviet Naval Units in the recent Mid East crises. Participants of this symposium will have no trouble in identifying this classical role of surface sea power in the past crises over Cuba, Formosa, the Suez, Greece, Yugoslavia, etc.

Nevertheless, the reader who doubts this overriding effect of the characteristics of the free surface in shaping sea power need only imagine the effect on history if a beneficent or perverse nature had given the ocean surface the characteristic of a marsh, or a mill pond or had covered it with ice--or had given man the technological skills to avoid the free surface through complete use of the under sea and the sea bed.

PART II

At the end of World War II, it was evident that the technological possibilities developed by that conflict could mature into the development of true submarine systems. A critical item in this development was of course the development of the nuclear reactor, but many other items were also required before a true submarine capability could be obtained. These included:

(a) the development of life support systems capable of sustaining a large crew in a small and nearly closed ecology;

(b) the development of precise navigation without an absolute dependence on surface aids;

(c) the development of communications systems;

(d) the development of hull structure and hydrodynamic form to permit significant excursions from the surface and its effects;

(e) the development of sensors and sonars for extension of the range of underwater visibility;

(f) the development of underwater egress for launch of large missiles and weapons; and

(g) the development of computer aided integrated ship and weapon controls.

The addition of the ballistic missile to this underwater capability provided, of course, a technological key to the feasibility of the strategy of deterrence as we know it today. This total set of new capabilities, when applied, to all forms of submarine warfare, are so totally different from those of the World Wars that they can hardly be regarded as the same system. Two additional technological capabilities now under partial development are required to produce systems which are completely unfettered by the free surface. These are the submarine to submarine transfer of personnel and cargo and the transfer of personnel and cargo from submarine to submerged off shore terminal. The former capability will first result on the completion of the rescue submersible of the U.S. Navy. The latter capability will develop more slowly, but when developed will free sea systems from the constraint of specific harbor and coastal configuration.

From the long-term strategic effect, the principle characteristics of these submarine systems are that they are effectively divorced from the free surface for the full extent of their mission and for future systems that they have obviated the need to return to the surface to enter existing ports and harbors. This divorce from the free surface results in the following constraints and opportunities:

(a) Operations are essentially independent of the conditions of wind and sea state and fully arisen seas can be negotiated without peril, and operations are essentially unrestricted by overlying ice.

(b) It will be possible under most sea conditions to make a transfer of personnel and cargo along arbitrary stretches of the coast. The sea system is thereby freed from the existence of a geologically defined network of sheltered harbors.

(c) The speed of transit will still be limited by power considerations, but will be essentially free of wave drag.

(d) Large volumes and tonnages can be accomodated, limited in general by structural and ballast considerations.

(e) The systems are nearly invisible in the optical and electromagnetic spectrums.

(f) The systems are, or will be, inaccessible to aircraft and quite invulnerable to surveillance or attack from the air.

These characteristics which are peculiar to the undersea should therefore be a factor in shaping the future law of the sea, its military tactics and strategy and redefining the geographic conditions which make for a favored nation. The cost and total technological resources involved in a true submersible system are such that, to date, only the United States has been able to avail itself of this new capability in significant quantities. Other nations having a limited number of nuclear submersibles or the potential for nuclear submersibles, are at present limited to the United Kingdon, France and the Soviet Union. It is therefore a legitimate question as to whether the true submersible will remain unilateral, bilateral or, at most, limited in its international capability.

The apparent major bar to the proliferation of underwater systems is the ability to acquire a nuclear power capability. Such a capability will, indeed, be beyond the resources of most countries for many years to come. In addition, for most countries, small, compact, nuclear power plants, suitable for other than major combatant units such as the Polaris-FBM submarine, will be even more difficult to obtain. An alternative to nuclear power, having the requisite staying capability, is potentially available in the fuel cell. It can be demonstrated theoretically that the fuel cell should be produceable at an efficiency that permits it to be either competitive with nuclear power from a weight and volume standpoint for submerged missions of about twenty days or acceptable in performance for longer missions, if volume is not a critical factor (as it is not). It is a fact of life, however, that an adequate fuel cell at appropriate power levels has not yet been developed and is not likely to be developed without an expensive major program involving advanced technologies and the expenditure of resource in the magnitude of hundreds of millions of dollars. The author believes this development will nevertheless take place even if motivated only by commercial interests. When it does, the ability to copy or reinvent the successful fuel cell will be available at reasonable cost to a large number of potential users. These users, however, will still be constrained in developing deep-diving, sophisticated military systems as the cost and technology involved is not lessened by the availability of submarine power.

In projecting the future of submarine warfare, therefore, one must recognize that for the next decade no major change in the relative ranking or availability of military submersibles of strategic significance will develop. The situation in the succeeding decade can only change somewhat slowly because of the long lead time involved in submarine building, and it will probably be late in the second decade before proliferation of this capability becomes a major problem.

Nevertheless, the protagonists having such a capability and even nations without this capability have their own interest in developing effective submarine countermeasures, as well as developing even an obsolescencing pro-submarine capability. The process will therefore evolve over many decades. To discern patterns, one must, as in the early days of privateering and anti-privateering, take the long term view. This is somewhat disappointing and tends to reduce serious study of the problem to academic exercise, since the development may well take place beyond our lifetime and even beyond lifetimes in being. But, if the long-term view is controlling, there is no other choice. Indeed, the long-term view may run counter to the present trend. For example, although the technological outcome of the privateering, antiprivateering dilemma might have been predictable as early as 1600, it was not necessarily in the national interest for nations of that period to accede to that conclusion. This was so since even a temporary capability to assert a partial strategic control of the seas can favor the aspirations and goals of a nation for a period of time. If, therefore, we can project the ultimate result of the submarine, anti-submarine dilemma it does not necessarily follow that the current trend of technological development ought to be immediately directed toward that result.

If, however, such a projection were available, more realistic long-term goals and less frustrating developmental goals could be established. Since the developmental maturity of submarine and anti-submarine technology has been far from reached, it may be rash to hazard a guess at the ultimate result. On the other hand, a great deal of study has been made of the physical mechanisms by which anti-submarine warfare developers might attain their desired objectives. On the basis of such mechanisms one can estimate (perhaps erroneously) the long-term prospects without revealing current state-of-the-art or its immediate projection.

With respect to area surveillance, the long-term prospect appears dim.

The absorption properties of water with respect to light, high energy particles, electromagnetic radiation, heat and other known forms of energy is such that, except for acoustic radiation, none of the mechanisms postulated have a detection range potential which is significant when compared with the vast areas available in the ocean. The ultimate test in this regard is the ability of the submersible to blend with and be masked by the environment. At near zero speed this ought to be quite attainable. The hotel load for life support and weapons readiness is modest and if, for example, power is supplied by fuel cell, the machinery associated therewith should be extremely quiet. Drifting in the current, at deep depth or at low speeds, the hydrodynamic wake would be insignificant. A further aid would be the capability to move in close proximity to the bottom rendering the submersible difficult to detect by long-range, active sonar. In the ultimate, the underseas weapons system could develop into something akin to a manned, on the bottom, slowly mobile mine. But, advanced systems will not however be restricted to such low speed. Depending upon the relative application of resource, some non-detectable speed will be attainable for future submersibles if designed with evasion as a primary goal. If this upper speed were only five knots then significant portions of the ocean could be utilized, provided patrol periods ranging from two to six months were employed. This would indicate that deployment areas as large as ten million square miles would be available. If it is not now evident that it is manifestly impossible to monitor areas of such size in order to ferret out a system whose detectable influence is less than one square mile, it will be evident to a frustrated posterity.

With respect to the prospect of establishing barrier lines, the long-range forcast is more optimistic. It should be possible to detect with high probability the passage of an intruder across a given line provided the line is sufficiently equipped with passive and active sensors and is continuously patrolled by submersibles or even surface craft having the capability to be vectored with adequate lead time to permit contact investigation and identification. This capability will be most easily obtained across straits and entrances to bays and across natural barriers. It should be obtainable along any arbitrary line on the ocean floor, but at a cost which will bear some relation to the depth of water, the proximity of land, the logistics of investigative craft, and the nature of the particular ocean environment. This optimistic projection, with respect to the barrier line, does not presuppose a differing technology than is available for broad ocean surveillance, but relies on the projected use of high frequency active sonar, magnetic anomaly detectors, and other high frequency (and therefore high resolution) energy radiators whose definition is high and whose range is consequently low. Such lines will therefore have a high cost per lineal mile and the decision to develop, build and deploy such barrier lines will be highly dependent on the developing law and strategy of the use of the sea.

The first and most obvious use of such barrier lines would be in the encirclement of ports of entry and exit for the purpose of detecting a transitor, and then maintaining track throughout his entire ocean voyage. It must be confessed that the long-term prospect for the success of such an operation is beyond the rashness of this paper's predictions. It is most probably a continuing measure-countermeasure game. The opportunities for maneuvers, decoys, jammers, environmental spoofing and other track-breaking techniques on the part of the evader seem almost non-denumerable. On the other hand, the use of mobile zonal reacquisition task forces seems equally large. Should this develop into a classical measures, countermeasure game, as has characterized mine warfare, or communications jamming, then the evader will always be able to regain, at least temporarily, his capability to deploy in the open sea once he has ascertained the nature of the tracking measure.

The sum of this projection is that the technological limit about which the law, and strategy of the undersea will stabilize is one in which it will be possible to fence zones, areas, preserves and egress to port and harbor, but where it will not be possible to prevent the unimpeded transitor from becoming lost in the major ocean areas. This is not dissimilar to the situation on land in thinly populated, heavily forested areas, fenced against poaching in game preserves or to the situation respecting air space within territorial limits. The substantial differences between these analogies is in the legal right to exert positive action including force at the fence in order to prevent the trespass. This right even if only statistically available serves as a deterrent. Such a right does not exist in the ocean except at the limit of the territorial seas. The awareness of this impediment to the effective use of the fence has led to the suggestion that the law of the sea might be changed. Certainly no revolutionary changes are in the offing. However, an evolutionary change in the law of the sea can be anticipated. Its developing trend is central to the prediction of the future strategic use of the sea.

The primary forcing function in the change in sea law or the creation of new sea law is forseen in the commercial development of the sea. If successfully pursued rights and benefits in the resources of the sea bed may vest in some legal entity as do rights and benefits of the water column when associated with a commercial interest such as fishing or weather prediction or waste disposal.

Two major development patterns can now be identified which will extend commercial interest in the oceans and may modify the basis for the further development of law in the underseas areas. These are:

(a) The development of saturation diving, i.e., the capability of placing man, as a free swimmer, on the continental shelves to depths clearly in excess of six hundred feet and perhaps to depths in excess of one thousand feet.

(b) The development of low-cost work submersibles capable of performing useful tasks on the bottom at any depth.

Two ancillary developments which in combination with the first two will enrich the commercial interest in the ocean are the development of stable platforms at the sea surface (manned and unmanned), and the development of techniques for mining and employing manned installations in the sea bed

Progress in each of these areas has not been as rapid in the past few years as the state of art of current technology would permit primarily because of the legitimate preoccupation of the major powers with the more conventional aspects of sea power. It has nevertheless been steady. Saturation dives at six hundred feet have now been accomplished many times in chamber complexes and a significant number of times at sea. The Deep Diver submarine, a commercially developed vehicle, has demonstrated the capability to easily lock saturated divers in and out of a small submersible. Other commercially available small submersibles in being, such as Aluminaut, Alvin, Star, and Deep Star, and in production, such as Soucoupe, Picard, Deep Quest, Deep Star and DOWB, are demonstrating that the small continental shelf submersible with diver lockout capability are within the reach of venture capital. The success of these operations is such that only the uninformed can not now perceive an extensive and expanding long-term work capability out to the geophysically defined limits of the continental shelf.

Fortunately, in this instance, the development of the law is in phase with the technological development. The treaty on the continental shelf has (insofar as the signatories are concerned) established sovereign rights on the continental shelf for the purpose of exploration and exploitation to a depth of two hundred meters or a depth admitting of practicable exploitation. The legislative history of the treaty clearly indicates that the ambiguous language does not contemplate extension of sovereignty for the purpose of exploitation to the deepest parts of the sea, but was meant to include the type of extension involved in saturation diving.

Since the geology of the shelves are merely an extension of the geology of the continents, we may expect the exploitation of the shelves from a mineral resource standpoint to be similar to exploitation on land. At present, the most successful off-shore resource development has been in oil and gas, but other exploitations conventional or bizarre have been attempted or effectuated. These have included the extraction of sulphur in the Gulf of Mexico, the mining of diamonds off the coast of Africa, the foundation for illegal television stations off the Netherlands and the locale for a gambling casino on the Georges Bank.

Among the many unanswered questions on these exploitations are the extent to which they confer exclusionary rights on control of the waters above. The continental shelf treaty attempts to avoid this issue by requiring a minimum interference with normal rights in the free surface as a result of bottom installations. In fact, just as low overflight is not permitted over land installations, so will the explorer of the bottom desire to keep the waters above him free from interference in the form of transitors which may jettison undesirable materials, or which may interfere with sensors and communication, or which may pose a mutual hazard of collision due to unexpected or emergency abandonment of the bottom installation. This is especially true if the area is occupied by saturated divers who are particularly vulnerable to local detonations, disruption by trawl or anchor, interuption of communication on other apparently trivial disturbances in the local environment. It is therefore highly possible that the exploitation of the continental shelves will create a need for greater control over the waters above than may have been anticipated.

The outer edge of the exploitable shelf is one possible locale for a sensor fence within which the passage of military submersibles is either regulated or denied, on the basis of international agreement. If this speculation proves correct (and it is a speculation not a recommendation) then an examination of the world bathymetry reveals major changes in the regulated sea domains of many nations. In particular, the great barrier reef of South East Asia would transform drastically the boundary relationships in that strategically significant region. The East Coast of the Americas, the West Coast of Europe and the Mediterranean would also be markedly affected. However, other domains, such as the West Coast of the Americas, would not be significantly changed.

The long-term projection for man as a free swimmer in the deep ocean as contrasted to the shelf does not inspire optimism. Captain George Bond, whose daring but technically sound insights perceived the feasibility of saturation diving, has made an estimate of the requirements to descend significantly deeper than one thousand feet. His proposed solution involves a surgical tracheotomy and the filling of lungs, nasal and oral passages with a saline solution. Even then, excursions to deep water for periods in excess of a few hours do not seem feasible. Alternative means for exploiting the deep ocean are thus required.

This alternative appears to be developing in the form of the small, deep submersible. Slow, but steady, progress is being made on components materials and techniques for producing reliable, commercially available vehicles which can operate at the deepest parts of the ocean. As a result, modest and more limited exploitations and explorations will be feasible at any point in the ocean. To be cost effective, these exploitations will probably be in the vicinity of islands or near surface sea mounts or other stabilized sites where bulk raw materials can be processed prior to transhipment in more economically transportable form. As in terrestial development, the "high ground" will be valuable for location of navigation and communication aids, or for sensors employed in the test and evaluation of military and commercial deep submersibles. It may be expected therefore that deep water domains in the vicinity of islands or of natural basins surrounded by sea mounts will form the natural basis for exclusion areas or partial exclusion areas. The perimeters of these basins are also suggestive as areas about which sensor fences could be effectively established. The net effect of such development would be equivalent to an increase in the number and location of islands in the world's oceans. Depending on their location and technological sophistication, these islands could approach in strategic significance such islands as Formosa, Madagascar, Malta, Iceland, Cuba and Hawaii.

The two ancillary developments; the stable platform and the manned excavation, provide as additional means for location of islands of jurisdiction throughout the oceans. The underground excavation is particularly interesting, since the cost of extending such an installation once an initial penetration, initial life support and initial power system have been installed should not be significantly greater than present costs for mine shafts and tunnels. If for example, a safety zone on either side of a tunnel is established which extends to the surface, then an additional mechanism is provided for enclosing areas in the oceans.

The total effect of these four technological developments could result therefore in an extention and change in the configuration and extent of continental jurisdictions, the configuration and extent of island jurisdictions and the establishment of additional islands and oases of jurisdiction throughout the oceans, either on a national or international or some sort of mixed basis.

As long as these areas of jurisdiction develop in response to the commercial, scientific and aesthetic aspirations of man, then vast areas of the ocean bottom will remain de facto res nullius. For these areas, the only appropriate fences appear to be the great ridges and sea mount chains such as the mid Atlantic ridge, the East Pacific rise and the sea mount chains associated with Melanesia and Micronesia. The non-utility of barrier lines across these physiographic boundaries was indicated earlier in the paper. If then, and after several development cycles in the pro-submarine, anti-submarine measure-countermeasure game have resulted in the invulnerability stalemate which has been predicted, the mutual securities of the protagonists in the game are still threatened, then the only recourse is mutual agreement of self restraint. This was the pattern in the privateering, antiprivateering dilemma that persisted for nearly five hundred years. It is the authors prediction that this is a highly, likely outcome of the submarine, anti-submarine game.

What form might these restraints take? They range from the extreme solution of a total demilitarization of the broad ocean areas through a spectrum of restrictions such as the prohibition of systems fixed to the bottom, or unmanned, or involving weapons of mass destruction to tacit or unilateral declarations not to deploy clandestine systems or systems having destabilizing characteristics.

In hazarding a guess as to the form of the stable solution, it should be noted that no drastic change in the constraints which affect systems operating on the free surface has been postulated. There is no reason therefore to anticipate that the law of the free surface will require a drastic revision. A clear delineation between systems on the free surface and between undersea systems appears most likely, just as a differentiation is now made between land law and the law of air space. With such a differentiation, the free passage of surface military ships could remain unimpeded and unregulated. The constraints are most likely to be imposed on underseas systems.

Granting this differentiation, a number of significant factors exist which will probably inhibit attempts to engage in agreements to demilitarize this portion of the undersea. In addition, it may become increasingly desirable for all protagonists to have a major segment of the strategic deterrence forces on or in the sea. This latter point has been much debated. The argument in its favor is that it supports a strategy which seeks to avoid collocation of strategic systems with the population to be protected. The population is thereby relieved of its "hostage" status and, in addition, isolated attacks or incidents directed against the strategic system will not escalate because of the ambiguity of the attack.

It is therefore anticipated that some sophisticated forms of arms control agreements will develop. In a previous paper, the characteristics of an arms controllable system were delineated. These were:

(a) that it possess the capacity for delayed response;
(b) that it is actually or statistically invulnerable; and
(c) that it is verifiably incapable of delivering a surprise attack.

A number of undersea systems operating in the broad ocean can be designed which meet these requirements. It is therefore anticipated that, if a continuing need for stable, strategic deterrent systems exist, then the broad oceans will be an effective place in which they can be deployed. It is therefore postulated that a stable ultimate solution is one in which agreed upon, inspectable, and arms controllable systems are deployed in the broad expanses of the deep ocean and that other underwater systems become fair game at the moment an illegal transit of an ocean barrier line is made.

It should not be expected that stable solutions of this type will be arrived at by plan or by programmed agreement between and among the protagonists in a deep ocean. The very complexity of the ultimate solution invalidates its political acceptability to the many national and international bodies which would be involved in the strategy of initial agreements. Such a solution, if arrived at, will be the result of an evolutionary process in which competing entities will seek other outcomes which match their particular national interests and technological capabilities. Indeed, the outcome that has been postulated is based on intuition, analogy and experience. When coupled with the range of alternate solutions which are available, even the author is not inspired to strongly defend the validity of the result. The rationale is believed, however, to be strong enough to inspire intelligent debate. To this end, the concluding summary presents in précis the major assumptions and conclusions as follows:

(a) To date, the law and strategy of the sea have been conditioned and controlled by the effects of the free surface.

(b) No substantial change in the major constraints on free surface systems is foreseen; therefore, no major change in the law or strategy of the free surface is foreseen.

(c) In the future, military and commercial systems will be developed which are completely divorced from the free surface, which will therefore condition and control the law and strategy of the undersea.

(d) This new technology will result in establishment of national or international jurisdictions over portions of the sea bed and portions of the ocean not now under control.

(e) It will be possible to develop barrier lines which detect a high percentage of clandestine underwater transitors.

(f) It will not be possible to develop area surveillance systems which can track a significant percentage of clandestine systems deployed in the broad ocean.

(g) It will therefore be possible to exclude military systems from limited areas of the ocean which are clearly fenced in and clearly exploited or exploitable for human needs.

(h) It will not be possible to exclude military systems from the broad ocean areas, unless immediate forces are exerted at a barrier line or unless the exclusion is by mutual consent or restraint.

(i) By analogy it appears that the competition for control of the undersea is similar to the privateering, antiprivateering dilemma which extended from the fourteenth to the nineteenth century. It will therefore be protracted and evolutionary in its development.

(j) Following this analogy, it is concluded that the ultimate, stable solution is one in which arms controllable undersea systems are deployed in the broad ocean under tacit or formalized agreement, at the same time, significant areas of the ocean will be placed under national or international jurisdiction in which the deployment of military systems are at the will and sufferance of the possessor of jurisdictional authority.

INSTITUTE FOR STRATEGIC STUDIES

9th ANNUAL CONFERENCE

THE IMPLICATIONS OF MILITARY TECHNOLOGY IN THE 1970's

COMMITTEE II - 3

Saturday 30th September Morning

Technology and the Battlefield

EDWARD C. CORNFORD

Introduction

The title of the contribution I have been asked to make to this Conference - 'Technology and the Battlefield' - amplified as it was by the suggestion of the Director that it should cover 'an expose of new development, that is in the last ten years and in the next ten that affect the nature of land warfare', encompasses so broad a field and so extensive a range of topics as to call for a most drastic process of selection to tailor the potential material to the confines of a single discussion period. Fortunately the titles of the contributions from other participants in the Conference appear to offer some help in this selection process, and in so far as there are papers dealing with such topics as the Communication Revolution, Developments in Chemical and Biological Warfare, ABM Systems, Satellite Surveillance, the Future of Manned Aircraft, Nuclear capabilities etc. etc. I have either omitted or strictly limited in this paper any discussion of the 'battlefield' aspects which might arise in these fields, on the assumption that these will be covered by others.

We now recognise a wide spectrum of types of warfare ranging from the all-out nuclear exchange at the one extreme, through conventional or 'limited' war at various levels of intensity, counter-insurgency and anti-guerilla warfare to internal security operations at the other. Although the boundaries between some of these are both somewhat arbitrary and ill-defined, each may be claimed to have its own 'battlefield' characteristics, and although there are many common areas in which the same technologies contribute to two or more categories of warfare, there are also classes of weapons and their supporting technologies which are to some extent characteristic of each type. Since there is a separate contribution to the Conference on 'Technology and Guerilla Warfare' I have confined my observations largely to topics which appear specially relevant to the conventional limited war battlefield.

But even with these limitations I have felt the need for yet a further basis of selection to reduce the field to manageable size, and the criterion I have tried to follow is that those areas of activity on the conventional battlefield to be selected for discussion should be ones in which there appears to be a high chance that advancing technology may produce a substantial change in the present order of things. There are of course many areas, particularly perhaps in the field of battlefield weapons and equipment, where the improvements in weapon performance stemming from advances in technology follow only a rather slowly rising curve over the years. There are, however, some fields in which, from time to time, there appears to be the possibility of something like a step-function change in capability. The identification and pursuit of these is clearly of the greatest importance.

In what follows I have sought to explore four major fields three of which, I believe, exhibit this characteristic of potential rapid change rather strongly, and the fourth perhaps rather less so. They are the fields of armoured vehicles and the weapons to counter them, battlefield surveillance and night fighting, close air support in the battlefield and battlefield air defence, and artillery weapons and their fire control arrangements. My particular choice of topics should not, however, be taken as in any sense implying the belief that technological advance has not made or will not make a continuing contribution in a variety of other areas - for example in the fields of infantry weapons, mines, mine detection and clearance, engineer equipment, hovercraft etc, but only that I find greater difficulty in these areas in identifying, other than in rather general and platitudinous terms, the nature of the impact which developments may have on the battlefield.

There is however one topic - perhaps more tactical than technological in nature - which is not pursued further in this paper, but which must be mentioned. This is the tremendous impact which the tactical exploitation of the helicopter has had on the conduct of land operations, both as a means of logistic support to the forward area, and for the rapid deployment of troops into battle. Both in Vietnam and Borneo its exploitation has allowed the area which can be dominated by a land formation of a given size to be vastly increased, particularly in terrain where surface communications are deficient, and where the difficulties of constructing airstrips for fixed wing aircraft are extreme. There is no doubt that even the existing level of knowledge will allow considerable improvement in the logistic productivity of helicopters, in their flying characteristics and in all weather operations, and in the weapon systems they carry to provide fire support in the tactical assault. The issue to which there would appear to be as yet no clear answer is the extent to which operations of the kind now being conducted by the US Army in South Vietnam would continue to be practicable in an increasingly hostile air environment.

In none of the areas discussed have I attempted any detailed catalogue or examination of the technological advances themselves which may lead to change but have sought rather to examine the kind of impact which the enhanced capabilities these may provide may have on the battlefield. In none of these fields is the future pattern fully clear, and I have not been either sufficiently brave or sufficiently foolhardy to attempt to forecast it. This I leave to emerge from the Conference discussion.

ARMOUR AND COUNTER ARMOUR WEAPONS

The last few years have seen considerable developments in the continuing battle between the armoured fighting vehicle and the weapons to counter it. Although the consequences of these developments are, as yet, far from fully established, they could well have a major effect in the field of armoured warfare. The main change appears to be a considerable swing in favour of the anti-tank weapon. The armoury of these weapons now includes, or is likely to include in the next year or so, not only a series of shorter range recoilless weapons of various ranges and calibres, but also potentially highly effective long range anti-tank guided weapons (A.T.G.W.). These weapons will carry a shaped charge warhead capable not only of defeating the heaviest armour that the future tank is likely to be able to mount, but also of inflicting considerable if not catastrophic damage after penetration.

There is, of course, nothing new in the existence on the battlefield of counter weapons to which the tank is vulnerable. The potential new factors lie in the small size and weight of the A.T.G.W. system and hence its ready man-transportability about the battlefield, and in its effectiveness up to the maximum range of three or four kilometres or more at which tanks are likely to be seen. Whether and if so, how far these new factors will change the methods of operation of tanks, and how the armoured vehicle might evolve to counter them is not yet clear. In what follows an attempt is made to examine both sides of the question, that is the problems which face the A.T.G.W. and its operator and the steps which might be taken to overcome them, and the counter steps which might be taken in the evolution of the armoured vehicle.

The Anti-Tank Guided Weapon

The first generation A.T.G.Ws developed in many countries have all relied on simple line-of-sight guidance systems. Throughout the time of flight of the missile, the aimer is required to observe its displacement from the line of sight to its target, and to generate signals, which are communicated to the missile down a wire-link to reduce the observed displacement to zero. The necessary operator skill can fairly readily be learned and demonstrated under training conditions, but there is little information about the extent to which operator performance might be degraded under the stress of battle, or, as yet, about the nature and extent of the continuation training required to maintain this skill at a high level. The extent to which degradation in performance, due to stress or to other reasons such as smoke and dust on the battlefield, is tolerable while still maintaining a high chance of a lethal hit may well not be very great.

Advances in technology will fairly readily allow some of the potential shortcomings of this kind of guidance system to be eliminated, but, inevitably, at the expense of some increase in system complexity. The operator's task can be reduced merely to the accurate tracking of the target by means of a pair of crosswires, with missile displacement from the line of sight thus established being determined automatically by means of a television or infra-red system tracking a flare on the missile, and with the automatic computation of the appropriate correction signals to the missile. By this means the load on the operator will be reduced, but his task is likely to remain a fairly demanding one, particularly at extreme range. Systems of this kind will obviously simplify the training problem, in that the acquisition and maintenance of skill in the task of the operator make no demand for missile firings.

Two other characteristics of the first generation systems may be regarded as important limitations. These are:-

(i) The rather low subsonic speed of the missile means that the weapon aimer is engaged for an appreciable period with each target, and the ability to engage successive targets is correspondingly poor.

(ii) The majority of systems allow little or no 'separation' between the aimer and the weapon launcher. In systems without separation any smoke signature or disturbance left by the missile at launch draws attention, and possibly direct counter-fire not only to the weapon launcher but also to the aimer. Some measure of separation, particularly in the vertical plane, also allows advantage to be taken of any concealment available for the weapon launcher, for example, behind a crest, and requires the direct exposure of no more than the periscopic head of the aimer's optical system.

The first of these limitations can easily be reduced by the adoption of a supersonic missile, but only at the cost of increased missile weight, and probably also of dispensing with the simple and effective wire-link communication system and replacing it by some form of radio or other 'wire-less' link. Provision for separation is also perfectly feasible technically, but again only at the expense of considerable elaboration in the arrangements to enable the aimer to 'gather' the missile on to the line-of-sight after launch.

The ideal guidance system for the anti-tank guided weapon in the longer term would be a system capable of homing passively on some characteristic of its target such that once the missile was locked on its target and launched it required no further attention. Remote though this prospect now seems, reports from the USA [(1)] of the so-called Area Correlation Tracker appear to offer some prospect in this direction. As this system is envisaged, a television system in the missile head compares, through an electronic processor, the currently scanned scene with a computer-memorised scene, and thus generates steering signals enabling the 'head' to remain 'locked on' to a particular feature of the scene. Some other techniques which might ultimately contribute in this field are discussed above. The adoption of some or all of the now

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(1) Missiles and Rockets, March 14, 1966.

technically feasible improvements suggested earlier to the first generation anti-tank guided weapons would add to the complexity and cost of the system and almost certainly lead to increase in system weight and hence reductions in portability. They would take the A.T.G.W. system steadily further and further away from the original highly attractive concept of a simple, cheap, robust, man-portable system with the missile able to be treated as a 'round of ammunition' requiring the absolute minimum of testing and support in the field.

The requirements of the ideal anti-tank guided weapon of the future - long range, short time of flight, high terminal lethality, aimer and launcher separation, suitability for night combat (which of itself will introduce a number of additional constraints), low system weight and a simple and robust low cost missile - though each by itself technically feasible, are together in conflict with one another. It will be of considerable interest to observe over the next few years the relative weights attached to these factors and the manner in which the anti-tank weapons of the future resolve these conflicting requirements.

Counters to the Anti-Tank Guided Weapon

There appear to be three main directions in which the tank might seek to improve its survivability on the battlefield in the face of large numbers of long-range anti-tank guided weapons. These are to improve the quality of its armour protection; to improve its mobility, by reducing weight or increasing engine power or both, and improving suspension characteristics in order to enable the tank to take greater advantage of such cover as may exist naturally or be created on the battlefield; and to mount some form of active defence against missiles attacking it.

The protective performance of armour has improved considerably over the years, and there is no doubt that improvements in the quality of the basic materials and in the disposition of armour will yield yet further benefits. If the future threat to the tank were to be confined either to the shaped charge or to the armour piercing projectile relying for penetration on its kinetic energy there might be a reasonable prospect of providing invulnerability against the one or the other by designing the armour protection specifically to exploit the particular characteristics of the attacking weapon. But so long as the tank must contend with both forms of attack the prospect of designing, within practicable weight and bulk, armour which will give full protection against both appears remote. Indeed, in the longer term, the balance of advantage, at least for the shaped charge increases steadily with its diameter, and although there are patently penalties in increased missile weight and cost and reduced portability in moving towards larger diameters, these would appear to be likely to be far less than the penalties to the tank in seeking to mount the increased protection required to match them.

The main reason for the desire to increase the speed and hence reduce the term of flight of the anti-tank guided weapon is that, in terrain with plenty of dispersed cover, its target may find cover during the rather long time of flight of the missile and thus spoil the operator's aim. In these circumstances improvements in the tank's acceleration and cross-country speed will increase the survival chance, but it is plainly very difficult to attach any quantifiable measure to the benefit of increased mobility. The full exploitation of improved power to weight ratio, particularly in rough country, is likely to require parallel improvement in tank suspension in order to ensure that the potential improvement in mobility is not in fact limited by the 'roughness' of the ride which the crew can tolerate.

Although it is certainly possible to envisage a rather sophisticated defensive system capable of destroying an attacking anti-tank guided weapon in flight towards its target, the prospect of mounting such a system in a tank would seem to be remote. A more likely approach might be to attempt to improve the means of disrupting the aimer's line of sight to his target or perhaps to interfere with the communications link between the aimer and his target. Neither appears particularly promising, although the combination of the simplest possible system for the detection of an approaching missile with a means for rapidly flinging a smoke screen into its path, would appear to merit some investigation. The wire link communications system is virtually invulnerable to countermeasures, and there is no reason to believe that any 'wire-less' system which might replace it need have any marked weakness.

As I have tried to point out, there are many 'ifs and buts' in the argument about the likely effect of the anti-tank guided weapon on the future battlefield, and there is little ground to justify the cry, sometimes heard, that it spells the end of the battle tank as we now know it. Nevertheless, it is difficult to resist the feeling that its likely impact is as yet far from fully appreciated.

The Tank in its Primary Role

It is evident from the rather different characteristics of the main battle tanks with which nations are now arming themselves that there is still considerable divergence of view among military authorities about the best compromise between the three main factors which determine tank design - that is fire-power, protection and mobility. It seems to be generally agreed that, given the primary role of the tank as the provider of mobile direct fire power on the battlefield for both offensive and defensive purposes, first priority should be given to its armament, but even so there is more than one view about the general form which this armament should take. Although this is required to be able to take on the full spectrum of targets likely to be encountered on the battlefield, its characteristics are dominated by the need to be able to deal with enemy armour - probably its 'hardest' and most elusive target.

The two main contenders for this purpose are the gun, firing a reduced calibre high density armour piercing projectile with a muzzle velocity around 5,000 feet/second, and the anti-tank guided weapon with its shaped charge warhead. There is little doubt that at the shorter end of the range bracket - up to say 1,500 metres - the high velocity gun with its very flat trajectory and short time of flight offers the better chance of securing a very rapid first round hit. It also offers a high rate of fire and the ability rapidly to engage successive targets. On the other hand, at ranges of 2,500 metres or more the anti-tank guided missile has advantages in the chance of a first round hit which the gun is never likely to be able to match. Each appears to be supreme in its own regime and such argument as there is relates only to the range at which the one takes over from the other.

The high-velocity gun is now a highly developed device with little obvious prospect of more than marginal improvement either in the gun or its ammunition, though the use of higher quality steels may well enable the same performance to be achieved with a somewhat lighter gun. The main immediate prospect of improvement lies in the fire control side, and particularly in the advent of the laser range-finder. Measurement of range rather than the inherent accuracy of the gun has always been the major factor in achieving a first round hit at longer ranges. The rapidity of response and precision offered by the laser range-finder could well move the crossover point between gun and guided weapon out to substantially longer range. The lines along which the anti-tank guided weapon might develop have already been dealt with in the previous section.

The choice of tank armament for the future is likely to remain something of a problem. Attempts to carry both kinds of weapon separately on the same vehicle seem unlikely to prove satisfactory, and it is of interest to note some of the different approaches now being made to this problem. In the United Kingdom, the Chieftain tank mounts the 120 mm high velocity gun with, in addition to its Armour Piercing Discarding Sabot ammunition, a 'squash head' round (which is particularly well suited to the attack of concrete emplacements, earthworks, etc.) to provide a general purpose HE capability. The long range anti-tank guided weapon is then carried either by the infantry or in a separate less heavily armoured vehicle. In the USA the Shillelagh gun-launched guided missile system, planned as the main armament for a version of the M60 tank and for the United States/Federal Republic of Germany main battle tank of the 1970's, seeks to combine the gun and the anti-tank guided missile in the one system. (1) Shillelagh's 152 mm gun launcher can fire either missiles or conventional ammunition. The missile, with its shaped charge warhead, is guided by a line-of-sight command system requiring the aimer only to track his target. It would appear that the rather large calibre has been determined by the requirements of the missile's shaped charge: it will be of interest to see how far this can also provide an efficient dispenser of HE and other conventional ammunition on the battlefield.

The two factors which contribute passively to the survivability of the tank - that is, protection and mobility - tend to be rather directly in conflict with one another in tank design. Improvements in the former tend to demand more weight for increased protection, whereas the latter benefits by reduction in weight or at least by the use of any spare weight which may be available to increase engine performance, improve transmission, suspension and tracks etc. Widely differing views are held about the proper balance between these qualities in the battle tank. There is on the one hand the school of thought which argues that, since whatever is done to protect it the tank is likely to remain vulnerable to the weapons designed specifically to combat it, there is little point in providing it with more armour than is required to give

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(1) Ordnance, Nov/Dec. 1966

it reasonable protection against the general hazards of the battlefield - artillery and mortar fire, AP HE from smaller calibre cannon, AP from machine guns, etc. The consequent reduction in weight would allow enhanced mobility, and hence some improvement in survivability, while at the same time leading to a smaller, lighter and cheaper but still well armed tank. The opponents of this view would hold that this approach would merely give an unnecessary bonus to the enemy by enabling him to defeat the lightly armoured tank by means of much lighter, cheaper and lower performance anti-tank weapons than are now required. They would claim in addition that, although high mobility on the battlefield is obviously an important attribute, this can be adequately met in the heavily armoured vehicle, and that in any case its contribution to increased survivability is only against the long time of flight anti-tank guided weapon and of little if any significance against the high-velocity anti-tank gun.

These differences in view will no doubt persist, and perhaps only be resolved on the battlefield itself. In the meantime, there is a wide range of advances in technology, touched on below, which should contribute not only to improved performance in the main battle tank, but also to more effective design across the whole spectrum of armoured fighting vehicles. These are discussed under four headings: - engines, transmissions, suspensions and tracks.

Engines

Up to the present time practically all military vehicles have been powered by piston engines and it is likely that such engines will remain competitive for many years to come because of their capacity for up-rating by supercharging the inlet air system and by recovering some of the waste heat energy available at the exhaust. These two processes may be compounded in several ways with the main engine. The fuel consumption of these already efficient engines is likely to be improved by at least 15%, and by raising the mean combustion pressure by a factor of two or more the specific power will be considerably increased. The very high peak pressures which this might involve could be alleviated by using variable compression ratio devices, thus avoiding the need to strengthen and, inevitably, to increase the weight of the engines.

Whilst many novel engines have been suggested from time to time only one of these, the NSU Wankel rotary piston engine, appears promising; its real advantage over a conventional piston engine is that it occupies only about half the bulk for the same power. However for small horse-power engines the basic engine size tends to be swamped by the size of the auxiliaries, and, in fighting vehicle engines, by air filtration units. On balance therefore it seems that the Wankel engine will not be a serious competitor for horse powers below at least 100 hp, and, for very large powers, such as are required for a main battle tank, it may well not justify the development costs for so small a market, particularly when it may have to compete with the gas-turbine engine. In the intermediate size the Wankel may well be the best choice for air-portable fighting vehicles, particularly if operation on gasoline is acceptable.

The gas-turbine engine is now becoming a strong potential competitor for the large fighting vehicle, mainly because of the small bulk of the bare engine and the reputation it has gained in aircraft usage for reliability. There will however be many problems in exploiting its potentialities in this new field. For example, the fighting vehicle load cycle and environment are likely to be far more demanding: the size of the engine required even for a main battle tank is considerably smaller than is used in most aircraft applications and therefore the fuel economy will be poorer, and the increased size of the air cleaner required in military vehicle applications may more than offset the bulk gain by using a gas turbine engine. In the vehicle application the engine is often required to produce shaft power at a level below the maximum and the part-load efficiency of the turbine is poor. Techniques such as variable geometry and the use of heat exchanges to improve the part-load fuel consumption add to the complexity and cost and detract from the reliability and simplicity of the gas turbine engine.

The relative merits of the advanced piston engine, the Wankel engine and the gas turbine in any armoured fighting vehicle application will be determined only as a result of a thorough study of the complete vehicle system, its intended usage and the development and production costs involved.

Transmissions

Present practice has favoured the use of mechanical gearboxes in military vehicles but the high mechanical efficiency of a stepped ratio gearbox has to be offset against the fact that this type of gearbox only permits maximum engine power to be available at one speed in each gear ratio. In tracked vehicles, when steering, powers exceeding the power of the engine have to be transferred from one track to the other. A mechanical gearbox transfersthis power efficiently but generally only permits a particular radius of turn for each forward gear ratio. For these reasons it would seem likely that future transmissions will be infinitely variable. These will allow a better utilization of full engine power, will give the driver greater freedom when steering the vehicle and will allow a wider choice of type of engine, all leading to a gain in mobility. In order to do this most effectively it is likely that the new transmission will combine both hydrostatic and mechanical elements. For wheeled vehicles with more than say four wheels additional problems arise in transferring power to the many wheel stations. A multiplicity of universally jointed shafts becomes unattractive both from space and vulnerability considerations. A more attractive possibility is the incorporation of hydrostatic motors within each wheel hub fed with fluid under pressure from a pump connected to the main engine.

Suspensions

The need to increase the speed of vehicles across country calls for improvements in vehicle ride which affects both crew and equipment. More attention will need to be paid to crew comfort and safety, and special seats developed so that this factor is not the limiting one across country. Vehicle suspensions will have to provide much greater movement than in the past and their deflection characteristics are likely to be non-linear. In order to achieve this for an acceptable size, units employing fluids as the springing medium will need to be developed and these should also provide a variable ground clearance for the vehicle, giving the advantage of a low silhouette when stationary. The longer term may well see the development of adaptive suspension systems which vary their characteristics to suit the nature of the terrain being crossed.

Tracks

Tracks on a fighting vehicle are subjected to a particularly severe loading cycle under bad environmental conditions. To survive, they have to be made extremely robust and their weight is a significant proportion of the total vehicle weight. They form part of the power transmission system and a very inefficient part at that. Future tracks are likely to look rather similar to present-day ones, the main improvement being in the use of new materials to reduce weight and in techniques to minimise the power losses which occur at the track link hinges, both improvements leading to greater mobility.

The Armoured Personnel Carrier and Air Portable Armoured Fighting Vehicles

There are two comparatively recent developments in the field of armoured fighting vehicles which deserve at least passing comment. These are the widespread adoption of the armoured personnel carrier designed to provide protection while carrying the infantryman and his weapons into battle, and the air-portable and air-droppable family of armoured fighting vehicles.

The armoured personnel carrier is of interest not only because of the influence it is likely to have on the balance of infantry tactics and on the weapons the infantryman will require, but also because it has caused considerable emphasis to be placed on a problem to which military technology has yet to provide a fully satisfactory answer - that is an efficient indirect fire weapon for the attack of armoured vehicles. This problem is touched on above.

One of the main limitations at the present time on the effectiveness of quick reaction air transported ground forces stems from the inability of current strategic and tactical transport aircraft to carry the main battle tank. These limitations may well be removed as the load carrying capacity of these aircraft increase, but until such time as it is there will be a continuing demand to provide, within their current pay-loads, the most efficient family of armoured fighting vehicles including armoured personnel carriers, armoured reconnaissance vehicles and an air portable 'tank'. These vehicles, and particularly the 'tank', place the most searching demands on the designer to squeeze the last ounce of fire-power, protection etc. out of vehicles of perhaps one quarter or one third of the all up weight of the average main battle tank. These demands have, for example, given considerable impetus to the development of aluminium armour and to the search for materials giving even better protection per unit weight, albeit at possibly much greater cost or difficulty in fabrication. The air portable tank is inevitably likely to be much inferior in many respects to the main battle tank, nevertheless these vehicles, typified, for example, by the US Shillelagh armed Sherman tank, should add a powerful armoured capability to air transported forces. Techniques which have been evolved for air dropping this class of vehicle, both from high and low level, will add 'vertical envelopment' to the roles of armoured forces.

BATTLEFIELD SURVEILLANCE AND NIGHT COMBAT

The evolution of radar during and since World War II has enabled combat in the air or on the surface of the sea to be conducted virtually as efficiently in darkness as by daylight. But, because of the complexity of the radar picture of the land battlefield and the difficulty of discriminating militarily significant objects from the natural background, it has made no such contribution to land operations at night. The removal of the limitations imposed by darkness on the land battle, or even their substantial mitigation, would be a step forward of the greatest significance. There are many indications that progress in this respect over the next few years is likely greatly to surpass the advances which have been made over the last decade.

What the soldier would like is equipment which would enable him to move freely over the battlefield, to gather intelligence of enemy dispositions and action, and to operate his direct-fire and other weapons as efficiently by night as he now does by day, while at the same time leaving the enemy as much in the dark as before. There will, no doubt, always be a place for flares, pyrotechnics, aircraft borne illuminating systems, illuminating shell, etc. and other means for 'turning night into day' on the battlefield but these tend, at least in some circumstances, to confer almost as much benefit on the illuminated as on the illuminators. Greater benefit will clearly be with night fighting devices, which swing the balance of advantage much more clearly in favour of their users. Most current night fighting aids of the more discriminating kind fall far short, in the ranges at which targets can be acquired, identified and engaged with direct fire, of what is possible by day, and also the times involved in the sequence of operations from target search and acquisition to weapon response are significantly longer at night. Although the prospect of making ground combat fully as efficient by night as by day remains remote, there are now becoming available a wide range of experimental techniques, some of which are already being exploited in first generation service equipments, which should go far to remove many of the current limitations.

Surveillance and night combat devices may be roughly categorised in two classes:-

(i) Instruments which directly enhance the visual capacity of the human eye - with or without auxiliary illumination;

(ii) Devices which present either a visual or an aural indication of some aspect of the battlefield before them.

The main current technique in the first class is the illumination of the night scene by some form of near-IR searchlight, and the observation of the reflected radiation by means of a viewing system using an IR image converter tube. This has widespread applications for general observation, direct-fire weapon aiming, night driving, etc. etc. and is of considerable value against an unsophisticated enemy. But equipment based upon it suffers from the disadvantages common to all active illuminating systems - whether operating in the near IR or other parts of the spectrum - that the source of the illumination can readily be detected and is then potentially subject to counter attack. While this risk can be mitigated tactically by the intermittent use and movement of the illuminating source the weakness remains, and systems of this kind are likely to fade fairly quickly from the battlefield.

Intrinsically more attractive is the class of 'passive' systems which rely for their operation, not on the 'active' illumination of the target, but rather on the amplification of the often very low level of reflected radiation from the natural illumination in the night sky. These image intensifiers, examples of which are already in operation in South Vietnam, should be capable of providing substantial ranges under clear starlight but moonless conditions, and some useful range even under heavy overcast. Improvements are likely to be possible in the efficiency, and reductions in the size and weight of the currently rather bulky and heavy image intensification systems, but even at the theoretical limits of sensitivity and with the largest practicable optical gathering systems the ranges obtainable are likely to leave something to be desired. In some applications it may be possible to circumvent intrinsic range limitations by the use of some highly specialised form of auxiliary illumination, perhaps with spectral characteristics matched to those of the viewing device and provided possibly by new low-light level pyrotechnics.

Night combat devices in the second broad class include those exploiting thermal detection and imaging techniques, the radar detection of movement on the battlefield and acoustic detection.

Thermal imaging devices, as the name implies, rely not on reflected radiation from the night scene, but rather on the radiation emitted from each object by virtue of its temperature. They are, of course, passive devices. The signal available in the far IR in say the 10-13 micron band, is generally very large compared with the reflected radiation from the night sky, and the main problem lies in the development of scanning and detection systems which will provide adequate spatial and temperature resolution. These problems will be to some extent helped by the fact that many military targets - man, vehicles, etc - tend to be rather hotter than the majority of backgrounds against which they are likely to be observed. Although a very great deal remains to be learned of the applications to the land battlefield of thermal detection and imaging techniques, it is of interest that there is already available on the commercial market a thermal imaging system, developed for medical purposes, which plainly demonstrates the military potential of the technique.

As has already been stated, conventional radar techniques have little to offer in the presentation of a useful over-all picture of the night battlefield. However, the exploitation of the doppler effect on the returned signals from moving objects enables the movement of men, vehicles, etc. to be readily observed. First generation battlefield surveillance radars employing this principle have been in operation for some years, and are proving their worth in South Vietnam. Considerable improvement, stemming mainly from the major advances in electrical circuit technology, should be possible in this field. This should reduce size and weight for a given level of performance, reduce power consumption, increase resolution and improve the processing and display of target information and generally increase the versatility of the equipment. A number of types of equipment will probably be required to meet all the needs of the battlefield. These are likely to include a heavier, probably vehicle mounted, set of range 10-20 kms or more, and a light-weight, man-portable set of some 2 or 3 kms range for use by patrols in the forward battle area. If the need were to be established it should also be possible to develop a very short range device weighing no more than a few pounds to be associated with the soldier's individual weapon.

The display of target information, at least for the longer range surveillance radars, is likely to be in terms of the range and azimuth of the moving targets within the field scanned. The facility can also readily be provided to present for any selected target an aural signal derived from its doppler response. This facility is provided in most current equipment, but although it is claimed that an experienced operator can extract a considerable amount of useful information about the nature and behaviour of the target from the aural signal, the role of the ground surveillance radar is likely to be limited to the first detection of targets, leaving their recognition and identification to a higher resolution device such as the image intensifier. The discrepancy which is likely to remain between the range of the radar device and the recognition range of the higher resolution equipment is likely to present a considerable problem in the evolution of an efficient over-all night fighting system.

Mention has so far been made only of radar for observation of the battlefield itself. Other surveillance radar applications of direct concern to the battlefield will include equipments for the location of enemy mortars by observation in flight of the bombs they launch, and possibly also similar equipments for the location of enemy artillery and free-flight rocket launchers. Emphasis in the field of mortar locators will be directed towards reductions in the bulk and weight of equipment to increase the ease with which these radars can be deployed in the forward area of the battlefield, and also on the silencing of their primary power sources. Fuel cells may well have an important part to play in this latter respect.

By comparison with the equipment required for mortar location, radars for the location of artillery and free-flight rocket launchers are likely to be very much larger, more complex and costly and will perhaps justify their existence only on the most sophisticated battlefield. Equipments of this kind will, of course, need to be intimately linked with the fire control systems of the weapons used for counter-bombardment, and in addition to their primary role will be able to contribute to the accurate adjustment of fire by observation in flight of counter projectiles.

There seem likely to be two main roles in future for acoustic detection systems. The first is their well-tried role of sound ranging for the location of artillery. Improvements in this role are likely to stem from improvements in the microphones themselves, but more importantly from the use of the digital computer to provide more accurate and faster processing of the raw data they provide. This kind of system, dependent as it is on stable meteorological conditions accurately known, and rather slow in deployment, is however likely to remain a rather inflexible, though perhaps cheaper competitor, to the artillery locating radar.

The second role in which acoustic detection has already proved its efficacy as a means of alerting and protecting patrols at night, or for the remote observation of specific lines of approach, for example in thick jungle, is the use of small geophones or seismic detectors planted in the ground and connected by wire, or possibly radio link, to a central unit, at which the movement of men or vehicles in the neighbourhood of any of the geophones can be presented to an operator. These techniques require a 'quiet' background against which to operate, and are likely to have their main application in guerilla-type warfare in remote and difficult terrain.

From the foregoing, it is clear that there is a wide variety of techniques which can contribute to the battlefield surveillance and night combat system of the future. The central problem over the next few years seems likely to be to determine how best to exploit these techniques in terms of the definition of the military characteristics required of specific equipments, and how best to weld the resulting range of devices into a coherent but flexible and mobile night fighting system. The appropriate balance will have to be found between passive and active devices, and this will need to take account not only of the various ways in which each is likely to be affected by atmospheric and meteorological conditions, but also, so far as the active systems are concerned, of the countermeasures which a sophisticated enemy might be expected to employ against them. This process of evolving a system will embrace not only the equipments themselves but also the problems of providing the necessary communications between them and the means for handling and displaying at the appropriate levels of command the data they will provide. In addition, restrictions in the scale of issue of particular equipments because of their cost or the limitations their weight might impose on mobility may raise new problems in the evolution of a night-fighting system. Whereas all direct fire weapons are likely to have an independent daytime capability for target acquisition and engagement, only a proportion of weapons and observers are likely to be so equipped for night action.

There seems little doubt that we are on the verge of a major step forward in the night fighting field. Nevertheless, the evolution of a much more efficient system is likely to prove a particularly complex and difficult task. But the prize for success is correspondingly great.

ARTILLERY WEAPONS AND THEIR FIRE CONTROL

Because of their generally high cost-effectiveness, conventional 'tube launched' artillery weapons are likely in the future to maintain their central position as the main provider of fire support on the battlefield. These weapons and their ammunition have reached a very high state of development over the years, and although advances in technology will give rise to marginal, though possibly important, improvements in their effectiveness, there seem to be little grounds for expecting anything like a step-function increase in weapon performance. In contrast, however, there appears to be scope for very significant advances in the whole area of field artillery ancillary and supporting equipment - the means for target acquisition, and for the optimum assignment of weapons to targets, equipment for rapid and accurate survey and for the computation of ballistic and meteorological data, and for the observation of the accuracy of fire etc - on which the over-all effectiveness of artillery fire depends.

There will no doubt be significant improvements in the surface-to-surface guided missile, but because of cost these weapons are likely to be confined to rather specialised tasks and, in particular, to the delivery of nuclear warheads. However, the development of an accurate unguided free-flight rocket could have a significant impact in the artillery field.

Improvements in the design of conventional artillery weapons are likely to stem mainly from advances in the field of materials technology. For example, once the problems of fabrication of very high strength steels are satisfactorily overcome, their use in gun design is likely to lead to worthwhile reductions in weapon weight, and to a corresponding easement of the problems of deployment by helicopter or other means. Material developments could also lead to some improvements in the charge to weight ratio of the artillery shell or to improvements in its fragmentation properties. Rocket-assisted shell may well prove a worthwhile means for achieving increases in maximum range without increasing the weight of the gun. The application of modern micro-electronic techniques to the design of proximity fuse for shell could lead to considerable reductions in fuse size, improvement in reliability and, perhaps, sufficient reduction in fuse cost to enable the enhanced terminal effectiveness of the proximity fused shell to be more widely exploited.

The advent of the small, rugged, reliable and 'battle-worthy' high speed digital computer, combined with the improvements in battlefield surveillance and target locating devices and in communications on the battlefield which are now becoming possible, will offer the opportunity of developing artillery fire control systems of almost unlimited sophistication. How far these are pursued is likely to be limited more by their cost in development and procurement than by any limitation in the necessary technology.

The artillery fire control function can be conveniently split into three parts:-

(i) The establishment of the co-ordinates of potential battlefield targets and of the weapons available to attack them in a common reference system;

(ii) The assignment of weapons to targets, having regard to all the relevant factors - target vulnerability, weapon lethality, range, accuracy, ammunition stocks of each weapon, etc.

(iii) The ballistic calculations, including the reduction of raw meteorological data, which produce the gun data required by each individual weapon to engage its allocated target. These calculations may be refined after fire has been opened by observation, either visual or instrumental, of the position of burst of the first few rounds.

The abundance of battlefield surveillance and target location devices which may exist in future on the ground and in the air are discussed above. Determination of the positions at least of the ground based devices, and hence of the targets they acquire, and of the artillery weapons in a common frame of reference will be greatly speeded and its accuracy increased by modern developments in methods of survey, navigation, and position location, ranging from comparatively simple laser or microwave distance measuring equipment, vehicle navigators and meridian indicators to elaborate area radio navigation systems in which the co-ordinates of each equipment within its coverage, including surveillance aircraft, would be automatically indicated.

The quantity of data for artillery purposes which the surveillance and target locating devices of the future are likely to be able to produce could well be such as to overwhelm current manual methods of information handling. Such data will lend itself readily to storage and handling by modern electronic and computer data processing techniques, and once this is accepted it is a short step, in theory at least, to the storage of artillery weapon co-ordinates and ammunition states, and to the determination of an optimum weapon fire-plan in which weapons and targets are matched in some 'best' sense. Admittedly, by this stage the computer will have grown somewhat in speed and size, and there will be considerable difficulties in translating into computer programming terms the thought processes employed by a skilled gunnery officer in arriving at his fire plan by traditional methods. Nevertheless, the complexities of the future battlefield would seem likely to press inexorably in this direction.

Developments along these lines should improve the effectiveness of artillery fire by increasing its accuracy and speed of response, and at the same time ease the training problem and reduce the growing computation load on the man. The digital computer solution of the ballistic problem will enable the traditional approximations of manual methods to be avoided, and the 'second order' effects - important under some conditions - to be properly allowed for. The increased speed of computation will improve effectiveness of engagement of transient targets or targets on the move, and will allow the accuracy of radar observation of burst positions to be fully exploited in the adjustment of fire. In addition, the use of the computer to process the raw data from the improved sensors likely to be available in future meteorological sounding systems to establish wind, temperature, pressure, humidity, etc. in the upper atmosphere, should provide the gunner with more accurate and up-to-date meteorological information than has been available to him in the past.

Just how far these techniques will be pursued for artillery fire control remains to be seen, but it is of interest that it is in this field that the first applications of the digital computer on the land battlefield are beginning to emerge - for the solution of the gunnery ballistic problem and for the reduction of meteorological information.

The potential applications on the battlefield of the digital computer and associated electronic data processing techniques are by no means limited to the field of artillery fire control. They have a potential contribution to make across the whole command and control field in higher headquarters, and particularly to the general problem of the collation, processing and display of all kinds of intelligence information, to a variety of aspects of logistic, supply and maintenance problems, to signal frequency planning, etc. But the realization of these wider potentialities would seem to demand a considerable period of very close work between the military and the electronic data processing engineer to establish when and how best these techniques can be exploited to fully cost-effective military advantage.

THE CLOSE AIR SUPPORT THREAT AND DEFENCE ON THE BATTLEFIELD AGAINST IT

There is naturally strong feedback between development in the means and methods of providing close support from the air to ground troops, and the weapons devised to combat them. Between contestants of roughly equal sophistication the former defines the threat which the latter must counter, and the means and their success in countering it in turn moderate the tactics and equipment for close support. Although it would be inappropriate in this paper to attempt any detailed discussion of the whole range of aircraft and equipment technologies which will influence the manner in which close air support will be conducted in the future, it is impossible to frame a reasonable discussion of developments in battlefield air defence without some review of the kinds of weapons which may be used for the attack of targets on the battlefield and the ways in which they might be employed.

Like all operations on the battlefield, close air support and, though perhaps to a lesser extent, defence against it are strongly conditioned by the nature of the battlefield terrain. The first problem, and in many circumstances the prime problem is the location and identification of the battlefield target. This problem has presented particular difficulties in the Malaysian confrontation operations and in South Vietnam where, for example, areas of tropical rain forest with a double and sometimes triple canopy of foliage have provided the most effective means for concealment. The methods which have been devised and the equipment demands which have been generated to meet the range of environmental conditions in South East Asia will no doubt have their part to play in other circumstances, but not all the close air support lessons learned there will necessarily read across directly to future military operations. In South Vietnam the character of ground defence against close support aircraft, though extensive, has been rather unsophisticated, and there has so far been a notable absence of enemy air over the battlefield. It is difficult to believe that, were there a serious threat of air interference for example, the extensive use which has been made of rather low performance aircraft in a number of important roles would be practicable.

Battlefield Target Acquisition

In the field of target acquisition from the air there would appear to be little if any prospect of advances in technology providing the means for penetrating the denser forms of natural cover except possibly in rather special cases where the target itself emits some helpful form of radiation. For example, airborne infra red detection systems show some promise for locating cooking fires and other strong heat sources through jungle canopy. Under visual conditions and in circumstances where natural cover is less dense or patchy the direct use of the human eye at present provides the more effective means for target acquisition and the refinement of tactical methods for exploiting this, rather than technical aids, have shown a very considerable pay-off in increasing the efficiency of close air support. The use of airborne 'forward air controllers', each highly familiar with the particular area of terrain which he patrols, and operating at rather low altitude and slow speed have provided, in South Vietnam, an invaluable means both of acquiring battlefield targets and of guiding higher performance close support aircraft in to attack them. Improvements are obviously feasible in the means for target indication, in the form of improved coloured smoke munitions either dropped by the airborne controller, or in more static situations, fired by forward elements of friendly troops. In the longer term the use of a laser beam to illuminate the target and thus indicate it accurately to a detecting system in the attacking aircraft might be advantageous.

There is a pressing need for much more effective means of battlefield target acquisition by night and under 'all weather' conditions. Active and passive airborne reconnaissance systems such as optical and infra red line scan, and sideways looking airborne radar make some contribution towards these problems, but there is a general requirement to improve either sensitivity to increase coverage or resolution or both. The development of 'forward looking' IR and radar ground scanning systems should also remove some of the tactical limitations of the current generation of 'sideways looking' devices which can observe targets only as they are passing the aircraft's beam. The development of low light level television systems, based on the image orthicon and other devices will provide the means for intensifying the ambient radiation reflected from the night scene, both for general viewing and for the guidance of aircraft or weapons. These devices which offer the ability to 'see' down to levels of illumination two orders of magnitude below the capability of the human eye have a considerable potential contribution to make to close air support at night.

The alternative approach to the problem of battlefield target acquisition at night is the direct illumination of the ground by flares or other means, to allow the use of visual and other 'daylight' techniques for target attack. The 'flare ship' has been widely exploited in South Vietnam and there are intensive programmes in the United States to devise improved methods of battlefield illumination including the use of xenon lamp systems, and the means for exploiting them. A reported aim, for example, is 'a xenon lamp illumination system capable of lighting a two mile area on the ground five times brighter than a full moon from 12,000 feet altitude'. (1)

Air to Ground Weapons

Until the last three or four years, development in the field of non-nuclear air dropped munitions has been more or less stagnant since World War II, and the weapons now available are, in the main, little different in kind from those then in use. This presumably reflects the pre-occupation of air forces with the evolution of equipment and tactics for the air delivery of nuclear weapons. The campaigns in Vietnam and Malaysia have given a much needed fillip to the military technology of conventional air dropped weapons. Of

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(1) Electronic News - June, 1967

the many possibilities in this field there are at least three concepts which would appear to offer a considerable step forward. These are the adaptation of conventional bombs for release at very low level, the development of cluster bomb weapons to provide a more efficient distribution of terminal effectiveness on the ground, and the development of guidance systems to improve the accuracy of delivery, particularly in the context of weapons which allow the attacking aircraft to stand-off from its target. (1)

One of the main objectives in recent years in the field of strike/close support aircraft has been the development of systems to allow high speed flight at very low altitudes above the terrain, so as to avoid detection by ground surveillance radar and to take advantage of the limitations which this tactic imposes in the coverage of ground defence systems, either because of technical limitations in the performance of fire control or weapon guidance radar or natural limitations from terrain screening. The development of airborne terrain avoidance and terrain following radars has largely enabled this objective to be achieved. But the conventional 'iron bomb' is unsuitable for release in these conditions because of the risk to the attacking aircraft from the explosion of its own weapon. However the addition of comparatively simple high drag retarding devices to the bomb should allow this limitation to be overcome without substantial degradation of the high accuracy of aim obtainable in those circumstances.

One of the characteristics of the conventional bomb is that against all but the hardest targets it tends to provide a region of intense overkill in close proximity to the point of burst with a rather rapid fall off in lethal effect with distance from the point of burst. The development of the means for distributing the pattern of terminal effectiveness more uniformly at no more than the level required to 'kill' the target under attack over as wide an area as possible thus smoothing out the 'peak' in the bomb pattern, would appear likely to offer a way of increasing, perhaps many times, the mean area of effectiveness against the 'softer' battlefield targets such as men in the open of 'soft' vehicles compared with the same weight of conventional bombs. The idea of distributed

(1) For a general discussion of the ordnance requirements generated by the Vietnam conflict see, for example, Missiles and Rockets 28.3.66 'Report from Vietnam'.

'terminal effectiveness' is far from new, and cluster bomb devices exploiting this approach are already being widely used by the US Air Force in Vietnam. This concept would appear to offer a particularly flexible addition to the armoury of air dropped weapons. In principle, adjustments within the bomblet dispensing system should enable the overall pattern size to be matched with the accuracy of delivery expected from particular conditions of release and the extent of the target. It is also possible to envisage a range of types of individual bomblet each matched to the vulnerability characteristics of the class of battlefield targets it is designed to attack. The cluster bomb concept also has obvious application in the role of 'area denial' or 'barrier creation' for the distribution of anti-personnel or other forms of 'minelets'. The ultimate cost effectiveness of weapons of this class will depend critically on the design of cheap simple and easily fabricated individual bomblets, and in particular on the design of cheap and simple individual arming and fusing systems.

Improvement in the effectiveness of ground based air defence systems, either already realised or confidently predicted, have given a strong impetus to the search for 'stand-off' weapons which will enable a target to be attacked without requiring the exposure of the attacking aircraft to local ground defences sited to protect it. This inevitably demands some form of missile guidance and the demand for stand-off is naturally coupled with the requirement to exploit the guidance system to provide much higher terminal accuracy than is generally possible with unguided air dropped weapons.

Although the guidance of air dropped conventional weapons, in order to improve their accuracy, has been pursued in a rather desultory fashion since the last years of World War II, it is only comparatively recently that this has been combined with the stand-off requirement. Weapons like the line-of-sight command guided Bullpup, for example, go some way towards meeting these needs, but because of the requirement imposed on the aircraft to track the target until weapon impact and the difficulties in target acquisition at long range, the stand-off capability is scarcely adequate even against very short range local defences. The next technical step forward is the carriage within the missile itself of some form of target scanning sensor which transmits the picture it sees back to the parent aircraft where steering instructions are determined and transmitted to the missile to guide it on to the target. Systems of this kind have the advantage that the target resolution available increases steadily as the missile approaches its target and the attacking aircraft has full freedom of manoeuvre once the missile is launched. The first form of target sensor likely to be exploited in this class of weapon, as for example in the Anglo-French Martel is the television system. Such systems will be restricted, at least in the first instance, to operation by day, but the development of low light level television systems may well extend their use in clear night conditions. There is also a wide range of other forms of sensor - near infra red, thermal imagery radar etc (1) - which might be exploited in this kind of system, each offering particular advantages either against some special class of targets or in some particular battlefield circumstances.

These weapon concepts all place a continuing guidance task on the operator until weapon impact, and there is a strong demand in some quarters for so-called 'launch leave and forget' systems which are completely self sustaining after launch and impose no further load of any kind on the releasing aircraft. There appears to be no immediate technical prospect of the emergence of the kind of missile homing guidance system which would satisfy this demand against battlefield targets generally, although systems of this kind can readily be envisaged which exploit the radiating characteristics of certain rather narrow classes of targets - for example surveillance or fire control radars and, possibly targets which radiate large quantities of heat. Perhaps the most promising of the more nearly general purpose concepts of this kind is the electro-optical scanning system having the ability to lock on to targets which contrast strongly with the background against which they are seen. In the longer term this limitation to 'high contrast' targets might be removed by the development of the area correlation pattern recognition system mentioned above. The most important weapon in the special purpose category is the anti-radar missile capable of looking on to the radiation emitted by a radar on the ground and homing to its source. This class of weapon is currently typified by the US Strike. Although this particular weapon is reported as having some shortcomings in operation this is clearly a field in which significant developments are likely.

This brief and far from comprehensive review indicates that advancing technology is likely to offer an extremely wide range of potential contributions to the improvement and extension of the

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(1) For some details see, for example, Aviation Week and Space Technology - December 1965

capabilities of close air support on the battlefield and elsewhere. While some of these new ideas are likely to be comparatively cheap and simple to exploit, very many of them, particularly those relating to stand-off weapons will be highly complex technically, and thus demanding in their support and maintenance requirements and costly in procurement. Although it is possible readily to envisage circumstances in which unusually expensive weapons will be more than justified by the reduction in risk to the aircraft - costing perhaps of the order of £1m - delivering them, these weapons are likely to be employed sparingly and only in circumstances that clearly demand their use. They will generally be more suitable for the attack of preplanned targets and at least their initial employmemt is likely to be against the more important and well defended targets - for example base installations, airfields, SAM defences etc. Their widespread appearance in the forward area of the battlefield would seem likely only to follow substantial improvement in the general level of effectiveness of battlefield air defence.

Battlefield Air Defence

Improvement in aircraft performance after World War II, and particularly the ability of jet aircraft to fly at very high speed and altitude completely and rapidly outmatched any potential that the heavy AA gun appeared to offer, and AA gun development in many countries, including the UK, virtually ceased. This weapon was of course replaced by the surface-to-air missile which has tilted the balance in the struggle for performance rather heavily against the high altitude aeroplane. The attack in its turn has sought to exploit the limitations of SAM (and also fighter defence) by adopting low level tactics to avoid detection by surveillance and fire control radar, and to take advantage of the restrictions on, and, in some first generation SAMs the virtual absence of performance against low flying aircraft. These restrictions stem partly from natural limitations imposed by the horizon or by terrain obscuration and partly from technical limitations on guidance systems and from the rather long minimum range of detection required for the engagement of low flying targets. Some of these limitations have now been removed but the SAM which retains useful high altitude performance is likely to remain a somewhat cumbersome system, scarcely suitable for mobile deployment forward on the battlefield, and likely to be restricted in its battlefield use to comparatively static situations and to complementing the interceptor fighter defence of rear areas.

The growth in emphasis on low altitude attack has boosted the importance of the light AA gun. Its ability to respond very quickly and to deliver large numbers of shell with short times of flight make it a highly effective weapon at close range against low altitude targets. Development has been concentrated on small calibre guns with high muzzle velocity, high rates of fire (including multiple barrels) and increased sophistication of fire control. These lines seem likely to be pursued further in the future, possibly with the application of the small digital computer to reduce the size and weight of the fire control equipment and the laser range finder to replace the radar for the provision of range input. They could lead to a complete system installation in for example an APC type vehicle which could live and fight with forward units.

The competitor to the gun as the means for providing defence against low-flying aircraft on the forward area of the battlefield is of course the short range low altitude surface-to-air missile system. Two distinct requirements for this type of weapon seem now to be emerging. The first is for a simple rugged vehicle or trailer-borne system readily deployable in forward areas and capable of giving a measure of area defence against targets up to say 10,000 feet or more. There would seem to be little technological reason why systems of high effectiveness should not be evolved to meet this need. Two main issues seem likely to influence the future role which systems of this kind will play on the battlefield. The first is to the extent to which the very high 'paper' effectiveness attributable to them will be maintained under operational conditions in the field. The second relates to their likely cost and the extent of their deployment. Inevitably such systems will be limited in their coverage by terrain and other factors, and their widespread deployment in large numbers on the battlefield would seem likely only if system complexity and costs, operating manpower requirements and other battlefield support facilities can be kept down to a reasonably low level. So long as the effective close support threat is largely limited to visual daylight conditions there would appear to be advantage in providing in low altitude SAM systems no more than the capability required to operate under these conditions. But as the threat extends its capability to night or all weather conditions there would appear to be a reasonable technological prospect of extending the performance of the low altitude SAM system, albeit at considerable increase and complexity and cost, to match .

The second low level SAM requirement is for a very lightweight system small enough to be carried and used by the individual soldier to provide a measure of local AA defence for units operating outside the coverage of the first type of system. Possible technical solutions to this need already exist, for example, in the US Redeye heat seeking missile and the British Blowpipe Visual Command line of sight system. The performance of weapons of this type is likely always to be limited by the alertness and ability of their operator to detect and identify his target sufficiently early to allow its engagement, but, in spite of this, their widespread deployment is likely to make air transit of the battlefield at low altitude substantially more hazardous than it has ever been in the past. Indeed perhaps one of the main problems their deployment would raise would be to devise means of ensuring the safety of friendly aircraft in passage. A solution to this problem might well have to be found along organizational and procedural rather than purely technical lines.

To summarise, the military/technical state of the art in the field of close air support on the battlefield and the means for countering it is in a very considerable state of flux. Technological advance is likely to offer wide scope for improvement in the quality of close air support while at the same time offering the means for making it a far more hazardous class of operation than it has ever been in the past. The immediate options are fairly readily discernible and the first few moves in the battle of weapon and counter weapon reasonably predictable. How the balance will work itself out in the longer term remains to be seen. It could well be however that the limitations are ultimately set not so much by the absence of technological solutions as by the availability of resources fully to exploit the whole range of technical possibilities.

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INSTITUTE FOR STRATEGIC STUDIES

9th ANNUAL CONFERENCE

THE IMPLICATIONS OF MILITARY TECHNOLOGY IN THE 1970's

COMMITTEE III - 1

Friday 29th ~~Saturday 30th~~ September   Morning

Some Implications of New Communications Technologies for National Security in the 1970's

LELAND L. JOHNSON*

NEW TECHNOLOGIES AND THEIR USES

Over the next decade exciting prospects exist for providing low-cost, reliable communications links spanning thousands of miles of land and water and reaching into many of today's remotest areas. Under the impact of continuing technological advance, geographical distance *per se* will become a progressively less important factor, being far out-weighed by the more prosaic considerations of terminal switching, local landline hook-ups, and administration. The vast potential benefits to society have already received much publicity and attention.

Developments in the field of satellite communications are especially noteworthy. Under the auspices of the International Telecommunications Consortium (INTELSAT) several satellites have been launched to provide telephone and teletypewriter service, and occasional television relay, across the Atlantic and Pacific. The INTELSAT Early Bird satellite orbited over the Atlantic in 1965, although officially an experimental project, already provides commercial service at lease rates roughly comparable to those of existing cable facilities. Within three or four years the consortium may orbit a satellite offering 100 times the channel-years

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(number of years of expected useful satellite life multiplied by channel capacity), but at a total cost no more than two or three times that of Early Bird. For the 1970's, even more advanced designs are in the talking stage.

The U.S. Department of Defense has underway an "Initial Defense Communications Satellite Program" to provide long-distance links of modest capacity serving special military needs. An advanced system with greater capacity is planned for use by 1970; a tactical system to provide communications between combat and other field units is in an earlier stage of development.(1)

The Soviet Union is moving rapidly ahead. Among other applications, telephone and television service via satellite is available between Moscow and Vladivostok. A consortium including the Soviet Union and Eastern European countries is to exploit further this new technology.

The French government is engaged not only in space vehicle development, but also in constructing an elaborate launching site near the equator in French Guiana - a location particularly attractive for boosting satellites into equatorial orbit. France and West Germany have recently announced plans to launch a joint communications satellite from this site in late 1970.(2)

Major advances are also being made in other communications techniques. High-capacity underwater cables, employing transitor repeaters as a substitute for vacuum tubes, can be installed at a fraction of the cost per telephone channel embodied in the existing transoceanic cables. Laboratory experiments with laser beams are well underway. In the more distant future, perfection of laser-beam "pipelines" would provide a truly enormous increase in telecommunications capacity.(3)

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(1) U.S. military systems are discussed in Committee on Government Operations, Forty-Third Report, Government Use of Satellite Communications, 1966.

(2) A summary of the current status and plans of INTELSAT is contained in Communications Satellite Corporation (Manager for INTELSAT), Report to the President and the Congress, Washington, D.C., 1966. For a brief account of French activities, see Aviation Week and Space Technology, June 20, 1966, pp. 209-211 and June 5, 1967, pp. 22-25.

(3) For a more detailed recent survey of these and other possibilities see "Communications, Searching Eye, Questing Ear," Forbes, July 15, 1967.

Use of these technologies for telephone, teletypewriter, and data traffic is both obvious and fairly straightforward. Two other applications - television service and facsimile mail transmission - are also potentially important, both in terms of commercial markets and implications for national security. But they involve special considerations that merit separate discussion.

Television and Facsimile Mail

The feasibility of instantaneous worldwide dissemination of television programming via satellite was dramatically shown as early as 1962 in the experiments across the Atlantic with the Telstar Satellite. Since existing transoceanic cables simply do not have the broadband capability to carry conventional television channels, the wholly new possibilities have attracted widespread attention. Transatlantic service is today routinely available, and special-event programs are relayed from time to time across both the Atlantic and the Pacific. With continued technological advance, not only will transoceanic service become progressively less expensive, but satellites will become serious competitors of existing terrestrial facilities for domestic use as well. For the United States, recent studies disclose that distribution of programming from network centers to outlying land broadcasting stations via satellite relay would be less costly to the commercial networks than the landline microwave facilities they now employ. (1)

To be sure, the value of instantaneous transmission is reduced because of time zone differences around the world, and requirements for local editing. Even in the continental United States, crossing only four time zones, it is generally necessary to delay broadcasting to local home receivers for the convenience of the viewer. Employing a satellite over the Atlantic or the Pacific requires in almost all cases that the program be taped at the receiving end for local re-broadcast at a more convenient time.

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(1) Much of the evidence regarding use within the United States is contained in responses to an inquiry of the Federal Communications Commission, Docket 16495. See especially the Ford Foundation, Response to the FCC Inquiry; American Telephone and Telegraph Co., An Integrated Space/Earth Communications System to Serve the U.S.; Communications Satellite Corporation, Technical Submission of the Communications Satellite Corporation, all December 1966.

In view of these delays, would not shipment of videotape by airmail be highly competitive with satellites, especially in the era of supersonic transport? In cases where programming is to be sent between two points, say New York and London where nonstop airline service is frequent, the satellite would indeed have little to offer. But to concentrate on such instances is to miss the point - the real potential of satellites lies in their flexibility in picking up programs in both central and out of the way places and distributing them simultaneously to ground stations around the world. A revolt in the Congo covered on the spot by television crews with an airlifted portable satellite transmitter station to relay material via satellite to dozens or hundreds of receiving stations in Europe, North America, South America and Asia; an urban riot in the United States likewise flashed around the world; an emergency United Nations session in New York transmitted as it is taking place, not just across the Atlantic to a few capital cities, but to every point north, east, west and south where a receiving station is available. The fact that the distant viewer sees the program with some hours delay turns out to be trivial. The timeliness and the liveliness of the presentation to viewers around the world made possible by satellite cannot be approached by any other now-known means of distribution.

Analogous to the case of airmailed videotape, it is the element of flexibility that gives the satellite an advantage over the recently perfected transistorized underseas cable mentioned above. These cables also have a capability to transmit television programs (unlike existing transatlantic and transpacific cables); if we were concerned only with communication across the Atlantic between two major points, such cable might involve no higher a cost than satellites. But a satellite together with a group of ground terminals scattered in countries on both sides of the Atlantic would provide a whole <u>network</u> of links. And more than that, the capacity over each link could be adjusted (within limits) to conform to peak daily traffic demands over that link. Plans are well advanced to establish a transistorized cable stretching 1250 miles from Florida to the Virgin Islands, and there is talk of yet other cables in the Caribbean and on other high-density routes. These cables will, of course, contribute importantly to satisfying regional needs and they will add a further desirable element of diversity to the physical structure of worldwide communications. But viewing current problems and prospects as they now stand, I conjecture that the thrust of the future will not run in the direction of extensive cable construction.

In a facsimile mail transmission system high-priority correspondence - technically limited only to any written or pictorial information expressed on paper - is scanned electronically at the point of origin, the information transmitted via landline or satellite relay to another point perhaps thousands of miles away, and then reproduced at the other end on a facsimile machine in essentially the original form. Reduction in the cost and complexity of facsimile reproducers, combined with growth of satellite systems, will very probably make this economically feasible during the 1970's. Instantaneous or overnight delivery to any point in the world included in the network would be highly attractive for firms operating internationally, individuals with friends and family overseas, and governments with each other and with their own foreign staffs.

THREE QUALIFICATIONS

One's imagination can be nearly carried away in considering the prospects for drastically reducing the costs of communication, opening up new rich markets, and reducing or eliminating geographical distance as a barrier to human interaction. But we must remember that these are prospects, not today's reality; while the promise is great it would be a disservice not to mention three major qualifications, before passing on to implications for national security.

Public Policy

First, the most serious difficulties and constraints in moving ahead may hinge not only on questions of technical and economic feasibility, but also on questions of how uses of new technologies are to be promoted, restricted, and regulated as a reflection of conscious choices and judgments about what constitutes the "public interest" and how it ought to be served. The presence of large-scale cost reductions afforded by a new technology does not necessarily means that users will reap the benefits as fully or as quickly as one might expect on the basis of comparative cost analysis alone. For the introduction of a new technology frequently gives rise to a host of issues regarding ownership and management, criteria for setting prices and conditions of access to users, and the degree to which use of the technology is to be restricted or prohibited to protect existing investment in earlier, obsolescent facilities.

In the United States these issues have been at the forefront during the emergence of satellite technology. Questions about who should own and operate satellite systems have been the subject of extended controversy. Only after long and bitter congressional debate was legislation passed authorizing a new entity - the Communications Satellite Corporation (Comsat) - as the American representative to establish, in co-operation with other countries, a global communications satellite system. Subsequently, argument has centered around a number of issues including the degree to which Comsat should be permitted to compete with existing American telephone and telegraph common carriers. (1)

The issue of competition came out clearly in the recent so-called "30-channels" case. In the summer of 1966 the Department of Defense was negotiating with Comsat to lease directly 30 satellite channels from Hawaii to the Far East. Comsat quoted a rate of $4,200 per channel per month, in contrast to $10,000 to $12,000 quoted by several of the common carriers in conformity with their then-existing rate structure for transoceanic cable. However, the Federal Communications Commission ruled that Comsat was not, in general, to offer services directly to the ultimate user - not even to the U.S. government. According to the FCC, the role of Comsat was to be that of a middleman leasing satellite channels to the common carriers, with the carriers in turn "retailing" them to the ultimate user. After extended debate, the Department of Defense was persuaded to lease through the carriers at a rate of about $7,000 - as against Comsat's earlier quoted $4,200 - reflecting a composite cost of satellite and cable facilities. This outcome is consistent with the long standing policy of the FCC that rates for a service performed by a common carrier are not to depend upon the cost of a particular facility used, but rather should reflect the average of costs of all facilities old and new employed in that service. In the words of one commentator:

> The public interest may well require a diversification of facilities, and it is certainly not in the public interest to let Comsat use its present cost advantages to inflict serious harm on the carriers before they get a chance to try to make cable technology into a viable competitor. But such a policy has its social costs - it could make international communications more expensive, and it inevitably slows the growth of the industry in general, apart from the new technology, in order to protect the value of possibly obsolete equipment. (2)

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(1) An excellent analysis of major current issues relating to Comsat is presented by Herman Schwartz, "Comsat, the Carriers, and the Earth Stations: Some Problems with Melding Variegated Interests," Yale Law Journal, January 1967. The issue of ownership and operation of satellites for use solely within the U.S. is treated in the submission to the F.C.C. Docket 16495 footnoted previously.

(2) Schwartz, op.cit., p.472. The "30-channels" case is discussed in detail in Government use of Satellite Communications, op.cit. pp. 33-56.

Co-operation and Economies of Scale

Conflict may arise between the most economical use of satellite technology and national interests perceived by individual governments. The large potential cost reductions discussed in the earlier sections are predicated on the notion of large-capacity satellite systems to take advantage of the economies of scale inherent in satellite technology. That is, the larger is the channel capacity of a system the smaller, generally speaking, is the per-channel cost. The kinds of worldwide services discussed above will require extensive sharing by numerous countries of common systems, if these economies of scale are to be enjoyed. To be sure, this does not mean that only one worldwide system operating as a monopoly will do. In the United States a separate system for domestic television distribution may not suffer serious disadvantage, because the very large television traffic volumes anticipated may be sufficient to exploit most of the potential economies of scale. Other countries may, under similar circumstances, find separate domestic systems economic. In general, however, extensive sharing of common systems will be essential. This in turn will involve complex agreements about a host of issues relating to such things as the sharing of ownership and control, rights of access to the system, questions of pricing and revenue sharing, and radio frequency allocations.

For a variety of reasons some governments may be tempted to establish their own separate systems to meet more limited domestic, regional and worldwide needs. The desire to exert a greater degree of control over the system, the hope of exerting general influence on other countries co-operating in the system, the desire to satisfy special needs inconsistent with the operation of an integrated larger system, and the prestige gained by appearing a leader in the exploitation of new and glamorous technologies, could conceivably lead to a proliferation of competing systems - each small, each suffering from high unit costs, and together denying to society much of the potential payoff from technological progress.

Complementary Ingredients. Enamoured of a bright new technology, the observer can easily underestimate requirements for other essential ingredients. For example, parallel development of transportation and communications technologies, with each complementing and reinforcing the effect of the other, is frequently of central importance. A promising business opportunity discovered in a remote region by virtue of improved communications would have little value unless transportation into the region were available; large jet cargo transports designed to lift military forces to any place in the world on short notice would be of restricted use without continuous and reliable communication with their control centers.

As another example, much discussion couched in glowing terms has been devoted to the potential of television, particularly in conjunction with satellite hook-ups, for educational purposes in less-developed nations. In view of widespread teacher shortages, rapidly rising school enrolments, and grossly inadequate school plants, television and satellites have been widely regarded as a new hope for improving the educational structure. Educational television is already being used in a number of countries. One of the most extensive efforts is in Colombia, where nearly 400,000 students per year are exposed to a classroom television series covering a variety of course material. However, a striking feature of the Colombian system is that its deficiencies have rather little to do with either television technology or with the absence of satellites. (1) The most serious problem is the severe lack of teachers adequately trained and motivated to use classroom television effectively. The Colombian experience suggests the pitfalls one encounters in pressing for a particular technological solution to a problem area without taking into account the crucial role of complementary ingredients.

COMMUNICATIONS AND NATIONAL SECURITY

In view of the extraordinarily rapid technological advances taking place, and the numerous promising applications, questions immediately arise about the implications for national security. The potential contribution of satellite technology to the problem of adequate communication in time of international crisis, and its use for command and control in wartime are two specific areas of concern. In addition, I shall discuss some broader implications relating to open and closed societies, the centralization and decentralization of decision-making functions, the process of bargaining and negotiation, the viability of alliances during crisis and war, and the long-run structuring and restructuring of national interests and alliances.

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(1) In fact, television is a surprisingly well developed industry in a number of less-developed countries. There are over 2 million television receiving sets in Brazil, over 1 million in Mexico, and 200,000 in Colombia. At recent count, Brazil has 47 television broadcasting stations, Mexico 32, Colombia 14, Peru 20.

Communications and Crises

A tense confrontation between countries, a revolution or insurrection, or a local war, can quickly tax existing communications facilities within and among the countries involved. Not only do urgent government requirements mount for information about events and how to respond to them, but additional loads are imposed by anxious relatives and friends and by business firms with interests in the area. Despite the fact that radiotelephone is subject to fading, distortion and complete blackout due to vagaries of the ionosphere, it is still employed in many areas of the world. (1) Telephone and telegraph cables, though rendering good quality service, have limited capacity to handle the special demands that arise in time of crisis.

A recent striking example of how facilities can be overtaxed is drawn from the recent Arab-Israeli confrontation. By the third day of the war, the American Telephone and Telegraph Company announced a backlog of 2300 telephone calls to Israel alone, and was informing customers of delays of up to 2 weeks. Not only had demand sharply increased, but problems were compounded by a magnetic storm, the result of sunspots, that hampered the use of radiotelephone facilities. (2)

The crucial importance of reliable communication links in evaluating and responding to crisis situations is well illustrated by the history of the "hot-line" teletype link between Washington and Moscow. The cable hook-up - passing through Helsinki, Stockholm and London - was established in 1963 to assist in coping with problems of miscalculation and accidental war. In the words of the <u>New York Times</u>:

> The need for a communications link was dramatized by the showdown over Soviet missiles in Cuba. At the height of that crisis both President Kennedy and Premier Khruschev found events and decisions overtaking their exchanges of opinion and bargaining positions ... They were forced to send messages by open telephone and radio channels, leaving little room for private diplomacy. (3)

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(1) Among other applications, it is used to link most of the less-developed countries of the world with the United States and with Europe, and in some less-developed countries it is widely employed for long-distance domestic service.

(2) Reported in <u>New York Times</u>, June 8, 1967, p.50.

(3) <u>New York Times</u>, June 6, 1963, p.1.

The value of the hot-line was clearly brought home when it was used officially for the first time during the Arab-Israeli war. As pressure mounted and the likelihood of war increased, Chairman Kosygin and President Johnson employed the line to express their great mutual concern about the situation. During the war itself, when Egypt and Jordan asserted that American and British planes were involved in the fighting, Johnson notified Kosygin that these charges were unfounded. When the U.S. ship Liberty was subsequently attacked by Israeli forces, and U.S. carrier aricraft were dispatched to investigate and to render assistance, Johnson rushed to Kosygin assurances that these planes were not entering the battle. Altogether, more than twelve messages were exchanged over the hot-line during the crisis. (1) In this context it is worth recalling that the hot-line, consisting of continuously available leased space on a regular commercial cable, is not immune to breakage. In fact, in December 1966 it was accidentally broken - in Finland - disrupting service for nearly twelve hours. (2)

An obvious application of satellite systems is to provide an expanded and more adequate network available in time of such crises. For the not distant future, we could envision ground transmitting and receiving stations located in capital cities and at other points of importance. With a number of high-capacity satellites in orbit, and with the ability of the system to transfer capacity among points in the network to satisfy peak demands along particular links, service would be available free from the effects of ionospheric vagaries that plague radiotelephone and in a volume unmatched by existing or presently contemplated cables. (3)

National Command and Control in Wartime

With continuing technological advances, ground receiving and transmitting stations will be reduced in size to the point where they

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(1) An interesting account of these events, from which the above description is drawn, is provided by Hugh Sidey, "Over the Hot Line - the Middle East," Life Magazine, June 16, 1967, p.24b.

(2) A brief account of the break was reported in the New York Times, December 20, 1966, p.33.

(3) The two INTELSAT satellites now over the Atlantic together have a total capacity (480 voice channels) roughly equal to that of all existing transatlantic telephone cables. For a good description of existing and projected cable and radiotelephone international systems see R.T. Nichols, High Capacity Submarine Telephone Cables: Implications for Communication Satellite Research and Development. The RAND Corporation, RM-3877-NASA, September 1963.

can easily be airlifted or transported by jeep, and carried on tanks, planes, ships and submarines. The U.S. Army already has under procurement contract a 23,000 pound terminal with an 18-foot diameter antenna suitable for airlifting in a single C-130E aircraft or by helicopter.(1) The Department of Defense tactical system calls for yet smaller, easily portable stations. The U.S. Federal Aviation Agency, in a joint government-industry experiment, has recently demonstrated the feasibility of satellite relays for long-range communication with aircraft employing relatively simple receiving equipment.(2)

Since satellite links would be free from the common ionospheric vagaries that affect conventional high-frequency radio, they would be valuable in both limited and general war. In nuclear war satellite links would be especially valuable because they would be less susceptible to nuclear "blackout" effects than is the case with conventional high-frequency radio.

On the subject of vulnerability, questions immediately arise about the possibility of enemy attack against the satellite system itself. How vulnerable are ground terminals? Cannot the enemy jam or destroy satellites in orbit? Without going into much detail here, I would make four points:

1 A variety of techniques are available for countering the threat of jamming, though generally at the cost of reducing capacity.

2 A satellite can, of course, be destroyed by an enemy warhead boosted into rendezvous orbit; but here we face the familiar "numbers" game. The larger the number of satellites in orbit, the smaller is the probability of destroying all or most of them with a given level of attack. If the satellite links are combined with back-up landline and conventional radio facilities as well, the overall system can possibly be rendered quite an unappealing target.

3 As ground terminals become smaller, less costly, and more numerous they too will become less attractive targets. Not only

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(1) Government Use of Satellites Communications, op. cit.18-19. The military program also includes "transportable" rather than "portable" terminals with 40-foot antennas and weighing 123,000 pounds, and still larger fixed terminals with 60-foot antennas.

(2) An interesting amount of the prospect for satellites used with ships and aircraft is provided by Eugene Ehrlich. "The Future Potential of Navigation Satellites," AAS 67-101, Proceedings, American Astronautical Society, 1967.

will it become progressively more feasible to install emergency back-up terminals, but reductions in their size will facilitate installation in hardened points.

4 Even in general war it is not obvious that the enemy would find it in his interest to destroy all communications facilities of the opposing forces. On the contrary, it may be in the interest of all participants to maintain communications with each other for the process of bargaining, negotiating and bringing the war to a close. In this process many instances can be imagined in which it would be in the interest of each belligerent for the opposing side to be able to maintain control over its own tactical and strategic forces.

Some Broader Implications

Open and Closed Societies. The expanded flow of communications will heighten the contrast between open and closed societies, and not necessarily to the advantage of the former. It is clear from earlier discussion that the national government will continue to have wide latitude in deciding the degree to which its own citizens will participate. It can build ground stations or not; it can choose to join international communications consortia or not; and it can monitor and filter incoming and outgoing telephone, telegraph and television traffic as it pleases. The open society, in contrast, will become that much more open. Its social, economic and political stresses and strains, especially of the sensational sort, will stand for the world to see; all the while, it must submit to whatever onslaught of outside material comes its way - some objective, some distorted, some the grossest propaganda - all more easily disseminated by virtue of the new and expanded communications facilities. Temptations and pressures to make the open society less open will mount.

One might ask whether new communications technologies do not themselves hold promise for penetrating the walls of a closed society. For example, there has been much talk, and some serious study, devoted to the possibility of developing a satellite sufficiently powerful to broadcast directly to home television receivers. (This case must be clearly distinguished from the systems described earlier in which programs would be relayed via satellite to ground receiving terminals from where the program would be re-broadcast in the conventional fashion to home receivers.) If such a satellite were built, could it not be used to carry programs to viewers even against the wishes of their national authorities? The answer is no. Satellite power requirements to broadcast directly to a conventional, unmodified home antenna would be extremely severe; so severe in fact that this approach is not being seriously contemplated, so far as I know, for the foreseeable future. What has been considered is a modified home antenna or receiver, housing a pre-amplifier and other equipment costing perhaps $50 to $100, as a means of reducing the satellite power requirement to a point where such a system might become technically feasible within the 1970's. (1) However, the system would be of little value in penetrating a country against the will of the authorities. The presence of modified home equipment, useful only for picking up satellite programs, would not be difficult to detect. Besides, it is not at all clear that many citizens would pay the equivalent of an additional $50 to $100 to receive broadcasts from foreign satellites, even if they were legally free to do so !

Centralized and Decentralized Decision-making. Implications also emerge for the centralization and decentralization of responsibility and authority in the structure of decision-making. Here two dimensions are relevant, (a) the hierarchal, relating to the allocation of responsibility and authority between higher and lower level decision-making units, (b) the geographical, relating to the locations of decision-making units relative to each other. With respect to the latter, the existence of instantaneous and reliable communication over long distances would reduce or eliminate distance as a factor in determining the relative locations of decision-making units. Other considerations of location, such as vulnerability to attack and access to transportation facilities, would have correspondingly greater weight. Since a distance constraint would encourage to placing of decision-making units close to one another, everything else considered, its removal would promote geographical decentralization.

Effects on the hierarchal dimension are less clear. One might expect that the enlarged and more rapid flow of information to the decision-maker and the greater ease with which decisions can be passed downward would together lead to a shift in responsibility and authority toward higher-level decision-making units - foreign offices in national capitals playing an enlarged role at the expense of embassies and foreign missions; tactical and strategic wartime

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(1) For example, the British Space Development Company has considered such a system for use in the United Kingdom, described by Fred Wheeler "Relay Stations in the Sky," New Scientist, January 19, 1967.

decisions made at the highest levels; more frequent contact between heads of state engaged in "personal diplomacy" in time of crisis. At the same time, several possibilities suggest a tendency in the other direction. (a) Better communications links between higher and lower levels might promote the delegation to lower levels of more responsibility and authority than the higher levels, fearing loss of command and control in emergency situations, would otherwise be willing to confer. (b) Direct and frequent high level contact between two opposing governments - for example, direct communication between heads of state - might generate criticism from allies and others that the two sides are conspiring. A government could be led ceremoniously to destroy or dismantle coding equipment and other facilities used for communicating with the opposing side, to assure its critics that high-level contact is being discontinued. As a substitute, more authority and responsibility might be delegated through the embassy level for less conspicuous contact with the opposing side. The shift would be facilitated by the existence of improved communications facilities between the embassy and the higher levels. (c) Use of direct communications facilities for high level contacts might come to be regarded as a valuable signal of extreme urgency, hence as something to be employed only very rarely. In this case, the internal allocation of responsibility and authority would remain essentially unaffected during normal times.

Bargaining and Negotiation During Crisis and War

In several ways, the process of bargaining and negotiation would be affected. As one example, improved command and control by country x over its military forces, afforded by instantaneous and reliable communication, would enhance the ability of x to threaten or coerce country y. At the same time, this improved command and control would also make x more vulnerable to threats from y: a threat by y to attack x if x attacks z would have little value if y knows that x has already launched an attack force against z, and that x does not have the ability (due to poor communications) to recall it.

Given the ability of both sides to communicate quickly with each other, and to formulate their respective positions more rapidly by virtue of improved communication within their own decision-making structures, additional opportunities might arise to explore alternative solutions, and to transmit clarifications and amplifications. This would contribute to reducing the probability of miscalculation and misinterpretation, and to discovering a basis for agreement more advantageous to both sides.

Of course, the mere existence of techniques for instantaneous and reliable communication does not insure that they will be employed. A refusal to communicate may, at times, prove advantageous. Especially, one side may deliberately avoid contact in order to insulate itself from threats by its opponent. In such cases, the role of new communications technologies would rest in expanding the range of choice available to the participants in either remaining in contact, or breaking contact, as an integral part of the bargaining and negotiation process.

Alliances under Stress. Several implications emerge regarding the effectiveness and viability of an alliance attempting to negotiate or bargain with, or to exert coercion against, an opposing side in time of crisis or war. The expanded flow of information from the field and elsewhere would enable the alliance to choose from an expanded list of alternatives and options. But the very fact that each member has instantaneous, reliable communication with each other and with the opposing side creates problems: Members can more easily express their interpretations, hopes, fears, and misgivings; and they can more credibly threaten to negotiate separately with the opposing side. In addition, the opposing side has expanded latitude to initiate contact separately with members of the alliance. The situation is further complicated by the fact that if privacy is assured over the communications links, members would be unable to verify whether each other is in contact with the opposing side and, if so, what is being said.

In other words, instantaneous and reliable communication can strengthen alliances, in terms of facilitating adjustment to new circumstances, maintaining unified command and control over military forces, and the like. But it also widens the latitude for internal disagreement and distrust, and it provides new opportunities for the opposing side to generate or exacerbate dissention within the group.

Some participants may find discomforting the obligations imposed by the expanded opportunities for communication with their allies. Preferring to play a lone hand in dealing with the opposing side, a government today may find convenient the argument that unreliable communications links with allies in time of crises and war would render effective co-ordination impossible. Or, a government exposed to an embarrassing unilateral action of an ally may plead, as a face-saving manoeuvre, its prior inability to communicate with that ally. The degree to which a member of the group really wants participation by its allies in coping with threats to itself and to others, and the rights and responsibilities of each member, may require painful reappraisal in an era of improved communication.[1]

<u>National Interests, Alliances, and Geography</u>. Rapidly expanding and inexpensive telephone and teletype links and facsimile mail service across oceans and continents will contribute to shifts in foreign trade and investment flows. Together with the impact of widespread international television, new sympathies, antagonisms, and understandings will emerge toward the problems, plights and situations of others. New areas of foreign influence will develop as old ones evaporate. New economic, political and military alliances will emerge as a reflection of changes in relations and ties contributed in part by the expansion of worldwide communications.

Geographical distance will play a progressively less important role in shaping the character of this dynamic process. In combination with continued advance in transportation technology, the growth of worldwide communications will drastically reduce the barrier of distance to interactions between nations. People and governments will entertain altered notions of what does and does not constitute the "national interest" in international affairs. Hemispheric or regional "solidarity" will count for less, relative to solidarity defined in other dimensions. Expansion of influence close to home by an enemy may generate little more apprehension than the enemy's expansion of influence anywhere else in the world (though both situations may be very perturbing). The proximity of members to each other as the basis for mutual security pacts, common markets, and spheres of influence will count for less. New conditions will ripen for crises and confrontations, but the locations, the participants, and the pressures may vary considerably from those familiar today.

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(1) Within the context of U.S.-European relations, the conflict between collective and independent action is discussed by Alastair Buchan, <u>Crisis Management</u>, (The Atlantic Papers, NATO Series II), especially pp. 57-59.

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THE IMPLICATIONS OF MILITARY TECHNOLOGY IN THE 1970's

COMMITTEE III - 2

Friday 29th September | Afternoon

Technology and Arms Control

JAN PRAWITZ

Throughout the postwar negotiations on disarmament there has been a general agreement that effective control has to be an element of disarmament measures. But in most cases this was the only thing agreed. In particular, disagreement over control, its procedure, functioning, staffing and other details has frequently been the declared reason for the notorious deadlocks. In many cases the question of control has been the most difficult problem involved and by that the issue that determined if success or impasse became the outcome of the negotiations. In other cases difficulties regarding control apparently were used as a convenient excuse for unwillingness to reach agreement.

The role of security

What makes control an unusually difficult question is the conflict between, on the one hand, the interest to observe as closely as possible all relevant circumstances regarding the object to be controlled and, on the other hand, the interest to protect as far as possible security on essential strategic information. A control sufficiently effective to constitute a meaningful verification to the signatories of a disarmament treaty would probably in practice gather more information than is necessary for its specific purpose and, therefore, it is likely to be unacceptable to a party to be inspected. It is frequently claimed that such an over-capacity could be used as an instrument for espionage. Inversely a control politically acceptable to an inspected party would probably not be effective enough to give the intended assurance that agreed obligations are complied with. The smaller the scope of the total disarmament agreed, i.e. the larger the remaining weapon arsenals, the smaller would probably be the willingness to compromise strategic secrecy. This has so far made impossible the simplest solution of the problem of arms control, permitting observers access to the governmental decision machinery of countries under control.

The ideal solution of any control problem would be an arrangement providing the necessary minimum of information but nothing more, which in most cases will mean something less efficient than human inspectors. In order to meet the need for methods of control simultaneously fulfilling technical functions and being politically acceptable there has over the years been worked out a number of proposals often relying on scientific equipment in addition to inspectors, often including special arrangements to avoid release of sensitive secrets as for instance nuclear weapon design but still obtaining the essential data. But in several cases the insurmountable political difficulties in arriving at an agreement on adequate control has led to a reversed approach: the substance of disarmament proposals has been adjusted to fit acceptable control arrangements.

The involvement spectrum

The list of proposals of disarmament control presents a spectrum of the amount of intrusive inspection and foreign involvement. On the one extreme there is a category of control of zero-involvement, that will always be politically acceptable, and which relies on the means a country can use unilaterally to gather information about activities abroad. These have been called "national means of detection". In this case the demands of politics have complete priority over any technical requirement. To this category belong surveillance satellites looking at ground activities from international space; equipment for recording seismic waves, radioactivity and other effects of nuclear explosions spreading beyond the borders of the country carrying out the test; electronic equipment for tapping telecommunications; radar scanning of space; acoustic scanning of open and territorial waters etc. These methods were in most cases originally developed to support national intelligence activities, but can certainly be given an important role in verification of disarmament treaties. After all, the objects to watch, military activities and arms, are the same; either they are limited by international agreement or not. A good example is the partial test ban, where the three original parties agreed that national means of detection were adequate for monitoring the treaty. It is significant that hundreds of millions of dollars have been spent on control although the word is not mentioned at all in the text of the treaty. Another example is the agreement on cutback of the production of fissionable materials for weapons' purposes which was so vaguely formulated that national observation, although incomplete, would guarantee the detection of actions infringing the agreement. It is only to be regretted that it now seems impossible to perform more than a few control tasks with nationally operated long distance instrumentation.

However, at the other extreme, proposals in which the political and security interests have to yield entirely to the technical requirements in order to permit and effective and accurate control, have raised immediate difficulties at the negotiating table. In the important field of the control of non-military nuclear activities, however, it has been possible to construct a control machinery based on regular reporting and on-site-inspection, in some cases even resident inspectors. This type of safeguard has now been accepted by a large number of states and has been implemented to such an extent that it now covers most of the plutonium production in non-nuclear weapon states, which means that a considerable non-proliferation effect has in fact been achieved even without a formal treaty. Also the Antarctic treaty, the Latin American Denuclearization treaty and the Outer Space treaty include provisons for on-site-inspections by nationals of signatory states or by officials of international organisations.

It is easy to imagine compromises between these two extremes, but it will probably not be so easy to negotiate successfully the compromises. An example of a compromise solution is the concept of "black boxes", unmanned technical devices for automatic recording of the relevant and only the relevant data on the territory of the state to be inspected. In particular the use of black boxes would eliminate the need for examination by human inspectors. They would be constructed in such a way to make it impossible for the host-country to influence the "activities" of the box or the data recorded. It is self-evident that the technical problems involved in constructing these boxes are large, because they are needed for purposes ordinarily entrusted to well-trained human personnel. There are certainly a large number of possible ways in which automatic equipment, seals and locks, etc. could be utilized to push disarmament control as far as possible towards the zero-end of the involvement spectrum. These possibilities will certainly be taken account of all the time, not only in order to minimize the presence of inspectors, but also to make the control more accurate, more convenient, and less expensive. But it is the demand for complete absence of people which causes the greatest difficulties, primarily in securing the long run reliability of the equipment and in assuring that attempts by the hosts to fool it will not pass unnoticed. Some years ago "black box seismic stations" were seriously proposed as means for test ban control. Their purpose would be to record seismic data which could not be obtained from outside the country housing the box. But as is well known, the proposal never materialized and therefore, we lack experience of the technical feasibility of the use of "black boxes".

Test ban control

A short analysis of the negotiations on two major problems of control reveals the intricate interplay between politics and technology. The topics discussed are test ban control and safeguards on peaceful nuclear activities.

The former is the most thoroughly discussed issue in disarmament control. It has been the object of endless negotiations, expert committees, scientific meetings, and extensive research efforts. As indicated above the simplest solution would be to place international observers within the agencies responsible for nuclear weapons development, but needless to say such a suggestion would be quite unacceptable. The reason is, of course, that the observers would be able to disclose not only any testing but certainly also a lot of the most sensitive information about the development of military nuclear technology of great significance for the prediction and management of the future balance of power. Instead interest has been concentrated on the means the super-powers have developed to watch the testing of each other.

As is well known, these means have been considered sufficient for test ban control by the USSR but in the view of the USA and UK they would leave a gap for tests conducted underground. The western nuclear powers have always insisted that this gap must be closed by a right to a limited annual number of on-site-inspections of suspicious events, while the Soviet Union has refused to accept such inspections on its territory. (For a short time after the Cuban crisis the SU was willing to accept a much lower inspection-rate than demanded by the West.) The negotiating powers facing this situation adjusted their aims according to the political realities, left the controversial underground explosions to future negotiations and concluded a limited ban on tests in the atmosphere, outer space and under water. Even if this modification of the test ban was not a consequence of the difficulty of reaching agreement on control alone, it is an illustrative example of its central importance.

But the influence of the issue of control is not limited to this. The partial test ban required a strict definition of the concept underground. It was clear that no methods using long distance instrumentation could determine whether a nuclear explosion was a very low altitude, an on-surface or a shallow subterranean one. The same on-site-inspections that would have been necessary to implement the ban on underground tests would again be the only way for an accurate assessment. Again the agreed solution fitted the idea that the control should rely on national means alone. The Moscow treaty permits only tests carried out at such a depth that they cause no radio activity outside the national borders of the testing country. Thus, the treaty forbids any tests which cannot be unambiguously identified as underground tests by outside observers.

Furthermore, there was a desire to distinguish between tests for the development of weapons and nuclear explosions for excavation, harbour digging and other peaceful purposes. Again it was impossible to find a method using long distance instrumentation to verify that a nuclear explosion declared as a peaceful one was not at the same time an experiment for military purposes. An assessment of that would include both a close review of the design of the device to be fired and a knowledge about the weapon development programme of the country concerned, which, of course, would be unacceptable. Again the solution arrived at was a zero-involvement one. The Moscow treaty refers only to nuclear explosions and, thus, no exceptions are permitted for nuclear shots for peaceful purposes. For instance nuclear digging of a new Panama Canal is not permitted.

The construction of the Moscow treaty is thus very much a reflection of the capabilities of control of the zero-involvement type, the only one politically acceptable.

The underground tests left out are still permitted. The means of detecting these tests have not been improved to such an extent that the western nuclear powers have found it appropriate to withdraw their demand for mandatory on-site-inspection, a demand the Soviet Union continues to reject. The relevant question now is whether the future development of seismology will make possible an acceptable control of an underground test ban on a zero-involvement basis.

The present state of the art makes it possible to detect underground nuclear explosions of seismic magnitudes larger than four, in some cases somewhat less, from distances greater than the extension of the largest countries by the use of a network of large arrays of seismographs of the type (LASA) now operating in Montana, USA. The explosion yield depends on the surrounding medium and is about one kiloton in hard rock, five to ten kilotons in tuff, about 20 kilotons in alluvium and perhaps ten times more for a decoupled shot fired in a big hole. All larger explosions can be recorded from the outside of the testing country but the data may have to be assembled from several countries. These exhaust the possibilities of seismic detection. Although even bigger arrays will lower the detection threshold noise and background events will rapidly increase and diminish the value of what is recorded. But the methods for distinguishing explosions from the large number of earthquakes also recorded are being continuously improved. More than 90 per cent of all earthquakes can be positively identified as such. The problem arises from the fact that a small number of dwarf quakes have a seismic signature similar to that of explosions, making impossible a proper classification. This number can be further reduced if seismic close-in data is available, but as far as the largest countries are concerned, such data will have to be provided partly by the country under observation, which makes this technique a non-zero-involvement method. Even if the identification methods are further improved in the future, which they no doubt will be, it is unlikely that the problem will be completely solved. However, as has recently been shown by my colleague, Dr. U. Ericsson, the methods now at hand are powerful enough to provide a prospective violator with a risk of detection hopefully large enough to deter him from clandestine testing. The risk of detection is further increased by the use of satellites or <u>conventional</u> intelligence.

Thus, it seems possible to arrange a control system for an underground test ban based on zero-involvement or near-zero-involvement methods provided that the governments concerned are willing to rely on a high probability of detection rather than a hundred per cent certainty, to leave the sub-kiloton shots uncovered, to forget about decoupled shots, to arrange a special control for peaceful explosions to include conventional kiloton explosions which are likely to be confused with nuclear explosions.

<u>Safeguards on peaceful nuclear activities</u>

For a long time states exporting fissionable materials, facilities, and equipment for atomic power production have acknowledged an individual responsibility to ensure that their contribution does not promote the spread of nuclear weapons. Exclusive peaceful use has usually been a condition for sale in the nuclear field. The relevant trade agreements frequently stipulate also control and inspection, i.e. safeguards, to assure that agreed obligations are complied with.

At present, safeguards are implemented either on a bilateral, a regional or an international basis. Best known of the bilateral arrangements are the control of the US Atomic Energy Commission over its atoms for peace programmes abroad. A regional system is operated by Euratom over all peaceful nuclear activities of the six states members of the European Common Market. Finally the International Atomic Energy Agency in Vienna has set up a safeguards system with a potential possibility for covering all peaceful nuclear power production in the world. In recent years many bilateral arrangements have been replaced by the IAEA-system, which now cover 120 installations in 27 countries.

From a technical point of view the difference between the various systems is not very large. They all rely on book-keeping of nuclear material, review of the design of principal nuclear facilities, and on-the-spot verification either by visiting or resident inspectors.

The technical standard of the performance of safeguards and the accuracy and reliability of the methods used has, of course, fundamental importance for the value and credibility of the control. But beside the purpose of safeguards a precise accounting for fissionable material is necessary also because of its high economic value and for reasons of safety and health. Several research centres are vigorously developing accurate, cheap and convenient methods of control. The field has become a special technological discipline named 'nuclear materials management'.

Included are the development of standards for accounting systems for special nuclear material being processed in enrichment plants, conversion plants, fuel fabrication plants, reactors, reprocessing plants and under stockpiling or shipment; physical measurement methods for materials present in the before-mentioned facilities; inventories of total stock of material in such facilities; inspection procedure for on-the-spot verifying of the accounting operations; accounting methods for material contained in scrap; the determination of what will constitute a reasonable loss of material in the light also of what is economically feasible and permissible from the health protection point of view. In addition there is training of people to be professional in nuclear materials management.

When the fissionable material is present in identifiable units, as e.g. fuel elements, it can be accounted for with precision, but when it is dissolved for separation or other processing the identity will be lost and the precision of the accounting will be determined by the methods of measurement, which means an accuracy of a few per cent.

High precision is indeed desirable. Within a decade many non-nuclear weapon states will annually produce enough plutonium for several hundred bombs. Diversion of less than one per cent will then in short time make the difference between non-nuclear and nuclear status. This prospect necessitates, if safeguards are to be effective, a very close observance of the activities under control always coinciding with the needs of the operators and managers, making so to speak safeguards a by-product of the industrial operation. The development of automatic equipment, seals and locks etc. to facilitate the control does not obviate the need for closer inspection and more involvement. All auxiliary devices will be badly needed. It is remarkable that the safeguards now covering hundreds of installations in more than 40 countries have been politically acceptable. The fact is a reason for optimism about the extension of safeguards. An increase in safeguards' reliability will certainly accompany the expected increase in plutonium production. If the use of safeguards is increased at the present rate, we will soon have established a situation, in which safeguards are automatically applied to all fissionable material produced in peaceful installations, allowing international co-operation and trade in the atomic power field to go on freely without strategic consequences. This is of fundamental importance as nuclear weapons will always be the key item for arms control whatever disarmament measures are agreed in addition.

An outline for the future

As stated in the beginning the ideal solution of the problem of disarmament control would be a system gathering the relevant and only the relevant data. Even if imperfect techniques makes this solution unrealistic methods of zero-involvement, however powerful, would always be politically acceptable. But what are the possibilities for designing acceptable control procedures of this kind for any disarmament measure? In the case of the partial test ban it was possible. In the case of an underground test ban there is a realistic hope that it will be possible. But I am afraid there will not be many more cases where an effective control can rely on ingenious instruments looking across the borders of other countries. After all nuclear explosions are probably the biggest and most intense objects that the controllers will have to deal with, comparable in their effects to elemental catastrophes. When control of smaller and less detectable matters is the aim we will have to rely in the first place on means of non-zero involvement.

When the objects to be controlled are located in international waters or territories (i.e. Antarctic) or in space it will always be possible to watch any activity without infringements of territorial rights. If this is sufficient for verifying a disarmament measure, then zero-involvement control is adequate, otherwise not.

But national means of control will always be useful even if they cannot alone make up an effective control. In the future they will be even more useful, though still not sufficient. A satellite may take extremely good pictures of a plutonium separation plant or a gaseous diffusion plant but it will not be able to measure the flow of weapon grade material.

Instead nuclear safeguards must be considered a more realistic model for verification of disarmament obligations. A control of this type will mean a great deal of involvement, but this does not necessarily mean that it must be unpleasant, especially if it is operated so as to be a by-product of the ordinary data-gathering. The procedures can be simplified if the requirements of future control is taken care of in the designing stage of objects to be controlled.

In the case of nuclear safeguards it has since long been a condition that the inspecting agency has a right to approve the design before actual construction.

In the case of control of a ban on the production of biological and chemical weapons, probably the most urgent <u>new</u> problem in the near future, some experiments have been undertaken. They indicate clearly that the control procedure will certainly be of the nuclear safeguards model, but certainly also more difficult because the techniques used for the manufacture of these weapons are more conventional. When in the future more and more of the governments' data sampling and steering functions, their control and command, are computerized, the interesting possibility is opened of disarmament inspectors sharing these systems with the controlled government. This can be done by letting the inspectors run a subroutine within the ordinary on-line processing, tapping just the data they want and nothing more. It also opens the possibility of influencing the command, if this complies with the object of the disarmament treaty. For instance an agreement on non-first-use of nuclear weapons could be verified by allowing the inspectors' subroutine to have a mathematical finger on a safety catch somewhere in the communication system. This may sound science fiction and at present it certainly is very much so.

But if the powers of the world agree on more and more disarmament measures, there will be more and more control and inspectors around. This control will probably be something very similar to nuclear safeguards or to the meat inspection in the slaughter-houses. Technology will play a fundamental role in data-gathering, in data-handling, in facilitating control by making the objects to be controlled properly adapted for control, etc. This role will be played by influencing a number of small things. There seems to be no room for ingenious inventions of remarkable equipment capable of carrying out all disarmament control regardless of distance or size or nature of the object. The control will probably not be very intrusive, as it will in most cases require less precision than the people running military activities and arms production. National means of control will provide important checking in the background.

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INSTITUTE FOR STRATEGIC STUDIES

9th ANNUAL CONFERENCE

THE IMPLICATIONS OF MILITARY TECHNOLOGY IN THE 1970's

COMMITTEE III 3

Saturday 30th September | Morning

Developments in Chemical and Biological Warfare

R. B. FISHER

If we assume that some of the major powers and some smaller ones have the capacity to wage some kind of chemical warfare, on some sort of scale, we are very unlikely to be wrong. We should have been almost equally likely to be correct at any time during World War II although no use was made of the weapon. If a new conflict were to break out in the near future would we be justified in discounting this form of warfare on the basis of past experience? I doubt if anyone would be foolhardy enough to try to answer this question. What I intend to do is to try to give an account of the nature of chemical warfare, of the possibilities of combating it, and of the situation that would most probably arise between an aggressor prosecuting such warfare effectively and a defender as effectively protected as possible against it.

Chemical Warfare in World War I

In the first World War, when chemical warfare was used it was referred to as 'gas warfare'. Initially this was a true description. Chlorine and phosgene were the chemical warfare agents. Both were gases heavier than air. Both could easily be liquefied under pressure, so that large quantities could be kept under pressure in cylinders. A gas cylinder, a regulating valve, a stopcock and a delivery pipe constituted all the equipment needed.

These agents were crucially dependent on weather. They had to be carried on the wind to the enemy, and the strength as well as the direction of wind were important. Too much wind was as bad as too little, since the eddies and gusts of a strong wind could dilute the gas by mixing it with a lot of air instead of simply pushing the heavy gas along the ground.

These agents were too dependent on uncontrollable factors to confer more than an initial advantage on their users. All subsequent essays in chemical warfare have depended on denser substances, less subject to dilution by the air, and on more effective means of delivery.

Mustard gas, which was used in the first World War, conforms to the requirement of a denser agent. Its name is misleading: it is a heavy liquid. If it could be put into artillery shells which would burst over the enemy it ought to be possible to make a spray of drops which would descend on the enemy: an allowance for wind drift of the spray could be made if the height of the burst could be controlled.

It ought, theoretically, to be possible to use this form of attack in a much wider range of meteorological conditions than those favourable to a true gas attack, indeed, almost whenever the commander wished to use it. But the technical difficulties of this form of delivery are very great. Neither ballistics nor fuse design were adequate for effective use of this kind of attack during World War I.

The effect that mustard gas was designed to produce was quite different from that intended to be produced by chlorine and phosgene, which severely damage the lungs and which maim for life if they do not kill. Mustard gas was designed to produce blisters. Since the major exposed parts of a man are his hands and his face, an enemy that uses mustard gas efficiently can count on a fair proportion of blistered hands. Since mustard gas persists on the surface of the ground, is absorbed by leather, and diffuses through it, the enemy can later count on a fair proportion of blistered feet. A force which cannot use rifle or machine gun with normal skill, which is at a disadvantage in serving its guns, which cannot use effectively its normal means of changing its position, is undoubtedly incapacitated. Mustard gas was the first chemical warfare agent designed to be an incapacitating agent. However, it is poisonous to the body as a whole and causes many deaths.

Lewisite, which seemed to be potentially the most dangerous chemical warfare agent at the time at which World War II began, was like a much more powerful mustard gas. It produced blisters, and it killed, and in both these actions it was much more powerful than mustard gas. Very small amounts could put men out of action for a long time, since the damage to the skin took weeks to heal, even in far more favourable conditions than those experienced by combat troops.

Early protective measures

The victims of chemical warfare attack were not passive in their response. Very early on in the first World War a group of British medical scientists was mobilized to meet the threat of chemical warfare.

The group soon evolved some ways of combating chemical warfare. The respirator with its charcoal filter would cope with gases which acted by being breathed in. Charcoal made in the right sort of way binds a great many kinds of chemicals very firmly, and if these chemicals are in the form of gases intermingled with the normal gases of the air, these kinds of charcoal remove the foreign gases with considerable efficiency.

Some forms of protective clothing were also evolved against droplets of mustard gas or other possible agents of this class.

In addition, the chemists worked out tests in which a specially impregnated piece of paper or a special liquid through which contaminated air was bubbled would show a striking change of colour in the presence of one or other of the chemical warfare agents. Tests of this sort could provide sufficient warning to enable a fair part of a threatened force to take action to protect themselves. If the tests indicated unequivocally the nature of the agent, they could indicate how to treat medically the victims of poisoning and perhaps even to provide medical protection in advance. Neither therapy, medical treatment of established poisoning, nor prophylaxis, medical treatment which protects against poisoning, was effectively instituted against the agents used in World War I, although detection methods were set up which were reasonably adequate in their context. The nearest to either was an anti-gas ointment which could destroy mustard gas as long as it was still lying on the surface of the skin.

This ointment would be better described as a decontaminant, capable of destroying by chemical means a chemical warfare agent which had not yet begun to exert its effect on a man.

The development of the treatment of CW poisoning.

It was not until the early part of World War II that therapy or prophylaxis became more than a hope, as the result of British biochemical research directed by Sir Rudolph Peters. His group unravelled the fundamental biochemical nature of the poisoning by lewisite of living tissues, and were fortunate enough to find a chemical means of opposing this action of the poison for long enough to enable the body to destroy and excrete most of the poison.

This achievement, which was of outstanding significance medically as well as in a military context, suggest to the unwary that chemical warfare cannot be of much account: the doctor can find the drug that will make the victim as good as or better than before. This is very unlikely to be true, for two quite separate reasons. These reasons are of sufficient significance to call for fairly extensive treatment.

The first reason is that there is no ground for supposing that there is an antidote for every poison. Any poison must act on some centrally important element of the apparatus on which life depends, but most poisons act on some specific site in the body and any measure which effectively neutralizes the poisoning effect must do so by acting at or very near this site in such a way as to deny the poison its chance to interfere with normal function. In other words the antidote has to interfere without interfering. We have to be thankful for the improbable combination of circumstances that makes it possible to bring off this kind of miracle occasionally, but we must not expect it to happen with any regularity.

Admittedly, there is occasionally another way of dealing with a known kind of poisoning. One can give powerful drugs which produce effects on the body which are the reverse of those produced by the poison. But powerful drugs are poisons, and if, in such an attempt to combat the disorders produced by a chemical warfare agent, the potentially therapeutic drug is used in a manner disproportionate to the intensity of the poisoning of the individual victim, it can fail totally to benefit him. Far too much skill is needed in this sort of therapy to make it feasible as a way of combating a major chemical warfare attack. Potential therapeutic agents in this class can only be used as marginal aids applied to reduce the general level of effect without an unacceptable degree of disadvantage due to their own toxicity.

The proliferation of intensely toxic substances

The second reason for disbelieving that medical advances will make it safe to ignore the threat of chemical warfare is the knowledge we now have of the number and chemical variety of intensely poisonous chemical compounds in existence. Anyone who has heard of chemical warfare has heard of nerve gas. This name refers to a class of simple compounds of carbon, hydrogen, oxygen, phosphorus and some other elements. The nerve gases are not gases, any more than mustard gas is one. They are liquids, and it is theoretically possible to make a large variety of different compounds of this class. They were first considered as chemical warfare agents in some countries during World War II and there is now a great deal of general knowledge about them because some of the members of the group have found employment as insecticides. The members of the group that have been considered as chemical warfare agents are intensely poisonous. One could walk through an atmosphere containing a highly lethal concentration of droplets of such a compound without the least warning from eye or nose, and only a very sophisticated apparatus could provide a substitute warning. I have no doubt that, whatever medical measures were taken, any man exposed to a reasonably effective attack by a reasonably effective nerve gas would be beyond help before any specific mdeical aid could be directed to him. Warning and physical protection would be the only way of warding off the effects of this sort of agent.

We are in a relatively favourable position in relation to compounds of this class. Because of their agricultural value there is a premium on understanding of their action and of methods of protection against poisoning. We know how they act. We can use the knowledge to design substances with some degree of antidotal power and we can find substances which will offset in some measures the effects of poisoning. But it is still true that unless all personnel at risk live continuously under physical protection, or unless, being surrounded by a full complement of fault-free promptly responding detectors, they don protective equipment instantly and completely effectively, medical aid is going to be of little use to them.

Incapacitating agents

So far as the other kinds of intensely poisonous substances are concerned, we know very much less. The Americans have said publicly that they are interested in substances that come into this class whose effects are to 'incapacitate', to make the victim incapable of military action without killing him. If a substance of this class could be found which was effective at such low concentration that it would be difficult to detect, it would clearly be attractive to some powers. Its use could be justified on the grounds that it was not designed to kill.

On general grounds I think it unlikely that such a pure incapacitator agent will emerge. Any chemical agent, a small does of which is capable of profound disturbance of bodily or mental function, is certain to be able to cause death in large doses, either primarily or secondarily, and no attack with a chemical warfare agent is likely to be designed with the primary object of avoiding overhitting. But I feel that the notion of a primarily incapacitating agent will be followed up, and this means that problems of detection and medical action are going to become more difficult, since it is likely that many kinds of chemical compound not so far considered as potential chemical warfare agents will be found to have powerful incapacitating effects. Many of the effects of drugs which could potentially be used for incapacitation are not readily definable in terms of the exact nature of their interference with bodily function. We cannot, in fact, define in fundamental terms how alcohol, one of the oldest of the incapacitators, produces its effects.

Detection of CW agents

At the very low concentrations at which an effective agent will work, specific detection as well as any attempts at medical protection or treatment will depend on knowledge of the fundamental mode of action. One can think in terms of non-specific detection - a procedure which indicates that something strange in the way of a fine powder, fine droplets or vapour is present in the air - but it is difficult to be confident that any such procedure could detect a low concentration of a chemical warfare agent in the air of a battlefield, in the presence of dust, exhaust fumes, the products of combustion of rocket fuels, the products of decomposition of several kinds of explosive and, probably, several kinds of smoke.

Protective equipment

However, let us suppose that this miracle of discrimination can be achieved. It is now necessary to use this detection capacity to warn troops to take personal protective measures. On a moderate breeze the toxic agent will move from detector to troops at about 5 metres a second. Thus, only if one can afford to leave 150 metres of the windward section of the position quite empty can one rely on a perfect warning device to give half a minute in which to protect oneself. It is impossible to rely on visual observation of the attack. Any of the modern kinds of airborne vehicle can deliver a toxic agent by techniques similar to those used for crop-spraying. Selection of appropriate height of release in relation to wind strength makes it possible to effect delivery at such a distance that attack is not perceptible in the target area.

It is just possible theoretically that some sort of 'chemical radar' could be devised, which could detect toxic agents before they entered the target area. But such a device would have to have enormous sensitivity and would still need to possess the degree of discrimination to which reference has already been made. It could not, like radar, simply depend on the reflection of a single kind of radiation from good reflecting surfaces; it would have to detect radiation coming back from very small poor reflectors and it would depend for success on identifying some property analogous to the colour of these minute reflectors.

Let us suppose that we could make it. Its range would be small compared with radar, because a minute fraction of its power would be reflected back to the detectors, compared with the fraction of radar power which comes back. An effective unit, then, would be something with very great power consumption, vastly greater complexity than radar and a range which does not look as though it could possibly be more than a few percent of that of a radar of comparable output power. In my view we should not rely on this sort of dream as likely to provide the basis of a practicable warning system.

The only way to compensate for the difficulties and uncertainties of detection is to use protective equipment at all times. The equipment can take the form of a building, a vehicle or personal equipment. So long as the equipment functions fully, this requirement merely reduces the effectiveness of the force in some measure. However, damage to protective equipment far short of its destruction could quickly have major effects. The disciplined use of unexceptionable protective equipment would not mean that chemical warfare was neutralized. It would mean that its role was then that of adjunct to normal softening up procedures. It would mean that bullets, fragments and secondary missiles could be made far more effective against personnel than in the absence of a simultaneous chemical attack, since their effects in breaching chemical warfare protective barriers would add to their direct effects on men.

Disadvantages inherent in the use of protective equipment

The problems of protection are just the same as they were in World War I. The soldier must be protected from breathing in toxic agents in the form of gases, fine droplets or particles. There is no fundamental difficulty in doing this by designing an appropriate gas mask.

But the best possible gas mask would not be enough. Protection against such agents as lewisite or mustard or any more recent agents which attack through the skin, calls for comprehensive protection for the whole body surface. This is technically very difficult indeed. It is not possible to keep a man in an impermeable garment. Unless the man can lose water by evaporation from his skin he will suffer heat stroke whenever he engages in vigorous exercise. His skin has to be allowed to 'breathe' freely. So the problem is to let water vapour freely away from the skin whilst denying access to it of toxic liquids, vapours and gases. Any attempt to solve this problem is unlikely to be more than partially successful. The garment will impair heat loss to some extent and will have a limited effective life.

Men wearing effective protective equipment are at a grave disadvantage. They are isolated from each other. They are not personally identifiable. Their fields of vision are limited. Their speech is affected in quality and carrying power. They are deprived of all the normal idiosyncratic sensory impressions which link them into identifiable groups. I find it difficult to believe that military groupings of such depersonalized men would maintain the desirable degree of cohesion in circumstances of stress.

Another disadvantage is that they must have means of collective protection readily available, associated with quite elaborate installations. Once an enemy succeeds in maintaining an attack for any considerable number of hours, the position will have to be evacuated unless sufficient facilities are available for getting rid of contaminated protective equipment safely and for donning fresh equipment. This is something that cannot be done simply in safety. Elaborate equipment on which men must rely for the ability to hold out constitutes another element vulnerable to traditional weapons.

My own view is that chemical warfare using existing agents constitutes a serious threat in the field and that even when a force is as effectively supplied with protective equipment as is possible, the CW threat imposes severe restrictions on the force's effectiveness. Persistent attacks with agents which could pass into the body through the skin could not be withstood unless elaborate facilities for feeding, sleeping and replacement of protective garments could be provided, and unless these facilities could be used in a rigorously disciplined fashion.

Biological warfare

There are many resemblances between biological and chemical warfare. Disease-producing bacteria and viruses can be thought of as poisonous agents which are particularly powerful because, once a sufficient dose has been introduced into the victim, it multiplies in amount by growing faster than the victim can destroy it, and so produces its fatal or incapacitating effect. In order to gain access such an agent will have to enter the body through the air, through food or drink or through the skin. Entry through the skin is unlikely except when it is broken, and can be counted out as a significant pathway of attack. The contamination of food and water is unlikely on a large scale; it is too difficult to achieve over a sufficient area. Most possible agents need a living host if they are to survive. Most of them are incapable of mere existence; they must multiply or die. Some can grow in such materials as ice-cream and cooked meats and can generate the powerful food poisons, but it would be difficult to set up a large scale attack by such means. Most disease-producing agents are destroyed in the digestive tract, so that the possibilities of attack through food and drink are in general specialized and difficult to carry out.

On the other hand, organisms breathed in have a fair chance of penetrating the lining of the respiratory apparatus and infecting the recipient. If appropriate organisms can be introduced into the air we breathe in sufficient numbers, it seems likely that many of those over whom the suspension of organisms passes will be infected - provided that the organisms survive for long enough.

If anyone contemplated biological warfare, this is the form I should expect it to take. I should also think it more likely to be used as a prelude to invasion than in the field of battle. Most infections take a time to develop; the agent has to multiply in the host before its effects are manifest, and when they do show themselves they may intensify slowly. It may be difficult to know when the attack has taken place. In large scale attacks it seems likely that the delivery would be offset, as has been suggested for chemical attack, and that the infective cloud would drift over the target. At first sight the combination of the unseen attack with the latent period between attack and effect may make one feel helpless against such warfare. But in my view this is wrong. Whilst large scale attack on civil populations is superficially easy by this method, counter-measures are not quite so difficult as in chemical warfare, though they are difficult enough.

To cover any large area the agent has to come down wind over correspondingly large distances. Only agents that can survive without food for quite a long time in a variety of atmospheric conditions can be used. It is not safe to use an agent against which you cannot protect your own people, since you cannot walk in and mop up a paralysed community unless you are protected against the secondary sources of infection that you have created. This restricts the possible agents again and it also means that specific vaccines or specific antisera against the organisms must be known. Such specific agents ought to be utilizable in some fashion for detection.

Since we are thinking that the great biological threat might be of this airborne kind it looks as though detection stations near the boundaries of a country ought to be able to provide a warning which could be effective for the major part of the threatened area. Infective particles are far less likely to penetrate enclosed spaces than are toxic vapours, so that protective measures could be relatively simple. Most infective agents rapidly lose their effectiveness and are fairly easily destroyed by established disinfectant procedures. Thus if it were possible to say from observation at the detector out-stations that some abnormal particulate concentration was coming in on the wind, normal civil warnings could combat the threat. If more specific investigations of the particles could confirm or exclude a biological attack with reasonable promptitude, the interference due to going to shelter could, one hopes, be kept small.

Thus, by the time any potential aggressor is protected against retaliation, he would have carefully to assess the likely balance of advantage. In addition, geography is generally against this form of warfare, except against very vast countries or against islands. If the scale of the attack is large enough to be significant, it will generally spill over frontiers.

Conclusion

I have tried to present major technical considerations involved in chemical and biological warfare to enable you to get a reasonably realistic picture of what is involved. In making use of what I have said, it should be kept in mind that no one person can hope to have in proportion all the scientific and technical considerations involved. So far as I am concerned, I ought to be regarded as more informed about the chemical than the biological aspects, **roughly** in the proportions in which I have devoted space to the topics.

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INSTITUTE FOR STRATEGIC STUDIES

9th ANNUAL CONFERENCE

THE IMPLICATIONS OF MILITARY TECHNOLOGY IN THE 1970's

COMMITTEE IV – 1

Friday 29th September Morning

The Diffusion of Nuclear Technology and Capabilities

JOHN MADDOX

INTRODUCTION

It is now the best part of a decade since a study by the National Planning Association in the United States first drew attention (and named) the nth power problem. The argument then was that "by 1970, most nations with appreciable military strength will have in their arsenals nuclear weapons - strategic, tactical or both". The National Planning Association itself quite quickly realised that there is a world of difference between a statement of the possible and the probable, and much of the public discussion there has since been of the nth country problem has been concerned to show that the mere possession of technical competence is not enough to ensure that a nation will set out to manufacture nuclear weapons for itself. As things have turned out, there are now fewer nuclear powers in the world than there might have been. The non-technological restraints have had some effect, at least. But the calculations of the past decade have usually been based on the assumption that a nation wishing to make nuclear explosives would create an industry specifically for that purpose. Will that still be necessary ten years from now?

If the twenties were the years in which the technology of the motor car swept the world, then the seventies will be the decade of nuclear energy. Of that there is no doubt. By now, enough is known of the advance planning of governments in countries of all kinds to make it plain that even in the early seventies, nuclear energy will be making an important contribution to the production of energy. But it is also clear that the seventies will see the introduction into commercial service of new kinds of nuclear reactors - breeder reactors - which will confirm the economic importance of nuclear energy as a source of fuel and which will provide an incentive for the diffusion of a kind of nuclear technology which bears even more directly on the technology of nuclear weapons than does the operation of the kinds of nuclear reactors now in service. Long before the decade is out, there may be more than a dozen countries knowledgeable enough to make nuclear explosives for themselves. No amount of diplomacy can alter that.

Obviously these developments will have an important bearing on the problem of the spread of nuclear weapons. So far, the cost and technical difficulty of nuclear technology have helped to restrict the diffusion of nuclear technology. In the seventies, by contrast, several nations will have such well developed civil technologies that the manufacture of nuclear explosives will seem to them to be comparatively simple and comparatively cheap. This implies that if the spread of nuclear weapons is to be contained, other than purely technological considerations will become increasingly important. Treaties such as the partial test ban treaty will be even more valuable in the seventies than they are now - provided that they last that long. Nations will also be even more aware than they are at present that the development of delivery systems is an indispensable part of the process of becoming a nuclear power. Even now, it is well understood that the explosion of a few bombs in China, or by France, is not a proof of the acquisition of real military nuclear power but merely a promise of things to come.

Nuclear Industry in the Seventies

Since the beginning of 1967, there has been a boom in nuclear energy or - more precisely - there has been a boom in plans for building nuclear power stations to come into service three or four years from now. To the manufacturers concerned, in the United States and Western Europe, the past few months have been quite dramatic. Instead of having surplus manufacturing capacity on their hands, they find themselves over-burdened with orders for the special materials necessary in building nuclear power stations - steel pressure vessels, control rods made from unusual metals, instrumentation of a kind more often found in laboratories than in industrial applications and cladding of various kinds for nuclear fuel. What has happened is that nuclear power stations have become a cheaper source of electricity than other kinds of power stations in several different countries.

There is nothing inherently improbable about this development - indeed it has been foreseen for several years, and perhaps the biggest surprise is that it has taken so long for nuclear energy to become the most favoured way of manufacturing electricity. In the United States and in Britain as well, parallel but different lines of technical development have led more or less simultaneously to the design of comparatively simple-minded nuclear reactors which are able nevertheless to compete successfully with oil-fired power stations of quite conventional design. Moreover, both the American and the British types of nuclear reactors are potentially available quite freely under licence throughout Europe, Africa and the Far East. (There has even been some excited talk of the possibility of selling British reactor equipment to the Roumanian Government.) But this is only a beginning. Several other countries - Italy, West Germany, France and Japan - are only some of those working hard and successfully on the development of reactor types which cannot fail to make an important contribution to the generation of nuclear electricity in the decade ahead.

It is important not to underestimate the economic importance of nuclear energy from the nuclear reactors of first generation now being built for commercial operation. In Britain, for example, it seems to be established that the nuclear power stations now being built will produce electricity at a cost which is some 15 per cent less than the cost of electricity from the most modern power stations burning coal or even oil (which is in real terms the cheaper). But the total cost of manufacturing electricity in Britain amounts to some $1000 million, and will double before the seventies are over. It follows that the potential saving to be achieved by substituting nuclear power stations for the conventional variety is somewhere between $150 million and $300 million a year a decade or so from now, even in the unlikely event that there is no further improvement in the efficiency of nuclear power stations. In the United States, of course, the potential economic saving is measured in billions of dollars, not hundreds of millions.

In the circumstances it is not surprising that forward estimates of the construction of nuclear power stations suggest that this industry is likely to be one of the fastest growing of all in the decade immediately ahead. In the United States, the Atomic Energy Commission has, for example, produced the following estimates of the growth of electricity generation by nuclear reactors between now and the end of the century.

	Megawatts of electrical generating capacity
1967 (actual)	1,950
1970	11,000
1980	110,000
1990	367,000
2000	950,000

According to this same estimate, by 1970 nuclear power stations will be coming into service in the United States at such a rate that American capacity will be increased in each year by 5,700 megawatts, which is nearly as much as the total capacity of the nuclear reactors at present in service in Britain (4,048 MW) and the United States (1,950 MW).

The forward planning of other countries seems to be equally ambitious. It would not be unreasonable, for example, to suppose that roughly half of the new electrical generating capacity on which work is begun in Europe in the next decade will be nuclear generating capacity, not conventional, which implies a further 50,000 MW of capacity or more coming into service between 1970 and 1980. Indeed, detailed plans already available from individual countries suggest that the pace of growth may be even faster. In Italy, for example, already third in the hierarchy of nuclear countries (with 622 MW in service in 1967), it is planned to add 3,000 MW of nuclear generating capacity to the system by 1975. In West Germany, with three smallish plants nearly completed, orders are about to be placed for two 600 MW reactors, and the chances are that a further three will be ordered in 1968. In Sweden there is an ambitious plan for a 3,000 MW nuclear station, and Swiss nuclear power stations, based on six reactors altogether, are likely to provide 2,100 MW of generating capacity by 1975. Plans have also been announced for nuclear reactors in Belgium, Holland and Spain. Apparently the Finnish Government has decided to shelve, at least for the time being, a proposal to build a nuclear power station near Helsinki, but plans are well advanced for sizeable nuclear reactors in Argentina, Jugoslavia and Australia (by 1975). In Japan, the two quite small nuclear power plants now in service (178 MW altogether) will be supplemented by at least five other, with a total generating capacity of nearly 1,500 MW, by 1975. Even in Czechoslovakia, where the whole of twelve years have been spent on the construction of a single nuclear reactor to a Russian design, it is planned to have between 1,500 and 2,500 MW of nuclear generating plant in service by 1980.

The plans imply the production of plutonium in very large amounts. The actual amount of plutonium produced by an operating reactor depends very much on the type of installation and the continuity of its operation. Nevertheless, it seems to be a good working rule that for each 1,000 MW of electrical capacity, a reactor will produce something like 220 kg of plutonium a year - or enough for 30 to 40 fission bombs. This could easily imply that the production of plutonium from civil reactors will amount to 10,000 kg a year by 1970 and ten times as much by 1980. (These are estimates produced by the International Atomic Energy Agency in Vienna.) In other words, plutonium production capacity will increase from the equivalent of about 1,500 fission bombs a year in 1970 to about 15,000 fission bombs a year by 1980. Evidently there will be a commensurate increase of familiarity with this material in the decade ahead.

These figures are important not merely because they demonstrate the confidence of several governments in the economic importance of nuclear power for civil purposes, but also because they imply a growing familiarity with the essential technology of nuclear energy. In this connection, it is significant that several of the countries which have embarked on substantial programmes of civil nuclear power have taken care to see that they will be in a position to manage the whole operation on their own account. The Italian plan for the next few years is typical of what may become a common pattern. Although the first reactors to be built in Italy will follow British or American designs, work is well under way on a prototype of a reactor (called Cyrene) which has much in common with the Canadian CANDU reactor design but which promises to be able to use uranium fuel with varying degrees of enrichment in the fissile isotope uranium-235, and which may also be used to burn plutonium as a fuel as well. And although the spent fuel from the Italian reactors now in operation is being reprocessed at the British Windscale plant under the terms of a contract intended to ensure that it is not used for military purposes, the Italian Nuclear Energy Agency has decided to develop two pilot plants for the reprocessing of nuclear fuel, one of them to handle the separation of plutonium from uranium and the other intended to separate uranium 233 (another fissile material comparable in most ways to uranium 235) from its parent material thorium.

The development of reprocessing facilities by nations such as Italy is evidently an important development in the spread, controlled or otherwise, of nuclear weapons. For it is plain that the springing up of nuclear reactors is not by itself a worrying development. Only if the operators of the power stations are also able to extract the plutonium produced by the transformation of a part of the uranium used as fuel will they be able to put their machines to military uses. This is why there has grown up among diplomatists a sharp distinction between nuclear power stations and uranium reprocessing plants. Power stations are held to be virtuous because they create economic prosperity, but reprocessing plants are the opposite because they can be used for military purposes - that is how the argument tends to go. Yet it is quite unrealistic to expect that the non-nuclear powers will invest enormous sums of money in systems of nuclear power stations without reserving for themselves the right to reprocess their own fuel. For one thing, there is always a danger that good management would dictate that the operators of nuclear power stations should not let an essential part of the process of winning electricity from uranium be handled by agencies abroad over which they have no control. But there is also the economic argument that dependence on foreign reprocessing plants would entail the risk that the costs of these operations would be greater than they need be. All this implies that the construction of reprocessing plants for extracting plutonium from uranium will be an almost inevitable accompaniment of the growth of nuclear power generation industries in industrialised countries. It does not follow that the nations concerned will use these plants for making military plutonium - indeed, some of them may be subject to inspection by the International Atomic Energy Agency or by other nations under the terms of bilateral agreements for the supply of nuclear fuel. Nevertheless, it is inevitable that several potential nuclear powers will be well acquainted with the technology of extracting plutonium from irradiated uranium by the end of the seventies. Some of them may have reprocessing plants under their independent control.

It would also be prudent to acknowledge that the present development of the nuclear power industry will bring with it incentives for nations to build for themselves diffusion plants for the separation of fissile from non-fissile uranium. A good many types of reactors - all those in commercial service in the United States and the more advanced of the types being introduced in Britain - require slightly enriched uranium as fuel. In the United States, the AEC has gone to considerable trouble in recent months to advertise its surplus of capacity for uranium enrichment, largely as an assurance to the commercial manufacturers that they need not fear a shortage of capacity for manufacturing the kind of fuel their reactors may require. In Britain, where there is only one comparatively small enrichment plant, steps are now being taken to enlarge the plant at Capenhurst so as to provide a supply of fuel for the advanced gas cooled reactor. The only other enrichment plant outside the Soviet Union and mainland China is that built by the French at Pierrelatte, which is likely to be engaged on the production of fissile material for warheads for several years to come. In the circumstances, it would be a great surprise if the nations now embarking on programmes of nuclear power were prepared to allow themselves to remain dependent on sources of enriched uranium outside their direct control. In other words, with diffusion plants as with separation plants, it is more than likely that some of the nations engaged on the development of nuclear power programmes will also embark on the building of a uranium enrichment plant. Given the cost of these installations - up to $500 million for quite a small gaseous diffusion plant, for example - it is possible that groups of nations may club together to build a jointly operated diffusion plant. (A scheme to do this within Euratom was pre-empted, some years ago, by the French decision to go ahead independently with Pierrelatte.) Whatever happens, however, it is probable that the plants now operated by the nuclear powers will be replicated elsewhere, and it is certain that the technology of gaseous diffusion will spread to others than the nations now familiar with it.

All this implies that within the decade of the seventies, nations will be persuaded by simple commercial considerations, particularly the need to make cheap electricity and the wish to do so without untoward commercial dependence on others, to duplicate for themselves the technology and many of the facilities which are at present still the monopoly of the nuclear powers. All the countries of Western Europe - with the possible exception of Spain - will be thus affected. So too will India, Australia and Japan. It is, however, improbable that the countries of South and Central America, Africa and South-East Asia will be moved by similar considerations within the seventies. Israel and the UAR should not be persuaded by strictly economic considerations to build up civil nuclear industries of their own, but there is always of course the possibility that one of them or both may justify such developments on strictly military grounds.

Uranium Shortage and Breeder Reactors

The extremely rapid growth of the nuclear power industry to be expected in the seventies is bound to create a shortage of uranium. This is already well discounted. In the United States, for example, the AEC is doing its best to encourage renewed prospecting for uranium without much success so far. In Australia the government has recently introduced regulations to limit the export of uranium, chiefly by the direct control of the production of the mines. It seems generally to be recognised that the price of uranium oxide, which has at times in the past few years been as low as $5 a pound and which is now something like $8 a pound, will rise to $10 or $12 a pound by the mid-seventies. By the end of the decade something like 700,000 tons of uranium oxide will have been converted into fuel for civil reactors, and the following decade (the eighties) will need more than twice as much again if the reactors then in service are to be kept in fuel. By then, all known reserves from which uranium can be extracted at a price of $10 a pound or less will have been exhausted, as will have been the new discoveries it is reasonable to expect. Unless there are unexpected discoveries of uranium ore, the price of uranium will rise still higher in the eighties.

The prospect of this shortage, now widely anticipated, is one of the principal incentives for the development of a breeder reactor which can convert inert materials such as non-fissile uranium and thorium into fissile materials such as plutonium and uranium 233. These devices literally produce more fuel than they consume. With their introduction into service, there is every likelihood that the impending shortage of uranium will not be reflected in an increase of cost that prices nuclear power out of the market. Although there have been some plainly over-optimistic estimates of the speed with which breeder reactors would be developed, there now seems to be no doubt that they will play an important part in the nuclear fuel economy from 1975 onwards. To begin with, breeder reactors will be based on a fast neutron system using more or less pure plutonium as fuel and non-fissile uranium as a source of extra fuel. Later on, it is probable that the considerations of fuel supply will also provide an economic incentive based on the conversion of thorium into uranium 233, for thorium is much more plentiful than uranium in the crust of the Earth.

The inevitability of these developments seems to be recognised by all those nations with reasonably advanced programmes of nuclear technology. For one thing, of course, nations such as Japan and Italy are vividly aware of the local shortage of uranium ore within their boundaries. Even without this incentive, however, it is more than likely that their determination to remain in control of their own development of nuclear power would have prompted them to engage quite heavily in the development of breeder reactors. Thus it is that the Japanese atomic energy commission has allocated nearly $500 million to a programme of research and development in the next ten years. The atomic energy agencies in West Germany, France and Italy are similarly committed to programmes of development in breeder reactors (and the French CEA almost succeeded in wrecking Euratom single-handed in its dispute with that agency about the terms under which it should be lent fuel for an experimental fast breeder reactor). In India there is particular interest in the thorium cycle, chiefly because of the thorium deposits which are comparatively plentiful there, although the immediate goal is the construction of uranium reactors using heavy water on the pattern of the two Canadian CANDU reactors (one already in operation) which have been built with Canadian help and credit.

There are several reasons why the interest in breeder reactors of nations developing nuclear power programmes has an important bearing on the development of nuclear weapons. For one thing, the provision of fuel for a breeder reactor involves some process for separating fissile material in substantially pure form - either uranium 235, plutonium or uranium 233. Then the technology of most kinds of breeder reactors is the technology associated with fast neutrons, which is also the technology of making nuclear fission explosions. In other words, all this implies that a team of scientists working on the development of a fast breeder reactor would find themselves having to take many of the steps necessary for the development of nuclear weapons. In other words, the design of a fission bomb would be almost a trivial by-product of the design of a fast breeder reactor. The technology of breeder reactors is also, however, a field of activity in which commercial competitiveness persuades nations to be self-sufficient. In the present state of development of breeder reactors, it is entirely fair for nations to hope that successful development will bring rich rewards. This, certainly, was a part of the reasons why several West German companies protested, earlier this year, at the proposal that German research facilities should be thrown open to inspection by the international agency at Vienna at a time when the corresponding facilities in France, Britain and the United States would remain secret if their operators so chose.

It is relevant that this development, like that of nationally autonomous nuclear energy industries, is certain to aggravate the differences between the haves and the have-nots during the seventies. The nations which are at present able to embark on national programmes for the development of conventional fission reactors are also able, without much extra trouble, to hold at least a watching brief in breeder reactor technology. By contrast, those which cannot do the first cannot hope to do the second. The threshold which divides one category from the other seems to be the ability to commit a thousand or so scientists and engineers of considerable skill to programmes of development which cannot possibly bring quick returns. It is noteworthy that India unexpectedly belongs to the haves in this connection, almost entirely because of a deliberate decision to commit an unusually high proportion of the country's stock of manpower to the development of atomic energy. For countries like that, purely commercial considerations will eventually imply the acquisition of more or less the entire technology of nuclear explosives. For the rest, the independent manufacture of nuclear weapons will need a deliberate and necessarily somewhat artificial (and costly) programme of separate development.

Because of the disparity between the known supplies of uranium ore and the rate at which plans are being implemented for the exploitation of nuclear reactors, it is inevitable that breeder reactors will be made somehow to play an important part in the nuclear fuel economy. The most likely course of events is that the first devices of this kind, working with enriched uranium or plutonium as a primary fuel and uranium as a source of plutonium, will be in operation in the mid-seventies. (At least three prototypes will have been operating for several years by 1975.) By that time it is inevitable that the technology of fast reactors and of the separation of fissile materials will have become a commonplace in those countries with pretensions to advanced development in nuclear technology. By the same token, the same countries will be knowledgeable about the technology of nuclear weapons, and able without much difficulty or delay to put together a few devices to explode. So much is now almost inevitable.

Unorthodox Technology and Weapons Testing

The assumption that the route of nuclear power is along the now traditional path of plutonium producing reactors and gaseous diffusion plants is not necessarily valid. Indeed, for several years there have been suggestions that other ways of obtaining fissile material could enormously accelerate the rate at which new nuclear powers emerge. One of the favourite candidates in this field is the gas centrifuge - a device which could be used, for example, to separate uranium 235 from uranium 238 by spinning a rotor filled with a gas made up from the same chemical compound of the two materials. Gas centrifuges came into prominence four years ago, when it became known that a number of companies in Western Germany were working on their development. In practice, centrifuges were considered as a means of separating uranium isotopes during the Manhattan Project, but development was discontinued when gaseous diffusion plants proved successful. More recently (in 1964) research and development on gas centrifuges in the United States and United Kingdom has been tightly classified. This year (in June) the United States AEC has lost some of its friends by requiring one private company to cease work in this field, that dispute is not yet settled.

What are the advantages and the prospects for gas centrifuges? Theoretically, this method of separating uranium isotopes would be well suited to comparatively small scale operations. Briefly, if the rotor of a gas centrifuge can be spun quickly enough, one centrifuge can produce a greater degree of separation of the isotopes than one stage in a gaseous diffusion plant, where performance is limited by the molecular properties of the materials being used. In other words, an isotope separation plant using centrifuges could yield uranium 235 of some specified degree of purity with fewer stages than are necessary in a gaseous diffusion plant. A hundred centrifuges or even fewer might for example do the work of a thousand cells in a gaseous diffusion plant. This implies a comparatively low capital cost for centrifuges, comparative flexibility and the possibility that such a plant could be used to process comparatively small amounts of material.

To offset these potential advantages, there are a number of obstacles. The chief of these is that of designing centrifuges which can spin quickly enough to produce a worth while degree of separation without themselves falling apart under the mechanical stresses occasioned by their operation. Five years ago it was clear that technology had not yet reached the point at which suitable materials could be designed. It is, however, only a matter of time before suitable materials are available. When that point arrives, gas centrifuges will be a potentially useful means of preparing fissile uranium. Economically, the cost of uranium from such devices may well be greater, gramme for gramme, than uranium from gaseous diffusion plants (at present roughly $10 a gramme), chiefly because of the comparatively high cost of operating and maintaining equipment. For a potentially small producer, however, a higher price might be worth paying if only to save capital and time. It is perhaps important to acknowledge that because centrifuges may have useful applications in, for example, the preparation of pure isotopic forms of materials unconnected with nuclear energy. It is entirely understandable that the American AEC should consider the dangers of unrestricted gas centrifuge technology so great that the potential applications in chemical industry can be considered comparatively unimportant. By the same test, however, chemical industries in countries which are not now nuclear powers understandably feel differently about the rights and wrongs of the policy of restriction which now applies.

Precisely when gas centrifuges will be practicable remains to be seen, although it would not be unreasonable to think that by the mid-seventies some tangible developments along these lines will be possible. Because a great many of the potential nuclear powers will be in a position to obtain fissile material as a by-product of their civilian power programme, however, and because the cost of that material will be less than centrifuges could provide, gas centrifuge technology will be important principally for nations on the borderline between the haves and the have-nots. Israel is the most obvious candidate for using centrifuges, for it is entirely possible that in the next decade Israel may be unable to mount a sufficiently large and autonomous nuclear energy industry to satisfy what she may consider to be her military need of fissile material. If, however, there should emerge in the next decade such a closely co-ordinated and comprehensive system of international safeguards applying to civil nuclear power stations, other countries may look to centrifuges as a means of obtaining nuclear explosives. And what applies to centrifuges applies to other comparatively expensive means of separating uranium 235 from natural uranium - devices such as the electro-magnetic separators tried out during the Manhattan

Project, for example. If in the seventies a nation considers it has an urgent need of small quantities of fissile uranium and is prepared to pay as much as $100 a gramme or more for the privilege, it should not be too difficult to arrange for the manufacture of uranium 235 at production rates measured in kg per year.

In some circumstances, of course, a little uranium can go a long way. By now it seems clear that for the construction of thermonuclear weapons, as distinct from fission bombs, uranium 235 is preferable to plutonium. This no doubt explains why the United Kingdom and the United States have been exchanging uranium and plutonium in the past few years, why the development of French thermonuclear weapons seems to hang on the completion of the diffusion plant at Pierrelatte, and why the speed with which the Chinese have been able to make thermonuclear weapons is linked with the fact that their first fissile explosions were based on uranium 235. Because the other components of thermonuclear weapons are comparatively easy to manufacture, it is therefore theoretically possible that a nation might be able to make a few thermonuclear weapons with uranium 235 produced on a small scale without having an arsenal of fission bombs of any size. In practice, this course of events is likely to be more hazardous than it may seem at first sight. It may now be comparatively easy to ensure by laboratory experiments that a fission bomb would explode. Thermonuclear weapons are more difficult to be sure of so that testing would seem to be an essential part of the process.

The possibility that thermonuclear weapons might be made without the use of fissile material of any kind has also been raised from time to time. Attempts to detonate material which is capable of nuclear fusion by means of conventional explosives were, for example, reported to the second Atoms for Peace Conference in Geneva in 1958. They were, however, unsuccessful. More recently, the U.S. A.E.C. has reverted to research and development directed towards thermonuclear weapons that are entirely free from fission, but there is every sign that even if these efforts are successful, the result will not be a simpler thermonuclear bomb but, rather, a more complicated one. In other words, smaller countries wishing to manufacture nuclear weapons are unlikely to rely on fission-free explosions.

Naturally the testing of nuclear weapons is likely to play as important a part in the development of nuclear arsenals in the seventies as it has done in the past two decades. In practice, however, countries may be inhibited from testing by their signature of the partial test ban treaty, which forbids testing in the atmosphere. It is therefore important to recognise that nations bent on making nuclear weapons, whatever their size and sophistication, are unlikely to be deterred by the difficulty of having to test underground. It is true that they will thereby gather less information than they would ideally desire about the working of prototype explosions, but on the other hand they would be able to demonstrate to themselves (and others) that their preliminary designs are really workable. In the circumstances, if the test ban remains a partial test ban, it is unlikely in the seventies to be more than a marginal impediment to the development of nuclear weapons by non-nuclear powers.

Safeguards in the Seventies

If it seems at this stage to be inevitable that the seventies will bring an advance in the diffusion of nuclear technologies, they are also likely to see a considerable improvement in the means used for safeguarding the uses to which nuclear materials are put. At present, safeguards systems operated under bilateral agreements between nations or under international agreements such as those within Euratom and with the International Atomic Energy Agency at Vienna are rudimentary to say the best of them. Although it is unlikely that the safeguards systems will ever be free entirely from dependence on people, there is obviously a great deal which can be done to use machines and instruments for monitoring the uses made of nuclear material. This seems clearly to have been recognised in recent months and, both in the United States and the United Kingdom, funds are being spent on the development of devices intended to assist with the operation of nuclear safeguards.

As yet, it is clear that techniques of inspection are in their infancy. Under the terms of various bilateral agreements between nations - that between Britain and Italy, for example - fissile materials are said not to be usable for other than civil purposes. If uranium is supplied as a nuclear fuel and plutonium is produced when it is used, the supplier has the right to repurchase the plutonium if for some reason the user does not wish to put it to further civil uses. In any case, the supplier has the right to inspect plants in which his materials are being used and to ask for whatever information may be necessary to ensure that his materials are not being used for clandestine military purposes. The agreement between the United States and Euratom, which covers the supply of up to 75 thousand kg of uranium 235, differs from this in that responsibility for inspection is delegated to the safeguards division of Euratom. In the early sixties, the first of the two Canadian reactors built in India was something of a scandal because the Indian Government was at first reluctant to accept the application of safeguards to the reactor; now, however, this first reactor and the second being built in India with Canadian assistance (technical and financial) is subject to the safeguards of the IAEA.

Evidently the Vienna agency is destined to become the chief instrument for the operation of safeguards in the seventies. Although it may be permissible for the United States to delegate to Euratom responsibility for ensuring the proper use of fissile material supplied by the United States to Europe, it is clear that such an expedient could not be written into an international agreement. For Euratom is by international standards merely a consortium of like-minded nations. Whatever its efficiency and however high-minded it may be, it is constitutionally not suited to be an international quasi-judicial body. Only the IAEA is suited for that.

For the past two years, the safeguards unit at Vienna has been working out procedures. At present something like 80 different reactors, some power reactors but most of them research reactors, are covered by agency safeguards. In addition, one separation plant for the extraction of plutonium from irradiated uranium is being studied. There are as yet no proposals for dealing with enrichment plants, but it is likely that fuel manufacturing facilities will soon be theoretically within the agency's terms of reference. With the agency as with the provisions of bilateral agreements, the closeness of inspection must vary with circumstances. In principle, the inspectors must have access to such information as may be necessary to allow them to decide that material is not being diverted from civil to military uses. In the nature of things, they are more concerned with the input and output of fuel and other materials from nuclear installations than with the details of operation, although the latter cannot entirely be ignored. Inspections consist of the regular supply of operational data by the operators of power stations and other facilities and visits by inspectors at intervals determined by circumstances. Altogether the agency has thirteen inspectors on its books. They are people with a background in nuclear engineering. Care is taken that inspectors do not join the agency and then leave quickly with everbody else's commercial secrets to dispose of. However, for all the care with which the Agency chooses its inspectors at present, there cannot fail to be uneasiness that their length of service is at present only two or three years. Operators of nuclear facilities have a right to decline visits from inspectors who might be particularly unwelcome.

It seems to be acknowledged that with techniques like these, the agency can ensure that nuclear installations are properly operated, and that the diversion of nuclear materials to military uses does not exceed two per cent or so of the total scale of operations. For a small reactor, of course, this is quite sufficient. Larger installations, producing perhaps 1,000 kg of plutonium every year, could well be used in part for clandestine purposes without this fact becoming apparent to the agency. This is one of the reasons why there has recently been a search for instrumental means of keeping a more continuous watch on the operation of reactors. Another is the acute shortage of people qualified to be inspectors. Several possibilities are being canvassed, from devices which can be installed in reactors to keep a continuous record of their power production (and thus of plutonium production) to devices for the rapid and accurate analysis of irradiated materials (which is at present a great obstacle to accurate inspection). The chances are high that by the mid-seventies some at least of these devices will have enormously simplified the problems of inspection. In other words, if nations are so minded, it may then be much easier than it is at present to operate international agreements for non-proliferation or, more ambitiously, cut-off of production.

Technology and International Agreements

Superficially, of course, the spread of nuclear technology in the next few years will increase the difficulty of preventing the spread of nuclear weapons by means of formal treaties. If, for example, half a dozen nations (Italy, India, West Germany, Sweden, Belgium and Japan) are able to carry out underground tests of nuclear weapons, there is a chance that the partial test ban treaty will be regarded either as a formality - a paper restraint on what may be done - or as an intolerable frustration to countries which consider that they too should be allowed to manufacture weapons for themselves but who may not be able to undertake underground explosions. At the same time, of course, with the spread of nuclear technology in peaceful applications, it is inevitable that the resources of the safeguards inspection organisations will be greatly strained. Will they collapse under the strain imposed upon them?

In the circumstances likely to obtain in the late seventies, it will be best if nations can somehow accept that the essential attribute of a nuclear power is not its possession of the technology of the manufacture of nuclear explosives but, rather, its determination to use nuclear explosives for military purposes. In other words, policies should be aimed not at preventing the spread of nuclear power stations but at providing machinery for making sure that these are not used improperly. To act differently is to try to halt a technological development which is being propelled by powerful economic considerations. Even if individual nations, deeply committed to programmes of research and development in the peaceful exploitation of nuclear power, choose to make token explosions, this by itself should not be regarded as proof that the diffusion of nuclear military power is continuing apace. It is true that such a policy will require that attempts to contain proliferation should be concentrated as much on delivery systems and on large scale production facilities as on test explosions themselves, but this is only to pay attention to the parts of the process of military power building which are of military significance. In the late seventies, tests, underground or elsewhere, are unlikely to be taken very seriously, even as proofs of technological advancement, if they are not accompanied by evidence that there is an arsenal of weapons in n being and that delivery systems are to hand.

But of course it will be best of all if even the symbolic detonation of nuclear weapons can somehow be prevented. This is where it may eventually be important to negotiate an extension of the nuclear test ban to nuclear underground explosions as well as those above ground. The chances are that the initiative for such a treaty will have to come from the non-nuclear powers. As things are, both the United States and the Soviet Union seem to be counting on their series of underground explosions for the development of improved warheads for new kinds of missiles.

The distinction between the haves and the have-nots which at present obtains both in the manufacture of nuclear weapons and the exploitation of nuclear power for peaceful purposes is likely to be eroded in the next ten years. In particular, countries which are at present not nuclear powers will be able to construct and operate advanced types of nuclear reactors, possibly as prototypes for the real thing. In those circumstances it is even harder than at present to imagine that the degree of asymmetry built into the proposed non-proliferation treaty can last for very long. Indeed, to the extent that the treaty if signed will ensure that nations becoming nuclear powers receive no help from outside, the existence of a non-proliferation treaty may well seem in several countries to be a challenge to be met by the independent manufacture of nuclear explosives. But will the treaty in any case be signed? So far, at the Geneva conference of the United Nations Disarmament Sub-Committee, the Soviet Union and the United States have tabled a draft treaty in which no details are given of the proposed safeguards system by which non-nuclear powers (but not nuclear powers) would be inspected by the IAEA to ensure that nuclear materials are not used for military purposes. A decade hence, this asymmetry will seem impossible but it is already galling for the non-nuclear powers. In the circumstances nobody should be surprised if they refuse to toe the line which has been laid down by the nuclear powers, particularly by the Soviet Union and the United States.

Yet a non-proliferation treaty would be well worth having if it could be signed and if it could command the respect as well as the consent of the countries on the borderline. There would seem to be two courses of possible action in the next few months. Either the treaty could be weakened so as to make it acceptable to all the parties concerned; one way of doing this would be to return to the concept of a treaty fashionable a year ago in which nations would make voluntary declarations of their activity in nuclear materials, but this would not be verified by direct inspection. The alternative is to strengthen the treaty, possibly by extending it to include a cut-off of the production of fissile material. Either way, it is extremely unlikely that the non-nuclear powers will agree to any form of treaty which deals differently with them and the established nuclear powers.

It is probably true that voluntary declarations would in themselves be of considerable value. For one thing, there are a great many circumstances in which voluntary declarations can be checked independently. For example, a nation without resources of uranium of its own would have to rely on external ore, and the quantities crossing its frontiers could be estimated with considerable accuracy. If such a system were to seem palatable to a great many countries, will it not be a valuable if less ambitious goal towards which to work?

In the long run, however, there would obviously be advantages in taking account of what safeguards are practicable before embarking on treaties which assume safeguards and inspection as an accompaniment of other technical objectives. One of the troubles with the non-proliferation treaty (as with the abortive complete test ban before it) is that the kind of inspection necessary to give the treaty teeth is necessarily difficult to carry out. Paradoxically, it might be easier to operate a system of cut-off under which the total production of fissile material is verified in each country by direct inspection and the extensive use of monitoring equipment.

The solution of problems like these, however, cannot by itself ensure that the proliferation of nuclear weapons will be entirely halted. There is nothing in the non-proliferation treaty, for example, to prevent a nation successfully developing nuclear weapons with its own resources independently. Whether nations choose to take this course will depend of course on political and strategic circumstances.

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INSTITUTE FOR STRATEGIC STUDIES

9th ANNUAL CONFERENCE

THE IMPLICATIONS OF MILITARY TECHNOLOGY IN THE 1970's

COMMITTEE IV – ?

Friday 29th September — Afternoon

The Diffusion of Conventional Weapons

JOHN H. HOAGLAND

INTRODUCTION

An examination of local military conflicts in the developing world since World War II reveals one predominant but scarcely surprising fact - that the weapons with which these wars have been fought, and which to varying degrees have shaped the strategy and outcome of battle, were obtained from sources outside the countries involved.

Even in the aggregate, the military capabilities of the developing countries are very small in comparison with the major powers. To provide some sort of perspective, it is useful to remember that six countries - the United States, Soviet Union, United Kingdom, France, Germany and Communist China - account for about 85 per cent of the world's military expenditures; and the remaining countries, about 130 in number, account for only about 15 per cent.

However, in spite of their limitations, the military capabilities of the developing world do represent important problems in international security. In a period of delicately balanced strategic deterrence between East and West, local military preparations and conflicts in the developing world have become a frequent source of international tension. For what they have felt to be compelling political and economic reasons, the major powers have been willing, ever since World War II, to supply large quantities of weapons to the developing countries and occasionally to enter their conflicts directly. In the same period, the developing world has been a locale not only of ideological competition but also of a rising sense of nationalism, both of which have resulted in a greatly increased demand for modern weapons.

For the foreseeable future and certainly throughout the 1970's, the developing countries will continue to be largely dependent on industrial states for the supply of military hardware and technology. Therefore, to understand why and how the technology of conventional weapons in developing countries may change in the next decade, it is first necessary to understand the process by which weapons and military technology are transferred from industrial to developing countries. In order to gain some insights into the variety of channels through which hardware and technology are diffused, three different categories of weapons have been selected for discussion here: small arms; jet aircraft; and ballistic missiles. Several other very important categories, such as artillery, tanks, naval vessels, and air defense missiles, are either omitted or mentioned only briefly. However, the characteristic patterns of international transfer relevant to all classes of weaponry should emerge from this detailed examination of the two ends of the weapons spectrum. Finally, the paper closes with a discussion of the motives underlying this traffic in arms and technology, and some of its probable impacts on regional and international security are identified.

Small Arms

A realistic look at the diffusion process must be a broad one. It must deal not only with the more obvious and well-publicized cases, such as the Middle Eastern or South Asian inter-state competitions to procure major armaments. It must also deal with the more obscure areas of the arms traffic, especially the transfer of light weapons, such as automatic rifles, submachine guns, and small mortars, with which some of the most disturbing conflicts in the developing countries since World War II have been fought, and which promise to be of considerable importance for many years to come. Unlike the larger weapons, small arms can be obtained from a multitude of sources, including private traders, and their movement in relatively small numbers from country to country is easily concealed. Yet despite these features, the demonstrable fact is that the bulk of the small arms traffic to the developing countries since World War II has consisted of large-scale transfers, normally involving hundreds of thousands of weapons in a single transaction, under military aid agreements between an industrial country and a client state. Connected with this point are the related facts that small arms, once introduced into the world inventory, are likely to remain there for a very long time and to change hands rapidly, in ways totally unforeseen by the supplying power. With regard to their longevity, it is interesting to note that, in the Cyprus dispute of 1963 to 1965, available evidence indicates that the Turkish Cypriots were probably armed in part with Mauser bolt-action rifles which the Turkish Army had purchased in large quantities from Germany between 1890 and 1905.

But more important is the fact that, within a very short time after their transfer into the developing world, small arms may change ownership in unforeseen and surprising ways, finding uses that are diametrically opposed to the supplier's intentions. It is useful to trace, for example, the path of weapons from Belgium and the United States, via Cuba, into the hands of the insurgents now fighting in Venezuela. During 1959, its first year in power, the Castro government appealed to numerous sources for arms to equip its growing national army. Cuba was successful, eventually, in purchasing from Fabrique Nationale of Belgium 65,000 standard NATO rifles, 1,000 Uzi submachine guns made in Belgium under Israeli license, and 200 machine guns, all representing the then current level of technology in small arms.

In addition, when Castro came to power, he also acquired a large arsenal of weapons that the United States had been supplying to the Batista régime throughout the 1950's under a military assistance pact, and intended to bolster the Cuban national forces against threats to internal security.

As the new Cuban army grew in size, it became increasingly important to locate a reliable large-scale supplier. By mid-1960, Soviet and Czech arms, including 125,000 automatic rifles, 10,000 submachine guns, and hundreds of field weapons, began arriving in Cuba. As a result, both the Belgian and U.S. arms were gradually rendered surplus as the army standardized on Soviet weapons. Then, within a very short time, these weapons found uses in Venezuela which neither the United States nor Belgium would have considered appropriate at the time of their initial transfer. An arms cache discovered in Venezuela in 1963, and intended for use by communist insurgents, consisted of automatic rifles made by Fabrique Nationale, Uzi submachine guns, 60mm mortars made in the United States and identified as having been given to the Batista government, as well as U.S. bazookas and recoilless rifles.

This is not an isolated case. To mention one other example, military assistance from the Soviet Union to Egypt probably brought on the retirement of the approximately 100,000 Lee Enfield rifles supplied to the Egyptian army prior to the British Military

Mission's departure in 1949. Some of these British weapons have undoubtedly found their way by now to other parts of Africa, such as Somalia for use in its dispute with Ethiopia, and their potential for future mischief is considerable.

One of the difficulties in attempting to impose any effective control over the small arms traffic is suggested by the fact that there are probably no more than a thousand insurgents in all of Latin America at the present time - roughly 350 each in Columbia and Venezuela, 200 in Guatemala, and about 100 in Bolivia. The result is that, since comparatively few weapons are needed to support their operations, a great many sources, both governmental and private, are capable of supplying adequate quantities of arms and ammunition - provided of course that they are willing to run the risks. The present Cuban government, for example, would be hard pressed to supply the small arms necessary for one of the sides in even a diminutive interstate war, but it is apparently capable of supporting several clandestine insurgencies simultaneously. Nevertheless, it must be pointed out emphatically that a country such as Cuba is capable of supporting these adventures only because it has previously received massive shipments of small arms from the major powers.

If the insurgents are fortunate enough to be able to operate from privileged sanctuaries in a neighboring country, then their actions may be conducted on a much larger scale, in larger units and with less secrecy, and using heavier and often more modern firepower. Accordingly, the patterns of arms supply may be substantially different. One striking example is the Greek insurgency of 1946 to 1949, in which the Greek Communist forces operated in large numbers from bases in Albania, Bulgaria and Yugoslavia, where they also received arms, ammunition, and other logistical support in a relatively open and methodical way. An insurgent force of nearly 20,000 was put in the field, armed with rifles, submachine guns, and even with heavier weapons such as mortars, recoilless rifles, and even artillery. These heavier weapons demand, of course, more intensive logistical support, particularly in the supply of ammunition. Sanctuaries in a neighboring country may enable a determined supplier to provide heavier and more modern firepower to the insurgents. A current example can be found in South Vietnam, where the insurgents have occasionally used 140 mm. artillery rockets to attack U.S. military installations.

The regular forces of national governments in the developing countries have most often been equipped with small arms obtained as part of an overall military assistance agreement. It is useful to note that, in all of these cases, international attention has focused mainly on the more sophisticated weapons included in the agreement. In the case of Egypt, for example, the Soviet transfer of medium bombers, jet fighters, and tanks has been well publicized; but the hundreds of thousands of Soviet small arms included in the agreement have gone comparatively unnoticed, even though their influence on regional stability may be felt for years to come, in many different countries, where their introduction even in small numbers will in turn prompt large build-ups by the opposing forces.

Any military force in the developing world, whether regular or irregular, must establish a dependable and uninterrupted source of supply of ammunition, spare parts and replacements for the weapons in its inventory. (It should be noted here, as Pakistan can testify, that it is sometimes easier to acquire the weapons than it is to store up enough ammunition for a prolonged conflict.) As a result, a few nations of the developing world have for some time been producing their own small arms and ammunition. To the extent that more countries follow suit, the world's sources of supply will multiply, and the arms market will be even more accommodating than it is today. One example is India, which manufactures not only small arms, but also artillery, tanks, and aircraft, usually on the basis of imported designs or foreign licenses. Before World War II, Britain assisted India in building several ordnance factories for the production of British-designed small arms, such as the Lee Enfield rifle, Vickers Berthier machine gun and Bren gun. The rifles and submachine guns now being produced in these Indian arsenals are essentially Indian modifications of British designs. India has also established production of a Vickers-designed tank, designated the Vijayanta. At present most of the parts are still made in Britain and shipped to India, but before 1970, 80 per cent of the manufacture is to be carried out in India. Similarly, Israel has been working toward self-sufficiency in the production of small arms and battlefield weapons and their ammunition. Israel has obtained licensing agreements from Belgium for the domestic production of the NATO 7.62mm automatic rifle and, in addition, produces its own flame throwers, 81mm mortars, and 92mm bazookas.

It is not possible to estimate with any confidence the size of the international small arms traffic. The numbers of rifles, machine guns, and other light weapons transferred outside the major alliances since World War II might lie anywhere from ten million to fifty million. It is also very difficult to gauge the real effects of this traffic on the security and stability of the developing world. Some basic questions remain unanswered and deserve a major research effort. What is the approximate world inventory, even within very wide tolerances, of military small arms? How is the ownership distributed? What are the rates of replenishment and attrition of the world inventory? How rapidly are the supply sources proliferating? To what extent have the most important insurgencies, particularly those which invoked major power participation, been initiated with weapons made available, directly or indirectly, by the major powers? What are the genuine long-term effects on regional security of large-scale transfers of rifles and automatic weapons to developing countries as part of a military assistance agreement? What is the probability that they will be used in unforeseen ways?

The effort to answer questions of this kind is just as important to the developing countries as it is to the larger nations. The technology of small arms is now improving very rapidly under the impetus of renewed major-power interest in conventional forces. Man-transportable artillery rockets and recoilless rifles, wire-guided anti-tank weapons, portable flame throwers, as well as equipment such as night weapon sights and target locators of various kinds, will inevitably find their way into the developing world, both to regulars and insurgents, much sooner than we may expect. Answers to some of the preceeding questions will provide at least some capability to predict what the more critical forms of transfer may be.

Jet Combat Aircraft

In contrast with the lack of data on transfers of small arms (as well as battlefield weapons and artillery), a great deal is known about transfers of larger weapons from the industrial to the developing nations, such as tanks, aircraft, and naval vessels. For several reasons, these transfers attract considerable publicity. To varying degrees, these larger weapons extend the range, speed, and scale of potential conflict, bringing larger territory under the threat of their fire-power and calling for more complex analysis of opposing strategies. Unlike small arms, their transfers occur almost exclusively between established governments, (with, of course, a few notable exceptions, such as the armed Magister jet trainer under control of the Katanga mercenaries or the B-265 recently in use by the Nigerian separatists.)

The decision to supply or receive modern aircraft is normally made at a high governmental level. The high cost of sophisticated systems, the many security aspects surrounding the technology they represent, and the need for policy decisions regarding the political and economic impacts of the transfers, almost inevitably require government participation on both sides of the negotiation. In some of the more heated regional arms races, notably in the Middle East, the spiralling build-up of combat aircraft has been the focal point of the competition, around which all the other military preparations are clustered.

Four suppliers - the Soviet Union, United States, United Kingdom, and France - have accounted for about 98 per cent of all jet combat aircraft shipped to the developing world since the end of World War II. In the post-war years, these nations have shipped over 5,000 jet combat aircraft (including at least 500 bombers) to the developing countries. According to available data, the overall breakdown by suppliers, as of 1966, was about as follows:

Soviet Union	1,870
United States	1,540
United Kingdom	1,280
France	420

In addition to these four main suppliers of combat aircraft, several other nations have strong existing or future potentials as sources of military jet aircraft for the developing world. Important among these are Sweden, West Germany, Canada, Italy, Japan, Czechoslovakia, and Communist China. Their export potentials do not, however, match those of the four main suppliers.

A striking case study of the competitive supply of aircraft by the great powers to regional adversaries is provided by the history of the Israeli and Egyptian military build-up from 1955 to the present. Egypt signed its first military assistance agreement with the USSR in 1955. In the course of an extremely rapid transfer of military equipment, Egypt received nearly 200 Soviet MiG-15 and MiG-17 jet fighters and Il-28 tactical bombers. This sudden destabilization of the regional balance was undoubtedly one factor contributing to the British-French-Israeli pre-emption of October 1956, in which an estimated 50 per cent of the Egyptian aircraft inventory was lost. Following the cessation of hostilities, the

Soviet Union responded quickly with new arms supplies to Egypt. Within six months, an additional 100 MiG-17 fighters and more than 50 Il-28 bombers had been delivered. In 1961 and 1962, about 100 MiG-19 fighters were delivered. From 1962 to 1966, about 130 supersonic MiG-21s, including 40 to 50 MiG-21D all-weather fighters, were sent to Egypt. In this same period, about 25 Tu-16 intermediate range bombers, capable of delivering a 10,000 pound bomb load, were added to the Egyptian inventory by the Soviet Union, marking a radical departure from what had, until then, apparently been a tacit restriction by the major powers on the range and payload of combat aircraft exported to the developing world.

A similar build-up was underway in Israel, drawing primarily on the support of France. Since 1956, France has sold to Israel about 80 Mystere and Super-Mystere subsonic fighters, 72 Mirage III supersonic fighters armed with air-to-air missiles, about 50 Ouragan fighter bombers, and about 25 Vautour fighter bombers. In addition, Israel has between 60 and 100 Magister jet trainers and ground support fighters, many of which were built in Israel under French license.

Clearly then, these are large and costly air forces - costly not only in monetary terms but in absorbing the energies of some of the most competent people in the countries involved. It is important, therefore, to ask what security they provided to either country or to the region generally.

For obvious military reasons the air power of one side must be matched, at least qualitatively, by the other. For this reason, competing build-ups in air power tend to occur in an upward-spiralling pattern. Yet the net gain in security, if a relative balance of power is maintained, may be negligible to either side. Furthermore, the strategies imposed by the possession of highly effective offensive aircraft, based on highly vulnerable airfields, may be especially unstable, favoring the use of surprise attack. Even more basic, however, is the question of how the influx of aircraft, tanks, and other large weapons affects the perceptions of the national leadership. The experience of the Middle East in 1967 and Kashmir in 1965 indicates that the possession of a vast armory may give the leadership unwarranted confidence in its ability to initiate and win a war. The experience of the Suez war of 1956 may further indicate that a rapid military build-up by one party can stimulate a pre-emptive attack by other parties.

Conversely, it should also be noted that sovereign nations must have the means of assuring the sovereignty of their airspace. In the coming era of supersonic transports and steady increases in the volume of jet transportation, the developing nations are more likely than ever to demand high-performance jet fighters and interceptors to police their national airspace, unless satisfactory international arrangements are made.

It can also be argued, provided the argument is not carried too far, that the possession of modern combat aircraft gives developing countries a greater range of expression, an ability to communicate degrees of intention and to make shows of force to the adversary, which conventional ground forces could not provide. It seems likely, for example, that the Turkish Air Force, by carrying out sorties over Cyprus in 1964, was able to communicate the most serious concern about the situation to the Greeks and to convince them of its readiness to intervene with troops if the situation did not improve. In some cases, then, the limited commitment of air power across national borders may serve as a substitute for attack by ground forces, with all the potential for escalation that would involve; but it is far more likely, as the Egyptian air strikes against Yemen indicate, that such uses of air power simply tend to downgrade the whole concept of sovereign and inviolate national borders.

What can be said about future trends in the transfer of sophisticated jet aircraft into the developing world? Of growing importance is the question of re-transfer - that is, the second or later international transfer of combat aircraft following their initial export from the country of manufacture. During the 20 years from 1945 to 1965, re-transfers represented only about one per cent of all the jet combat aircraft transferred to the developing countries. Since 1965, the number has been increasing rapidly. For example, West Germany has, in the last four years, disposed of at least the following surplus aircraft: F-84s to Turkey and F-86s to Greece and Turkey; 90 Canadian-built F-86s to Iran; French-built Magisters to Nigeria; 40 Fiat G.91s to Portugal; and over 50 U.S.-built F-86s to Venezuela. Therefore, it does seem obvious that the continuing re-equipment of air forces around the world is beginning to create a relatively large surplus of jet fighters and bombers, aircraft whose longevity is impressive. It would be useful, in the German case, to identify the economic pressures and motivations underlying these exports - for example, their relationship to additional imports of military equipment from the United States.

To counteract their overdependence on outside suppliers for spares and maintenance, some of the more advanced developing countries have established either licensed production of foreign aircraft on their own soil or have attempted to design and develop their own combat aircraft. In recent years, for example, the Egyptian government has attempted to develop its own supersonic fighter-bomber, the HA-300. The HA-300 design came into being shortly after World War II, when Willi Messerschmitt of Germany became associated with Hispano Aviacion of Spain. When the Spanish government decided, in the late 1950's, to cancel the project, an agreement was reached with the Egyptian government to transfer the entire program to the aircraft plant at Helwan, Egypt. German, Spanish, and Egyptian technical personnel and factory workers were employed, and an Austrian aeronautical engineer became head of the project. The results of this program have demonstrated how difficult it is for a less industrialized country to mount such an effort without large quantities of outside support, thereby defeating the main purpose the program was meant to fulfil. It became necessary to set up recruiting and procurement activities in Switzerland in order to obtain qualified personnel, technology, and material from Western Europe to keep the program moving forward. Even with considerable outside participation, the project has met with little success. When the German government in recent years began pressuring its personnel to return home, the HA-300 program encountered progressively greater administrative and technical difficulties. In spite of the fact that European aircraft companies contributed the use of test facilities and technical assistance to the Egyptian program, the lack of a broad domestic technical and industrial base has apparently proved insurmountable. Dependence on external assistance was perhaps most strikingly illustrated in 1966, when an entire fuselage section of the HA-300 was shipped to England for testing of the pressurization and air conditioning systems.

Even in India, whose aircraft industry is well established, the attempt to develop indigenous high performance combat aircraft has been for the most part unsuccessful. In the mid-1950's, the wartime chief designer of Focke-Wulfe emigrated to India and led a design team made up mainly of German engineers in the preliminary development of a supersonic all-weather fighter, designated the HF-24. The effort has progressed at a much slower pace than corresponding programs in the highly industrial countries, and there have been continuous, difficult, and to date unsuccessful negotiations with other major powers such as the United States, Britain, and Soviet Union, to obtain a suitable power plant for the HF-24. Even for less complicated parts and sub-systems - for example cockpit canopies or flight controls - the participation of foreign suppliers has been an essential element. Although the HF-24 program has resulted to date in the manufacture of several subsonic pre-production versions of the aircraft, it has not succeeded in its main purpose of providing a wholly independent capability.

Licensed production, on the other hand, appears to be a compromise solution in that it provides at least a slight amount of domestic control over the source of supply. A current example is the establishment of licensed production in India of the Soviet MiG-21 fighter. Under the terms of an agreement reached in 1964, the Soviet Union has assisted Hindustan Aeronautics Ltd., in the establishment of three separate manufacturing complexes - one each for the airframes, engines, and electronics. The Soviet Union has supplied production equipment for the plants, as well as personnel to supervise their installation. As in most instances of licensed production, India will first assemble MiG-21 aircraft that have been produced in the USSR and then gradually assume more of the responsibility for sub-assembly and the actual fabrication of parts. Prior to the current program, India manufactured large numbers of British jet fighters under license, including the Vickers Vampire and Folland Gnat. A successful licensed production effort has also been undertaken in Israel, which manufactures the French Potez Magister jet trainer under license; and in South Africa, where Atlas Aircraft Corporation is establishing licensed production of the Italian Macchi MB.326 jet trainer. In the past month, Israel has taken the unusual step of purchasing an entire U.S. aircraft manufacturing firm, in order to move its production facilities to Israel.

Although licensed production assures the availability of spare parts and undoubtedly helps to raise the level of domestic industrial technology, it has also proved to be extremely costly, difficult, and time-consuming. Even within a single U.S. aircraft company, the initial unit cost of manufacture at a second facility is much higher than at the original source. The rate at which costs at the second source approximate those of the primary source depends to a great extent on the industrial and technical skill and experience of personnel at a second source. When that source is a different country, all of the various management, industrial, and technical problems are multiplied greatly.

Therefore, although licensed production programs may slowly become more important in the more advanced of the developing countries such as India, the sale of completed aircraft will almost certainly continue to be the predominant form of transfer to the developing world.

Ballistic Missiles

Early in 1966, it was reported in the American press that Israel had entered into an agreement with France to purchase a large number of French ballistic missiles. The report was immediately and convincingly denied, both in Paris and Tel Aviv. French spokesmen were also quoted as saying, however, that the French government would not object if French private companies were to co-operate with Israel in rocket research and development. In particular, Israel appeared to be interested in developing a two-stage vehicle based on the Topaze, a research rocket which had been developed as part of the French military ballistic missile program. The exchange of statements illustrates two interesting points which, at least for the present, remain valid. The first is that the direct transfer to a developing country by a major power of complete and ready-to-operate offensive ballistic missile systems is an extremely sensitive matter, one which is virtually certain to stir up strong political reactions. The second point is that the transfer of technology, even a great deal of it, to support an ostensibly indigenous effort, may rouse less opposition because many of the details can be held secret and because the results are not immediately apparent.

The process of ballistic missile diffusion to the developing countries is just beginning, and it is not likely to advance very rapidly. The problems encountered by Egypt, similar to problems earlier described in its aircraft development, illustrate the complexities of missile diffusion. The story is so familiar that it scarcely needs recounting in any detail here. It is useful merely to point out that, beginning in about 1960, the Egyptian government recruited rocket designers in West Germany and elsewhere, and brought them together at a missile complex in Heliopolis, Egypt. By 1962, there were over 250 West German rocket experts and technicians in Egypt, along with a total labor force of about 1,000. The development of three different liquid-fueled ballistic missiles, somewhat reminiscent in their configuration of the V-2 missiles, was undertaken. The largest of these was to be a two-stage missile capable of propelling a warhead of 2,000 lbs. across a distance of about 500 miles.

The first publicly-announced test flights of Egyptian missiles occurred in July, 1962. Shortly thereafter, the two smaller of these missiles, of 200-mile and 325-mile range respectively, were displayed in the annual Revolution Day parade in Cairo. President Nasser claimed at that time that both of the missiles were in quantity production, but a few months later one of the German technicians was reported as saying that it would be several years before the rockets were ready for military use.

It is obvious that the perfection of an effective ballistic weapon system has remained beyond the capabilities of a limited design team operating under adverse circumstances. However, the initiation even of a technically unpromising effort, when it involves ballistic missiles, has enough political potency to create very strong repercussions. The Israeli program of terrorism against the German personnel, as well as their political pressures on West Germany, are sufficient evidence of the political implications of ballistic missile procurement. Furthermore, the cost to Egypt was clearly enormous in exchange for what it received. Some of the senior personnel are said to have been paid over $100,000 annually for their consulting services on the program. Similarly, the prices paid for equipment and materials procured in Europe were obviously inflated.

In total, the Egyptian experience to date appears to indicate that developing countries will be faced with almost insurmountable difficulties if they attempt to develop, on a relatively autonomous basis, effective ballistic missile systems. Without becoming involved in too much analytical detail, it is worthwhile to consider the broad requirements for developing and producing a 500-nautical mile ballistic missile, the kind of vehicle that might be of interest to Middle Eastern nations. In a modern industrial country with a well-developed aerospace industry, the development and production of such a missile would require approximately 10,000 experienced workers, including about 2,500 engineers. At this level of effort, the project from preliminary design through deployment would be accomplished in about a six to eight-year cycle. The total cost of development, production, and deployment of a force of 50 missiles would be about 500 million dollars over the eight-year period. Available evidence from aircraft experience indicates that the cost in a developing country would be substantially higher because of dependence on outside suppliers and difficulties in program management.

It is this kind of calculation, added to the uncertainties of trying to undertake such a program without the necessary domestic industrial base, that may lead some developing countries either to seek the procurement of complete missile systems from abroad or to carry out what would be, in effect, only a domestic facade for a foreign-executed program. Rough calculations indicate, for example, that if a country such as Israel were to draw on an experienced missile-producing country such as France, it could effect reductions in the time and resources cited above amounting to about 30 per cent of total program manpower, 50 per cent of scientific manpower, 20 to 30 per cent of total program cost, and about a two-year shortening of the total program cycle. These savings could be achieved by acquiring production licenses or direct procurement of guidance and control packages, co-operative adaptation of existing French rocket motors, and the use of French ranges for the test program.

By 1970, there will be about five countries capable of supplying complete ballistic systems and about 10 additional national suppliers of sub-systems such as guidance and control, propulsion, or aerodynamics. By 1975 it seems likely that there will be as many as eight suppliers of complete systems and 11 additional suppliers of sub-systems. Although it is difficult to predict much further into the future, it seems possible that by 1980 there could be as many as 16 suppliers of complete systems and 12 additional suppliers of sub-systems. (See Table 1). This expansion will result not only from military programs, but also from the increase in space activities throughout the world. Japan, for example, has already supplied sounding rockets to Yugoslavia, Indonesia, and others. As the number of potential missile suppliers grows, the bargaining power of potential recipients will increase, and the enforcement of controls over missile diffusion, in the unlikely event that controls are attempted, will grow steadily more difficult.

Although no one really knows exactly what may be the ultimate effects of ballistic missile diffusion to the developing countries, at least some possible effects can be identified. Because the cost of the fully-deployed system is so great, it may demand the selection of targets whose value is commensurate with the cost of the system, such as cities or large economic complexes. For similar reasons, missile procurement is virtually certain to stimulate interest in weapons big enough to destroy large and valuable targets. In addition, the introduction of ballistic missiles into regional environments will almost certainly introduce new and unfamiliar strategic considerations among adversaries which could, at least initially, produce marked instabilities.

It is especially pertinent to note that the end of a local interstate war usually marks an important take-off point for the next round of an arms race. The termination of fighting in the Palestine War of 1948, Suez in 1956, the Sino-Indian war of 1962, and Kashmir in 1965 marked the beginning of a major step-up in arms procurements by one or both sides. In each case, there were important changes both in the quantity and quality of weapons procured, accompanied in some cases by changes in supplier alignments (e.g. Pakistan-China). The reasons are obvious. After combat experience, better assessments can be made about the performance of different types of weapons, and there is also a pressing need for re-equipment due to use and attrition. Furthermore, in the wake of the crisis, the leadership is particularly responsive to military requests. The next round of the Middle Eastern arms race could possibly include, on both sides, a more determined effort to procure ballistic missiles and more efficient warheads, perhaps involving a change of suppliers. Egyptian attempts to develop missiles have been inadequate, to say the least. Although the experience has been so discouraging that Egypt may abandon the effort, an alternative course would be to look for a new, determined, and reliable national supplier of missile or warhead technology, to replace the difficult and haphazard process of hiring individual technical personnel under separate contracts.

TABLE I

POTENTIAL SUPPLIERS OF MISSILE SYSTEMS AND SUBSYSTEMS

	SYSTEMS	SUBSYSTEMS	
1965-70	U.S. USSR France UK China	U.S. USSR France UK China UAR West Germany Japan	Italy Canada East Germany Australia Sweden Switzerland Israel
1970-75	Above plus: UAR Japan Israel	Above plus: Netherlands Belgium Czechoslovakia India	
1975-80	Above plus: West Germany Italy Canada East Germany Australia Sweden Switzerland Netherlands	Above plus: South Africa Poland Norway Yugoslavia Pakistan Indonesia Argentina Brazil Chile	

CONCLUSION

Why do major powers supply arms to the developing world? Certain economic motivations are apparent. The desire to sell surplus equipment, to assure orderly and sustained production runs, and to help the national balance of payments, have all been important factors. But far more compelling, particularly to the competing super-powers, have been the political motives associated with the Cold War and the encounter of ideologies.

The West has, on balance, made more efforts to restrain and control the flow of arms into the developing world than is generally realized. Transfers have, furthermore, often been made for what seemed in the West to be the right reasons - such as protecting a legally constituted government from subversion and disorder; or trying to maintain some kind of stable military balance between states in a region. In fact, when American officials testified before Congress this summer in defense of U.S. arms exports, they stressed the good intentions underlying their policies. But good intentions are not really at issue. They merely pave the road on which we are travelling. The point is that, even when the motives seem acceptable, the results may be very unpredictable, as some of the preceding cases have indicated. When all of the different motivations have been examined and are understood - and are even accepted in some instances as valid - what remains is an increasingly complicated and dangerous process which in many aspects is not in the long-term interests either of the developing world or the major powers.

In the case of interstate wars, one ironic fact deserves a great deal of consideration, because it calls into question the whole rationale of the arms traffic. The fact is that, when hostilities finally break out in an interstate conflict, the same major powers who made the conflict possible have almost invariably joined in common appeals for a cease-fire. In the Horn of Africa, for example, even though the United States and Soviet Union were involved in competitive build-ups of Somalian and Ethiopian forces, they joined in a direct appeal in 1964 to bring the fighting to an end. Similarly, the United States, United Kingdom, and Soviet Union worked urgently for a cease-fire in the Kashmir dispute of 1965. All this despite the fact that in many of these conflicts, there are grounds for suspicion that the influx of weapons from a major power provided the aggressor with the confidence he needed to start the fighting.

There are no easy answers to the question of how to control the international traffic in armaments, and the prognosis is not especially hopeful. The Soviet Union, which since 1955 has tended to set the pace of the traffic, shows every sign of continuing its present course. In spite of setbacks both in Indonesia and Egypt, the Soviets have given ample evidence recently, in their re-supply of equipment to Egypt and in the hasty introduction of weapons into the Nigerian conflict, that they are not ready to abandon arms exports as an instrument of their national policy toward the developing world. In part, it may simply be that, once a bureaucracy has been developed in Moscow (or for that matter in Washington) to handle this type of transaction, the momentum of the activity becomes sufficient justification for its continuance. An additional sign is that Soviet logistical capabilities to support this type of activity, in the form of air-lift and sea-lift capabilities, have improved dramatically in the last few years and appear to portend more extensive Soviet arms exports in the future.

It is obvious that, for a long time yet to come, sovereign nations will still need arms. The beginning of wisdom will be the recognition by all parties, in the East, the West, and the developing world, that we do not really know what we are doing; that very little is known about the ultimate effects of the international arms traffic on international security; and that a greater international effort is needed to measure its scope and calculate its present and possible future effects.

Initiatives of various kinds to investigate international arms transfers have been made from time to time. In November 1965, for example, the Maltese delegation to the United Nations placed a draft resolution before the UN General Assembly which called for the UN to establish "a general and effective system of publicity to transfers between states, whether by way of trade or otherwise, of arms, ammunition and implements of war". This constructive resolution was defeated at least partly because the delegates were tired and needed a recess. It certainly deserves a second chance in the Assembly. In the Maltese draft resolution, it was recalled that the League of Nations had published a "Yearbook on the Trade in Arms, Ammunition and Implements of War" for many years. Similarly in June 1967, the President of the United States proposed an arms registration system, under UN auspices, for all weapons shipped to the Middle East. Probably underlying both of these proposals was the assumption - doubtless a valid one - that publication of transfers, would, in itself, constitute a partial deterrent to the traffic. But the value of publication could also go much further.

A more intensive public or private international effort to assemble a base of information on arms transfers, even if it were not totally reliable, would inevitably result in a better understanding than we have now of the international traffic in arms. Until more professionals in the fields of defense, strategy, and arms control become better acquainted with the details of the problem, it will not be possible to confirm or deny, by analysis, the intuitive suspicion now shared by many hard-headed and practical observers that the international arms traffic represents a net loss in international security affairs.

One suspects, for example, that weapons do occasionally precipitate conflicts; that the traffic in arms provides a tacit but clear major power endorsement of military conflict and competition in the developing world; that the large-scale import of military hardware or technology is producing, in the developing countries, effects of a social, political, and economic nature that no one really understands; and finally, that a tone is being set in the conduct of international relations that may someday react very adversely on the major powers themselves.

When more professionals, in a wider number of countries, can be provided with more complete information about the international arms traffic, then it may be possible to find better ways than we have so far discovered to improve the stability, prosperity, and security of the developing world.

AUTHOR'S NOTE

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THE IMPLICATIONS OF MILITARY TECHNOLOGY IN THE 1970's

COMMITTEE IV — 3

Saturday 30th September Morning

Defence Technology in a Major Developing Country: India

K. SUBRAHMANYAM

The series of successful nuclear tests by China in the last three years has drawn world attention to the diffusion of defence technology to developing countries. The speed of acquisition of defence technology by such countries appears to be determined by their aggregate defence expenditure and not by their relative richness or poverty in terms of per capita income. It is also influenced by the levels of skills already available and the rate at which general industrial development progresses. With reference to these considerations, India and China represent the limits in regard to this process among the developing countries. They have armed forces which are the fourth and third largest in numbers, and their aggregate defence expenditures are the eighth and the fourth largest in the world. In terms of GNP, and perhaps in industrial output too, these two rank among the first ten. Among the developing countries next in aggregate income are Mexico, Brazil and Pakistan with GNPs a half, a third and a fourth of India's. No developing country other than India and China has a defence expenditure very much above $500 million. Taiwan, South Korea and South Vietnam have armed forces exceeding half a million; but for defence technology, they are dependent on the United States and this is reflected in their low aggregate defence expenditures, incommensurate with the size of their forces. The other developing countries which appear to have laid emphasis on establishing an indigenous defence production base are the United Arab Republic, to a lesser extent Turkey and lately, Pakistan. Here it is proposed to consider the limiting models, India and China, and especially the former as more information is readily available in her case.

Defence Technology as Part of the Industrialisation Process

The production of conventional armaments can be regarded as part of the normal industrialisation process. In both cases, technologies in the fields of metallurgy, engineering, chemicals and electronics are involved, with greater need for precision and quality control in defence production. Therefore, any developing country in a position to devote the economic and manpower resources required can aspire to develop a conventional armament industry within a reasonable period. But the high-cost defence technologies relating to advanced electronics, aerospace, missiles, nuclear weapons and propulsion are in a different category altogether and their acquisition and development depend not only on the amount of resources devoted to them, but also on the level of sophistication already reached in the industrialisation process. Advanced weapons systems generally integrate a number of component sub-systems derived from the different high-cost technologies mentioned earlier. A breakthrough in any one sector is likely to bring about a spiralling effect in other related ones. Unless the general technological developments in different fields have reached commensurate levels and are in phase, very high costs will be involved both in development and in subsequent production stages. These costs are likely to be of a much higher order than those incurred for the same operations in advanced industrial countries. It is difficult to be certain under these circumstances whether the military power inherent in such unintegrated and incomplete weapon and equipment systems can be translated readily into political power. Once having launched on this course there will be a natural compulsion to keep up with countries whose weapon technologies are continuously advancing. While the development of sophisticated weapon systems may be directly related to the skilled manpower and financial resources a country is in a position to spare and is willing to apply, there are absolute limits to what can be attempted by developing nations in this field during the period of their development. There would thus appear to be a vital distinction between high-cost and conventional defence technologies, and this seems to have influenced different countries in different ways in their efforts to acquire the former.

The paths followed by India and China in the development of defence technology reflect their historical experience, their perception of threats to their security and their self-images in regard to their roles in shaping the world order. India, having attained her independence by an orderly transfer of power, not having felt any significant threat to her security in the first twelve years of her independent existence, and considering her role to be a promoter of rapid, but progressive, development of underdeveloped societies, including her own, has adopted a style of progressive development in regard to industrialisation as well as defence technology. China, presumably influenced by the manner in which the People's Republic came into existence, her immediate confrontation thereafter with the United States in Korea and elsewhere, and her conception of her role as a promoter of national liberation wars and revolutionary ways of economic development, appears to have opted for a leap-forward strategy, not only in her industrialisation, but also in defence technology. She failed to reach her objective in the economic leap forward, and it remains to be seen whether she will succeed with defence technology.

China's Development by Transfer of Technology

While India spent her first five year plan period (1951-56) in developing her technological infrastructure and started on her industrialisation by transferred know-how only during the second plan period (1956-61), China telescoped the process and straightway initiated large-scale industrialisation as well as establishment of her technological infrastructure. China had the advantage of a single source of massive technical and financial assistance and a single technological training base. By 1963 the Soviet Union had assisted in setting up 198 enterprises and was assisting in a further 88 industrial enterprises and projects. She handed over to China 21,000 sets of scientific-technical documentation, including more than 1,400 blueprints of big enterprises. Giving the above figures, the 'Open Letter' of the Communist Party of the Soviet Union of 14th July 1963 further stated 'With the assistance of our country such new branches of industry as automobile, tractor, aircraft, manufacturing and others were created in China... We have unswervingly assisted China in consolidating the defence of the country and the creation of a modern defence industry'. It has been computed that 14,000 Chinese students had their higher studies in the Soviet Union and 38,063 apprentices were trained in Soviet factories. 10,800 Soviet experts and 1,500 East European experts assisted in Chinese projects. ('China under Mao' Ed. R. Macfarquahar, M.I.T. Press. Chapters on Economic development and China's industrial development by Choh-Ming Li). An agreement for the transfer of technological know-how for atomic weapons was concluded in 1957, to be repudiated by the Soviet Union two years later. During the period of co-operation, a 10 megawatt reactor was supplied by the Soviet Union. 950 Chinese scientists had been enrolled in or graduated from the Dubna Institute for nuclear research in the Soviet Union. Some observers believe that during this period the Chinese almost certainly received substantial aid (including, perhaps, needed but hard-to-produce pumps) in the construction of their gaseous diffusion plant. (pp. 74 and 80. China and the Bomb by Morton Halperin).

During this period (1953-60) Chinese defence expenditure was of the order of 1,900 to 2,100 million dollars per year (p.37. Communist China and Arms Control by Halperin and Perkins). Since the withdrawal of Soviet technicians starting from 1961, the Chinese advances in weapon development accomplished by their own efforts are the spectacular nuclear and thermonuclear tests and the test of a short-range delivery vehicle with a nuclear warhead. The delivery vehicle has also been ascribed a Soviet origin in some quarters, (page 7409 Asian Recorder, and page 80 China and the Bomb by Halperin). However, there is a general expectation that China will be able to produce MRBMs and ICBMs in due course. It will be difficult to contest that the Chinese defence technology, both conventional and advanced, owes its development largely to the transfer of know-how by the Soviet Union. It will be misleading to conclude solely on the basis of their success in developing nuclear and thermonuclear weapons and a short-range delivery system that they have arrived at the stage of technological autonomy. Their efforts to maintain a balance in the different fields of high-cost defence technologies will be watched with interest. China still appears to be in the developing stage in industrialisation, and the period that has elapsed since they started their research and development (R & D) base does not warrant the conclusion that they could have reached a position when they can depend entirely on their own resources. The emphasis on engineering education and the comparatively smaller number of graduates in natural science should also have their impact on the development of their R & D base.

The Indian Development of Technology

India started negotiations for foreign assistance, but no significant amount was received during the first plan period (1951-56). During the second and third plan periods (1956-65), while technical and financial assistance came from a number of countries and gave her the option in a number of cases to select the most suitable individual technologies, the diversified sources of the technological transfers also meant delays in their acquisition. During the earlier part of this period (1956-61) India obtained the know-how for the production of certain conventional arms and equipment, and also procured limited quantities of second generation jets, up to date armour and some naval vessels. The Indian defence expenditure during this period was about four to five hundred million dollars per year.

In 1962 the situation changed completely, with the Chinese attack on India. With an army expanding to 825,000 and a planned squadron strength of 45 for the Indian Air Force, India had to develop rapidly her defence production base. It was not possible to maintain such a large force on imports of arms or on military assistance from those countries willing to give aid. India had an acute balance of payments problem which ruled out the former course of action and the number of countries willing to give assistance, the order of assistance they were willing to extend and the equipment and weapons they were prepared to offer made it difficult for India to adopt the latter. Since the confrontation with China was at high altitudes, India had a special requirement for weapons and equipment for use at these altitudes. This was not all obtainable from countries which were prepared to extend military aid. Brandt mortars, Nissan trucks and jeeps, L/70 anti-aircraft guns, Alouette Helicopters, the Indian self-loading rifles, Indian mountain guns and DA PRC/261 wireless sets are examples of this type of equipment.

Since the requirements were large; adequate industrial capacities in the fields of metallurgy, engineering and chemicals could be easily made available; and know-how had already been acquired in a number of cases; it became economical to produce most of the conventional arms in India. The production was based on the know-how derived from a number of countries - UK, USA, USSR, France, Japan, Sweden, Switzerland, Czechoslovakia, Germany and Holland. By this time Indian R & D had produced successful designs for a supersonic jet fighter (Maruth), a jet trainer (Kiran), a self-loading rifle (Ishapore), a mule-portable mountain gun, and a wide range of electronic equipment, including local warning and field artillery radars. But the R & D base was neither strong enough nor broad enough, and it had not been in existence long enough and had not yet developed design expertise in adequate measure in various branches of defence technology, to enable the production establishment to dispense with foreign know-how. It will be imprudent for a developing country to devote effort to developing those technologies which can be acquired at reasonable prices in the technological super market, provided by the advanced industrial nations. Further, in defence technology, unlike civil technology, it is not enough if the weapons or equipment perform their roles adequately from one's own point of view; as a range of items they must match the performance of equipment the potential enemy has. It therefore becomes necessary to acquire know-how for weapons required to match those available to a potential enemy and within a time frame determined by him. This compulsion to act within a time frame very often results in acquiring know-how which is already under development in the country. This confronts the decision-makers with the choice of dropping the development or of proceeding with it as a learning process. In a technologically advanced country, where development is only a matter of financial and man power resources and the required design expertise and technical skills are available,dropping the development project,may be preferred, but in a developing country the learning process is of considerable significance. In skills of this type, there is little incentive for advanced countries to train R & D personnel from developing countries. In the technological super market not all items are for sale at reasonable prices. The morale of the R & D organisation in the early stage of its career is also a factor not easily ignored: a developing country is therefore inclined to continue with its own projects in some of the high cost technologies. There are also hopes that, since the R & D in such cases is engaged in a much higher level of skill than is available in the industry concerned, there may be some technological spin-off.

However, for a developing country which takes a realistic view of the technological development process and the time factor involved in its various stages, such expensive learning processes should be the exception rather than the rule. This seems to be the case for India. Generally wherever the number of items to be procured was uneconomical for production, or the technology concerned was too advanced, or the time by which the item was required did not permit of indigenous production under licence, India has opted for purchase.

With regard to the source of technology, India appears to have been guided by pragmatic considerations. In the choice of her weapons and equipment she had to select those which would fulfil her requirements at high altitudes. She had also to take into account the availability of manufacturing know-how and appropriate financial arrangements. She has an acute balance of payments problem with the West and her trade with the Soviet Union and Easter European countries is expanding faster than her trade with the West. Suitable payment arrangements have also been worked out with them. These financial considerations have also played a part in determining India's choice of weapons and equipment.

It is only reasonable to presume that in transferring defence technology to other countries, advanced industrial countries are influenced to a considerable extent by political and strategic considerations and this applies both to transfer of equipment and to manufacturing know-how. The policy of non-alignment has been both an advantage and a handicap to India in this respect, but considering the developments since 1962, especially where the acquisition of technology is concerned, India has reason to be satisfied with it.

This policy of non-alignment is bound to influence the levels of armament and munition stockpiles she has to maintain and consequently the economics of defence production. As a non-aligned country, she must expect to counter any aggression primarily by relying on her own forces. She has chosen a mix of weapons and equipment suited to her own needs, for which she will find it difficult to get large-scale logistic backing from any one source in case of hostilities. Her main adversary is China, who has considerable staying power, and the confrontation is in a region where communications are difficult and easily interdicted. India may therefore be inclined to go for a larger stockpile than is considered necessary in countries whose strategic planning is done within alliance systems and within certain thresholds of hostilities beyond which there is a presumption of escalation to nuclear war.

Rationale of Autarchic Defence Production

Autarchic policies of defence production have been criticized on economic grounds. This criticism is at two different levels. The first relates to licensed production and the second to local efforts at development. In the first case, criticism is generally concerned with the issue of economy of scale and the duplication of effort and costs in the customer country of production facilities already available with the seller. In the second case criticism relates to duplication of R & D efforts which, since the R & D costs are amortised on a lesser number of items produced in countries with lower requirements, results in higher unit costs. These considerations may be of some validity for industrialised countries with nearly full employment and considerable capability for converting indigenous production into exports. In such circumstances a nation can choose between devoting its resources to indigenous defence production at higher costs or using the same resources to expand its exports and using the earnings to import armaments at lower unit costs. But these considerations do not apply to India, whose present export earnings rely mostly on commodity exports, the elasticity of which are comparatively limited. Even if the industrial and manpower resources devoted to defence technology are applied to industrial production, in the conditions of scarcity in India the likelihood of that production being absorbed within the country and not going for export is rather high. As an aid-receiving country there is also the possibility of any extra export earnings arising out of such an effort being taken into account by the aid-givers in adjusting their economic aid. Lastly, all the defence requirements of a country may not be available for purchase in the necessary quantities, at the right time and at reasonable prices.

Apart from these considerations, in the current stage of technology in India there are considerable cost savings in local production as compared to landed costs of various equipments. The productivity of the Indian skilled worker is lower than that of a worker in an industrialised country; but his wages are also low. So long as the ratio of productivity to wages works out in India's favour, local production costs are likely to be lower. This appears to be the case for a number of items and this ratio is likely to be even more advantageous to India following the devaluation of the rupee in June 1966. Even when this is not the case, it is considered worthwhile to go for local production if there is a substantial foreign exchange saving, for reasons mentioned earlier.

High Cost Technology

There are significant qualitative differences between high-cost defence technology and that of a conventional nature, especially for a developing country. The metallurgy involves production and alloying of rare metals, and engineering technology to handle this has to develop. Electronics enters the micro-miniaturisation stage and the instrumentation is of a type not normally encountered in the industrialisation process of a developing country. Missile technology has no civilian counterpart at this stage of development. The know-how for manufacture of most of these products is not normally available from advanced industrial countries. The development costs for sophisticated weapon systems run into hundreds or thousands of millions of dollars and the costs for developing countries may be even higher.

Such countries are also not likely to have developed within the last two decades a sufficiently large R & D manpower base with adequate expertise in all sub-technologies to design successfully advanced weapon systems on their own, within a reasonable period. These are fields where access to theoretical data and laboratory training for personnel from developing countries are not readily available from advanced countries. Furthermore, the industrial base in developing countries is not able to support the R & D requirements continuously, and testing facilities are prohibitively costly and, again, not readily available.

A developing country is compelled to enter into such high-cost technologies only if she foresees a threat to her security from a major industrial power, or a possibility of a hostile neighbour being equipped with advanced weapon systems by an industrial power. In either case, she will not be in a position to match these weapons in time with similar systems developed by herself. By the time she develops them, therefore, they are likely to be made obsolescent by further advances in the industrial nations. Sophisticated weapon systems generally integrate specialised communication environment and controls and have to be matched up with exploiting capabilities and logistic mobilities of a different order of magnitude from those for conventional armaments. It is, therefore, doubtful whether developing countries can hope to develop on their own credible advanced weapon systems until they go beyond the stage of technological take-off. For this, due time allowance has to be made for their industrialisation to reach a self-generating stage and to progress to a further degree of sophistication and for their R & D base to broaden and to acquire adequate expertise.

Electronics and Nuclear Power as General Industrialisation Processes

There are, however, two fields of advanced technology which a large developing country finds it worthwhile to make special efforts to develop, not as parts of a weapon development process but as accelerated general industrial development. These are electronics and nuclear power. In the field of electronics, the demands of civil industry, communications, consumer goods and defence are so large in a country like India that the economics of local production are extremely favourable. The likely size of the industry, based on a realistic assessment of India's needs over the next decade, can support a significant R & D programme. India has also a decade of expertise in this field. There are reasonable grounds for believing that among the advanced technologies this is likely to be more easily available by transfer in view of the extremely wide civil application and the number of sources.

India Atomic Energy Programme

India started to develop her nuclear technology at an early stage and her atomic energy Commission was established in 1948. Her first reactor went into operation in 1956 and she has now three experimental reactors. Two nuclear power stations are under construction and work on the third has begun. A prototype power reactor is under design. A three stage nuclear power development programme has been envisaged, with U 233 as the fuel in the last stage. India has vast resources of thorium for conversion to U 233. Since nuclear power is a comparatively recently developed technology, and by a conscious attempt expertise has been developed and is being sustained, India hopes to keep reasonably abreast of others in this field. She has also been able to secure assistance for her programme from a number of advanced industrial nations, notably Canada, USA and UK. The first two power stations are being constructed by the International General Electric Company of USA and Atomic Energy Canada Ltd. There is a possibility that the third station may be constructed by the Indian Atomic Energy Commission itself. One her own, India has built a chemical separation plant, heavy water production and concentration plants and fuel fabrication facilities. By December 1964 the Indian Atomic Energy Commission had a strength of 7279 personnel. The annual recruitment rate is about 1000, of which 70% are scientific and technical staff. The facilities of the Atomic Energy Establishment train annually 150 post-graduate engineers and scientists and there are other institutes for higher training, such as the Tata Institute of Fundamental Research, the Saha Institute of Nuclear Physics, apart from universities and national laboratories.

The Indian Atomic Energy Commission has also entered the space research field in a limited way. An Equatorial Rocket Research Station has been established under UN sponsorship and agreements have been concluded with NASA of USA, Hydro Metereological Services of USSR and CNES of France for collaboration. Centaur and Belier sound rockets are to be produced in India under an agreement with SUD Aviation of France. (Annual reports of Atomic Energy Commission of India, from 1958-59 to 1964-65); Asian Recorder pp. 7715, 7602, 7481, 6297).

The Indian Atomic Energy Commission's efforts illustrate both the possible speed and the inherent limitations in developing an advanced technology in industrialising countries. While the commission has perhaps no difficulty in mobilizing the required number of highly skilled personnel, and also laying the foundation for an adequate R & D base, there have been limitations caused by the stage of environmental technology in India. These have been sought to be overcome by planning a large programme of power development - which happens to fulfil a vital need in industrialisation - and establishing a specialised industrial base in support of it, in the hope that the rest of industrial development will in due course catch up with it. The underlying expectation is that the atomic energy programme will serve as a nucleus around which other sophisticated technologies can develop. It is significant that the Indian Atomic Energy Commission deals with nuclear power, electronics development, space research and rare metals technology. Indians see in their nuclear power development the path for their technological take-off.

The programme of technical manpower development in India is geared to the requirements of this progressive advance of technology. The annual output of engineers is expected to go up from 24,700 in 1965-66 to 30,000 in 1970-71, the technical personnel from 49,900 to 68,000. The enrolment in the science courses in universities is expected to reach 800,000 at the end of the IV plan from the present level of 440,000. The annual output of craftsmen will rise from 116,570 in 1965-66 to 225,000 in 1970-71. (Fourth Five Year Plan - a draft outline pp. 70, 118, and 326).

Possibility of Obtaining Technical Collaboration in Advanced Technologies other than Electronics and Nuclear Power

A possibility arising out of the developments in nuclear weapons and missiles in China, which may be debated in India and abroad, is whether India will seek and be able to obtain technical assistance in the field of advanced weapons in order to have an overall balance in defence technology during the next decade, and whether she will not be forced into this course in case of successful Chinese MRBM tests. The course of action to be adopted by India will be dictated not merely by the Chinese missile achievements but by the overall credibility of advanced weapon systems developed by China. Irrespective of the credibility of guarantees by the super powers against nuclear threats or attacks by China, and even if there be none at all, any India-China confrontation involving nuclear weapons will have to be considered in an environment of two super power influences. Technological advances made by the two super powers in anti-missile defences will be a significant factor in determining the overall credibility of the Chinese nuclesr posture. It appears to be reasonable to assume that those countries which strongly urge India to forego her nuclear option and sign the non-proliferation treaty are not likely to be keen to extend to India their know-how for delivery systems, unless there is a major reappraisal of their present stand on the part of one or both of the super powers.

France is likely to be outside the non-proliferation treaty and therefore may be considered as a possible source for advanced technology. But she has obtained a considerable portion of her missile know-how from the US and it is not clear whether she will be in a position to transfer that part of her know-how, even if she is otherwise willing to assist India. (See p. 9 of Adelphi Paper 38, The French Strategic Missile Programme by Judith Young. The US licensors are Rocketdyne, Vanadium Alloys Steel Company, Cubic Corporation, Keanfott Division of General Precision Inc.).

Another possible source is Japan, where solid fuel rockets equivalent to the Minuteman in thrust have been developed. (p.304. Survival, September 1967). But whether Japan, in view of her proximity to China, the likely development of large and fruitful trade relations with her and her own continuing special treaty relationship with the US, will be inclined to launch on a course so provocative to China and not likely to be approved by US is an interesting speculation.

It has been estimated that the modest French missiles and nuclear programme is likely to cost France 5,720 million dollars up to 1970, and many observers feel that the cost may ultimately be nearer 10,000 million dollars. It is also expected that costs of a similar strategic force would tend to be higher for a less advanced nation like India. (pp. 6-7 The French Strategic Missile Programme by Judith Young). Unlike France, India is not in a position to offset such expenditure by cutting down her conventional forces. Though this course has been advocated by some Indian observers, the long borders with China, the acclimatisation problem and the Chinese strategic posture rule out this possibility.

Further Development in Advanced Technology in India

India, in the next two to three plan periods, as her industrialisation rapidly gathers momentum, is likely to develop two advanced technologies - electronics and nuclear power. While this may give India capabilities in certain areas of advanced defence technology like communication equipment, radar, computerisation, and fissile materials, she will still have quite some way to go in regard to aerospace, submarines and missile technologies. It is difficult to envisage India making the additional outlays of the order of magnitude required for a balanced advanced weapon system development, with the necessary foreign exchange component, without slowing down her economic development programme to an unacceptable extent. Even then she is not likely to acquire such capabilities in adequate measure in less than 15-20 years. Investment in advanced defence technologies, other than nuclear power and electronics, will not help in her industrialisation and contribute significantly to her economic growth. India sees no threat from any advanced industrial power and she has wisely avoided antagonising any of them. China, who is her major concern, is in the same stage of industrial development as she is. China has gone ahead in certain fields of advanced weapon development and may pose a nuclear threat to her. But whether to catch up with China in specific fields where she has overtaken India or to continue with her present strategy of technological development, which will take her into the realm of advanced technology in the eighties, and with all component aspects of it in phase, is the central issue of debate in India today.

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THE IMPLICATIONS OF MILITARY TECHNOLOGY IN THE 1970's

COMMITTEE V -1

Friday 29th September   Morning

The Effect of Military Technology on Civil and Military Planning

FRANK COOPER

This subject is too wide to attempt to treat fully in a short paper. It is only possible, therefore, to select a number of the more important ways in which military technology is inter-acting with planning and policy making and with the organisation of Government decision taking.

There can be little doubt that the "effects" of military technology are only as yet beginning to be realised and it is important that the problem to-day should be considered as much in terms of the "pressures" that are exerted. The word "pressure" is particularly helpful in that it implies resistance to change and the effort needed to overcome it. It is the diversity of technology which presents a particularly difficult internal problem to defence ministers. It has given rise in particular to the need to have machinery capable of sifting, costing and evaluating the vast amount of technological and other data that becomes available in ever increasing quantities.

Another main pressure exerted by military technology relates to time. The time-scale in which defence technology develops is largely independent of what might be called administrative convenience. It has increasingly complex relations with military requirements, politico/military strategy and cost. These and other factors are changing the relationship between defence and other departments of government and bringing pressure to bear not only on this relationship but on the process of government as a whole. Defence decisions have to be taken as a matter of course which can radically affect the structure, equipment and capability of the armed forces and thus the strength and standing of a nation for ten or fifteen years ahead. But these decisions must be related to the formulation of foreign and economic policy which are, in many cases quite properly, more subject to short term exigencies. The often wisely reticent diplomatist is still cagey if asked about his attitude on a specific problem next year. Responsible economists are regarded as courageous, or foolhardy, if they attempt long term forecasts and claim precision for more than a year or two ahead.

Decisions on defence technology are difficult enough in terms of defence alone but they can prejudge issues and limit future choices for the whole field of government activity far beyond the time-scale in which foreign offices and treasuries have been accustomed to formulate policy. There is therefore not only a problem for defence but also for government as a whole.

The task, therefore, is to consider some of the pressures and effects which the increasing complexity of military weapons systems, their lengthening lead time, their growing cost expressed in terms of research, development and production expenditure, and their added effectiveness in whatever terms expressed, is having on the processes and machinery for formulating and planning foreign and military policy.

SOME PRACTICAL FACTORS

It is not proposed to argue these statements at length but typical, simple, examples are needed. They are not difficult to find. The electric generator power required for the equipment in a modern frigate is more than double that of 15 years ago. In terms of ship building effort, modern frigates have a work content equal to, or greater than, that of many cruisers built 20 to 30 years ago. It is not so long ago that surface ships were basically equipped with guns and depth charges, whereas to-day they are armed with guided missiles and with a variety of sensing systems (which take longer to develop than the ship does to build) to provide surveillance above and below the surface. The cost[1] of a nuclear-powered Hunter/Killer submarine is about 7 times that of a conventional submarine but it can move more quickly, stay submerged longer and dive deeper.

The latest rifle has 170 components compared with its predecessor's 102 components. It takes 25 hours to manufacture as against 12 hours. It is semi-automatic, has more rounds in the magazine, greater accuracy up to 300 yards. The present day mortar takes 138 hours to manufacture against its predecessor's 70 man hours. Tooling up for production though is four times as expensive and its production cost is greater by a factor of rather more than

(1) All cost comparison in this paper are at approximate current day prices.

two. The development cost of the present day battle tank is roughly twice that of its predecessor as is its production cost but it has improved lethality at greater ranges, better protection against a variety of weapons, has cross-country performance and improved radius of action and engine life. All communications equipment is now far more complex than it was say ten years ago. Its cost has increased considerably and, for example radio sets cost at least three, and sometimes much more than three, times as much as their predecessors but the equipment is easy to set up and operate, is smaller and lighter to transport, and has a higher reliability and a much improved mean time between failures as a result of such changes as micro-miniaturisation of components which can put 1,000 active components into an area 1½ millimetres square. Sets require many times more power, have a greater range, a wider choice of frequencies, greater reliability and vastly increased coverage in the number of channels that can be used.

The same position applies in the aero-space field. For example, the F111 and the Canberra are a similar size, are powered by the same number of engines and have the same crew. The Canberra's initial fit consisted of a visual bomb site, a secondary radar relying on ground support, a rudimentary navigational computing aid, and a communication kit comprising one VHF box with some 16 channels. In contrast the F111 has terrain following radar, a primary radar, a computerised navigation/attack system, and a communications kit giving full cover from VHF to UHF on several hundred channels. In addition it has a much greater load carrying capacity. The F111 is likely to cost twelve times as much as a Canberra. Generally speaking, the cost of present day aircraft has increased many times compared with those of a decade ago. Furthermore, there is a large range of offensive and defensive aero-space and other projects that did not exist a decade since.

It is difficult to generalise about lengthening lead times but it is a fair generalisation to say that in nearly all countries the majority of technologically advanced pieces of equipment takes from five to ten years from the start of development to entry into service.

THE NEED FOR QUANTIFICATION AND CONTROL

The factors of complexity, effectiveness, time and cost are quantifiable, contain some elements of flexibility and are susceptible to systematic management. Much effort, in many countries, has been devoted during the past few years to securing control of these factors and, though great progress has been made, much remains to be done in most, if not all, countries and not least in determining the kind of technological policy to be followed. The need to examine the relationship between the cost and effectiveness of a particular project or equipment is now generally recognised but however thoroughly this work is performed it can scarcely be regarded as meaningful unless it is based on data which is reasonably accurate. In other words unless the effectiveness is matched by the performance of the finished product and the estimate of research, development, production costs together with operating expenses is forecast with reasonable accuracy than the chances of the right decisions being taken are severely reduced.

These problems have been, are, and will remain among the most severe that face those concerned with the production of military programmes and plans. Certainly there is no possibility of coming to correct decisions on the basis of uninformed judgments and "best guesses" which characterised so many of the decisions involving technology some ten to fifteen years ago. There is now an absolute requirement for the most thorough investigation of the operational requirement, involving a major operational analysis of the relevance, usefulness, time and cost and effectiveness of competing solutions to particular problems.

It is essential not only to be in a position to consider the total input costs of a project (capital investment covering research, development and production plus annual recurrent costs) over a significant period but also to have the facility to consider these costs on an output basis in relation to the defence programme as a whole and to the roles, tasks and objectives that the forces within the programme are required to achieve. Market research and sales potential must be thoroughly investigated. There must be exhaustive consideration of the proposals for managing a particular project to ensure that its performance matches up to what is required, that the time factor is kept under control and that costs can be subjected to continuous close scrutiny. This is essentially a task in which research establishments, industry and government must work together if there is to be any prospect of success and it is significant that the use of resource management systems has to a large extent been generated by the complexity and cost of military technology.

In short, there is a continuous process of examination, analysis and control from the conception of any military requirement involving technology until it is actually introduced into service. There can be no weak links in this chain. All the modern resources of operational analysis, resource management and control must be deployed from the earliest stage. It should be rare indeed that decisions are taken without examining a considerable number of particular possible solutions to particular problems in a variety of circumstances and often competing environments.

Some people argue that this analytical approach is not only unnecessary, at least in any depth, but also fundamentally wrong not least because, it is suggested, it stifles innovation. Both these criticisms are surely ill-founded. Given the factors of technological choice, intensity, time, cost and effectiveness it is surely by definition wrong not to explore these in sufficient detail to quantify what on the face of it seems likely to be the most effective project in a variety of circumstances and is the best value for money. There is no country in the world which is not under pressure as regards its defence spending to a greater or lesser extent and for one reason or another. This situation is not likely to change. It is caused at least as much by the vast range of technological choice that is increasingly available as by the ever present economic pressure. But all countries have a special responsibility to their own population and to the world at large to ensure that their spending on defence is not only relevant but also necessary and cost conscious.

So far as innovation is concerned the argument can run that the period of analysis is so long and so much is rejected that many inventive minds are deterred from putting forward new ideas and techniques. It is difficult to see that this argument has much substance. It is true that a period of analysis takes time. The ultimate aim is, however, to secure military hardware which is not only intrinsically important but also frequently requires the expenditure of very large sums of money over a long period of time from a wide area of choice within a rapidly changing scene. There is a need to balance the various competing sectors and resolve the equation. The basic factor is that the complexity and scope of choice is so great that a much closer degree of control must be exercised. The number of major projects is likely to diminish not only because of their cost but because of their more widespread capability and also because of their greater effectiveness. This can best be seen as a challenge to innovation rather than a reflection upon it.

It is also said that professional advice and judgment are being rejected. This is certainly true on occasions but the grounds are frequently sound. There is no excuse for failure to define the objectives, for ignoring the need for a thorough and objective analysis of possible solutions, and for not determining the solution on the basis of efficiency, relevance and cost. This is not to say that judgment is not needed. In the final analysis it is judgment which determines the decisions and indeed, the analysis itself contains a very large number of individual judgments which, taken cumulatively, have a significant effect on the solution. But the judgment itself must be based on the widest possible illumination of the problem and not on what is thought to be the desired answer backed up by arguments and reasons which, on examination, do not hold water. In the past financial considerations have always influenced both civil and military planning; but to-day the rapid escalation in cost of sophisticated equipments, the pace of technological change, the climate of national and international opinion, national economic objectives and many other factors must be taken into account. This is not to belittle judgment, from whatever source, but it should only be exercised when all the factors have been adequately identified, quantified wherever practicable, analysed, and related to policy objectives.

It is unlikely that any particular set of methods or any particular organisation can serve as a model for all countries. Constitutional and administrative practice differ too widely and there are more fundamental differences caused, for example, by the size of the scientific and technical base, the size and structure of research and development in both government and industry and, of course, disparities in national wealth and objectives. But the pressure of technology demands changes in methods and machinery. There has been, and still is, resistance to change. There is the passive, conservative resistance to change to which bureaucracies are prone. This could not be otherwise. An established, superficially effective Governmental hierarchy typifies order. But technology has in many countries exposed this superficiality. It will go on doing so. The minimum requirement is to have an uncommitted unbiassed, and objective area within ministries of defence which have a substantial capability for operational analysis and evaluation, the ability to forecast total costs on an input and output basis, and an effective apparatus for systematic project management. Such an organisation must fuse together, on the basis of their interdependence, the military and other professions.

SOME CONSEQUENCES OF NUCLEAR TECHNOLOGY

The technological factor which has dominated foreign and military policy for many years past, and is likely to do so for many years to come is the nuclear one. Nuclear weapons represent a technological innovation on a scale which has never been witnessed by previous history. It is not perhaps the amount of devastation that can be caused but the fact that total catastrophe can occur with such devastating speed and completeness. It is not proposed here to consider the effects of nuclear technology in detail but there are a number of points which are relevant to the problem that is being considered.

The most powerful nations in the world already possess nuclear weapons and a number of other nations have the capability to develop and produce them. It is the nations that have these weapons which can, to a greater or lesser extent, in the last resort influence the course of world events although this is not to say that there are not very large areas of possible conflict - perhaps increasingly large areas - where foreign and defence planning activity needs to take relatively little account of these weapons. Nuclear weapons illustrate in an especial way and perhaps more clearly than any other weapon system two basic criteria. First, that military technology is not a factor which can stand independently in its own right; it is only one essential element in the formulation of foreign and defence policy and plans of which the other most important and interdependent elements are international policy, military strategy, cost and effectiveness. Second, that any consideration of military technology except within a framework of overseas policy, military strategy, effectiveness and cost is not meaningful and that there is a requirement for the development of an overall technological policy and for its application in both the civil and military spheres.

This is not, of course, to deny that nuclear technology does not represent a very special and major problem but the choices that it offers can only be determined in the light of other relevant criteria. Some of the more important of these spring readily to mind. The national and international scene - such factors as the general and particular relationship between individual states, the climate of national and international opinion, the threat assessed in terms both of capability and intention, the position over testing and proliferation, and so forth. The strategical assessment - the overall nuclear and military balance, the relationship between offence and defence, and overall strategy related to national and international policy objectives. The effectiveness assessment - such questions as the technological capability to produce in a given time or cost a weapons system which would not only be effective but also relevant and credible. The cost assessment - in terms of resources to be allocated for defence and in terms of the make-up of the defence programme as a whole and the individual objectives within that programme. Obviously the weight given to these various factors must vary depending on the situation but the real point is that no one would now suggest that simply because a particular country has the "know-how" then it should proceed to manufacture nuclear weapons or, on the reverse side, that it should fail to assess and analyse the problem in depth.

Nuclear technology illustrates particularly well the significant effect that technology has had on planning for external affairs as well as for defence. It has played perhaps the most significant part in forcing departments of external affairs to consider technology as a subject for world examination and negotiation and led directly or indirectly to a much more broadly based examination and discussions of disarmament as a whole and in particular fields such as limitation of conventional arms, limitation of conflict, inspection and the whole problem of escalation. The result has been a dialogue which is essentially technologically based and which has been increasingly conducted in public and subjected to academic research.

It is true that, on a more limited scale, there have been international dialogues of a related nature in past history but the nature of nuclear technology is such as to require not only an international dialogue in the nuclear field but increasingly in other military areas as well. There is here the prime example of technology having produced the weapon but at the same time having forced statesmen to conduct a searching examination of the effect on international diplomacy and international action on a scale unparallelled.

TECHNOLOGY AND POLICY

This is perhaps the right place to consider what is in many ways the central problem posed by military technology. It is that the number of possible choices (it is the numerical complexity of the options that technology offers rather than the complexity of technology itself that is important in terms of formulating policy and plans) and the fact that pace of technological change is so dynamic as to require constant preoccupation (in technological terms most military equipment can be regarded as potentially obsolescent before it enters service). Two world wars have provided a hothouse for new technologies and new industrial applications but it is the decisions about the scope and rate of industrial application of new technology that can produce the real gaps between national capabilities. It must be recognised though, that no technology will remain a unique secret for a long period of years though once research or industrial application is abandoned it may well be difficult, or even impossible, ever to catch up.

In practice virtually all this change has happened in the 20th century. The scale and comprehensiveness of technological advance in the last 25 years has been quite incredible. For example, there are large numbers of new materials (plastics, solid fuels, steels and metals of various kinds). There is the new technology of electronics (transistors, solid state, micro-miniaturization). There is the reliability and variety of communications (radio, television, satellites, Van Allen refractions). There is the overwhelming change in speed (space, aircraft, automatic data processing, missiles). There is a much increased number of options as to which discussion should be used for the application of technological possibilities (aero space, land, above or below the sea). Finally far more sophisticated means of dealing with the administrative processes have been made available through computers and the whole field of resource and system management.

It is not surprising that this hothouse growth has faced Government with problems of peculiar difficulty. The variety of choice and cost is so large and the rate of potential obsolescence so high that the whole problem of decision making has become one for much examination and argument. Any modern industrial undertaking sets itself objectives which can be expressed even on the narrowest basis in terms such as profits, sales forecasts and production targets but none of any size or standing would mention an existing programme or develop a new one without defining its objectives and target and charting its forward path after a thorough examination of its existing and potential market. The problem of government is inherently more difficult. Governments can apply no formulae of equivalent and relevant simplicity. As has been suggested the analytical approach can throw a great deal of light on the problem but by itself it is insufficient because the essence of government is the relationships between a government and its own people, between the various departments of government, and between governments either on a bilateral basis or on a multilateral basis.

Military technology has been the pace-setter in facing governments with a field of activity with which only they can deal and involving a complexity of choice for which most bureaucratic organisations have not been naturally endowed or organised to resolve and have not initially been noticeably quick to adapt themselves. The Governments of all countries, whether large or small will increasingly have to face up to this issue of technological choice. The area of choice is now so great, and in consequence the number of possible options so large, that the production or purchase of advanced technological equipment requires the application of new methods and processes of administration. This situation has hit defence ministries first, and probably hardest. As governments come increasingly to grips with technology, it will hit other areas. But many defence issues are increasingly not for defence ministries alone.

In the last ten to fifteen years the United Kingdom has cancelled a considerable number of advanced military technological projects after considerable sums of money have been spent. The most significant feature of these cancellations is that few of them fell out because of technological failure. Most of them were cancelled because of subsequent doubts as to their genuine relevance to the political and strategical situation and to the unacceptable time and cost relationship. In other words because of the inadequacy of the decision making process. It is not a coincidence that throughout this period the United Kingdom's role in the world situation at large underwent substantial alteration but the fundamental point is that the cancellations do not contain a dramatic list of technological failures; they are a reflection of the inadequacy of the decision making processes and of forward policy planning in both the fields of external policy and of defence policy. Many other countries have experienced similar difficulties which can, of course, extend out of the Research and Development area into the ineffectiveness with which manufactured equipment purchased by one country from another or supplied as aid is used in military service. This is where the waste of resources may not appear on the surface to be as great as an actual cancellation but can have a far more fundamental effect and in terms of effectiveness represents an even greater waste of resources.

The essential problem is, therefore, that of choice and this can by no means be exercised solely on the basis of an analytical approach. Can, or should, the choice be resolved by defence planners alone? The first and vital task is for governments as a whole. Some experts on foreign affairs suggest that countries should not be expected to have a foreign policy other than an ability to stand up for themselves coupled with a sense of purpose. Such an attitude should be unacceptable to anyone concerned with defence policy and plans. There is a clear requirement for a close and continuous dialogue between those concerned with the formulation of foreign policy and those concerned with defence policy. This must be concerned not only with the immediate present but with a period of five to ten years ahead because of the technological lead time, technological complexity in all its aspects, and the allocation and use of resources.

The defence policy planner has a clear duty to inform, with complete honesty, the foreign policy planner of the technological possibilities and the consequent military capabilities that exist or can exist and to draw attention to military and technological developments in other countries. The foreign policy planner has an equally clear and honest duty to set down for the military planner, and in as much detail as possible, the objectives of the foreign policy which his government is seeking to achieve on both an area and a world wide basis, the possibility of achieving these objectives in relation to a specified time-scale, the potential consequences of achieving the objectives, and a forecast of the other external forces at work and their attitude towards the stated objectives. In addition it is necessary for the planners of external affairs and those of defence to consider together the type and nature of potential conflict in particular areas and perhaps also the methods that might productively be used to deter its outbreak or deal with it should it occur.

What should be the end product of the kind of exercise described? Obviously this will differ according to the needs of particular countries. But it should cover the gamut of a country's national and international interests. It is very much to be preferred that it should deal not only with what might be described as "local" interests, which on the basis of a narrow interpretation can be regarded as vital interests, but also with wider problems in the world which are vital to world security as a whole and are, or should be, the subject of international debate. One would expect to emerge a policy planning directive, which should form the basis of planning in both the diplomatic and the defence areas, and covering such matters as the nuclear problem, the defence needs of the territory of the country concerned and of any other territories for which it has constitutional responsibility, attitudes towards Alliances in general and more specifically to those of which the country concerned may be a member, the United Nations, peace-keeping with Allies, identification of areas of high risk and a fairly detailed examination of the intentions of other countries. This is the essential background on which military strategy should be based. Without it the chance of producing a meaningful military strategy, and making the right technological choices, must be severely diminished.

Arrangements are necessary for such a document to be produced annually and for it to be amended and revised during the course of the year if any significant events take place. There is no reason why such a document should not contain optional objectives and the military, financial and other consequences of such options can be examined. It can chart areas which require more detailed and thorough study. It is essential that it should result from a joint dialogue between the policy planners in external affairs and those in Defence. The question must be asked whether economic planners should be associated with such a document. Obviously those concerned with its production must have a substantial knowledge of the country's economic background and objectives and ideally they should have an economic forecast as a basis for this work. But though they should have the right to call for economic information it would be wrong to associate economic planners directly with the production of the document primarily because this is not an exchange about the economy as such but about overseas affairs and defence. This is in no way to decry the importance of an economic base and of economic factors world wide (including trade relationships, overseas investments and balance of payments questions) when coming to conclusions.

It may well be said that the exercise described represents the highest art of the uncertain. It is certainly true that the field of external policy is not readily predictable and there is often some risk in attempting rationalisation. But this is no argument for not producing a policy, provided that it is not regarded as being absolutely rigid and inflexible and subject to provision being made for up-dating it and amending it as circumstances change. In the end everything must rest on policy and there is a clear requirement that Governments should define and communicate their policy in as much detail as possible to those concerned with the production and implementation of detailed plans as it is the essential basis for sound planning. It is only when this has been done in the field of external affairs (for defence policy must be the servant of foreign policy not its master) that it becomes practicable to define the role and tasks of the military forces, examine what kind of forces are needed and where they should be deployed, and determine the weapon systems with which they should be equipped. Moreover, it must form the background against which the guidelines for any basic research programme should be defined. Without this kind of planning guidance it is surely true that technologists and industry, including particularly the innovators, cannot be given the essential background they need so as to ensure that the work which they do is relevant and pointed in the right direction.

In short, it is the responsibility of governments to define in far greater depths than has previously been the case their forward looking external policy as a basis for defence policy. It is only when this has been done that it can be assumed that there is a reasonable chance of taking the right decisions about military technology on the basis of a thoroughgoing analytical approach. It is also the responsibility of Governments to ensure that the correct organisational and personnel environment is created in which this process can take place and to introduce, in co-operation with industry and the non-Government world, the necessary measures and techniques to enable adequate - but not overadequate - control of the planning, technological and administrative processes involved to be exercised and freely debated.

Technology has opened up an ever increasing area of choice. Put another way technology has the capability to provide an over-sufficiency of power. It is for governments, and for their civil and military planners, to ensure that the technological choices that are made are relevant and directed towards the achievement of policy objectives. This makes it inescapable that the policy objectives be defined, in as much detail as possible, as the essential preliminary step to taking full advantage of the tools of modern administration so as to analyze the way in which the technological possibilities should be harnessed to these objectives.

TECHNOLOGY AND CONFLICT

The diversity and power of the military technology that is available for application by military forces in the field coupled with the speed of modern communications have brought one relatively new problem which deserves a special, if necessarily brief mention. It is the amount of control to be exercised by Governments in the detailed application of military force. In one sense it is an absolute prerogative of Governments to decide whether any force should or should not, be used. In another sense, and at the top end of the military power scale, the fact of control is known and exists even though conflict has started. But there is an increasing area in which the application of too much military technology of the wrong kind may retard, rather than advance, a successful outcome. The risk is likely to be at its highest when countries with disparate technologies are facing each other. Even disregarding the risks of escalation, it seems likely that the present trend whereby the definition of the political objective results in political limitations being imposed on weapons and targets will accentuate. Put another way it seems likely that some conflicts at least will, because of both the inadequacy and overadequacy of military technology, become increasingly politico-military conflicts. There seems scope here for a good deal of further study on the meaning, control and application of power.

TECHNOLOGY AND GOVERNMENT.

Technology has made obsolete the old routines and practices of government. The pressures it generates are forcing many defence ministries to re-organise. It will force others and particularly those with a substantial research and development programme. The volume of information can no longer be assessed and examined within the old framework; the range of choice is too great for the old machine. Foreign and economic ministries are coming increasingly to understand that where foreign policy and economic policy relate to defence, as well as vice versa, they must be worked out in relation to the diversity, cost and time-scale imposed by military technology. This requires not only a change in methods and organisation for dealing with particular problems but, just as important, a deliberate attempt to define national policy objectives in the longer term and, in particular, the acceptance and implementation of common policy and planning objectives by defence and overseas ministries. Technology often at some cost, has provided defence ministries with special education. Because of this they bear a special responsibility to educate others and can make a major contribution to the efficiency of government and the development of national and international affairs. This is a heavy responsibility but it should be recognised and accepted. There is much to be done and the solutions, whether good, bad or indifferent, will play an important part in ensuring that technology is used in a sensible, coherent, productive and profitable way in the coming decades. Man must control technology, not vice versa.

SOME QUESTIONS

The outline given above leads naturally to a number of questions to which there is no single, unusual answer. Much will obviously depend on the nature, organisation and resources of individual countries. But whatever these may be certain questions need to be asked and answers found.

First, granted that the long lead time and diversity of technology requires long term planning, how is this to be reflected in the external affairs field and notably in the provision of forward looking guidance on diplomatic objectives which are the essential prerequisite for the formulation of defence policy and the definition of military roles and tasks?

Second, what kind of evaluation, decision making and management control machinery is required, given that the diversity, complexity and high cost of military technology demand on analytical approach?

Third, how are the problems created by military technology, to be resolved within both a national and international framework, in such a way as to ensure that declared objectives have a reasonable chance of attainment without too much risk to the necessary balance between politico/military relationships and economic foundations?

Fourth, is the necessary mixture of human skills available and correctly deployed with the aim of producing answers in the proper time-scale and in a form which will stand up to public examination?

Fifth, how is a degree of flexibility to be retained in policy making and planning and too how can the danger of the planning processes becoming over-complex be lessened or averted?

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THE IMPLICATIONS OF MILITARY TECHNOLOGY IN THE 1970's

COMMITTEE V 2

Friday 29th September — Afternoon

The Economic and Technological Impact of the U.S. Space Programme

RICHARD L. LESHER

I am honoured to be here and to have the opportunity to discuss with you some aspects of the economic and technological impact of the U.S. Space Programmes. I must emphasise the phrase some aspects for obvious reasons: first, the major economic impact of the programme will lag actual expenditures by as much as 15 or 20 years; and, second, technology most often moves forward in mosaic form rather than in a straight line, and therefore, we can never know with certainty the total of the impact. Regardless of these reservations, however, I believe we can assess the very significant impacts that have already occurred and identify the directions of the forces which are now in motion.

I

I can best give you an appreciation of the broad range of the technical interests of the National Aeronautics and Space Administration (NASA), I think, by taking time here at the beginning for a few words about our flight programmes themselves, which define the scope of our research.

Public attention has focussed in recent months on our unmanned, scientific missions. Precisely manoeuvreing Orbiter spacecraft have recently taken hundreds of photographs of potential sites for the first manned landings on the Moon. From higher orbits they have mapped much of its forbidding landscape, including the far side. Our Surveyors, with roving TV eyes and robot claw, have landed gently and examined the lunar surface at close range. Mariner 5, even now, steers its four-month course across 216 million miles of space toward our sister planet Venus, bearing scientific instruments to probe the secrets of her atmosphere. Of the earlier Mariners, No. 4 travelled 228 days and a total of 325 miles to send back the first close-up pictures of the Martian surface; and it is still - after two years - returning useful data from record depths in space.

In manned flight, despite recent serious problems, the Apollo programme for a manned landing on the Moon is moving toward flight tests this Fall of the gigantic Saturn V rocket and preliminary manned flights early next year.

Apollo, designed to carry three men, builds on the achievements of the two-man Gemini flights which consisted of 10 missions in 20 months for a total of 2,000 manned hours in orbit. When Gemini was originally planned, we set three major requirements, all of which would be extremely important in the Apollo programme. These were: rendezvous and docking; long duration missions to learn if human beings could live and work safely in space for extended periods; and the ability to bring a spacecraft down to Earth close to a desired landing point. All these things, and more, were successfully accomplished, not withstanding some tense moments.

Flight missions represent the most visible part of NASA. But, to more fully understand the impact of the U.S. space programme both economically and technologically, I think we should examine briefly the organization of the agency and its partnerships in the industrial and academic communities. For, after all, the creation of the industrial and technological capabilities is, perhaps, the real accomplishment, and the specific missions are dramatic demonstrations of those capabilities.

The Congress created NASA by passing the Space Act of 1958 which called for the new civilian agency to carry on aeronautical and space research and development for <u>peaceful</u> purposes for the <u>benefit of all mankind</u>.

Beginning with a budget of $330 million in 1959 and increasing to approximately $5 billion last year, the agency in nine short years has not only amassed an impressive record of progress and successful flight missions, but has also become a major force in our society and in pushing outward the frontiers of man's knowledge in practically every field of science and technology.

NASA's operations are carried out at 18 locations across our country, in addition to some 40 small tracking stations around the world. These laboratories and field facilities, plus Headquarters in Washington, are manned by approximately 35,000 civil service employees. When you do the arithmetic, you see that this is a relatively small staff for the dollars involved. The answer is that more than 90 cents of every NASA dollar is spent with private industry, universities, or other private organizations - some 20,000 contractors in every state of the union employing full-time the hands and minds of nearly 400,000 men and women at the peak of activity which occurred last year.

A major part of this complex and dynamic Government-industry-university effort centres around developing the capability for successfully carrying out the mission set for us by the late President Kennedy to land men on the Moon and return them safely to Earth. Within the next few weeks the eyes of the world will focus on Pad 39 at Cape Kennedy for the first launching of the gigantic Saturn V rocket - unmanned in this initial, earth-orbital test but later to carry the lunar astronauts.

On its launch pad, the Saturn V is the Western World's largest and most complex vehicle ever conceived to carry three passengers. It stands 365 feet tall and weighs as much as 2,000 American automobiles. In just 2½ minutes its monstrous engines, swallowing three tons of fuel a second, will accelerate the immense structure to 6,000 m.p.h., or roughly a dozen times as fast as a high-speed rifle bullet.

During the later three-day trip to the Moon precise manoeuvres must be performed to prepare for lunar orbit and landing. Once an acceptable lunar orbit has been achieved, two astronauts transfer to the Lunar Module for descent and landing. After their exploratory and scientific work, the two men begin their critical countdown for rendezvous with the command module orbiting overhead. Split-second timing is all important; the one major engine in the lunar lift-off module must perform with complete reliability. No maintenance facility is nearby to replace a defective pump or relay.

When rendezvous and docking with the command module has been accomplished, the three astronauts must return to Earth. Excellent marksmanship is imperative: their target, from a distance of a quarter of a million miles, is a re-entry keyhole just 40 miles high - with unacceptable penalties for error.

To make possible all those things, aerospace scientists and engineers have had to devise life-support systems that will operate in a hostile environment for a total of one and a half man months. They have had to fashion valves, filters and switches that function with a reliability hitherto unattained. They have designed new bio-engineering instruments, compact new electronic parts, new alloys, new adhesives, new lubricants. They have come up with ingenious methods of shaping and joining metals and clever ways of assembling huge but delicate thin-wall structures. They have devised pumps that will handle almost unbelievable torrents of volatile fuels. They have broken new ground in materials technology in order to fashion a heat shield that will withstand the 5,000-degree Fahrenheit temperature of re-entry into the Earth's atmosphere at 25,000 miles an hour. To provide in-flight power they have brought the fuel cell from the stage of being a laboratory curiosity to that of being a serious contender for driving automobiles and lighting homes. They have advanced the state-of-the-art in measuring, sensing, and testing.

More than 5,000 industrial contractors employing some 150,000 technical, production and support personnel have been at work on the Saturn V programme alone. To channel all their efforts in a score of different disciplines from the laboratory, workbench, assembly plant, and test stand to Pad 39, the firing room, and the control centre has called forth new management techniques - systems analysis, project management, procurement procedures to insure that the nation's best efforts are brought to bear on this largest, most complex technical programme ever undertaken by free enterprise.

II

It is obvious that these demanding technological requirements, vividly focussed with premiums on light weight and reliability, have made research and development efforts necessary in virtually all fields of science, engineering, and management.

Space requirements have stimulated substantial advances across a broad front in much less time than could have been expected at the normal pace of technological progress. Many of these advances are important to industry generally.

I will take time here to mention only a few:

<u>Remote Control Systems</u>. Devised only a few decades ago to handle radioactive materials, remote control systems have been further developed for use in hostile environments such as space. The same basic ideas are being employed aboard submarines and in plants where toxic and explosive materials are handled. Such concepts are likely to be embodied in artificial hands and legs for physically handicapped persons.

Temperature Controls. Basic to progress in aeronautical and space technology, these also set operational limits in such industrial processes as petroleum refining. Research during the last decade, much of it stimulated by NASA's needs, has approximately doubled the temperature capabilities of advanced alloys and refractory metals.

Microelectronics. Miniaturization of electronic devices while actually increasing their reliability and life expectancy has been speeded up by limitations on the payloads aboard spacecraft. The change from vacuum tube to transistor circuits increased the service life of radios, TV sets, and other devices tenfold about the same time that men began to think seriously of going to the Moon. Integrated circuits have brought another such jump, and still another is projected with future microelectronic technology now under development for further exploration of the solar system. This technology applies directly to making better and smaller industrial, office, and home electronic devices.

Power Sources. The earth is blessed with an abundance of solar energy that can be converted into electrical power. Some spacecraft now carry solar cells that weigh only a fifth as much as their equivalents did a few years ago. Batteries have been improved, too, and the automobile companies and electrical equipment makers suddenly became far more interested in fuel cells when the Gemini flights focussed engineers' attention on their potentialities.

Metal Fabrication. Once the nation had decided to send men and instruments into space, necessity prompted metallurgists and engineers to produce substitutes for heavy, cumbersome equipment. To-day's trade journals are full of descriptions of resulting new methods of joining aluminium, titanium, beryllium, and the refractory metals, involving the use of such new tools as electron guns, plasma guns and lasers. These and related techniques are fully as applicable to the improvement of hardware for military, industrial and consumer use as to the construction of rockets.

Much of this new technology will transfer under its own thrust to non-aerospace industry because the same engineers who are designing and building tape recorders, thermal insulation systems, and other devices for space exploration are producing similar things for those of us who will use them for utterly different purposes than going to the moon. Or, having been trained in aerospace industry, technicians may move to companies engaged in making commercial products or consumer goods. Finally, the aerospace companies themselves are beginning to apply their newly developed skills and techniques in non-space pursuits.

In managing space projects, engineers and executives of those companies have developed a systems approach and learned to cope with a complex of disciplines that are also involved in many of today's social and economic problems. Increasingly, they are applying these techniques to those fields, particularly to the pressing needs of our cities. A recent sampling by an industry group found 21 companies engaged in 99 different projects in nine areas: environmental resources management, information systems, logistics, materials applications, oceanology, medical applications, power generation, transportation, and urban affairs. Individual projects included repurification of waste water, a means of predicting earthquakes, weather modification, automation of library and hospital functions, design of long-life electrical batteries for urban vehicles, reduction of noise and air pollution, design of a rapid transit system, studies of crime and city lighting, and development of new building materials.

Discoveries of great magnitude which impact on entire fields of technology, such as some of the examples listed above, generally have sufficient inherent force to bring about their own exploitation. However, the incremental advances that singly seem of minor importance, but which in combination are the foundation of our industrial strength, are less easily brought to the attention of the many who can benefit from them. Their transfer requires a deliberate effort and special mechanisms. To identify, document, evaluate, and disseminate those less conspicuous items of new technology constitute the principle activities of the NASA Technology Utilization Programme. This programme was established in direct response to the responsibility imposed upon NASA by Congress in the Space Act of 1958 to disseminate widely, to all who can use it, the new knowledge generated by our exploration of space and the upper atmosphere.

III

The Office of Technology Utilization, which I head, has two operating arms. One, the Scientific and Technical Information Division, collects reports on new research results in all areas of aerospace science and technology from all possible sources, both public and private, throughout the world. These are announced in two semi-monthly abstract journals that you may be familiar with: Scientific and Technical Aerospace Reports (STAR), which covers report literature from governmental agencies and research institutions; and International Aerospace Abstracts (IAA), which covers journal articles, books and technical meeting papers.

New documents announced in the journals are stored in our central collection near Washington and distributed, automatically or upon request, to NASA laboratories, Government contractors, other Federal agencies engaged in technical research, universities and engineering schools, and public and technical libraries. They are also distributed in microfilm form - 4 by 6 inch flat negatives, called microfiche, each carrying up to 60 page images. Magnetic tape indexes to the total collection, regularly updated, go to NASA Centres and our major contractors. The Division also publishes scientific and technical documents and books reporting the results of NASA's own research or of interest to scientists and engineers working on NASA programmes. This Scientific and Technical Information system, which totals around 300,000 documents and which is growing at the rate of 6,000 per month, is a valuable resource which was conceived to serve the aerospace community. Once established, however, it obviously has valuable potential for use in the non-aerospace community as well.

Our other operating arm, the Technology Utilization Division, channels new knowledge resulting from space research outward to non-aerospace business firms, educational institutions, the medical profession, and other potential users - including national, state and local government agencies.

The activities of this Division are designed to shorten the time gap between the development and use of new knowledge; aid the movement of this knowledge across industry, disciplinary, and regional boundaries; stretch the returns from aerospace research dollars by finding additional uses for the results; and develop better ways of communicating and applying government-generated technology in the private economy.

Briefly, this is how the programme works:

Specialists in all NASA field installations continuously review research and development projects for promising new ideas. In addition, NASA contractors are required to report inventions, discoveries, innovations, and improved techniques they develop in their work for NASA.

These reports from the field centres and contractors are screened and evaluated by independent research institutes, and the ones that may have non-aerospace use are announced in technical bulletins, called Tech Briefs, or more detailed publications. We are issuing Tech Briefs at an annual rate of about 1,000, and by the end of this year will have published nearly 2,500. Each describes briefly a separate technical innovation, many of which by themselves could become the basis of a new business enterprise or an important segment of industry.

The most comprehensive of our publications are Technology Surveys, which review the state-of-the-art in a technical area to which NASA-supported work has made major contributions. These are written for us on contract by noted authorities in the subject field and make the advanced technology in that field generally known a good deal more quickly than it would normally be disseminated in the course of textbook writing and publishing.

Our publications are distributed on request to industry, universities, research institutions, the trade and business press, and libraries and are sold to the public through the Department of Commerce. They are also distributed to paying industrial clients that subscribe to the services of NASA-supported Regional Dissemination Centres operated by eight universities or research institutes.

The regional centres also provide their clients with other information services, including rapid access to the NASA Scientific and Technical Information collection by means of computer searches of indexes maintained on magnetic tape. The tapes are updated twice a month, and the computer system can provide not only searches of the entire collection for answers to a specific problem but also regular announcements of selected new documents that may interest a client company.

The number of paying clients served by the Regional Dissemination Centres has grown from 29 the first year to more than 260 in the third year, and each of the centres is expected to become self-supporting from industry fees within five years of start-up.

Although it is still too early to expect many specific transfers of space technology to other sectors of the economy, we have already identified several hundred promising innovations. New products and processes developed to meet the exacting requirements of space exploration are beginning to appear in American stores, factories, and hospitals.

Let me cite only a few examples:

- Builders of giant rockets at the Marshall Space Flight Centre in Alabama invented an electromagnetic hammer that smooths and shapes metal without weakening it. The new tool is now being used in shipbuilding and the automobile industry.
- A computer technique that was used by the Jet Propulsion Laboratory in California to enhance television pictures of the Moon and Mars sent back by Surveyor and Mariner spacecraft is now being developed to clarify medical X-ray photographs.
- Our Lewis Research Centre in Ohio developed a ceramic-bonded dry lubricant for use on a rotating seal of a pump for liquid fluoride propellants at high temperatures in a vacuum. A commercial company is now marketing bearings coated with this lubricant.
- Small biosensors used to monitor the astronauts' physical condition during flight are now being used in hospitals to permit one nurse, seated at a console, to monitor the condition of many patients at the same time.
- Reports on aerospace research supplied by a NASA-supported Regional Dissemination Centre helped a small company in Pennsylvania to improve its methods of growing crystals for industrial use and thus increase its sales by $100,000 a year.
- NASA metallurgists discovered that a hexagonal crystal structure provides a better bearing material than any other. Resulting new alloys will be useful not only in industrial and commercial devices but possibly also for making artificial human hip joints.
- Research for spacecraft trajectory models has been compressed into a new educational device that permits a student to quickly determine the relative positions of the planets on any day between the years 1900 and 2000.

- A small remote sensor designed to report extremes of temperature in a spacecraft is now available on the commercial market for use in laboratories and industrial plants as a probe for obtaining accurate temperature measurements in inaccessible places.

- Studies at the Langley Research Centre in Virginia on the causes of airplane landing accidents on wet runways have led to safer designs for highway and airport runway surfaces and have already saved millions of dollars and many lives by reducing the number of rainy-day accidents.

- A meter designed to detect micrometeorite hits on a spacecraft has been adapted to a medical tool that, by measuring minute muscle tremors, may help in early diagnosis of neurological ailments, including Parkinson's disease.

- An unusually tough coating developed for spacecraft is the basis of a new long-wearing paint now on sale in retail stores. More than 100 companies have expressed interest in this paint, and we licensed 25 to produce it.

- A six-legged vehicle proposed by a NASA contractor for unmanned exploration of the Moon has been redesigned as a walking chair for crippled children. It can cross rough terrains and surmount obstacles that would stop an ordinary wheelchair.

In addition to spreading knowledge of space generated innovations through its publications and Regional Dissemination Centres, the Office of Technology Utilization is conducting a number of experiments in the design of new bridges for the transfer of technology across interdisciplinary barriers.

One of these seeks to stimulate secondary use of computer programmes produced for NASA's use. Some of these have cost as much as $1,000,000 to develop. Many can be adapted to industrial jobs - inventory control, accounting, data processing, control of automatic production flow, structural testing, and the like. A new centre operated by the University of Georgia makes these programmes available to industry at only the cost of reproducing and distributing them. In the first year, it has sold more than 1,000 programmes at an average charge of about $75 each, and they are presently being sold at the rate of more than 100 per month.

In another experimental activity, we are attempting to help apply aerospace technology to problems of crime prevention and law enforcement by aiding 18 organizations, mostly universities, working on such problems under the sponsorship of the Office of Law Enforcement Assistance in the U.S. Department of Justice.

Still another experimental programme, begun in 1966, aims at applying aerospace science and technology to biomedicine. Three Biomedical Application Teams have been formed at three independent research institutes. These small teams establish relationships with groups conducting research and development in biology and medicine at universities, clinics, and research hospitals. The multidisciplinary teams assist the researchers in identifying and defining the barriers impeding the progress of their work. These barriers - or problems - are then described in non-disciplinary, functional, terms in a "Problem Abstract".

The Problem Abstract forms the basis for a computerized search of the NASA information store to seek out relevant information - especially engineering and physical science know-how that would be relevant to solving these life science problems. The Problem Abstracts are also circulated to Technology Utilization Officers at NASA field installations who seek ideas, concepts, and approaches toward the solution of those problems from NASA scientists and engineers.

In one case in which results have already been achieved, the problem concerned pediatric studies. In the past, subjects have been forced to breathe through a rubber mouthpiece. It is uncomfortable, but more important, the mouthpiece often slips and exhaled air is lost, thus damaging the accuracy of the measurements.

A solution to the problem was found in the Gemini helmet which provides a respiratory environment for an astronaut. The basic concept of the helmet has been adapted for pediatric use at a hospital in Kansas City. A suction pump in the breath analyzer provides negative pressure in the helmet, preventing any escape of exhaled air. And the elimination of the mouthpiece permits the patient to breathe normally. Exhaled air is analyzed to determine its composition; oxygen consumption and other data is read out graphically.

IV

So far I have been talking about the secondary, or bonus, benefits from space research and development. These are in addition, of course, to the important economic benefits flowing from our practical operations in space, particularly the communications, weather, and navigation satellites now orbiting the earth on regular schedules.

Our communications satellites have already demonstrated their practicality in facilitating transmission of television and other data between continents. In the future, we could expand our communications stations in space to provide direct television broadcasting to receivers in homes and public buildings all over the world. The use of such satellites as an educational tool could lead to one of the greatest breakthroughs in mass education in all history, bringing vast new knowledge and information to millions of people around the world.

Marked gains have already been made in improved weather forecasts as a result of regular worldwide satellite observations. The potential economic impact of improved long-range forecasting is still greater: an estimated $2 to $2.5 billion in annual savings to farmers, fuel producers, public utilities, builders, and water managers in the U.S. alone, according to a study by our National Academy of Sciences - National Research Council. And these estimates do not take into account the economic benefits that might be obtained in various industries associated with tourism and recreation, or the intangible savings of individuals.

Weather patterns are only one of the many earthly phenomena that could profitably be observed from orbiting spacecraft. Some of you may have seen the beautiful colour photographs of Earth taken by the Gemini astronauts. Those pictures were shot with simple hand-held cameras. Much other valuable information could be obtained by sophisticated photographic and other remote-sensing equipment in space.

For example, satellites in earth orbit, equipped with suitable sensing elements, would be able to take regular inventories of food supplies. They could tell a rye field from a barley field, or soy beans from corn. These sensors would be able to distinguish a healthy crop from one covered with stem rust or fungus. They could even tell us the causes of crop deficiencies, such as lack of water, chemical imbalance in the soil, frost bite, or sun scald.

Satellites could also help us increase food supplies by measuring the phenomena of the oceans, such as ice movements, water temperature, and salinity. Recording the movement of plankton, on which fish feed, could tell us where to send fishing fleets for best results.

By using a variety of remote sensing techniques, we could survey mineral and oil reserves and many other natural resources. It would be possible to locate underground fresh water reserves and springs by measuring the small differences in soil temperatures above them. This would help to offset the growing consumption of surface water, and would have particular significance in the more arid regions of the Country. In addition, snowfall could be measured, and spring thaws predicted, for the subsequent control of floods and management of water levels in storage lakes.

In summary, I have attempted to make these main points:

- The extreme requirements of space science and technology are forcing advances in practically every field of science and engineering.
- Many of these technical advances are already impacting heavily on non-aerospace industry.
- Some will transfer from the space community to industry generally under their own thrust; others require a special effort to reach potential secondary users.
- NASA has mounted such an effort and can already point to many specific results.
- Experimental programmes also have been undertaken to discover new and better ways of stimulating technology transfer.
- Besides the secondary benefits of space research, great practical economic benefits already are flowing from U.S. operations in space, such as our weather satellites, and can result from more sophisticated future observations from earth orbit.

V

Yet, for all of this evidence, we still can't prove conclusively our answers to some of the fundamental questions. Using our experience and our understanding of the history of technological advance, however, I would like to close by stating some of these questions and posing some preliminary answers.

First, is a nation's technology best advanced by the direct approach of product improvement - that is, the upgrading of old technology to solve old problems - or by a search for new solutions to new problems through a broad multidisciplinary effort such as our attack on the problems of space exploration?

We have found:

1 That while multidisciplinary research is often lauded, it is less often used (in industry or universities) than some would have us believe;

2 That this approach is imperative in the space programme;

3 That knowledge has no boundaries except those that are artificially imposed;

4 That solutions to technical problems in any given technical field often come from outside that field, but only if and when able minds in other fields are addressed to those problems; and

5 That when able minds in all disciplines focus on the <u>pacing items</u> (that is, those questions which, if not solved, will delay the entire programme), those problems are likely to be solved. In other words, the hostile environment of outer space raises many technical questions and demands certain answers from qualified persons in all fields on a demanding time schedule.

Second, is a relatively large government R&D effort necessary to keep the economy moving forward, or can a nation keep pace by borrowing - plagarizing, if you please - bits and pieces of new technology developed by others? Preliminary examination of economic growth rates does not confirm that one policy is to be preferred over the other for all countries. One factor which makes this question difficult to answer is the normal time-lag of 15 to 20 years from drawing board to market place. Hence the major part of our pay off from space research will not be in evidence before about 1975. My own view is that a large, diverse economy requires both approaches, particularly in a country such as ours. A good, but not perfect, analogy for comparing countries technologically is to compare industries technologically. Some industries are narrow and have little, if any, R&D effort while others are large, diversified and carry out company R&D programmes and also support independent, industry-wide efforts in order to achieve economies of scale and to broaden their perspectives. It is these companies that most often are inclined to seek new knowledge and technology wherever it exists. In my view, a nation with a large, complex, diversified industrial base cannot afford not to have large, diversified R&D programmes.

Third, and finally, is the U.S. space effort, as some have charged, diverting scientific brainpower from more urgent tasks? A simple examination of the data shows that in the nine years of the space effort in the United States, we have seen a growth in research and development in all fields, and we have more, not less, effort in medicine and other areas of human welfare. Those who assert the contrary have really not examined the facts. There are three basic reasons why space R&D efforts have not detracted from research in other areas but have, on the contrary, strengthened those as well:

First, it appears that there was a large pool of technically-trained personnel who were capable of conducting R&D programmes but were being under utilized.

Second, as I mentioned earlier, the programme has been conducted in industry, on a project basis; and as the individual projects are completed, these resources, enhanced by exposure to new science and technology and benefiting from the systems engineering approach, can be turned to other problems, many of which lie in the public sector.

Third, there are a number of researchers who have concluded that the visibility gained for science, technology, and systems management has encouraged more young people to enter these professions; has convinced other governmental and industrial organisations that dollars spent for R&D will return a substantial return on that investment; and has fostered a faith that virtually anything is possible. The space programme, perhaps more than any other activity, has helped to make this era known as the "Research Age" - a period where man's intellect occupies the central role in all problem-solving situations.

In brief, space exploration in its broadest meaning and in all of its ramifications has already become a powerful force in and of our Nation, exerting great influence upon our present and future - socially, economically, and politically. It expands our horizons even as it shrinks our world. It is a complex combination of many related elements. It is a broad-based scientific and technological endeavour. It is a creator of new technologies, new techniques, and new methods of management. It has great significance for our national security. It is a stimulus for our economic and national growth. It is a catalyst to the achievement of the goals of our society. It is an investment for our future.

In the space programme we have learned to marry the disciplines of science, engineering, and management into one team that tackles problems of any size or complexity. I am convinced that in the future we will marshal the same forces in much the same way to conquer other large problems.

As we approach the second decade of the space era, detailed assessments are premature and precise predictions unwise. Like Columbus when he set sail into the Western Ocean, we cannot now know all that we shall learn and all we shall gain; like the three Princes of Serendip in the old fable, we may find that the most important things we discover will not be those we set out to seek. Only one thing sure can be said about the future: Whatever forecasts we make to-day will prove tomorrow to have been too timid.

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INSTITUTE FOR STRATEGIC STUDIES

9th ANNUAL CONFERENCE

THE IMPLICATIONS OF MILITARY TECHNOLOGY IN THE 1970s

COMMITTEE V - 3

Saturday 30th September | Morning

A European Arms Production System?

ALASTAIR BUCHAN

Outline

1. Technological questions causing increasing European-American friction. US spends four times as much on R and D as W. Europe and employs twice as many people in it. European dependence on American technology accepted: fear for certain European technological industries as consequence of this lead plus policy of maximising military equipment sales. Feeling in Europe that by more comprehensive procurement system competitive position may be strengthened. Change in British and German attitudes and French dilemma, make it propitious moment for discussion - though action may be blocked for several years more.
(US - European comparison see Table I)

2. The European Dilemma

Why this malaise in Europe? It is reconciled to overwhelming US strategic strength in NATO: why not in other fields?

(1) Technological industries modern source of national pride. Europe confronts sophisticated potential adversary and has had to keep up high level of defences unlike Japan. Consequently most official support for technology has been through defence funds. But

final market much smaller than in US. Also US has comprehensive range of military equipment under development at all times. Fear of all European governments is that if they embark unilaterally on advanced projects, they will find US product being developed faster and cheaper which European neighbours will prefer. Faced with abandonment or waste of resources. Aggravated by US arms sales policy.

(2) In climate of détente, and increasing cost of both manpower and weapons systems, must procure as cheaply as possible.

(3) Geographic situation forces the European countries to maintain most modern weapons. Pace of military innovation set by Soviet Union which is in turn set by US.

(4) Few in Europe wish to weaken strategic link with US or to develop protectionist system in technological field. But no question of a balanced trade with US in weapons. No possibility of Atlantic common market or Kennedy round negotiations in this field.

(5) Organisation of Europe itself. Increasing inter-European trade has not led to concept of inter-dependence in defence technology. No progress of European political or defence community. Europe can only offer negative evidence so far. (i) Purely inter-governmental machinery inadequate, e.g. ELDO. (ii) National or bilateral projects do not provide wide enough market. (iii) Existing supra-national institutions have little bearing on the problem.

(6) Disparate size and methods of European countries.

(a) UK and French aerospace industries comprise 77 per cent of all European aerospace activity. British, French and German procurement amounts to nearly 80 per cent of European NATO procurement. 95 per cent of European military procurement concentrated in seven countries.

(b) Difference in defence production industries.

3. <u>American interest in European cooperation</u>

No fault of US that present situation has arisen. Not a conscious policy of technological domination. NATO commitment strain on US balance of payments. Arms sale policy, though unwise, undertaken partly to offset strain on payment caused by US investment in Europe which is to its advantage. No great change in basic situation likely in near future. But three factors may cause US to look with greater approval on development of more comprehensive European system of arms procurement.

(1) Appreciation of political damage that unequal relationship is causing. One of main motive forces of "Gaullism" outside and inside France. European fear of becoming a technologically underdeveloped area. US will not promote a European system, but might acquiesce in it.

(2) Problems of arms sales to underdeveloped countries. US domination of European market forces all European arms producers, especially aerospace, to look for markets elsewhere.

(3) NATO strategy. Logic of defence economics must lead to replacement of forward strategy by concept of greater tactical mobility employing fewer forces. Means greater standardisation of equipment and facilities, especially in Central Area. And if NATO cannot develop more mobile strategy in Europe, then US will not be able to exploit developments in strategic mobility such as C5A, without damaging European-American confidence.

4. <u>Common US-European interests</u>

(1) Evolution of relationships in technological area that create minimum political friction.

(2) Make better use of European resources. Otherwise danger of precipate defence reductions.

(3) Neither side should acquire motive to withhold fruits of its technology. Criteria for development of technological cooperation are essentially political; relationship that will sustain European pride and growth, maintain reasonable degree of European influence in alliance, enable it to bear its proper share of load and keep Europe stable. Some Europeans see her as a "third force": will refer to technological implication of this later.

5. <u>European resources, requirements and experience</u>.

Sweden important in European context because of her pioneering techniques in use of defence resources. Would hope that any European system would eventually embrace Norway, Denmark. But for our purpose will concentrate on WEU powers. Three ISS studies available on European defence resources, systems under development and requirements of next decade, and of experience in cooperative projects. Provide some guidelines.

(a) <u>Policy</u>.

US spends one third of a procurement bill of $21 billion on R and D (excluding space). Europe less than a quarter of $7 billion procurement bill on R and D. US-Europe ratio is 4 to 1 in R and D. Under 3 to 1 in defence production. Emphasises European dependence on US technology: relative importance of defence production in Europe. Degree of self-reliance varies. UK 100 per cent autonomous till late 1950s. Still meets 80 to 90 per cent by value of own requirements. Now trying to reduce R and D expenditure and more interested in cooperative projects.

France has moved in opposite direction. Forces rebuilt by US aid in 1940s and early 1950s. Now even more autonomous than Britain though she spends only 60 per cent of UK figure on procurement. Now facing problem of markets for defence products in acute form: will it be Europe or Israel, India, etc.

Germany for past ten years has been major importer of weapons and defence technology. 1964 accounted for nearly 30 per cent of European procurement expenditure, but less than 10 per cent of European military R and D expenditure. Between a third and a half of defence requirements hitherto purchased abroad. Close interest in cooperation. But no longer willing to undertake fixed commitments to purchase US or British equipment.

Striking contrast between big three, and Benelux and Italy. They account for less than 15 per cent of European defence procurement. More interested in European equipment, e.g. Belgian purchase of <u>Leopard</u>, Dutch possibly of <u>Chieftain</u> tank. Air forces still basically American.

(b) Resources

What segments of Europe's military requirements in the 1970s and early 1980s can be met from European resources? Attached table is summary of detailed examination of principal area. In naval and army system European resources adequate either by national production and purchase or by joint R and D or by sub-contracting. Significant exceptions are nuclear submarines (dependent on US legislation) and certain aspects of ASW. Same is not true of aerospace or larger missiles. European dependence on US strategic system likely to increase in 1970s. In air force tactical system some doubt as to whether WEU powers can produce them for the 1970s at a comparable cost to US, e.g. Phantom or F.5. Anglo-French AFVG collapse. Complicated by unresolved military arguments.

(c) Structure

But precisely in aerospace and electronics that European defence industries most suited to collaboration. Vehicles only small part of large civilian industries. UK and France produce tanks largely in government arsenals; Germany through private enterprise. Naval shipbuilding unsuited to collaboration. Reverse true of aerospace: and European military electronics procurement ideally suited to collaboration.

(d) Cooperation

European experience in cooperative projects now quite extensive. Either in NATO common production projects or bilateral, e.g. Jaguar, or licensing, e.g. Rolls Royce engines. Or in smaller missile systems, or NADGE. Unfortunately no successful cooperation on tanks.

(e) Timing

Some systems ripe for immediate cooperation on design, e.g. successor to five European main battle tanks now in production: anti-tank missiles: medium surface to air missiles. Opportunity lost for time being on low level or ship to air missiles. A European procurement system would have to extend its responsibilities piecemeal.

6. The Range of Alternatives

Irrelevant ideas. (a) European nuclear deterrent. (Heath, Strauss) based on Anglo-French nuclear "arrangement". Apart from political problems would require concentration of R and D resources that would be ruinous to European technology as a whole. Spin-off from nuclear development overrated. (b) European Arms Cartels (Sandys, Beaufre). Also disastrous to European technology, as well as creating legitimate grounds for American opposition. (c) European ABM system. Ruinous diversion of resources, even if it could be achieved in Europe, and if European governments prepared to face 10 - 20 per cent increase in defence expenditure.

Pragmatic improvement

Re-invigoration of extensive NATO system and deliberate reversal of trend towards ad hoc co-operation. Enough experience to make system work better. NATO can improve its techniques, e.g, NPG, DPWG, new political directive to military committee, Harmel committee. Why not reform in procurement procedure? Director of Standardisation. $150 million budget for feasibility studies: rules on bidding and consortium organisation evolved in light of earlier experience.

Many advantages: little dislocation of existing arrangements. Little danger of protectionism. But doubts if it can be done.
(1) Declining authority of SACEUR and NATO military staffs. (2) Would involve considerable restraint on part of US: abandonment of $1.3 billion arms sales target. (3) Absence of France from NATO makes coordinated decisions in NATO on aerospace very difficult.

What is wrong with present system of ad hoc arrangements. (1) Constant uncertainty about the market. Collaboration raises R and D costs by at least 20 per cent and up to 50 per cent if different versions required. Two country market may be insufficient to offset their costs. (2) Waste of resources. (3) Impossible to develop common logistics if forces are using different types of weapons. (4) Danger that bilateral UK-French and German-US collaboration will produce differing defence philosophies for Europe.

7. <u>European alternatives</u>

Three ways of looking at problem. (a) Coordinate technological industries: same approach as ECSC or Euratom. (b) Isolate defence because it is a governmental activity. If the latter choice, can aim at comprehensive European defence system, or (c) coordinate only that element of defence that involves advanced technology.

<u>European Technological Community</u>

Case for starting with institutions aimed at stimulating technology as a whole is that it does not involve as close political agreement as defence community: security less of a problem. But would require "Community" in Brussels sense, linked to the EEC, i.e. with long term budget and parliamentary control: Powers to encourage common European company and patent law and formation of European companies.

Difficulties (a) Involves UK membership of EEC, i.e. dependent on French policy. (b) what is a technological industry? How do you separate military and civil aerospace or electronics? (c) Could such a community acquire sufficient authority to coordinate activities of highly competitive European firms and reverse trend towards technological nationalism.

Advantages, if it could be launched (a) need not be protectionist re US: would permit association of Sweden and Switzerland. (b) Would not arouse East European suspicions and would increase attractive power of West Europe. (c) Need involve no structural change in NATO.

(b) A European Defence Commission

The alternative approach naturally proceeds on different assumptions. First, it can be argued that the European-American gap in civil technology is wider than in defence technology (other than strategic systems): that American industry has displayed no marked superiority in the design or production of tanks, ships or strike aircraft, whereas its lead in space communications or computers may be unbridgeable even by coordinated European programmes. Might it not be sounder to organise European cooperation around a series of technologies where European and American progress is more equal, in a narrower field and where governments define the end product? Second, the apparent disarray of European defence technology springs from the fact that no attempt has been made to hammer out a common requirement for new generations of weapons: as Calmann puts it, "having discovered an operational requirement they (West European powers) seek a partner with a similar one".[34] But now that Britain is relinquishing extra-European military commitments (as France has already done), which have led to quite different operational requirements from her neighbours, now that American systems are being designed with global rather than European requirements in mind, the process of finding common ground in Europe on future operational requirements may be considerably easier. But this requires a framework in which common tactical doctrines can be evolved. Finally, it can be, and often is, argued that while there may be no case today for a European strategic force or a European ABM system, given the uncertainties in the whole structure of the balance of power which a rapid pace of technological innovation inevitably creates, Western Europe may have to assert its strategic independence, if not in the 1970s then perhaps in the 80s or 90s. This implies a Europe that is not only politically unified but militarily integrated, something that would take many years to accomplish. There is therefore a case for making a start now.

[34] Calmann I, p.20.

These assumptions lead one to re-examine the earlier proposals for a European Defence Community which collapsed in 1954. This, it will be recalled, would have involved the integration of forces above the divisional level under the authority of an Organisation headed by a Council of Ministers (one from each participating state), whose executive arm was to be a Board of nine Commissioners. The Board was to be responsible for the preparation of a common budget and procurement programme, the organisation and supervision of the Community's forces, the appointment of officers to basic units, and to higher commands with the approval of the Council of Ministers after liaison with the NATO Council. It was clearly implied in the discussions on the Treaty that the Commission should have wide powers over procurement.

Much water has flowed under the bridge since 1954. On the one hand, this type of international organisation which seemed revolutionary at the time is now quite familiar in Europe, and its pitfalls have been thoroughly explored in ECSC. in Euratom and in EEC itself. Second, the skeleton of such a community exists in WEU, including methods of parliamentary scrutiny, though France and Britain have never given it much flesh.(35) But then France and Britain now have an incentive to make such a system work which they did not have until recently. On the other hand, the European forces have been equipped with two generations of weapons systems on a national basis since 1954, and the process of evolving a common procurement system or common tactical doctrines could by no means be started from scratch.

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(35) Kramish is, I think, mistaken in suggesting as one reason why such a system would be inoperable that, "Much of the detailed information which is made available directly to the public and through Congressional Hearings in the United States has no counterpart in Europe. Consequently, any public dialogue within an all-European defence system is likely to be uninformed; these restraints are felt even within the close confines of national councils and parliaments, or in international bodies like the Assembly of WEU." Many of the Annual Reports of (contd)

The steps by which a European Defence Community might be established in the late 1960s, and early 1970s, are therefore different from the early 1950s. For one thing, its scope would have to be limited to exclude the British and French national nuclear programmes, regarding this as forms of purely national insurance with an uncertain future, if the kind of problems to which I adverted earlier were not to sink the project at the start. In theory the first step would be the entry of Britain and the Scandinavian NATO members into the EEC, for this is now accepted as the basis of permanent integration in Europe. If this is feasible in the near future the second, would be the conversion of WEU into a European Defence Commission as an instrument of the EEC Council of Ministers, with its own budget. What this would really involve is the creation of a European general staff. For years soldiers, airman and systems analysts have argued about requirements with their American counterparts. The EDC would create the focus to argue with each other. This would need a planning element, which means the hammering out of a common European doctrine on the practical requirements of European defence in the 1970s and 1980s, but also a common European policy on arms supplies to the Middle East or India or force levels in Europe, a process involving foreign offices and treasuries as much as ministries of defence.

The third step which need not wait for definitive progress in the second, would be the evolution of common requirements for major weapons systems. This would be done by stages as opportunity presented itself: for instance, as I have suggested earlier, the next few years may be the right time to engage in common design and feasibility studies on a successor to the current Chieftain, Leopard and AMX 30 tanks, on a European anti-tank or medium surface to air missile. The time for cooperative work on new ship to air or low level surface to air missiles might be later: the need to agree upon a European strike fighter might be an immediate preoccupation if the Commission were operating by 1968: by 1970 the opportunity might have been missed for six or seven years. There might be

(35) contd.
the Defence Committee of the WEU Assembly are better informed than much of the material that is given to or emerges from Congress.

no virtue in trying to develop, say, a European frigatem but there might be considerable scope for a European fire control or navigation system. The method could be pragmatic. Once this had made progress - and it might take several years - the fourth step would be to embark on the creation of a common European logistics system, certainly for armies, so as to reduce the considerable waste that is involved in operating a number of national ones.

The final objective would be the creation of something like a Western European army, navy and air force, perhaps national at the level of the brigade or the squadron, but with a European command and logistics structure above that.(36)

The standard objection to so far-reaching a proposal is that it could not be realised, not only until after Britain is a member of EEC, but until a political Community has been created to transcend the Economic Community and to create some mechanism for the coordination of foreign policies. The orthodox wisdom in Europe since 1954 has been that progress on defence must follow progress on political integration. I think this view now needs some qualification. One can question it on the grounds that the whole future of the EEC itself is now seen as much in terms of its political as of its economic value, and that when France accepts Britain's application to join the Economic Community it will be a sign that both sides understand the political implications and are ready to confront them.

But there are grounds for thinking that a practical European defence organisation could make considerable headway before a Political Commission, let alone any form of political union, had been agreed upon. The Defence Commission would have no operational responsibilities, at any rate in the first instance, and, if strategic weapons are not included in its responsibility, the more metaphysical aspects of defence policy need not encumber its discussions. It would be faced with some tough

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(36) If it should prove both necessary and possible to develop and deploy a European ABM system at a later stage it could only be done under the control of an authority of this kind.

problems, the reconciliation of the old cross-channel argument about speed and armour in tanks, armed helicopters versus VTOL versus light strike fighters: and in addition there would be very tough bargaining about the finance and power of the Commission ~~ax~~ in its relations with the various European defence industries. But the initiation of these professional arguments need not necessarily wait on more fundamental agreement in Western Europe about its role in the world or its ultimate relationship to the super-powers. And since the desirability of a high degree of practical interdependence in the defence field, especially in the procurement of advanced weapons and their logistic support has now been identified, the sooner these professional arguments begin the better.

Nevertheless, there would be serious hesitations in Europe about such an initiative. It would have an effect upon NATO in terms both of organisation and of attitudes. In terms of organisation its effect might be beneficial in leading to more effective European-American bargaining and compromise on arguments both about policy and weapons systems. But most European powers would wish to be clear that such a proposal commanded wide American support, even though it might somewhat prejudice the sales of American arms in Europe: otherwise they would fear its misinterpretation by American opinion as a form of European isolationism, which might create its mirror image in the American attitude to Europe. The position of France in relation to NATO would have to be redefined: though her relationship with West European defence is now less significant in military terms and in military terms alone an EDC could be created without her, it could not be organised as part of the European Community, nor embrace such vital technologies as aerospace without her. Germany and other countries might fear that such a move would have a retrograde effect on pan-Europeanism and relations with the East, though a European Defence Commission would not cause as much difficulty as the European deterrent, and would have the added advanatge for Germany of providing a continuing international framework for the Bundeswehr.

The smaller countries, Benelux and Italy, would have to decide whether a European military system, involving close relations with three much stronger powers, suited their economic,political and technological interests as much as a looser Atlantic one. And there would be difficult problems of national and commercial security to be overcome if the work of the Commission was to be conducted with the intimacy and candour which would be essential for its vitality.

But it is the logical way of proceeding at a time when the costs of defence are bearing hard on the resources that governments are prepared to make available. And when it has become clear that unless a number of governments (not just two) can reach full agreement on a military requirement, an adequate market to justify the investment in research and development may not be forthcoming.

(c) A European Advanced Projects Authority

If a European Defence Commission is too ambitious a project to consider at this stage, the alternative approach remains - of developing an international system concerned specifically with the problem to which this series of studies has been principally addressed, namely complex and expensive military systems involving a high R and D element. It need not be wholly confined to defence equipment but could include space and oceanography, but it would be concerned with products of which the consumers are governments. It would require some supra-national authority, in a sense of an undertaking by governments to submit their national programmes in specific fields to coordination by the Authority, and it would require a central budget to give it power to stimulate research, though not perhaps development or production. But it would not require the broad powers of coordination over many aspects of defence in addition to those which involve technological problems, that a European Defence Commission would have to have.

Its purpose would be functional, to assure a European-wide market for expensive defence products by getting prior agreement on requirements, by spreading the cost of research, and organising development and production where ever the most effective facilities exist. It would not be as ambitious an objective nor require as much delegation of national authority as a European Defence Commission, and it would not need quite as strong a political framework. It could, for instance, be created within WEU before the negotiations on British entry to the EEC are completed: it could in fact be started tomorrow and get to work immediately on the kind of problems I have described above as the third step in the creation of a European Defence Commission. It could follow the established European pattern of a board or commission composed of individuals working under the authority of a Council of Ministers, persumably Ministers of Defence or Technology from the Seven. It would require a highly expert permanent staff, but not necessarily a fully fledged general staff. Its procedure and function could in part be very similar to those of the Military Standardisation Agency in NATO but on a West European scale.

If such an authority could be c eated, it would become an interest of the larger WEU governments to use it. Though multilateral discussions on requirements may be more difficult than bilateral or within one government, while the organisation of genuinely international bidding for a contract may be more complex than a quiet bilateral deal between two semi-monopolistic national industries, events of recent years in this field suggest that it is only by making the customer part of the decision making process that European projects can survive in the face of strong American competition. It would be in the interest of the smaller countries to participate because participation ensures a good prospect of getting a share of the work.

If such an authority had sufficient resources to initiate its own feasibility and design studies in response to the agreed requirements of the member states the subsequent stages could be handed over largely to European industry, using the kind of sensible safeguards about national undertakings on production orders and finance outlined by Rhodes James in the light of NATO's experience with the Atlantique.(37) The careful reader of this series will note a dichotomy between Calmann's view that consortium techniques will not necessarily produce a fair or efficient answer in Europe, with the consequence that an international authority must have strong powers of supervision, and Rhodes James's view that industrial arrangements are best left to industry.(38) I think that on questions of production Rhodes James is right. And there is less danger of such a European agency being accused of protectionism or depriving Europe of the benefits of American technology if production arrangements are left to industry, simply because a European consortium on an advanced project would be certain to include the participation or sub-contracting of American firms or their European subsidiaries.(39) But on problems of research and development, especially the latter, a European defence procurement system would represent little advance on present arrangements unless the authority had power to encourage specialisation and "centres of excellence" by the award of its contracts. The guiding principle of such an authority would have to be efficient fulfilment of a requirement on which it has obtained agreement, not equity still less the protection of national industries. If every participating country insists on having, say, a final assembly line, as was

(37) Rhodes James III, p.13.

(38) Cf Calmann I, p.19, and Rhodes James III, p.19.

(39) Though, as Rhodes James has pointed out in relation to the Hawk programme, European production of an American weapon is not aa efficient as of a European design. III, p.8.

the case with the F.104G, or if production becomes too geographically dispersed in Europe as happened with Hawk, then the speed with which a project can move from research to the final user will compare unfavourably with production of a similar system in the United States, and European cooperation would break down. Perhaps the residual power of the participating countries to opt out and "buy American" might be its surest guarantee of efficiency.

The projection of such an authority carries fewer difficult implications that an EDC. It would have little or no effect on relations with Eastern Europe. Its scope could be limited to the fields in which cooperation is easiest, aero-space and electronics. It need not be anti-American in its operation, and might indeed leave the United States a certain market in weapons systems with which the authority was not concerned to help finance her European commitments. But it would carry a clear implication for the participating European countries themselves: if the efficient satisfaction of a widened market is its criterion, then the countries taking part cannot expect full protection of their national tecnological industries, and must be prepared for the consequences -increased mobility of resources and risk taking - of intensified intra-European competition. Here the analogy between Europe as a whole and the United States is relevant: for all the intense political pressures that local interests can generate in Congress, it has become accepted that when Boeing wins a contract Lockheed or North American lose it, though their Senators may denou the Pentagon at the top of their lungs. The WEU powers would have to accept that, in the technological field at least, the requirements of an expanded market imply the need to regard Western Europe as one country.

VII.

This series of studies contains many omissions and suspended judgements. But if it achieves no other purpose, it has at least illustrated the complexity of the material and the difficulties, political, financial or industrial, which attend any alteration in the present system of defence procurement. I have included a sketch of alternative kinds of institution in my own contribution, primarily in order to suggest different avenues for further exploration and research. Each of them presents its difficulties and there is no ideal and easy solution either for Western Europe or for the West as a whole. But the fact that there are alternatives worth discussing suggests that this is a moment of good fortune not of misfortune for Western Europe.

One thing, however, is certain: which ever method of approach is adopted - and there may be many permutations and combinations of the basic alternatives I have sketched - will profoundly affect not only technological vitality but also political and military confidence and effectiveness within the Atlantic world for a long time to come. This is the time for active discussion not precipate action. It is our hope that this series has made a modest contribution towards formulating the agenda of discussion.

Table 8. DEVELOPMENT AND PRODUCTION OF WEAPON SYSTEMS IN THE WEST IN THE 1970s

Category of weapon systems	*Continued national development and production in Europe*	*European Co-operation*				*Atlantic Co-operation*				
		Research and development	*Joint production*	*Interchange of subsystems and/or subcontracting*	*Intra-European purchase*	*US–European R&D*	*European production of US systems*	*US–European interchange of subsystems and/or subcontracting*	*Atlantic purchase: Europe from US*	*Atlantic purchase: US from Europe*
GROUND FORCES										
Armoured Vehicles										
Main battle tank; Light tank; Armoured personnel carriers; Self-propelled artillery	√	possible	possible	√	√	√ (US–Ger)	√	√	√	√[a]
Guns (and Ammunition)	√[b]	√	—	—	√	—	—	—	√	√[c]
Missiles—Anti-tank										
Heavy/vehicle-borne; Light-weight	√	√	√	—	√	—	possible	—	possible	possible
Missiles—Surface-to-Air										
High[d]	—	—	—	—	—	—	possible	possible	possible	—
Medium	possible	—	—	—	possible	—	√	—	√	—
Low	√	√	√	√	√	—	possible	—	possible	possible
Unit self-defence	√	possible	possible	possible	possible	—	possible	—	possible	possible
Missiles—Surface-to-Surface	(France)	—	—	—	—	—	—	—	√	—
Vehicles	√	—	—	—	√	—	—	—	possible	—
Target acquisition devices	√	possible	possible	possible	√	possible	√	√	√	√
Counter insurgency weapons[d]	—	—	—	—	—	—	—	—	√	—
Chemical and biological weapons[d]	(Minor agents)	—	—	—	—	(Research)	—	—	possible	—
NAVAL FORCES										
Surface Warships										
Attack carriers	—	—	—	—	—	—	—	—	—	—
Anti-submarine warfare carriers	—	—	—	—	—	—	—	—	—	—
Commando/helicopter carriers	√[e]	—	—	—	—	—	—	—	—	—
Cruisers	—	—	—	—	—	—	—	—	—	—
Destroyers/escorts; Minesweepers/fast patrol boats/smaller craft	√	—	—	possible	√	—	—	possible	√	√[f]
Submarine—Attack										
Conventional	√	—	—	—	√	—	—	—	—	—
Nuclear-powered	√ (Britain, France)	—	—	—	—	√ (Anglo–US)	—	—	√[g]	—
Nuclear Propulsion for Naval Ships	√[h]	possible	—	possible	possible[i]	possible	possible	—	possible[i]	—
Air Cushion Vehicles	√	—	—	√	√	√	—	—	√	—
Other Ships										
Hydrofoil types	√	—	—	—	√	—	—	—	—	—
Landing ships; Logistic ships	√	—	—	—	√	—	—	—	—	√
Missiles										
Ship-to-air	√	possible	possible	possible	√	—	possible	possible	√	—
Ship-to-Surface	√	√	√	possible	√	—	possible	possible	√	—
Anti-submarine	√[j]	—	—	—	—	—	—	—	√	—
Submarine Detection	√	√[k]	—	—	√	√[k]	possible	possible	possible	—

Table 8.—*Continued*

Category of weapons systems	*Continued national development and production in Europe*	*European Co-operation:* *Research and development*	*Joint production*	*Interchange of subsystems and/or subcontracting*	*Intra-European purchase*	*Atlantic Co-operation:* *US–European R&D*	*European production of US systems*	*US–European interchange of subsystems and/or subcontracting*	*Atlantic purchase:* *Europe from US*	*US from Europe*
AIR FORCES (*Tactical Systems*)										
Combat Aircraft										
Aircraft electronics	√	√	—	√	√	√	√	√	√	√
Strike/interceptor/reconnaissance	√	possible	possible	possible	√	possible	√	√	√	—
Light strike/ground-attack/light fighter/trainer . .	√	√	√	√	√	—	√	√	√	—
VTOL/VSTOL	√	√	—	—	possible	possible	—	√	—	possible
Patrol/maritime aircraft . .	√	√	√	—	√	—	—	—	√	—
Transport Aircraft										
VSTOL	possible	√	possible	√	possible	—	—	√	possible	—
Light Aircraft (fixed wing) . .	√	—	—	√	√	—	√	possible	√	—
Helicopters	√	√	√	√	√	—	√	possible	√	—
Missiles										
Air-to-surface	√	√	√	—	√	—	possible	—	√	√
Air-to-air	√	—	possible	—	possible	√	√	√	√	—
STRATEGIC OFFENSIVE FORCES										
Inter-continental ballistic missiles[d]	—	—	—	—	—	—	—	—	—	—
Manned bomber[d]	—	—	—	—	—	—	—	—	—	—
Air-to-surface missiles[d]	—	—	—	—	—	—	—	—	—	—
Strategic reconnaissance[d] . .	—	—	—	—	—	—	—	—	—	—
Ballistic missile submarines . .	√	possible	—	possible	—	√	√	—	√	—
Intermediate/medium-range ballistic missiles	√ (France)	possible	possible	possible	possible	—	—	—	√	—
STRATEGIC DEFENSIVE FORCES										
Ballistic missile defence[d] . .	—	—	—	—	—	—	—	—	?	—
Manned interceptor[d]	—	—	—	—	—	—	—	—	—	—
Surveillance[d]	—	—	—	—	—	—	—	—	—	—
Anti-satellite warning[d]	—	—	—	—	—	—	—	—	—	—
Ballistic missile warning . .	—	—	—	—	—	√	√	√	√	√

[a]Probably armament only.
[b]Chiefly smaller calibres.
[c]Anti-tank.
[d]Development in US only. (But, with respect to 'Strategic Offensive Forces', see p. 29.)
[e]Or some ship for this task.
[f]Limited to smaller ships or components.
[g]Components?
[h]Britain, France, Italy?
[i]Fuel and reactors.
[j]Excluding nuclear.
[k]Through NATO ASW Centre.

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