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NATO Standardization and Technology Transfer

VOLUME II – MAIN REPORT

LEVEL III

by

Robert A. Gessert, Project Director
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and

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Prepared for:

European/NATO Directorate
Office of the Assistant Secretaty of Defense
for International Security Affairs

August 1977

Contract No. MDA 903-76-C-0284

Short Title: Technology Transfer

Contractor: General Research Corporation
Contract Project Director: Robert A. Gessert
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This study reviews current literature dealing with the problem of technology transfer; reassesses the importance of technology transfer to NATO standardization; evaluates lessons learned about technology transfer in the cases of Roland II, Sidewinder and Sparrow. and the F-16; and examines current US governmental policies, regulations, and procedures for controlling and releasing militarily significant

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technology. Conclusions and recommendations for US technology transfer policy affecting NATO standardization are presented.

PREFACE

NATO standardization and technology transfer have been two subjects of widespread and increasing interest in the US defense community since about 1975. Both bear a direct relation to improving the US and NATO conventional posture vis a vis the Soviet Union and the Warsaw Pact. The US and NATO have counted on technological superiority in fielded systems - particularly in Central Europe - to help offset some of the advantages of Pact numerical superiority in deployed forces.

A major study by a Task Force of the Defense Science Board brought concern with export policies affecting technology into sharp focus in early 1976. Though that Task Force dealt principally with commercial transfer to the Soviet Union and other communist states, it seemed to augur tighter controls on militarily significant technology in general as it warned of imminent erosion of the West's technological lead. Following completion of its earlier examination of NATO standardization and licensing policy, including related industrial and technological matters, the General Research Corporation (GRC) was requested by the Office of the Assistant Secretary of Defense for International Security Affairs (OASD/ISA) to undertake this examination of the convergence of these two subjects.

GRC, and its subcontractor and consultant for this report express their appreciation to the government officials and representatives of US industry who gave freely of their time, particularly for the case studies examined. Special appreciation is expressed to Major General Richard C. Bowman, Director, European and NATO Affairs; to Colonel

Larry J. Larsen, Chief, and Colonel Harold W. Holtzclaw, Project Officer, in the NATO Standardization Division of ISA; and to Mr. Jerrold K. Milsted, Contracting Officer's Technical Representative, for their patient and wise guidance in the conduct of this study.

The views and judgments expressed in this report are those of the authors and do not necessarily reflect the views of ISA or any person interviewed in the performance of the study.

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Chapter 1

INTRODUCTION

PURPOSE AND SCOPE

The purpose of this study is to review and assess problems of technology transfer in relation to NATO standardization and interoperability; to examine the criteria, policies, procedures, and mechanisms that have governed the transfer and control of technology; and to recommend modifications in those that can facilitate the controlled release of US technology to achieve greater NATO standardization subject to the constraints of US national security and industrial competitiveness.

BACKGROUND

As the title indicates, this study was prompted by the emergence of two key international policy issues that are likely to affect US security well into the 1980s: NATO standardization and technology transfer. US Executive Branch and Congressional interests, as well as US industrial interest, in these two issues have grown apace with the policies and practices of detente and allied interdependence, sometimes converging, sometimes diverging. Both are of keen interest to US allies in NATO and to their industries. Both have been subject of much study and high-level attention inside and outside the governments of all the principal NATO countries.

Standardization of weapons and equipment among the allied forces of NATO, especially in the central region, is now widely recognized as highly desirable, if not essential, to the improvement of the conventional leg of NATO's triad of capabilities at a cost that is affordable. The payoff for standardizing weapons and equipment is expected to be in improved allied force effectiveness and, hopefully, in more efficient and economic use of collective resources. All the principal NATO countries are now engaged in efforts to find ways to achieve greater NATO standardization, or at least interoperability, without sacrificing other national interests, including their domestic industrial interest.

By whatever means greater standardization is achieved—by common procurement from a single source, by co-production of a commonly-selected development, or by co-development leading to co-production—weapons technology is transferred from one country to another within the alliance. Thus, one of the potential costs of standardization is some loss of control of sensitive technology. This may have repercussions for the competitive position of national industries in international markets as well as repercussions for national security if strategically significant technologies are involved and the chances for their dissemination beyond what is intended are increased.

A previous GRC report to OASD/ISA on "NATO Standardization and Licensing Policy" identified technology transfer as a key problem area in co-production and co-development programs undertaken to achieve greater NATO standardization/interoperability. Examination of previous US experience in licensing within NATO noted that "it may well prove essential to the success of standardization--that national disclosure policies be rationalized more liberally" (Ref 1, p. A-30). And, further, that:

> In the case of weapons developed and produced under a NATO standardization program, the US will be dealing with weapon systems derived from mixed US-European technology. The fact that items standardized in the future may contain large proportions of US-European derived technology naturally affects the approach to be taken to monitor and control the transfer of technology. This may require changes in US policy as well as in methods of controlling transfers of technology in order to accommodate NATO standardization. (Ref 1, p. A-33)

From another perspective, the US defense-industrial community has become increasingly concerned in recent years about the erosion of the technological lead the West has traditionally enjoyed vis a vis the Soviet Union and its allies. This lead has been counted on to help off-set the quantitative imbalance between the forces and equipment of the Warsaw Pact states and of NATO. One of the ways this lead appears to have been eroded is by the transfer of US and European-developed technologies to the Soviet Union and its allies for explicitly civil programs. Another is by the diffusion of militarily-applied technologies in the fielded weapons and equipments of the US and its NATO allies and in the sales of such items to third world countries. Both suggest tighter controls on the transfer of any technology that has a militarily significant application and in which the US enjoys a strong competitive position.

DISCUSSION

In the late fifties, beginning with President Eisenhower's offer to NATO in December 1957, the US committed itself to a policy of sharing US technology with its European NATO partners. Major programs carried out under this policy included licensed production in Europe of 4000 Hawk air defense missiles, 5000 Sidewinder air-to-air missiles, 4000 Bullpup air-to-surface missiles, and 1000 F-104G Starfighters. Such programs had the double aim of achieving NATO standardization in critical systems and of transferring technology to European NATO allies to assist them in rebuilding their technological-industrial capacity to supply more of their own defense needs.

The success of the earlier policy in achieving important goals has also partly contributed to de-standardization as European industries and consortia have developed and produced systems that are competitive with US technology and designs. These include many European collaborative projects such as the British-French Jaguar ground attack/ trainer jet and the Lynx, Gazelle, and Puma helicopters; the German-French Alpha-Jet trainer/ground attack aircraft and the Roland surface-to-air missile system; and the British-German-Italian Multiple Role Combat Aircraft (MRCA). Other examples of significant European systems include the

Harrier VSTOL aircraft, the HOT and MILAN antitank weapons, the Exocet and OTOMAT anti-ship missiles, and the Rapier and Crotale surface-to-air missiles. While not all of these match US technology, it is clear that European technology has become competitive with US technology in some areas.

A significant US technological lead vis-a-vis Europe continues to exist in several key areas that are important to civil as well as military projects. These include areas such as electronic warfare equipment, propulsion systems and fuels, advanced guidance systems, and solid state devices. In most of these areas, the US technological lead is militarily and strategically significant in relation to the communist countries, and widespread dispersion would be contrary to US security interests. In some areas, the technologies in question also have large-scale or important commercial applications, and dispersion might be unfair or disadvantageous to US developers who have invested heavily in R&D. In either military or commercial applications, it is generally the design and manufacturing know-how of the key technologies and not the text-book theory or principles that provide the principal advantages. This point was made forcefully in a key study by a Task Force of the Defense Science Board, "An Analysis of Export Control of US Technology-A DOD Perspective" (Ref 2). This study, chaired by J. F. Bucy of Texas Instruments and widely known as the Bucy Report, concluded that transfer of US technology to non-allied hands is a major problem and recommended that the Department of Defense develop objectives and strategies for tighter control of high technology.

Problems associated with the transfer of technology, including design and manufacturing know-how, have not gone unnoticed in NATO. A Working Group on Industrial Property (AC/94) under the NATO Conference of National Armaments Directors (CNAD) published in November 1976 a comparative study on "Military Equipment and Industrial Property Legislation" among the NATO countries (Ref 3). A second volume of this NATO brochure will contain a compendium of the national submissions, on which the comparative study was based, containing summaries of national laws, policies and regulations covering patents, technical data, industrial designs, and other industrial property rights and control of the export of these (see Ref 4). The AC/94 working group was assigned the mission in December 1976 of conducting a follow-on study of licensing policies and intellectual property rights in NATO standardization projects.

NATO working groups of experts have also prepared NATO Agreements on "The Mutual Safeguarding of Secrecy in Inventions Relating to Defense and for Which Applications for Patents Have Been Made," including "Implementing Procedures," and on "The Communication of Technical Information for Defense Purposes" (cited in Ref 5). NATO brochures have been published providing "Guidance for Drafting International Cooperative Research and Development Agreements" and "Guidance for NATO Procurement Authorities" (cited in Ref 3). Other publications completed or in process include "Regulations in NATO Countries Concerning Employee's Inventions" and "National Practices Regarding Proprietary Rights in Cooperative Research and Development Programs" (cited in Ref 3). Besides such publications, the NATO Industrial Advisory Group (NIAG), formed in 1968, has developed procedures for the free exchange of ideas under constraints of safeguarding national security and industrial privacy, a "moral code on the free exchange of ideas," and guidance for the standardization of protective clauses in industrial property rights.

Despite such studies, agreements and guidance, many problems exist in facilitating the free exchange of ideas that involve the design of high technology systems and components and the manufacturing know-how to produce them efficiently and competitively. National and industrial leaders naturally wish to hold back design and manufacturing know-how in particular if either a risk to security or to industrial competitiveness would be involved in release of such know-how. US legislation, such as the Munitions Control provisions of the Mutual Security Act of 1954 as Amended, places certain formal constraints in well-defined areas, but additional constraints operate in many informal ways on technical representatives and negotiators in international collaborations.

Complaints are frequently voiced in Europe that the US attempts, for example, to get NATO Europe to buy AWACS or NAVSTAR without release of technical performance test data. US industrial-technical representatives who must meet with European corporations, which sometimes have labor representatives in their corporate structure representing Western European communist parties, may be expected to carry a double burden of secrecy in meetings that are nominally devoted to exchange of ideas and technology.

There currently is no clear policy guidance for US contractors who want to cooperate or collaborate or share technology with European contractors in weapons development. Major obstacles exist, which are too much for contractors to overcome alone without strong government backing, for forming collaborative arrangements with Europeans.

If NATO standardization/interoperability is to be achieved by greater use of co-production or co-development arrangements with European allies, there is an urgent need for reviewing, revising, and consolidating US criteria, policies, procedures, and mechanisms for affecting release of critical technology without jeopardy to US national security and US industry.

APPROACH AND ORGANIZATION OF THE REPORT

To support DOD policy making at the critical juncture of NATO standardization and technology transfer this study seeks answers to such questions as how technology transfer has been handled in recent and current NATO projects to determine what obstacles have been created for NATO co-production and co-development by a concern with technology transfer; what risks to either national security or to industrial proprietary interests and competitiveness transfers have generated; what institutions and interests (government and commercial) play a role in impeding or facilitating transfer; what criteria with respect to the types of technologies involved have operated in decisions to release or control particular technologies; and what criteria can be postulated for a policy aimed at an optimum solution to achieving the apparently conflicting goals of maximizing NATO standardization/interoperability while safeguarding national security and industrial competitiveness.

Building on the previous GRC work for OASD/ISA, the study reviews current literature dealing with the problem of technology transfer in Chapter 2; reassesses the importance of technology transfer to NATO standardization in Chapter 3; evaluates lessons learned about technology transfer in the cases of Roland II, Sidewinder and Sparrow, and the F-16 in Chapter 4; and examines current US governmental policies, regulations, and procedures for controlling and releasing militarily significant technology in Chapter 5. Conclusions and recommendations are presented in Chapter 6. Appendixes A, B, and C present case studies on which Chapter 4 is based. Appendix D is a reference bibliography.

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Chapter 2

TECHNOLOGY TRANSFER IN PERSPECTIVE

GENERAL

The Bucy Report brought into sharp focus within the defense and defense-related industrial communities a critical question of the relation of technology to US foreign policy and defense goals. That report was concerned specifically with the export of US technology and its impact on the maintenance of US technological superiority vis a vis the Soviet Union in areas of significance to national security (Ref 1).

Prepared for the Director of Defense Research and Engineering (DDR&E) and issued in February 1976, The Bucy Report reinforced a theme that had become central in the annual reports of Dr. Malcolm Currie, then DDR&E, to the Congress on the DOD program of research, development, test and evaluation — namely, that technological superiority is an essential ingredient of the US military posture especially in view of the Soviet commitment of greater numbers of men and materiel to their posture (cf Ref 2). At the time the Bucy Report was issued, the US had had three years of experience in increased scientific and technical cooperation with the Soviet Union under a series of eleven agreements initiated at the Nixon-Brezhnev summit of May 1972. These, together with increased trade and commercial technology transfer programs, had begun to raise serious concerns that the US was eroding its technological superiority without a material improvement in the political-military environment. The Bucy Report sounded a somber warning on this score and urged immediate steps to tighten control on the export of US technology.

Additional urgency was given to this recommendation when Dr. Currie stated in his last report to the Congress:

> The trends with respect to the Soviet Union are especially sobering and portray a potentially grave situation in the mid-1980s. Given an extrapolation of current trends, and without appropriate action on our part, it is my judgment that on balance, and including a combination of quality and quantity, <u>the Soviet Union can achieve dominance in deployed military technology in the 1980s</u>. (Ref 3. Underlining in original.)

Prior to the Bucy Report, the Congress had held hearings on US-USSR advanced technology transfer in December 1973, on detente in general in May-July 1974, and on US-USSR cooperative agreements in science and technology in 1975 (cited in Ref 4). In January 1975, the General Accounting Office had also released a report on the progress in the US-USSR cooperative science programs (cited in Ref 4). As might be expected, such hearings and reports presented significantly differing perspectives on the benefits and risks of programs of cooperation with the Soviet Union.

Shortly after issuance of the Bucy Report, hearings were held again in April and May of 1976 on export licensing of advanced technology (Ref 5 and 6). By then a more pessimistic view of the risks and accomplishments of programs of cooperation with the Soviet Union had come to dominate the review. In May of 1977 the Subcommittee on International Security and Scientific Affairs of the House Committee on International Relations published a comprehensive review of technology transfer and scientific cooperation between the US and the Soviet Union prepared by the Congressional Research Service of the Library of Congress (Ref 4).

Such studies, reports and reviews led, in late May 1977, to the inclusion in the International Security Assistance Act of 1977 (Ref 7) of a provision for the study of technology transfers. Section 24 of of that Act provides that:

> (a) The President shall conduct a comprehensive study of the policies and practices of the United States Government with respect to the national security and military implications of international transfers of

technology in order to determine whether such policies and practices should be changed. Such study shall examine--

(1) the nature of technology transfer;
(2) the effect of technology transfers on United States technological superiority;
(3) the rationale for transfers of technology from the United States to foreign countries;
(4) the benefits and risks of such transfers;
(5) trends in technology transfers by the United States and other countries;
(6) the need for controls on transfers of technology, including controls on the use of transferred technology, the effectiveness of existing end-use controls, and possible unilateral sanctions if end-use restrictions are violated;
(7) the effectiveness of existing organizational arrangements in the Executive branch in regulating technology transfers from the United States;
(8) the adequacy of existing legislation and regulations with respect to transfers of technology from the United States; and
(9) the possibilities for international agreements with respect to transfers of technology.

(b) In conducting the study required by subsection (a), the President shall utilize the resources and expertise of the Arms Control and Disarmament Agency, the Department of State, the Department of Defense, the Department of Commerce, the National Science Foundation, the Office of Science and Technology Policy, and such other entities within the Executive branch as he deems necessary.

(c) Not later than the end of the one-year period beginning on the date of enactment of this section, the President shall submit to the Congress a report setting forth in detail the findings made and conclusions reached as a result of the study conducted pursuant to subsection (a), together with such recommendations for legislation and administrative action as the President deems appropriate.

It may be expected that this Congressionally-directed study will be materially facilitated by the "Implementation Study Program of the Defense Science Board Report" that constituted DDR&E's follow-on to the Bucy Report. With widespread participation in the Department of Defense and contractual support from Battelle Columbus Laboratories, Science Applications, Inc., and Veda Incorporated, this Implementation Study Program, scheduled for completion in the summer of 1977, has aimed at:

- Identification of principal technologies that require export control;
- Study of active mechanisms for technology transfer;
- Improvement of the administration of export control, including simplified criteria for product control, review of the administration of export control, and a computerized data base;
- Study of specific policy recommendations, including end use statements and safeguards, technology transfer to the free world, and other provisions (Ref 8).

While clearly directed at problems of technology transfer to the Soviet Union and its allies and not at technology transfer within NATO, the Bucy Report and other recent literature on the export control of technology has been widely interpreted as portending a generally more restrictive US policy on technology transfer that could have severe implications for allied cooperation in defense development and production and, thus, on NATO standardization. The next two chapters will deal with the specific importance of technology transfer to NATO standardization; the remainder of this chapter aims at identification and clarification of issues that are deemed most critical in the broad area of technology transfer in general.

MEANINGS OF TECHNOLOGY TRANSFER

The general literature on technology transfer in the 1970s contains three rather distinct but related meanings of the term "technology transfer." These are:

a. Intra-US transfer to other uses and agencies, including state and local governments and the private sector, of technologies developed at taxpayer expense under US government sponsorship or within federal laboratories.

b. Export or import of commercial technologies developed within the US or abroad either under government sponsorship or by private technological-industrial sectors.

c. The transfer of arms-related technologies under programs of arms sales and military assistance, and under programs of defense cooperation including military trade and co-production or co-development of weapons and equipment.

Many factors account for the growing interest in technology transfer in all three of these primary meanings. Heavy federal expenditures in military and space R&D have partly been justified by their potential spin-off technologies with commerical applications to improve the US standard of living. R&D funding in the federal budget ranged from $17.4 billion in FY 1974 to $23.5 billion in FY 1977. In those years, military R&D accounted for about half of federal R&D funding with space R&D representing an additional 12-14 percent (Ref 9, p 28). About half the federal funding for R&D is spent in US industry, and over 90 percent of this is in defense. The federal government itself performs about 25 percent of federally funded R&D, or about 15 percent of all US R&D (federally funded R&D representing over half of all US R&D) (Ref 9, p 33).

In view of such heavy expenditure on and performance of R&D by the federal government, the federal laboratories and the National Science Foundation have sponsored programs of technology transfer to assure greater utilization and secondary applications of federally-funded technology (cf Ref 10, 11). One outgrowth of such concern for greater utilization of federally funded technology is a NATO-wide conference on technology transfer in Lisbon, 7-11 November 1977, with tri-service US support.

Of most direct relevance to this study are the second and third meanings of technology transfer, that is, export (or import) of technology — either for intended commercial applications or for intended military applications.

Commercial Technology Transfer

US policy on the export of technology for commercial and civil applications has developed in three general contexts, each of which has in different degrees and at different times encouraged deliberate transfer of selected technologies to further US foreign policy goals. Patterns of technology transfer have varied widely in these contexts and have met with debatable degrees of success. Broadly, the general contexts are: aid to developing countries, trade with friends and allies in the industralized world, and detente with the Soviet Union and other communist states.*

Recognizing that technology is at the heart of economic and social development, the underdeveloped and lesser developed countries of the world have sought the transfer and transplantation of industrial technologies from developed countries. Primarily as an instrument of aid and, in the longer run, to enhance trade and other foreign policy goals, the US, along with other industrially developed countries, has sought to transfer relevant and absorbable technologies to developing countries. Policies followed have frequently been controversial and have produced widely divergent patterns of growth in particular countries. There are complex issues as to what is most relevant and absorbable for recipient countries and as to the rate of introduction as well as by what political and private mechanisms transfers should take place. One study of the role of imported technology in a country's economic growth concludes that "the importation of technology is the major determinant of economic growth in medium developed countries" (Ref 4, p 61). Since the end of World War II, the US has followed a broad policy of offering selected technical assistance and technology transfer to less developed countries to assist them in economic development and to promote particular US foreign policy goals.

With respect to allied or friendly industrialized democracies, the US has generally also fostered commercial technology transfer in furtherance

*An excellent overview of the international transfer of commerical technology is presented in Part II, Section I, pp 55-76, of Ref 4, based on PhD dissertation research by George Holliday. The discussion in the next few paragraphs draws heavily on Mr. Holliday's research.

of US goals. The importation of technology by developed countries, if less important in terms of overall economic growth, may nonetheless play a crucial role in development of particular industries and in the overall trading pattern of both the importing and the exporting countries. Technology transfers among the Western trading partners can be seen in this light. Vis a vis Japan, Canada and Western Europe, the US has been on balance an exporter of technology and an importer of products — some of them reflecting the technologies exported earlier. The policies a nation adopts to channel or control either the importation or the exportation of particular technologies may have critical long term effects on trading patterns in commercial products. Two different importation policy models are sometimes identified: that of Belgium, which in the early 1970s encouraged the importation of technology by promoting direct foreign investment by multinational corporations; and that of Japan, which in the 1950s and 1960s took a significantly different course of governmental selection and control of importation by licensing arrangements designed to give maximum incentives to build indigenous capability (and ownership) on top of imported technologies and to assure freedom aggressively to develop foreign markets for the products of imported technology (Ref 4, p 71). Clearly, the commercial interests of technology exporters are affected in significantly different ways in relation to these two importation policy models.

As noted previously, technology transfer to the Soviet Union and its allies has been largely a phenomenon of the detente policies of recent years. The technology importation policies of the Soviet Union have, in the 1970s, adopted some of the features of both the Belgian and the Japanese models. The Belgian model attempted to solve absorption problems by providing for the importation of whole manufacturing technologies including production techniques and processes, management systems, equipment, and plant facilities. Soviet policies have sought similar goals through turnkey contracts and direct purchase rather than through accepting direct forign investment. Acquisition of product technology and design information has also been as important as in the Japanese model that sought to limit foreign ownership and control of transferred manufacturing technologies.

US policies of technology transfer to the Soviet Union and other communist states have been cautious and, even under detente in the 1970s, have sought to restrict such transfers to commercial or civil technologies and have excluded military products and associated technologies, as represented on the US Munitions List. US allies in NATO and Japan have similarly agreed through the informal Coordinating Committee (COCOM), consisting of all of NATO less Iceland plus Japan, to limit exports of products and technologies to the Soviet Union and other communist states to items that have no military or strategic significance or potential. There appear to be two principal difficulties with such policies. First, many if not most advanced product technologies with significant military applications are inherently dual-purpose, capable of either commercial or military applications. Second, the manufacturing technologies (know-how) associated with specific product technologies are inherently more difficult to control once they have been transferred. Thus in both regards, end-use agreements or limitations and patent and copyright safeguards, which are counted on heavily in US export policy with allied trading partners to protect the interests and rights of transferors of technology, are of little avail in controlling technology transfers to the Soviet Union.

Arms-Related Technology Transfer

The export or transfer of arms-related US technology has inevitably taken place in the large-scale programs for direct arms transfer or sales by which the US has previously sought to strengthen and support the military capabilities of allies and other friendly states. As the Bucy Report aptly notes, however, the sale of end products is one of the least effective mechanisms of transferring the critical technologies that go into the design and production of the end products. "Reverse engineering," especially of sophisticated, high technology systems is an exceedingly difficult process and is rarely successful without active accompanying mechanisms of transfer. Nonetheless, potential hazards of losing control of sensitive technology do exist, for example in cases such as the controversial proposed sale of the E-3A airborne warning and control systems (AWACS) to Iran.

Technology is much more readily transferred when direct arms sales are accompanied by training, logistic support, and technical assistance for operation and maintenance of the arms that are transferred. The transfer of sophisticated, high-performance equipment to developing countries like Iran and Saudi Arabia has required this assistance to develop an infrastructure for use of the equipment and arms supplied. Arms technology is most directly transferred when licensed production or co-production arrangements are entered into as a vehicle for arms sales and military assistance. The two dominant reasons co-production arrangements have been sought by arms recipients are: (1) their need for some form of "offset" to reduce the impact of large foreign expenditures on their balance of trade and payments and to support domestic employment; and (2) their desire to develop and sustain a domestic technological-industrial capability to supply defense needs and to have spin-off effects on their own general industrial development. In recent years, the former has been compelling in US arms sales to NATO allies (especially in central Europe), while the latter has been compelling in arms sales and transfers to the Middle East.

While, in general, arms transfers and related technology transfers to allies and other friends is seen by the US to be a primary requirement of US security, they are also used to support or provide leverage for other foreign policy goals, including: creating interdependencies with recipient states, offsetting US oil importing accounts, and providing markets for high-cost arms and related technologies to reduce unit costs. NATO allies — especially Britain and France and to a lesser extent West Germany — with substantial, high investment armaments industries have similar incentives for arms transfers and related technology transfers. In the aerospace industries in particular where, for example, Britain and France require substantial export to utilize their present investment and to sustain employment, the US and its NATO allies are in competition for transfers to third world countries.

The technological character and magnitude of US arms transfers to the third world has been of increasing concern to the US Congress and this concern has been reflected in the new arms transfer policies formulated by the Carter Administration and in the creation of an interagency Arms Export Control Board under the chairmanship of the Under Secretary of State for Security Assistance. Besides defining arms transfers as an "exceptional foreign policy implement" the use of which rather than the denial of which must be justified, two features of the new policies are especially significant for the transfer of arms technology. These are the principles that the US will not be the first to introduce into a region "newly-developed, advanced weapons systems which would create a new or significantly high combat capability," and that sales or co-production of US-designed weapons would be prohibited "until they are operationally deployed with US forces" (Ref 12).

The new arms transfer policies do provide exceptions for transfers to NATO allies with respect to most of the direct proscriptions, such as those cited above. However, there appear to be differences of opinion within the Administration as to what the indirect consequences of some of these proscriptions will be with respect to another central goal of the Administration - namely increased cooperation in defense development and production among the NATO allies to achieve greater standardization. In particular, the issue focusses on whether to achieve the desired reduction in technological arms races in other regions, the new policies will impose such end-use and re-transfer limitations on arms technology transfers to NATO allies as to make arms technology transfer with the principal NATO allies economically if not politically infeasible (Ref 13).

Thus, in two broad areas where technology transfer has been seen in the recent past as a positive instrument of US foreign and defense policy - commerical transfer to encourage detente with communist countries and military transfer to support free world allies and friends - there is now sober concern about how well technology transfer programs have supported policy and whether they can be better controlled and channeled. At the same time - as the next chapter will discuss - technology transfer appears to be an essential ingredient of new efforts to achieve NATO standardization.

WHICH ASPECTS OF TECHNOLOGY ARE TRANSFERABLE?

US policy with respect to NATO standardization and technology transfer requires some working answers to the question that is the heading for this section. An attempt to provide such answers might usefully begin with a clarification of what is encompassed by the term "technology."

To assist the Congress, the Science Policy Research Division of the Library of Congress Congressional Research Service prepared a "Working Glossary," first published in April 1972 and revised in 1973 and again in 1976, providing annotated definitions of about 240 common terms used in connection with science, technology and public policy (Ref 14). That glossary avers that technology "has come to signify tools and their development and use in the broadest possible sense." And, further, that "technology encompasses all basic and applied research, -- all manufacture and use of products, all knowledge rationally applied --- and any other rational human actions toward intended results." It distinguishes - with acknowledged difficulty - between technology and science, basic and applied, by asserting that "basic science is an information function; and applied science is an information function with a useful purpose in mind; while technology is the development and social use of information" (Ref 14, p 82).

Such a broad definition of technology at least assures that nothing will be overlooked in attempting to determine which aspects of technology are important. A further distinction in the Working Glossary is of more help. The Glossary suggests that:

> A distinction can be drawn between technology as a process and as a product. One author suggests: "Technology-as-process is those patterns of action by which man transforms knowledge of his environment into an instrument of control over that environment for the purpose of meeting human needs. Technology-as-product is understood as comprising the range of tools, machines, procedures, etc., produced as result of technological action." (Ref 14, pp 82, 83.)

Such abstract definitions and distinctions are used in this study to enumerate systematically some of the activities (technology as process) and things (technology as product - ideational and material) that are regarded as technology. This enumeration is based on general activities and things associated with military and commercial technology. It provides a basis for an assessment of which aspects of technology are transferable, which are important to transfer, and the principal mechanisms for transfer. A later discussion considers substantive types of technologies (e.g., airframes and jet engines, navigation and guidance, electronics, computers, etc.) that have critical military significance.

Technology as Process

Activites covered by the concept of technology as process include:

a. pure research
b. applied research
c. designing
d. developing
e. testing and evaluating
f. planning and managing
g. manufacturing
   - fabricating of components
   - assembling
h. quality control
i. distribution
j. support and maintenance
k. operating or employing (i.e. using)

Such activities all fall within the definition of technology as "knowledge rationally applied." They suggest the range of purposeful activities or processes frequently referred to as the "know-how" necessary to bring a complex system into being, from concept to a fielded end product. Such activities or processes are based on scientific and engineering principles, imagination and innovation. They are carried out by people who "know how to get things done." Such people may be individual entrepreneurs, inventors, and managers; but in a complex technological-industrial society, skilled teams of entrepreneurs, inventors, and managers with proven "track records" are at least as important as individuals in "getting things done."

The processes enumerated represent what is implied in the Bucy Report by the phrase "design and manufacturing know-how." Design covers such activities as those identified in b - e above; manufacturing in that Report appears to include f - i above. These activities or processes may be thought of as knowledge or skills in action. Such skills may be relatively simple and well known or complex and esoteric, depending on the substantial characteristics of the end product or system for which they constitute the design and manufacturing know-how. Moreover, in the competitive industrial world, some skills (technologies) may be "firm specific" in contrast to or in addition to being "system specific." Holliday distinquishes firm specific and system specific technologies in addition to "general technology" (Ref 4, pp 69ff). General technology, in his usage, refers to "the practices and procedures peculiar to a [whole] industry" rather than to a specific manufacturer (firm) or a specific product (system).

Export of technology as process may be immediately accomplished by direct foreign investment that is accompanied by the transfer of people — i.e., key teams of entrepreneurs, managers, and skilled workers. By transferring some of his own people with the critical skills, the transferor may also maintain a strong measure of initial control over the know-how that is tranferred — at least, in the sense of guiding and managing its early development in the new environment. However, it must be adapted to the laws, mores and infrastructure of the recipient country and must employ and train indigenous labor and leadership if the transfer is to be effective. In the long run, then, direct foreign investment frequently results in rather complete transfer or transplantation of technology to the recipient country with some measure of management control remaining in the hands of a multinational corporation, which can also facilitate further transfers including flow-back or two-way transfer. This is true particularly for firm specific technology and, to a lesser extent, system specific technology in contrast to general technology.

As suggested above, the transfer of technology as process (know-how) inevitably requires training of the recipient. In the absence of direct foreign investment, this is generally accomplished under a contractually agreed program of technical assistance. The technical assistance required by the recipient depends on many factors: the recipient's overall technological infrastructure and level and character of general technology, the compatibility between firm specific technologies of the transferor and the transferee; the character of the system specific technology involved in the transfer. Technical assistance is most easily definable and successfully accomplished when it is system specific and provided from one industrial entity to a well-known and comparable industrial entity in the recipient country. The transfer of firm specific technology by means of negotiated technical assistance is more difficult and costly to accomplish than the transfer of system specific technology; but the latter may require the former where complex systems are involved and the transferee industrial entity is not well-known to the transferor or is undertaking a system specific technology for which his firm specific technology is not well suited. The tranfer of general technology by means of negotiated technical assistance is exceedingly difficult if not impossible to accomplish.

Terms used in the literature, such as "high technology", "advanced technology", "sophisticated technology", and "militarily or strategically significant technology", are almost always system specific technologies. In the context of US foreign policy and defense goals vis a vis both the Soviet Union and NATO standardization, system specific technologies are the foreground issue. Nonetheless, the broad situation or balance between transferor and transferee in firm specific and general technology are important background issues. The higher, more advanced, a system specific technology is the more it depends not only on these background issues for transfer, but on active training and teaching mechanisms for transfer or transplantation of skills through direct investment.

In a worldwide survey of chief executives on the international transfer of technology conducted by the Conference Board, a Canadian respondent asserted: "With some exceptions, the purchase of technology in the form of documentation alone is expensive and wasteful at any price." Oriented to transfers to developing countries, this respondent further suggested that: "The most efficient and effective method of transfering technology is through the establishment of subsidiaries or joint ventures of companies that have the technology and see the need for its introduction in a developing country for economically sound purposes" (Ref 15, p 13). Purchase of technology by means of licensing agreements that are accompanied by technical assistance is the major alternative to direct investment in providing an active mechanism for transfer in the technical assistance arrangement.

A British respondent in that same survey sees another mechanism that is more-or-less intermediate between purchase of technology and direct investment. He suggests that:

> ...investments and operations are frequently undertaken, not by individual government or private entities, but by consortia. The costs, risks, provision of services, expertise, etc., are thus shared. In many countries, developing or developed, the local government or state oil corporation is frequently involved as a partner with private companies, and so-called "technology transfer" takes place without any formal arrangements or payments.
>
> This process has been taking place for a number of years not only in new developments, but also in established operations, in that many countries have been acquiring shares by participating in, or nationalizing, existing private companies or consortia (Ref 15, p 14).

In the area of allied cooperation in defense development and production, multinational corporations, joint ventures, and consortia — with varying degrees of government participation and ownership in particular industries - have clearly been dominant patterns for transferring and sharing technology within NATO Europe (see, especially, Volume III of the previous GRC Report, Ref 16).

Technology as Product

Things covered by the concept of technology as product include:

a. basic principles
b. applications concepts
c. specifications and requirements
d. models and prototypes
e. test and evaluation equipment
f. test and performance data
g. technical design data
h. production plans
i. manufacturing plant and equipment
j. support plant and equipment
k. maintenance plant and equipment
l. end products

This list includes a mixture of documentation and physical objects under the rubric "things." All are intermediary or end products of some aspect of technology as process; they are what is made by know-how. They record or embody know-how and could thus be thought of as "know-what." The end product could be said to embody all the other types of products and their associated know-how most completely. In a given process of development and production from initial concept to a fielded system, all the types of intermediate things listed are required to some degree and represent the evolution of system specific technology as product.

At the earliest end of the evolutionary chain, basic principles and even some applications concepts are widely available in published scientific and technical literature. Applications concepts and some aspects of specifications and requirements may also be available, in advertisements, in proposals, and in trade journals. At the other end of the evolutionary chain, end products are widely available for sale and re-sale. The market for end products is, of course, a principal determinant of the price at which technology as product may be sold and of the willingness of entrepeneurs and managers to invest in all the intermediate technologies as products and as processes.

Any aspect of technology as product is capable of transfer by sale and purchase, whether in the form of documentation or physical objects. The sale of physical objects generally implies a relatively unrestricted transfer of ownership from the seller to the purchaser. Unless specifically negotiated as a condition of sale, about the only restriction on the transfer of ownership is an assumed obligation not to copy or reproduce any patented or copyrighted aspects of the object purchased. As noted earlier, without specific design information, documentation and technical data, copying or reproducing would be an exceedingly difficult process anyway. Sale of technical design data and documentation is by far the more effective way of transferring technological know-what than sale of physical products.* Sale of technical design data, therefore, normally involves carefully negotiated restrictions on the use of the data along with specific and limited authorizations to use them. Authorization is granted, where patents and copyrights are involved, by means of a license for which the recipient pays a direct fee. To compensate for unknown market losses to the seller, the recipient normally also agrees to pay the seller a royalty on each end product the recipient sells under the license.

Within a domestic economy, there is normally only one consumer for military products. Among other things, with respect to technology development and transfer, this has generally required that the government become an important element as producer as well as consumer. The government becomes the principal risk taker and supporter of R&D, especially for advanced technology systems where development costs run high and the risks of not developing a usable product may also be high. In the US, to assure producibility and performance at affordable costs, development contracts are commonly competed among two or more industrial suppliers. Moreover, the potential at least to compete production contracts is also used as a device to assure production at the best price (or least cost).

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*Sale of intermediate products, such as testing and manufacturing equipment, more effectively transfers both know-what and know-how than sale of end products.

For these reasons, as well as for specific national security reasons, the government becomes either the sole owner of the technology it pays for (documentation as well as objects) or it assures that it has complete and royalty-free rights to all necessary technical data. Where specific classified data and equipment are involved, the government also controls all transfers of these on the basis of industrial security regulations and strategic disclosure policies and procedures.

In contrast to commercial technology transfer, in military technology transfers governments virtually always play a direct, active role as owner or controller as well as a passive or negative role in approving or disallowing specific transfers to specific countries. This is especially true in relation to technology as product (where ownership is generally clear and protected by patents) in comparison to technology as process (where "ownership" is less clear and technological know-how resides largely in industrial management, design and manufacturing teams). Government ownership or control of rights in data can work either to facilitate or to complicate the international transfer of military technology. As discussed in more detail in Chapter 4 which reports on case studies undertaken for this study, the type of rights in data generally required in US military development and production contracts tends to assure the existence of a transferable technical data package that is relatively complete. This can materially reduce mechanical and administrative problems in transferring technology from one industrial entity to another even across international boundaries. On the other hand, as noted also in that chapter, a recipient government's requirement for complete rights in data may make a foreign industrial entity less willing to transfer its technology — especially in those areas where its own government has not acquired complete rights in data. This problem becomes more complicated when two or more governments have supported the R&D in a particular system and share or have distributed between themselves and their industrial entities various rights in data.

MECHANISMS OF TRANSFER

The above discussion has indicated that there are many shades and nuances to the meaning of "technology transfer" and the determination of what aspects of technology are important for technology transfer policies. The principal mechanisms for the transfer of technology as process or as product are briefly discussed in this section, along with comments on the effectiveness of these mechanisms.

Mechanisms for Transferring Know-How

Four principal types of mechanisms for transferring technology as process can be identified. These are: (1) direct foreign investment, (2) joint ventures, (3) contracted technical assistance, and (4) information exchanges.

Direct Foreign Investment. As implied above, this mechanism is first of all a mechanism for transplanting more than "transferring" technological know-how. To guarantee return on his investment, the investor normally transfers some of his key personnel to the foreign country where he intends to transplant his capability. To be successful he needs to employ and train local personnel and stimulate the development of an indigenous infrastructure that is compatible with his investment and foreign operation. Transfer of the investor's technology to the foreign soil is accomplished by these requirements and, as the literature suggests, may be highly effective. Though the original investor generally desires to maintain control of the technology transferred through an initial period to guarantee return on his investment, control of his technology may later progressively pass to indigenous leadership.

Joint Ventures. This is in some sense an alternative to, or alternative form of, direct foreign investment. Two or more industrial entities decide to pool their resources, including specific technological capabilities, to accomplish together what neither may be able to accomplish alone. Particularly where military technology and equipment is involved, the governments in which the industrial entities operate may take the leading role in shaping the form of cooperation and determining both the type and the mode of technology sharing. In this context, technology transfer is generally reciprocal rather than one-way.

Contracted Technical Assistance. This is the purest form of direct transfer of technology from a transferor who possesses special expertise to a transferee who desires that expertise or know-how for some specific purpose. The quid pro quo for transferring is generally direct payment for services rather than expected return on investment or exchange and co-ownership of technology as in the former two, respectively. Contracted technical assistance may take different forms ranging from general consulting contracts, to contracted studies and analysis, to system specific technical assistance negotiated in connection with a license to produce a particular system designed and developed by the transferor. In the latter case the transferor may expect other benefits from transferring besides his fee or direct payment. These include: advertising through wider acceptance of his product, direct supply and sale of some components, new industrial contacts that may lead to new markets, and flow-back of any technological improvements that the transferee may make to the licensed design.

Information Exchanges. Information exchanges may take many forms. Included in this broad category are such media of exchange as trade journals and exhibits; advertising and submission of proposals; scientific and technical conferences and symposia; industrial and commercial visits; and formal governmental agreements to exchange certain types of requirements data and RDT&E data. One of the characteristics that distinguishes this category is that the exchange is generally "free" — that is, not involving direct payment or immediate, specific return on investment. The quid pro quo that is expected by transferors is access to reciprocal information that otherwise might have been difficult or impossible to acquire. Information exchanges are therefore in a very broad sense, technological and industrial intelligence operations. Their degree of effectiveness varies widely depending on the extent of personal contact provided and the quality of the personnel involved.

The foregoing types of mechanisms are all effective devices for transferring different aspects of technology in particular situations. In general, direct foreign investment could be identified as most effective for transfer of general technology in one industrial sector to a country in which that sector is underdeveloped. Joint ventures are particularly effective in transferring firm specific technology since they generally require close industrial collaboration. Contracted technical assistance under a co-production agreement is the most direct and effective mechanism for transferring system specific technology. Within any given industrial sector, the international transfer of technology among several countries commonly takes place by a mix of these types of mechanisms and general information exchanges. The mix and degree of employment of all the types of mechanisms is as important as the existence of any one type. Within the context of NATO standardization joint ventures and technical assistance agreements seem clearly to be the most important types of mechanisms for technology transfer of know-how.

Mechanisms for Transferring Know-What

Again, four principal mechanisms for transfer of technology as product may be identified. These are: (1) turnkey factories, (2) processing and manufacturing equipment, (3) end products, and (4) technical data and documentation.

Turnkey Factories. A contract to design and install an entire factory including mechanisms and procedures for its operation, for turnover to local operators and managers is comparable to direct foreign investment as a device for transferring technology from a transferor whose technology is highly developed in a given substantive area to a transferee who is less developed or underdeveloped in that area. Two distinctions with respect to direct foreign investment are important. First, the recipient clearly desires above all to purchase the physical means for a particular production capability and place them under his complete control. Second, though the transplantation of people with their know-how is involved in both cases, in a turnkey factory contract this is regarded strictly as instrumental and limited in its duration until the know-how associated with the physical plant and equipment has been adequately transferred. In direct foreign investment, on the other hand, the installation of plant and equipment could almost be regarded as instrumental to the transfer of know-how. The Bucy Report regards the design and installation of turnkey factories with necessary training and assistance as the most effective mechanism for technology transfer. The "transfer" by definition in contrast to direct foreign investment is intended to be complete; like direct foreign investment, it is also a mechanism intended to bridge an existing technological gap between a developed transferor and a developing or underdeveloped transferee in a particular industrial area.

Processing and Manufacturing Equipment. Sale and installation of processing and manufacturing equipment is essentially a limited version of a turnkey factory contract. The purchaser or recipient in this case is generally at a higher stage of development in the general industrial technology involved, but may require some system specific equipment to develop or to fabricate critical components or some firm specific type of equipment to improve the quality of his product or the productivity of his operation. The sale of processing and manufacturing equipment bridges an existing technological gap, but one that is specific and limited. The transferee has an existing development and production capability, which he desires to maintain and to improve.

End Products. The literature is virtually unanimous that technology is "transferred" in the sale of end products for use, but that this mechanism is a relative ineffective way of transferring the design and manufacturing technology that could produce the same or similar end products. The principal exception to this, in the sale or transfer of military end products, is that design technology is transferred indirectly when the sale is accompanied by extensive provision of operating and maintenance equipment and instructions. Otherwise, end products are generally difficult to copy, especially if they involve high or advanced technology in their fabrication. On the other hand, for those end product transfers that the transferee can easily copy, he generally has the technology to produce them in his own right. For a variety of other reasons he has elected to purchase them outright rather than produce them himself.

Technical Data and Documentation. The sale and purchase of technical data and documentation as a form of technology as product is, like technical assistance, a rather pure and direct mechanism for transferring system specific technology from a developer to another user. The developer's design of a specific system is documented, in varying degrees, in technical data, including engineering drawings, patented designs and processes, component specifications, fabrication and assembly procedures and manuals — in general, all the information necessary to produce the specific system. Much of this material may be protected by patent and copyright law — or, more generally, what has come to be known as "intellectual property laws." Some of it may not be covered by specific patents, but still be protected as proprietary information or part of a firm's intellectual property. To use such information and technical data, a transferee generally must obtain a license from the owner of any intellectual property granting him the right to use it for specified purposes and pay a price for this right. In practice, both the extent of the rights purchased and the price paid for them are negotiated between offeror and purchaser on the basis of many factors and calculations by each concerning the specific system. The offeror takes into consideration the extent of his possible market losses as well as the cost of his development; the purchaser takes into account the value of a market he believes he can reach with the licensed product and the cost to him of developing an alternative but comparable product. Generally the offeror requires, as a condition of his offer, royalty-free rights to any technical data reflecting improvements in the system the licensee may develop in direct consequence of his license. As noted previously, the licensee normally pays the licensor an overall fee to obtain the technical data required plus a royalty on each item produced or sold under the license. Moreover, he also generally accepts specified limitations on the portion of the market that he may seek to reach. When two or more developers share in a development, they may agree in advance to co-own all the data or to grant each other royalty-free and license fee-free rights to data that may be owned by each. They generally also negotiate market shares and production work shares in advance. Especially for system specific technologies that are advanced or complex, sale of technical data through a licensing arrangement is generally accompanied by a contract for technical assistance to effect the transfer of know-how along with know-what.

In the context of NATO standardization, the principal mechanisms for technology transfer are the sale and purchase of end products with operating and maintaining provisions, or the sale and purchase of technical data through licensing arrangements, or the sharing and co-ownership of technical data through joint ventures in development.

IDENTIFICATION OF CRITICAL TECHNOLOGIES

The Bucy Report emphasizes that "control of design and manufacturing know-how is absolutely vital to the maintenance of US technological superiority." Recognizing that control of militarily significant technology has previously been exercised primarily through end product control, the Report further declares

> For the long perspective, beyond the limitations of current laws, regulations, and practice a new approach to controlling technology exports is overdue. This perspective should focus wholly on technology and not end products of technology --excepting for those critical items of direct military significance. (Ref 1, p iii)

The Mutual Security Act of 1954 as amended provides for export control of military end products, their components and parts, and any technical data associated with them. These have been enumerated in twenty-two categories (three of which are reserved for later designation) of articles "designated as arms, ammunition, and implements of war" that constitute the US Munitions List (Ref 17). These categories represent types of military equipment and weapon end products and include:

- I Firearms
- II Artillery and Projectors
- III Ammunition
- IV Launch Vehicles, Guided Missiles, Ballistic Missiles, Rockets, Torpedos, Bombs, and Mines

V	Propellants, Explosives, and Incendiary Agents
VI	Vessels of War and Special Naval Equipment
VII	Tanks and Military Vehicles
VIII	Aircraft, Spacecraft and Associated Equipment
IX	Military Training Equipment
X	Protective Personnel Equipment
XI	Military and Space Electronics
XII	Fire Control, Range Finder, Optical and Guidance and Control Equipment
XIII	Auxiliary Military Equipment
XIV	Toxicological Agents and Equipment, Radiological Equipment
XV	—
XVI	Nuclear Weapons Design and Test Equipment
XVII	Classified Articles
XVIII	Technical Data
XIX	—
XX	Submersible Vessels, Oceanographic and Associated Equipment
XXI	—
XXII	Miscellaneous Articles

The difficulty with the adequacy of such a list — as seen by the Bucy Report — is that technology is not controlled directly except insofar as it is identifiable with specific military systems. Even technology as product in the designs of components (e.g., engines) and parts (e.g., semi-conducters) is generally dual-purpose, i.e., capable of both commercial and military applications. Most importantly, technology as know-how in designing and in manufacturing is virtually always dual-purpose in this sense. For these reasons, it is vital to focus on technology as such.

The Bucy Report strongly recommended that DOD take the lead in establishing new criteria, policies, and procedures for screening and controlling all exports of technology whether for direct military or for ostensibly commercial purposes. Such criteria, policies, and procedures should:

- focus on design and manufacturing technologies,
- emphasize the more active mechanisms of transfer, and
- identify strategic technologies.

These principles are reflected in the Report's specification of three "actions" that should constitute the center of implementation of the Task Force's recommendations. These are:

1. The Department of Defense should identify principal technologies that require export control.
2. The administration of export control regulations should emphasize the scrutiny and control of the more active mechanisms of technology transfer.
3. A comprehensive study of active mechanisms for transferring technology that are beyond the normal scrutiny of export control administration should be made by the Department of Defense and recommendations developed for monitoring and controlling them. (Ref 1, pp 34-39)

The Implementation Study Program that was undertaken by DDR&E on the basis of the Bucy Report concentrated its initial efforts on the identification of the principal technologies that require export control. Four broad criteria were postulated for determining whether a substantive type of technology is strategically significant to the US, warranting tighter export controls. These criteria are: (1) whether the US currently enjoys a competitive (leading) position with respect to the technology; (2) whether the technology is critical to US military systems; (3) what the military status of the technology is; and (4) what the transfer capability is <u>vis a vis</u> the Soviet Union. Qualitative rankings of high, medium, and low were defined for each criteria to provide an initial basis for screening. Figure 1, reproduced from a January 1977 status report of the Implementation Study Program, shows these criteria and the definitions of high, medium, and low that were used for ranking.

Figure 1

STRATEGICALLY SIGNIFICANT TECHNOLOGY (SST)

SELECTION CRITERIA AND RANKING

U.S. COMPETITIVE POSITION	CRITICAL TO U.S. MILITARY SYSTEMS	MILITARY STATUS	TECHNOLOGY-TRANSFER CAPABILITY
*HIGH: U.S. LEADS IN ALL IMPORTANT ASPECTS MEDIUM: U.S. LEADS IN MOST/SOME ASPECTS LOW: U.S. LEADS IN AT LEAST ONE ASPECT	**HIGH: DEGRADES PERFORMANCE OF AT LEAST TWO PRIMARY MISSION PARAMETERS MEDIUM: DEGRADES PERFORMANCE OF ONE PRIMARY MISSION PARAMETER LOW: DEGRADES OPERATIONAL EFFECTIVENESS OF OTHER MISSIONS	***HIGH: IN OPERATIONAL SYSTEMS MEDIUM: SPECIFIED FOR SYSTEMS ENTERING INVENTORY LOW: LIKELY IN FUTURE GENERATION SYSTEMS	****HIGH: CAN BE EASILY ABSORBED BY SOVIET INFRASTRUCTURE MEDIUM: CAN BE ABSORBED LESS EASILY LOW: CAN BE ABSORBED ONLY WITH DIFFICULTY

Reproduced from Ref 8.

A preliminary screening of technologies, coordinated by Battelle Columbus Laboratories and Science Applications, Inc., produced a candidate list of twenty technologies that could be identified as strategically significant. These, together with the tentative rankings assigned within each criterion, are listed in Figure 2. Preliminary reports on each of these technologies examined in Phase 1 of the Implementation Study Program were presented to DDR&E in October 1976 and provide the basis for the Figure 2 Overview (Ref 18). The preliminary reports — in varying degrees — identified current US military systems for which the technologies are critical, examined civil applications, evaluated the design and manufacturing aspects of the technologies, and identified some of the "keystone" equipment and processes on which design or manufacturing is dependent. Such considerations in addition to the primary rankings by criteria are summarized for one of the technologies for illustrative purposes in Figure 3.

It is beyond the scope of this study to provide a separate identification and assessment of critical technologies. The Implementation Study Program briefly discussed here is engaging scientific and technical resources from both industry and government in conducting its identification of critical technologies. The new study of technology transfer required by the Security Assistance Act of 1977 will engage more resources and further refine such identification of critical technologies and criteria, policies, and procedures for export control of them. Although tighter controls are likely to be directed primarily at exports to the Soviet Union, other communist countries, and third world countries, European NATO partners are likely to watch this process with keen interest for at least two reasons. First, one intended outcome of this process will be proposed revisions of the list of embargoed commodities for COCOM countries, which include Japan and all of NATO except Iceland. Second, tighter export control policies and procedures for technology transfer may have some unintended effects and implications for NATO standardization.

Figure 2

OVERVIEW OF STRATEGICALLY SIGNIFICANT TECHNOLOGIES — PHASE 1

TECHNOLOGIES / CHARACTERISTICS	U.S. COMPETITIVENESS POSITION*	CRITICALITY TO MILITARY SYSTEMS**	MILITARY STATUS***	TECHNOLOGY TRANSFER CAPABILITIES****
1. ELECTROCHEMICAL ENERGY STORAGE	HIGH	HIGH	HIGH	HIGH
2. LOW LIGHT LEVEL IMAGING	MEDIUM	HIGH	HIGH	HIGH
3. SUPERCONDUCTORS	MEDIUM	MEDIUM	LOW	HIGH
4. BORON FIBERS	HIGH	HIGH	HIGH	HIGH
5. METAL MATRIX COMPOSITES	MEDIUM	HIGH	HIGH	HIGH
6. CARBON CARBON COMPOSITES	HIGH	HIGH	HIGH	HIGH
7. CAD*CAM*SOFTWARE AIRFRAMES	HIGH	HIGH	HIGH	MEDIUM-HIGH
8. AIRFRAMES	MEDIUM HIGH	HIGH	HIGH	HIGH
9. PHYSICAL VAPOR DEPOSITION	MEDIUM	HIGH	HIGH	MEDIUM
10. ELECTROFORMING	HIGH	HIGH	HIGH	HIGH
11. INERTIAL NAVIGATION SYSTEMS	MEDIUM	HIGH	HIGH	HIGH
12. MICROPROCESSORS	HIGH	MEDIUM	MEDIUM	HIGH
13. INFRARED DETECTORS	HIGH	HIGH	HIGH	HIGH
14. CENTRIFUGAL COMPRESSORS	LOW	MEDIUM	HIGH	HIGH
15. NUMERICAL CONTROL	MEDIUM-HIGH	MEDIUM-HIGH	HIGH	HIGH
16. INTEGRATED CIRCUIT MFG	HIGH	MEDIUM-HIGH	HIGH	MEDIUM HIGH
17. REMOTE SENSING	HIGH	MEDIUM	HIGH	MEDIUM-HIGH
18. JET ENGINES	MEDIUM	HIGH	HIGH	HIGH
19. HIGH DENSITY OPTICAL RECORDING	HIGH	HIGH	HIGH	MEDIUM HIGH
20. HOT ISOSTATIC PROCESSING	MEDIUM	HIGH	HIGH	MEDIUM

*CAD - Computer-aided design; CAM - Computer-aided manufacture.

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Figure 3

EXAMPLE OF STRATEGICALLY SIGNIFICANT TECHNOLOGY

BORON FIBERS

U.S. COMPETITIVENESS POSITION	CRITICALITY TO MILITARY SYSTEM	MILITARY STATUS	TECHNOLOGY TRANSFER CAPABILITY
HIGH U.S. LEADS, BUT OTHER COUNTRIES ARE GAINING COMPETENCE	HIGH WILL BECOME INCREASINGLY CRITICAL FOR FUTURE SYSTEMS, PROVIDES LIGHTWEIGHT HIGH-STRENGTH COMPONENTS	HIGH IN CURRENTLY OPERATIONAL SYSTEMS AND IN FUTURE SYSTEMS	HIGH GREAT SOVIET INTEREST; EXISTING INFRASTRUCTURE
U.S. MILITARY SYSTEMS	**CIVIL APPLICATIONS**	**DESIGN/MANUFACTURING CONTRIBUTIONS**	**KEYSTONE EQUIPMENT**
– F-14 – F-15 – B-1 – SPACE SHUTTLE – FUTURE: AIRCRAFT ENGINES	CURRENT: – TENNIS RACQUETS EXPECTED: – COMMERCIAL AIRCRAFT – AUTO ENGINE COMPONENTS – LEISURE PRODUCTS – PROSTHETICS	PRIMARILY DESIGN THROUGH HIGHER STRENGTH MANUFACTURING BY HIGHER MATERIAL UTILIZATION (LOWER MU FACTOR)	CHEMICAL VAPOR DECOMPOSITION AND DEPOSITION EQUIPMENT

Reproduced from Ref 8.

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Chapter 3

TECHNOLOGY TRANSFER IN NATO: THE INDUSTRIAL-POLITICAL CONTEXT

GENERAL

At the same time that President Carter was reaffirming the United States commitment to standardization of weapons and equipment among Allied forces at the NATO Summit meeting in London, Business Week magazine carried a story on NATO standardization under the banner headline, "NATO: Nobody Wants Standardized Weapons" (Ref 1).

The goal of NATO standardization, which President Carter embraced for his Administration, has been proclaimed with varying intensity by every US administration since NATO was formed and increasingly enshrined in US legislation since 1974. On the European side of the Atlantic, every principal NATO member government (except France) and the three principal forums for intra-European cooperation on defense matters -- the Western European Union (WEU), Eurogroup, and the independent European Programme Group (EPG) -- have also asserted the necessity for achieving greater standardization and affirmed their commitment to that goal. Yet the Business Week story was not entirely wrong in its interpretation of difficulties in each of the major recent weapons programs that have been shaped by and have tested the goal of standardization: the F-16, AWACS, the German and American tank developments, and Roland.

The enumeration of these current major programs -- F-16, AWACS, XM-1/ Leopard 2 and Roland -- illustrates the problem and the gap between goal and implementation. The first two are products of the high technology US aerospace industries that compete with and threaten to overwhelm European aerospace industries and make many Europeans suspicious that standardization is a Trojan horse for US industrial dominance. The tank selection is complicated by strong national predispositions concerning armor requirements and tactics as well as by intense competition in automotive industrial capabilities and seems to confirm the inability of the two most industrialized NATO partners to reconcile military interests with competitive industrial interests. The Roland case is unique in representing US adoption of a product of European missile and electronic industries, but is marred by widespread belief (however inaccurate) that US industry and the US Army have "Americanized" the European technology and design and thus de-standardized it.

In different ways, thus, all four of these current standardization projects seem to pit national defense industries against one another and against accomplishment of the goal of weapons and equipment standardization on a basis that can accommodate or satisfy vital national economic, industrial and political interests among the Allies.

DOMINANT THEMES

Two themes have dominated most public and official discussions of NATO standardization in recent years and have become part of the standard rhetoric - especially in Europe. These are the themes of the "two-way street" between Europe and America and of "rationalization" of European armaments policies and industrial capabilities. It would be hard to exaggerate the political importance of these two themes. Two illustrations will suffice.

The first theme was used perhaps most dramatically by Herr Carl Damm, the West German who headed a group of Eurogroup parliamentarians in unprecedented testimony before a committee of the US Senate at hearings on European defense cooperation in March of 1976 (Ref 2). Herr Damm used the "two-way street" to link German support of AWACS directly to a US decision to select the German Leopard 2 over the US XM-1 as a future tank for NATO. Though Herr Damm was not speaking for the Government of the FRG, he expressed an attitude if not an expectation that is widespread in Europe: unless the US is willing to select more European weapons designs for some of its forces, Europe will resist "buying American" even in cases where no clearly competitive European design exists.

On both sides of the Atlantic, the name of Thomas Callaghan is most prominently associated with the theme of the "two-way street." Through his well-publicized writings (Ref 3-5), he has advocated a growing balancing of trade between Europe and North America in military systems, eventuating in a "common market" in military trade, and proclaimed that "rationalized military trade is the only course which could offer continuity of benefits for the United States, for Europe, and for the Alliance" (Ref 3, p 26).

Many Europeans remain skeptical about the "two-way street" of balanced military trade, but it has become vital to political acceptance of US systems, and they are willing to use this slogan to resist US pressures to accept an AWACs or to bargain for offset production of the F-16. Few Europeans openly criticize the slogan, although M. Jean-Laurens Delpech, the French armaments director, was willing to do so in a critical article in the influential, défense nationale (Ref 6). Privately, however, many acknowledge that a common market in defense may be neither feasible nor desirable from either an American or a European point of view.

Europeans have laid far more pragmatic stress on the second dominant theme: rationalization of European armaments policies and industrial capabilities. When Europeans have seemed slow to embrace US policy initiatives on NATO standardization -- such as the US proposal in mid-1975 to create a permanent committee on standardization to report directly to the North Atlantic Council (NAC), -- it has been largely because they fear that in a NATO-wide context individual European states might play their short-term, intra-European competitive interests off against one another in separate dealings with the United States (or have their intramural interests so played). It has become commonplace to argue that Europe must "get itself together" before a better balance can be struck across the Atlantic on cooperation in military development, production, and procurement. This theme runs throughout meetings of the

WEU and Eurogroup and was a major reason for the creation of the EPG since neither WEU (without Norway and Denmark, for example) nor Eurogroup (without France) provided an adequate framework for representing all West European interests. As the rapporteur for the opening session of a recent major symposium on European armaments policy, sponsored by the Assembly of the WEU in Paris 3-4 March 1977, noted:

> the European countries had not managed to agree on the means of co-operating with the United States, which prevented them from defining a coherent armaments policy. The American industrial and technological potential was so great that it was difficult to establish a two-way flow of trade between the two sides of the Atlantic which would allow a balanced development in Europe and in the United States of armaments industries which were advanced to an equal degree.
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> The Europe States were condemned to agree between themselves in order to protect themselves against excessive American competition. ...
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> It was necessary to reorganize the armaments industries in Europe. Rationalization of these industries might raise Europe to the level achieved by the United States. There were thus two problems: the possible protection of European industries in face of American competition and compensation to be granted when certain activities had to be reorganized or terminated. (Ref 7, Summary Record of the First Working Sitting.)

Whether there is much more hope that the rhetoric of the requisite European rationalization will be realized than that the "two-way street" will be realized is open to question. During the past two decades, a great deal of rationalization of European industry has already taken place as individual companies have been consolidated into national industries and several key forms of international cooperation have evolved for collaborative research and development and co-production. In the armaments area, the list of current ad hoc international consortia includes:

PANAVIA (UK, FRG, Italy) for the Multiple Role Combat Aircraft (MRCA)

SEPECAT (UK, France) for the Jaguar

ALPHAJET (FRG, France)

EUROMISSILE (FRG, France) for Roland, HOT, MILAN

HELI-Europe

Two difficulties about such projects are frequently noted. First, they commonly include only two or three principal NATO partners thus excluding many others; and, second, they are based on individual projects and, if they follow the pattern of previous armaments collaborations, may fragment again after production has been completed on those projects. The reasons that European rationalization to date has not been able to accommodate more than two or three partners or to outlive individual projects are deeply rooted in the complex and changing complexion of intra-European economics and politics. In particular, rationalization of European industry may cast the big three - the UK, the FRG, and France -- in a role vis a vis the smaller states not unlike that perceived to be the present US role vis a vis "Europe." The rapporteur's notes on the First Sitting of the above-mentioned symposium ended with: "It was widely known that there was nothing more political than the policy of armaments" (ibid).

EUROPEAN INDUSTRIAL INTERESTS, ISSUES AND CAPABILITIES

Alliance-wide, the driving motivations for the current interest in standardization in NATO are: (1) to improve the combat effectiveness of NATO forces by enabling interoperability and cross-servicing of weapons and equipment across national lines; (2) to economize in the allocation of collective resources by eliminating duplicative research and development and dual logistics and support systems; and (3) to achieve economies of scale and improve returns on investments and reduce unit costs through larger or longer production runs for an alliance-wide market.

To such alliance-wide goals must be added the goals of individual countries to maintain stability of employment and a high technology research and development capability that can enhance long-term industrial competitiveness. These domestic goals frequently compete with, rather then complement or support, the alliance-wide goals. This is especially true for European countries, who individually cannot come near matching either the across-the-board technological-industrial capacity of the US or the size of its own armed forces, who represent the primary markets for domestic suppliers. The cost growth of high technology systems exacerbates both problems of comparison to the US in capacity and in markets for European producers which, in turn, further complicate the problem of achieving standardization within NATO.

Rationalization within Europe of armaments policies and capabilities represents an attempt to integrate a portion both of the market and of the technological-industrial base for armaments. For all intra-European collaborations, thus, the critical issues for negotiation are: (1) work (or employment) sharing; (2) technology sharing in research and development; and (3) market sharing. Such collaborations are typically carried out only after a common military requirement has been identified and sources have been selected to carry the project through from conceptual design to production with the expectation that commitments will be maintained on the negotiated issues. This is in marked contrast to the US procurement philosophy which generally fosters competitive research and development through the prototype development phase and, even when selection is made, at least theoretically requires the possibility of other or second source production and procurement.

Rationalization in Europe necessarily implies a much more intimate relation between industries and governments than obtains within the US. For strictly national reasons (or economic necessities) some key industries, such as the British aircraft industry, have become increasingly nationalized with degrees of government ownership or control that have no parallel in the US. Rationalization across national boundaries tends to abet this trend even further.

To American industry -- with its philosophical emphasis on free enterprise, competition among alternative developers and producers, and government "control" by formal regulations and standards (as opposed to ownership or collaborative negotiation) -- the European pattern of governmental-industrial cooperation seems "foreign." On the one hand, it is alleged to contribute to long-term inefficiencies, particularly in the use of capital resources, low productivity rates in comparison to US industry, and inconsistently applied standards of quality and configuration control. On the other hand, it is believed to give European industries a distinct advantage in negotiating with American counterparts. European labor policies are also believed to contribute to these alleged difficulties—particularly the labor policies restricting the use of multiple shifts and overtime.

Because of the political, as well as economic, nature of the problem, further rationalization of European armaments policies and industrial capabilities confronts a problem as to whether rationalization as integration can be accomplished without eroding or at least levelling rationalization as efficiency and productivity. Both dimensions of rationalization of the European armaments industries will be important to whether an increasing two-way flow across the Atlantic is feasible and desirable, as the US government-to-industry relation remains far more monopsonistic than the European government-to-industry relation.

Despite such caveats and cautions, the evidence so far suggests that consolidations and international collaborations have dramatically contributed to overall European development capability and probably to efficiency and productivity by building on the well-capitalized industries of the principal European partners (see especially Vol III of Ref 8). Particularly in the high technology areas, British and French collaboration has led to the Lynx, Gazelle, and Puma helicopters and the Martel ASM as well as the Jaguar ground attack/trainer jet; French and German collaboration to the HOT and MILAN antitank weapons and the Kormoran air-to-air missile as well as to Alpha Jet and Roland; French and Italian collaboration to the OTOMAT SS naval missile and the air-to-surface Albatros. Many of these systems are clearly competitive with US designs on a systems performance basis.

European technological capabilities that could be competitive with US designs are not restricted, however, to international collaborations or consortia. The British, French, and Germans all have, for example, impressive national capabilities in the design and development of tanks and other armored fighting vehicles as well as guns. Nor are competitive designs and developments restricted to the big three: the Belgians, for example, are noted for small arms designs and the Dutch for electronics as well as some aircraft and shipbuilding designs.

THE SEARCH FOR A POLITICAL FRAMEWORK

In his comprehensive and impressive study for the International Institute for Strategic Studies (IISS), on "Weapons Procurement in Europe," Roger Facer outlines the "range of choice" that Europeans face in defense production and procurement. He summarizes Europe's dilemma by asserting that "taken as a whole, Europe has neither a market for defence equipment comparable with that of the United States nor an industry anything like as large" and, further, that "no European country is self-sufficient in defence equipment, whether in industrial or market terms" (Ref 9, p 28).

According to Facer:

> There are a number of possible ways out of this dilemma. European countries can, collectively or individually, specialize in certain areas and leave others alone. They can import a good proportion of their equipment needs from the United States. They can protect and develop their own defence-related industries. Or they can join with other Europeans in developing and producing equipment in collaboration. (Ibid)

Along with other Europeans, Facer clearly opts for increased intra-European collaboration in developing and producing equipment and is dissatisfied with the ad hoc bases on which this has taken place in the past despite accomplishments in developing and producing individually impressive systems. He looks for the political framework that will be able to establish intra-European collaboration on a more rational and enduring basis.

Facer's paper was written shortly before the creation of the independent European Programme Group (EPG). In a very recent IISS paper in the same series, David Heyhoe, another British civil servant in the Ministry of Defence, takes a hard look at the EPG to assess its prospects for becoming the framework for rationalizing European armaments policies and technological-industrial capabilities. After examining the delicate political relationships among the EPG, NATO's Conference of National Armaments Directors (CNAD), The Eurogroup, and the WEU, Heyhoe asserts that:

> The EPG is a logical, but not a necessary, development from the events which preceded it - for example, it might have been formed as a European sub-committee of the CNAD. As things stand, however, the EPG is potentially a more vigorous solution. In the past other attempts to achieve European co-operation--classically the WEU, and even to some extent the Eurogroup--have been stifled by anxiety not to offend NATO. What is basically a healthy instinct can be taken too far, and it is therefore to be hoped that the EPG will be able to strike a balance, by keeping both NATO and the United States well informed of its activities. (Ref 10, p 27.)

With some despair about protracted and sensitive political negotiations, but with cautious optimism about yet one more try to find the right political framework, Heyhoe prudently concludes:

> It is important that Atlantic co-operation should not be made to wait upon the achievement of European co-operation. ....The two levels of co-operation ... need to progress hand in hand. ...It is true that there is a potential clash of interests between the two, just as there often is between national and Alliance-wide objectives, especially in the field of rationalization. The only way in which this situation can be changed is through development of the Alliance into what it ought to be, namely an interdependent body with greater trust and mutual confidence. (Ibid)

ALTERNATIVE FORMS OF TRANS-ATLANTIC PROCUREMENT

The present trends toward industrial collaboration on ad hoc armaments projects within Europe, the search for a political framework for rationalization of European armaments policies and capabilities, and the trans-Atlantic dialogue on NATO standardization -- all place great pressure on the United States to select more European designs or European-developed systems for its forces. At present the Franco-German Roland air defense missile, the British Harrier VSTOL aircraft, the Belgian MAG-58 machine gun, and potentially a German or a British 120mm gun for the XM-1 carry only very limited hopes of satisfying Europe's desire (or demand) for a "two-way street" in armaments selection. Among these, the Roland is the most visible at the moment, and that is being "Americanized" in production if not in design -- to be procured almost wholly within the US under licensed production arrangements from Euromissile to Hughes and Boeing.

Despite the evident commitment of the US Executive and Legislative branches to NATO standardization, including a "two-way street" that provides for US selection of European designed and developed weapons systems, the obstacles to selection of European systems for US forces are formidable. At least the Services and Congress will generally require that a European candidate system be shown to be clearly superior to an existing (or even foreseeable) American alternative: this is exceedingly difficult when the relative US and European expenditures on research and development are taken into account along with national pride and the relations of the Services to their traditional suppliers. European systems will have to compete on a cost basis as well as on a performance basis: this is also typically difficult given the relative productivity rates, especially between the US and the industrially weaker European countries, and the currency exchange rates with the industrially stronger European countries. Moreover, since a potentially competitive development and production capability generally exists within the US for almost all major systems, US industry and labor will be highly sensitive to dislocations that may be implied or required by a US selection of a European system. This was clearly evident e.g. in the US Army's selection of the Belgian MAG-58 which appeared to threaten job losses in Maremont Corporation in Sacco, Maine.

Although the rhetoric of the "two-way street" and increased trade in military equipment fosters the notion that selection of European designs means direct purchase from European producers, present trends indicate that this form of the "two-way street" has only very limited application even in European selection of US designs. The F-16 selection by Belgium, Denmark, the Netherlands, and Norway under offset co-production arrangements and the US production of Roland under license arrangements suggest that this is the more likely pattern for major systems in the immediate future. Intra-European industrial collaboration and rationalization of European armaments policies and capabilities tend to support rather than to lessen the growth of this pattern despite some popular belief. Which of these patterns of procurement of another country's design is selected -- direct purchase, licensed production, or offset production -- will greatly affect the program costs and the economic, industrial, and political implications of the selection.

The "traffic" in US designs flowing to Europe has shifted dramatically from direct sales to offset production. Licensed production to European firms has also declined somewhat. Those European industries capable of producing whole US systems have shown more reluctance to do so in favor of supporting their own research and development by producing European designs. With direct sales to Europe declining, the US is not likely to undertake major purchases from Europe. Competitive US armaments industries would be reluctant to accept offset co-production arrangements if the US adopts European designs; they would prefer licensed production arrangements as an entry fee into trans-Atlantic collaboration or a new product line. This raises the question of whether selection of current European designs should also be evaluated as a basis for eventual trans-Atlantic co-development -- a pattern presently more in evidence in the civil field than in the military field, and a pattern that could greatly affect the long-term future of rationalization within Europe and between Europe and America.

IMPLICATIONS FOR TECHNOLOGY TRANSFER

Political forums and mechanisms for achieving greater NATO standardization or at least interoperability are not lacking. The incentives seem to be high for NATO as a whole and for individual nations faced with constrained defense budgets and an increasing Warsaw Pact conventional threat. Payoffs are promised in improved alliance force capabilities and in improved allocation of collective resources. Yet there are strong conflicting interests to be reconciled, especially in the industrial sphere. These concern principally the competitiveness and rationalization of national and transnational industries and take hard, concrete focus on issues of division of labor and markets. At the WEU Symposium in Paris in March, referred to earlier, the Warsaw Pact military threat to Western Europe was almost matched by the putative US industrial threat as the justification that gives urgency to a coordination of European armaments policies. Besides rationalization of European defense industries in the senses discussed above, assuring their advanced technological capability and status appears paramount to most Europeans. Therefore, sensitivites are acute to problems in the transfer and protection of technology.

From the point of view of industrial competitiveness as well as national security, the US has generally sought to maintain a technological lead in world markets. From their point of view, European NATO partners have sought to achieve something approaching technological parity with the US as part of the two-way street. This faces Europeans with a serious dilemma: on the one hand, they desire access to the latest, most advanced American technological developments (e.g. precision guided munitions and guidance for cruise missiles); on the other hand, they resist US technological domination and prefer to maximize incentives to stimulate and sustain an indigenous technology.

A recent report on NATO standardization by the Congressional Research Service of the Library of Congress sharply delineated three major approaches to achieving greater standardization across the Atlantic (Ref. 11). These are:

(1) Agreed common procurement, preferably from single sources to achieve the economies of long production runs, with a delicate balancing of arms trade across a spectrum of agreed weapons requirements (the Callaghan approach).

(2) Co-development against agreed requirements with pooling of R&D resources to avoid duplication of effort, followed by shared division of labor and markets in a co-production consortium (the intra-European approach).

(3) Common selection and procurement of independently or competitively undertaken developments, facilitated by a licensed production or offset co-production arrangement to divide labor and markets (purportedly, the preferred DOD approach).

Each of these approaches has advantages and disadvantages. It is unlikely that any one could or should be attempted across the full range of country and NATO requirements. Theoretically, they may be equally attractive in improving the combat effectiveness of allied forces, though the second approach—without competitive development—may be less attractive than the others in this regard. The scope and size of potential economic benefits are different among the three, with the third being least attractive in this regard except in reducing duplicative logistic and support costs. The requirement for and type of technology transfer is significantly different among the three approaches.

All three approaches require technology transfer at the level of information exchanges—especially with respect to ongoing military R&D, replacement and procurement schedules for major systems, mission requirement statements and specifications (at least to the level of detail in a request for proposal) for proposed systems, and test and evaluation standards and measures. The technological content of such information exchanges may be significant enough to warrant security classification. But it should be remembered that it is the security of all NATO partners that is at stake and not just one of the partners. In all but the most sensitive areas, the benefits to security vis a vis the Warsaw Pact to be gained by exchanging information at this level among the NATO partners who have the technological potential to be developers and producers of advanced systems far outweigh the risks that exchanges within NATO will significantly accelerate diffusion of western technology to the Soviet Union and other communist states. The "risks" of fostering industrial competition where it did not exist before within the Alliance are greater. It should, however, be noted that it is in the long term interests—and within their rights as supporters and consumers of military development and production—to foster reasonable competition in military development and production alliance-wide.

Other than this information exchange level of technology transfer, the agreed common procurement from a single source requires the least direct technology transfer. In particular, design and manufacturing technology is hardly transferred at all, except insofar as end product transfer is accompanied by extensive operating and maintenance support. In fact, one of the arguments in favor of this approach is that it not only does not require extensive transfer of critical technology, but that it fosters independent development and specialization in the technologies for which individual nations or industries are best suited. That is, by the greatest free market competition, it encourages technological specialization and development by "natural" processes of selection.

As noted in the previous chapter, co-development requires technology sharing or pooling almost more than "transfer" as such. That is, it represents a deliberate effort to combine resources, including design and manufacturing technology and know-how, and to forego competition in specific technological areas. This approach, in contrast to the former, has taken place in those industrial areas where design and manufacturing technology requires heavy investment in plant, equipment and skilled personnel, such as the European aerospace industry. Willingness to share or transfer technology for military development is present not despite a presumed untoward impact this might have on national industries, but because of favorable impacts it is expected to have. The fact that this willingness is far more European than American is likely to complicate and defer many significant trans-Atlantic co-developments.

Common procurement on both sides of the Atlantic is most likely to involve licensed production or offset co-production arrangements in the foreseeable future. Competition between US and European sources will, broadly, continue under such an approach and seem—sometimes unfairly—endangered by particular selections as winning developers appear to be forced to transfer to competitors some of the technological lead that led to their selection. The potential industrial competitive interests (in contrast to the national security interests) of suppliers and recipients of technology in NATO come most sharply into play in this approach. A supplier of technology generally wants to give up as little technology as is necessary and to provide components and parts for recipient assembly. The recipient, on the other hand, generally desires full transfer:

a. to be able to control and support the acquired system without external dependence throughout its lifetime,

b. to enhance its own state of the art and to derive reasonable spin-off benefits of the technology, and

c. to be able to satisfy (or even extend) normal markets for its own defense products.

These goals are in conflict with those of the supplier of the technology (increasing from a-c). With respect to European NATO partners, the US by the size and diversity of its technological-industrial base and its internal markets is generally in a stronger position to have its way on all three goals—whether as supplier or as recipient, thus complicating the apparent equity of the "two-way street."

Such issues and conflicts—potential and real—are examined in greater detail in the next chapter which deals with case studies of technology transfer and NATO standardization.

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Chapter 4

CURRENT EXPERIENCE IN TECHNOLOGY TRANSFER WITHIN NATO

GENERAL

In preparation for this study, OASD/ISA, with concurrence of ODDR&E, suggested that the study examine representative cases of weapons systems adopted for co-production by one or more NATO countries to identify any problems encountered in technology transfer and to assess current mechanisms of transfer.

Appendix A of GRC's report to OASD/ISA on NATO standardization and licensing policy (Ref 1) presents an overview of US experience in licensing within NATO. That overview identified technology transfer as a problem requiring attention and policy accommodation to facilitate allied cooperation in defense production as well as R&D. Experience with US procurement of the British-designed B-57 aircraft (Canberra), the Dutch-designed WM/22 gun fire control system (American version: MK-87 MOD/0 gun fire control system), the French-designed AN/TPS-58 radar, and the French-German-designed Roland II short range air defense system was briefly reviewed. Similarly, that overview also reviewed experience with European procurement by licensed co-production of US-designed systems including the M-113 armored personnel carrier produced in Italy, the basic Hawk and Hawk II (HELIP) low altitude air defense systems produced by a consortium of five European countries for Hawk* and seven for HELIP**, the CH-53G medium transport helicopter produced in Germany, the NATO Seasparrow shipborne surface-to-surface and surface-to-air missile system

*Belgium, France, West Germany, Italy, and the Netherlands.
**The original five plus Denmark and Greece.

produced in Europe by a consortium of five countries*, and the F-16 lightweight fighter aircraft being co-produced in Europe by a consortium of four countries**. Experience with the European co-developed and co-produced multiple role combat aircraft (MRCA) called Tornado was also briefly reviewed.

Roland II, Sidewinder (AIM-9L) and Sparrow (AIM-7F) air-to-air missile systems, and the F-16 were chosen for further analysis in this study. Appendixes A, B, and C present details of the case studies prepared for this study by GRC's subcontractor, Hoagland, MacLachlan & Co, Inc. (HMC). This chapter presents inferences drawn by GRC and HMC from these case studies and from the previous GRC work which reviewed US experience in technology transfer under licensing and co-production arrangements.

THE ROLAND CASE

The American Roland program was inaugerated in early 1975 with the award of an Army contract to Hughes Aircraft Company as prime contractor and Boeing Company as principal subcontractor for technology transfer, fabrication and test (TTFT) of the French-German system. Hughes and Boeing are co-licensees to Euromissile, the consortium of Aerospatiale of France and Messerschmidt-Boelkow-Blohm of West Germany for the Roland system. The TTFT phase is scheduled for completion in FY80.

Before discussing the program itself and the lessons learned, it is useful briefly to summarize the requirements and developments situation in US air defense for the 1950-1970 period. The US air defense community from the mid 1950s to the early 1970s insisted on a requirement for an automatic and all-weather system designed to insure that the missile would win the aircraft/missile end game. This end game includes the maneuvers or countermeasures that the aircraft takes after the missile is launched and the counter-countermeasures that the missile takes. It was only in the early 1970s that it became apparent that the choice was between less than this idealized capability or none at all. At this point a US

* Belgium, Denmark, Italy, the Netherlands, and Norway.
** Belgium, Denmark, the Netherlands, and Norway

system with a good capability had not been developed, the requirement for the "better" having been a discouraging factor for the US development of a "good" system. Consequently the US began to consider the good systems that had been under development in Europe during the 1960s, the Roland, Rapier, and Crotale.

Roland in its initial configuration is a short range optically (command) guided missile. In its "all weather" version (Roland II), radar command guided direction is added. A US short range air defense missile system with a complex hybrid command/homing guidance and greater sophistication in concept, the Mauler, had been in development in the late 1950s and early 1960s, but the program had been aborted. Thus in the Roland II program the Europeans were in the right place at the right time, and in addition they had balanced cost and technological capabilities realistically against the air defense ultimate mission of shooting down all enemy aircraft all the time. It can be conjectured that US industry could have designed and produced an optically guided missile akin to Roland and its European competitors, Rapier and Crotale, as early as 1960 and could have applied automatic guidance techniques to it that were less complex than those of the Hawk. Thus the American Roland program involves principally the transfer of specific design technology, and not the importation of innovative or particularly advanced technology, and essentially no new manufacturing technology or know-how.

Problems experienced in the transfer of Roland technology, however, included some of those that were present in previous US attempts to manufacture European-designed systems in the US. There were two major differences: (a) the problems were better foreseen and US government and contractor management of the program were very sensitive to them; (b) problems did not exist to such an extent as had been the case in previous programs.

With respect to foreseeing "Americanization" problems, the Congress laid down clear guidelines for the program. There was to be as little deviation as possible from the European design. To this end the Roland

Project Office has been able to procure exact equivalent US parts down to the component level for 90 percent of the 76,950 parts needed. Of the remaining 10 percent a considerable number are European connectors for which it is simply uneconomical to set up a US production source. These numbers which are used to substantiate the claim that the European design is being strictly adhered to, incidentally, tend to support the observation that there has been no significant transfer of new technology or manufacturing know-how from Europe to the US. There has, indeed, been "Americanization" of Roland, but only in the restricted sense that its production will be almost entirely American for the US procurement.

Early in the program, reports and rumors in the press and in the defense communities of both Europe and the US alleged that the US Army had Americanized Roland and thus de-standardized it or even made it non-interoperable with the French and German systems. Both the Project Office and the US licensees have attempted to dispel such reports and rumors and are prepared to document their case, but allegations persist. The Norwegian desire to procure Roland from the US rather than from Euromissile for reasons not related to the technical design of the system only tended to confirm the European fear of "Americanization" in the somewhat rumor-ridden trans-Atlantic aerospace industry.

While there is little evidence that the content of technology transfer has been significantly greater than in previous cases, there is some evidence that in this case the Europeans have been better able to control the terms of transfer. The Hughes-Boeing license with Euromissile had been negotiated without benefit of clear guidelines laid down by the US government. Although the US Army fully reviewed this license before award of contract, lack of precedence as well as guidelines precluded anticipation of serious issues that would develop. For example, US requirements for competitive procurements and third-country sales had to be negotiated after the US was committed to Roland. What may now appear to be hard won concessions from its European developers (Euromissile) probably could have been routinely negotiated in the intense competitive situation which existed prior to US commitment to a specific system had they been foreseen.

One source of difficulty in the Roland program was the sequence of inter-governmental and inter-company arrangements. The Project Office believes, in retrospect, that it would have been best to negotiate a Memorandum of Understanding between governments before the two industries began to negotiate their license agreement. It is this sequence of events that has served the F-16 program so well. However, in the case of Roland, Hughes and other US companies were encouraged to approach Euromissile and other European competitors before the US Army's RFP was issued, and the ensuing license negotiations took place without benefit of any government intervention or the precedent of an MOU on which license negotiations would be based. Consequently, the US government had no opportunity to examine the license until the competition was already in process. As a result, the Project Office feels that the US government's interests in such questions as third-country sales and second-source procurement were not adequately covered, resulting in the need for extensive subsequent amendments to the license.

Of particular concern to the European industry was the provision for second sourcing, which raised the specter of very broad-scale dissemination of their data package. European companies are obviously just as concerned about the loss of proprietary data through technology transfer as their American counterparts and are wary of US industry, if only because of its vast size and competitive capabilities. They fear that the release of proprietary data is tantamount to creating a competitive giant in the world marketplace.

The piecemeal approach to the Roland license agreement has also, in the eyes of the Project Office, led to difficulties in accurately estimating contractor costs. According to the Project Office, Hughes was originally given only enough data by Euromissile to permit them to respond adequately to the Army's RFP. On the basis of the initial data, Hughes assumed that all of the other necessary production data were also available, but this eventually proved not to be so, because the Roland was not fully engineered for production.

Officials in the Roland Project Office in the US Army Missile Research and Development Command feel, in general, that unless the US government takes an active lead in establishing guidelines or international understandings, US contractors may be at some disadvantage or at least in an awkward position in negotiating with their European counterparts, who usually operate in close concert with their own governments. This view is generally shared by Hughes, which was the principal US industrial negotiator on the program. The Roland Project Office goes so far as to argue that under some circumstances the US government should itself undertake the licensing negotiations, possibly even to the point of acting as licensee. This is particularly important, in the view of the Project Office, with regard to the government's need for adequate price competition and the ability to negotiate a second source. Hughes disagrees with this view, pointing out that European firms would be very reluctant to place their complete technical data packages at the disposal of the US government without a firm production contract and a US industrial licensee who could be held contractually accountable for control of the data package.

In the Roland agreement, as in almost all cases, there was also an underestimate of the amount of technical assistance that would be required in early phases of the technology transfer. Both Boeing and Hughes failed to take adequate account of the amount of support and assistance they would need from the various European contractors on the program to acquire, translate and interpret the total data package.

The German and French governments, as well as MBB and Aerospatiale, have been restrictive in their control over technical data. Even with the amendments to the original license, full data cannot be released to potential second sources until the US government notifies the French and German governments of its intent to proceed with full-scale series production of Roland, which will not be undertaken before 1980*. It is

*Hughes, the prime contractor, does not expect to have a US production package until 1980.

interesting to compare this situation with the more generous data exchange of the F-16 program. It suggests that willingness to transfer technology may depend inversely on the capacity of the licensee to absorb the technology; and it also shows that a restrictive view of technology transfer is as evident in Europe as in the United States.

Regarding configuration control, Appendix A shows that there is the prospect of an agreement between Roland producers that interchangeability will be maintained for over 600 field replaceable units or modules in the system. However, this expectation is mitigated by the fact that no configuration control agreement is yet in effect. This, coupled with differing US and European concepts for reliability and techniques for maintenance, could produce some downstream de-standardization. At present Roland II includes built-in and automatic test features, but these are not as extensive as found in US systems currently in development.* US user experience in the field may lead to demands for changes in this area. Moreover, unless the US is willing to accept a closer relationship between factory maintenance and repair and field units, some of the identity of design mandated by Congress may necessarily be lost.

This latter point suggests that not only are there scheduling problems in the NATO nations' acquisition of new systems, there is also a problem in the unevenness of the development of technology and associated concepts for reliability and maintenance. The current concern of US developers and users with reliability and maintainability is the product of many bitter post World War II lessons. These lessons have been learned not only in training bases in CONUS, but in combat far from producer support. European nations cannot be expected to have the same approach to these aspects of weapons developments as the US. On the other hand, it is difficult for the US to forego US concepts of reliability and maintenance whose need has been so graphically demonstrated.

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*Address by Dr. Leonard Gross, Hughes Aircraft Company, "Working a Standardization Case." Executive Seminar on NATO Standardization and Interoperability Sponsored by the American Defense Preparedness Association, August 4, 1977.

The Roland experience demonstrates rather clearly that the US government must in some way take a more aggressive role in the licensing process than it has in the past. Leaving it solely to industry to make licensing arrangements is not in the best interest of the government because of the likelihood that aggressive industrial enterprises will achieve sole source positions. These may result in increased procurement costs for items for which the government could just as easily have obtained a direct license. This course of action requires a certain basic level of expertise on the part of government negotiators and an aggressive program for licensing and exploitation of licenses.

THE SIDEWINDER AND SPARROW CASE

Raytheon, with a long history of licensed production of its tactical missiles in Europe, is one of the most experienced firms in the United States in matters of co-production, co-development, and future avenues to standardization. The Raytheon commentary on licensing Sidewinder and Sparrow reported in Appendix B makes the obvious point, typically made by US industry, that from the immediate standpoint of benefits to the originating firm, direct sales of the complete product and its supporting software and services are by far the most beneficial to the firm itself and probably to the US government as well. The decision to go either to direct license or co-production is made when external factors dictate the more complicated work-sharing formulas involved in courses other than direct sales. In other words, licensing, co-production, and co-development are usually accepted when they provide the most reasonable access available to a marketplace that would otherwise be denied.

Raytheon points out that in the United States the government typically acquires rights to the data package on a weapon systems so that, if it desires, it can procure the weapon readily from a second source in open price competition. As a result, if the data package is provided to a foreign government or contractor, as part of a licensed production program, the supporting services expected of US industry are likely to be rather limited. However, this will be true only in the case of a foreign licensee who has sufficient technical competence to assimilate the material in the data package, but who will still require assistance for the transfer of manufacturing know-how.

Since the license fee is only one part of the typical license production arrangement, an intelligent contractor is naturally sensitive about the amount of information that will be transferred to a foreign licensee. Discussions with US companies indicate that there is no one well-established formula for gaining revenues in overseas licensing. The three main components are: the front-end license fee, the royalty payments on sales, and the hardware and technical assistance package. The amount of royalty fee that can be collected depends on the strength of the foreign licensee, his ability to sell in the marketplace, and the likely size of the production run, all of which will make the royalty payments on sales more or less attractive.

Raytheon argues that industry often is not involved early enough in government-to-government negotiations that ultimately lead to company-to-company licenses. There are a number of companies, such as Raytheon, which have long prior experience and great continuity of senior personnel in the negotiation of international licenses and collaboration. In those cases, it is undoubtedly true that industry is able to provide valuable support to the government during the MOU negotiations to develop agreements best suited to the interests of both government and industry.

In contrast to American experience, European governments and industries almost always work closely together from the outset, with the government very much in control, a fact which can put the US government and industry at a disadvantage. The conclusion is that US industry should play an early and more prominent role in negotiations leading to European licensed production of US designs. However, US industry may occasionally lack the experience to do so.

With specific regard to technology transfer, it is Raytheon's view that government and industry must work very closely together to decide what the impact will be for technology transfer in any given program. Government must, with industry's inputs, decide which basic technologies should or should not be transferred to each country, based on the interests of national security and national policy. Industry is usually in the best position to judge what its overseas counterparts can do and to know how easily foreign industry can develop the design or manufacturing expertise involved in a particular program. The point is that experienced US companies should have a strong voice in making decisions about technology transfer.

Since the original production version of the Sidewinder, AIM-9B, all foreign sales have been by direct procurement of US manufactured missiles. The AIM-9B was licensed for manufacture in Europe, with Bodenseewerk Geratetechnik, GMBH (BGT) as the German prime contractor. In late 1977, the US was negotiating an MOU with the Federal Republic of Germany that would permit the licensed manufacture of the AIM-9L by a European consortium to be headed again by BGT. In the context of these negotiations, Raytheon expressed some concern that there was not more opportunity for industry to participate in the development of the MOU.

Sparrow is a large and successful international program. The AIM-7 Sparrow has been sold directly to many countries and has also been licensed by Raytheon for co-production in Italy, Japan, and Britain. Raytheon considers information as to what portions of Sparrow each of the licensees is licensed to manufacture to be proprietary information. Obviously, the company wants to maintain as much flexibility as possible, based on its assessments of a particular partner's capabilities and intentions, in transferring technology and licensing production.

Because of the development status of the AIM-7F program, the US government was not yet ready to license the AIM-7F in Great Britain, and therefore the British pursued the alternate course of licensed production of the AIM-7E missile with the addition of a British-developed Marconi seeker and EMI fuse, resulting in the XJ-521 Skyflash program. As part of this program, Marconi and EMI granted Raytheon licenses for the seeker and fuse.

The F-16 CASE

At the declaratory level, the principal objective of the F-16 co-production program is the achievement of greater standardization within the NATO alliance. Certainly this is, in fact, an important objective of the program which even the most cynical of European critics would recognize as genuine. On the other hand, there are also some other important motivations which have had at least as much effect, below the declaratory level, in promulgating the effort. As in the Roland case, a long evolutionary process, requiring the integration of many different factors, has been necessary.

On the US side, the history of the light-weight fighter competition, and the long battle by the Air Staff to get funding for the concept, is a very complicated one. The present study does not trace the course of events that led up to the competition between General Dynamics and Northrop, and which threatened in the process to damage the prospects for the far more expensive F-15, which is designed for absolute air supremacy during its lifetime. It is sufficient here to note that a confluence of events and interests, in part fortuitous, opened the way for high-level interest and support, on the part both of the Office of the Secretary of Defense and the US Air Force, in promoting the idea of an international co-production program for the light-weight fighter.

On the US side, according to the recollection of some USAF officers who were close to the situation, the European co-production prospect came to light at a time when the promoters of the light-weight fighter were looking for every conceivable means of selling their concept within the Department of Defense. The prospect of European co-production was not viewed as the primary goal but as a means of enhancing the prospects for the US program. It also seems likely that all of the missionary work that had been performed by Northrop Corporation, especially by its President, in behalf of the P-530 private co-production venture, had helped draw attention, both in the United States and abroad, to the feasibility of the light-weight fighter co-production concept.

On the European side, there had been a long and steady buildup of pressure for a "mini-consortium" of smaller NATO countries to co-develop or co-produce an F-104 replacement that would be lighter, cheaper, and more rapidly available, than the MRCA. It is necessary only to trace the early history of the MRCA consortium to recognize the importance of the Netherlands as the focal point for this planning, beginning as early as 1968. The Netherlands chose very early to break away from the MRCA consortium and began, by the beginning of the 1970s, to coalesce the mutual interests of the smaller NATO countries in the procurement of an F-104 replacement. This was a long process, lasting over five years, but it had an inexorable quality.

It was possible for close observers in the United States and Europe to predict as early as 1969 who the partners would be and what the total production would be. Well-placed observers in the Department of Defense, especially those connected with foreign military sales, were able to predict with some certainty as early as 1970 that the NATO mini-consortium in fact offered possibly that last great opportunity for the United States to participate in substantial procurements of jet fighters in Western Europe. It was generally recognized that the era of the F-104 and F-4 sales and licensed production had come to an end with the major allies and that, for a variety of reasons, the US market potential was closing down rapidly.

The particular composition of the European light-weight fighter consortium was extremely important. The Netherlands had a great deal of experience in working with the United States through the F-104 and F-5 programs and also had a substantial interest in maintaining a strong US presence, both military and economic. At the same time, officials in the Netherlands Ministry of Defense, as well as parliamentarians, made it clear that, in the next round of procurements, it was important for them to work jointly with the Belgians and not permit another split such as the one that had occurred between the F-5 and Mirage V procurements in the two countries. It seemed likely at the time that, if the price for such cooperation was Dutch purchase of a French aircraft, this might have to be acceptable.

The Scandinavian members of the consortium, on the other hand, were under little pressure, such as the Belgians might feel on the continent, to be "good Europeans" and prove their credentials by purchasing a French aircraft. Norway in particular was most concerned with the maintenance of the US presence within NATO and would naturally be disposed to continue its strong defense industrial ties with the United States. Thus, although the competition was hard-fought between the US and French contenders, there was a strong and possibly unique set of predispositions, in a political sense, which marginally favored the United States in every country but Belgium.

Of equal or greater importance was the fact that, because the fly-off competition was well underway, and because the United States had made so many remarkable advances in aerodynamics and propulsion, there was, at exactly the right moment, a product that was far in advance of any competing European proposal. In terms of energy-maneuverability in the air-to-air role and range payload measurements in the air-to-ground role, the US offering represented an entirely new generation of fighter aircraft. In addition, because of the need to sell the concept to the Congress, and also because of the growing interest in NATO standardization, it became expedient for the very top level of the Pentagon to take an interest in the European co-production prospect and to pave the way for full disclosure of the program and the technology to the potential European participants.

Trans-Atlantic programs of this magnitude do not occur very often. They are difficult to get underway, and their success depends on the coincidence of a great many different kinds of interest, both domestic and international, occurring in a sequence that permits support for them at the highest levels of government. Furthermore, a superior product must be available as it was in the case of the F-16/17 and the European low-altitude SAM discussed earlier. Standardization in itself is not a sufficient goal.

Finally, as noted in Appendix C, the F-16 co-production program can, in a sense, be viewed as an anachronism. It is the outcome of a set of interests, within the smaller European NATO countries, that began to crystallize in the late 1960s and will probably not be repeated. Furthermore, the F-16 project is, to some extent, an echo of the F-104 co-production program. Many of the same divisions of industrial labor of the F-104 program - especially in terms of division of airframe sub-sections, can be found once again in the F-16 project. The fact that it is so much more complicated now to negotiate such a project than it was in the early 1960s, when the F-104 consortium was being put together, cannot be attributed solely to the fact that the F-16 involves US co-production whereas the F-104 did not. There is also a strong implication that European partners, even when the major industries of Germany and Italy are excluded, have become much tougher and are no longer willing to be regarded simply as subcontractor job shops for US industry. If the F-16 program included the principal aerospace industries in Britain, France, and West Germany, a number of more difficult issues would have emerged, especially with regard to greater sharing of technology in airframe, engine, and radar co-production.

Consequently, it would be very difficult to hold up the F-16 co-production program as a model of future NATO standardization efforts. It is unique; and, in fact, the hypothesis could be put forth that any major trans-Atlantic collaborative program will be unique, deriving from a particular set of circumstances that gives it force beyond the simple goal of standardization.

One strength of the F-16 program, in the early negotiating phase, was that the federal government itself took the primary negotiating role with European governments. The international negotiating process began before a final selection of the prime contractor had been made in the United States. Consequently, the burden of preliminary negotiation of the terms of the Memorandum of Understanding fell on the Office of the Secretary of Defense and the Aeronautical Systems Division of the US Air Force. This fact not only gave credibility to the program; it permitted a flexibility in the early negotiating that can come only from the high levels of government. By the time General Dynamics entered the scene, the most important basic guidelines had been laid down.

Because of the weakness of the industrial infrastructure in some of the European member countries, it seems fair to say that the establishment of co-producers for several subsystems and components has required substantial technology transfer and resulted in the creation of capabilities which previously did not exist, requiring in turn new investment in plant and equipment. Appendix C indicates several instances in which facilities have been established in the participating countries which duplicate facilities already existing in the major European aerospace producing countries and which, to compound the problem, are under-utilized. The establishment by technology transfer of new capabilities within Europe for aircraft heat exchangers and for landing gears, when the competition for business is already severe, is bound to have some aggravating effects elsewhere in Western Europe.

As noted in Appendix C, the ability of the SPO at Wright Field to integrate senior national representatives of the four European partners, on a fully participatory basis, has undoubtedly been one of the strongest elements in keeping the program on track. In further support of this full participation, the US Air Force has made it a firm policy to be as open as possible in the disclosure of technical information and engineering choices. Furthermore, the sensitivity of the business managers within the SPO to classical European concerns over employment stability and the privacy of financial data have also aided in keeping the program on schedule.

In spite of the openness that characterizes the F-16 SPO, some important efforts have been made to withhold technology in critical areas. It could probably be demonstrated that Westinghouse has withheld some critical technologies in the radar system, especially in view of the rather low level of some of the work that is being performed by the European partners. In the case of the engine, Appendix C makes clear that blade technology, especially with regard to the casting of super-alloys, has been carefully withheld from the consortium partners. The F-16 engine co-producers, none of which is primarily in the engine business, have readily accepted such constraints. A stronger argument for technological sharing might have been put forward if major partners such as Rolls and SNECMA had been involved.

Some of the initial difficulties encountered by General Dynamics in getting acceptable cost proposals from the European co-producers indicate the importance of having as much international negotiating experience as possible at the contractor level. Fortunately, General Dynamics is a large and well-managed company which has been able to work on the problem until it was solved. However, some of the initial problems at the contractor level suggest that, in the best of circumstances, the contractor needs help and guidance from a well-organized facility within the Department of Defense which has total program control and which can speak with authority to the European governments - especially in view of the fact that, in Europe, the industrial contractors are far less autonomous than in the United States.

Conversely, however, if the US industrial partner has a great deal of international operating experience (e.g., Hughes and Raytheon), it is likely to be impatient with what it regards as government interference, preferring instead to handle the international negotiations directly. This appears to be the principal theme of the contractor observations in the Raytheon case study; and it is interesting to speculate what the relationship between SPO and contractor might have been if Northrop, with all of its international experience, had won the light-weight fighter competition.

However, the main conclusion to be drawn, for purposes of the present study, is that there is a considerable risk of underestimating the true cost of the collaborative program in any situation where the contractor must make his proposal before he has full knowledge of the European co-producer, his method of operating, and the amount of technical data that will actually be available at the outset of the program. This appears to have been a contributing factor to the underestimating of costs both in the F-16 and Roland programs. One solution, frequently mentioned, would be the negotiation of licenses taking place from government to government, permitting resolution of technical and manufacturing issues within government before going out for competitive bidding on a much tighter set of specifications - in other words putting a governmental buffer between the industries of the participating countries. It seems likely, however, that these same objectives could be achieved by strengthening the MOU.

Although the production rate will increase rapidly in the United States over the next five years, it would be very difficult for the European participants to expand their rate of production. By the early 1980s, it is entirely possible that US production at Forth Worth will be in excess of 40 aircraft per month, as a combined result of learning curve benefits and buildup of the work force. The European lines, characteristic of European practice in general, will remain at a steady cadence of six per month throughout the duration of the program. This discrepancy will undoubtedly create problems, further down the line, in matters of third-country sales and the degree to which the European members will actually be able to participate.

IMPLICATIONS FOR THE TWO WAY STREET

The two way street concept implies that technology transfer, as well as trade, will flow both ways. In attempting to learn from the technology transfer that has taken place one is handicapped in that there has been relatively little flow from Europe to the US. Also, even in cases where it has occurred the US buyers of the European product would argue that it has not been new technology or industrial know-how that has been transferred, but applications of existing technology which was available both in Europe and the US. Also, these technology importers would argue that there were only certain segments or portions of the technology applications of imported systems that were useful and these did not usually include, among other things, production management expertise, quality control techniques, value engineering, and built-in test and maintenance equipment and procedures. To make up for any deficiencies in these areas and to establish an American production base it is further contended that changes had to be made in European designs, and that these changes have been erroneously labeled unnecessary American "gold plating" or "Americanization" of European designs.

With respect to the flow of technology to Europe, which has been extensive, the US typically exported not only basic technology but also the complete complex of industrial know-how that characterizes contemporary US production methods. There was little "Europeanizing" of the designs, apparently because European industry had little to add in these areas and because it recognized the utility of US production methods and was anxious to gain experience with them wherever possible. In addition, as the case studies show, US exporters often had the leverage to retain configuration control and continue to manufacture key parts of the systems exported which would have made "Europeanization" of American designs very difficult.

The Flow From Europe to the US: A Trickle

US imports of technology from NATO allies have occurred when the right European system was at the right state of development at the right time. There has been no planned US import program or policy. Many of the best European systems have not been considered for US acquisition. Thus, transfers from Europe to the US do not reflect an optimum technology flow, but a rather haphazard one.

The first instance of US acquisition of European aircraft technology is the British/US Air Force Canberra/B-57 bomber program, which occurred in the early 1950s. The previous GRC review of this program concluded that at the end of the B-57 Canberra production "all that remained of the original Canberra was its silhouette" (Ref 1, p. A-12). The aircraft had been almost completely re-engineered and Americanized, and the record indicates that this was necessary for its production in the US.

Later, in the 1960s, when the US Navy decided to adopt the Dutch WM/22 gun fire control system, the US contractor attempted to transfer Dutch technology directly, but was not able to. Among other problems reportedly encountered were "large bundles of drawings, some of which were out of date and some of which were not even related to the WM/22" (Ref 1, p. A-12). Again expensive and time consuming "Americanization" appeared to be a necessary component of the process of establishing a US production base.

In another case, in the late 1960s, the Army decided to buy 24 TPS-58 radars from France along with the rights to produce them. A production base was set up in the US. Although special precautions were taken, including the selection of a US contractor who had corporate connections with the French developer, the problems encountered were similar to those encountered in the Canberra and the WM/22 radar.

While problems such as these do not exist to anything like the same extent in Roland II, technology transfer and Americanization of a production base have been similar to previous experience and more difficult than anticipated. As discussed earlier, they have been due largely to differing American and European procurement philosophies, government-to-industry relationships, and reliability and maintenance concepts and requirements that have persisted even while European technology has advanced.

The Flow from US to Europe: The Main Stream

The case studies concerning technology transfer from the US to Europe uniformly do not mention technical problems of the type encountered in transfers from Europe to the US. This is possibly an artifact of the limitations under which the case studies were conducted, in that the data came principally from the US recipient of European technology and from the US supplier of technology transfers to Europe. Thus, had the European recipients of, for instance, the Sidewinder and Sparrow systems transfers been interviewed, technical problems might have loomed longer than they did in Appendix B. Nonetheless, and in spite of US data bias, the case studies suggest that the transfer of technology from Europe to the US encounters different types of problems than the transfer to Europe.

The relationship between the US government and US defense industries is relatively clear. The US government has ownership or rights in the research and development that it pays for. While it sometimes gives up some of these rights (e.g., for commercial applications) in the process of negotiating development programs, it is clear that there is always a quid pro quo involved. When the opportunity to transfer technology arises, the US government exercises two prerogatives: first, the legal constraints built into the law governing approval of technology transfers of any kind; and second, in the majority of cases outright control of the technology itself. European governments do not typically enjoy the second prerogative to the same degree, making it more difficult for them to provide a complete technical data package and to dispose or direct a technology transfer without the active participation of the industrial developer.

In the post-World War II era it has become apparent that US industry and US industrial personnel like to export technology, particularly to Europe. US-to-Europe programs generally involve large US industry teams in Europe providing technical assistance. In the last three decades such assignments have been regarded as lucrative and enjoyable. In contrast the Europe-to-US programs have not involved Europeans working in the US to any comparable extent.

With respect to US industry, although there has been concern over fostering European competition, there is little doubt that US firms use US-to-Europe technology export to make industrial connections with the European market and in a broad sense to penetrate that market. Hawk, NADGE, Sidewinder, or Sparrow have greatly assisted US industrial penetration of world markets. The US competition for such programs is intense.

The US government has found itself over the past two decades in an excellent position to export US defense technology. It owned data packages which were relatively easy to transfer and had access to industrial corporations which were both willing and competent agents in their transfer. It could deal with problems of configuration control, third nation sales and royalties from a position of great strength. There is little doubt that what trans-Atlantic NATO standardization has been accomplished during these two decades has been largely due to US strengths in this regard.

US industry is not entirely happy with this situation. US industry believes that the government, in negotiating MOUs or licensing agreements within NATO, has largely deprived itself of the experience which US industry has gained and ignored legitimate industry goals. As a result, a more Europeanized approach using selected industrial cooperatives as instruments of the government is sometimes recommended by US industry.

PRINCIPAL FINDINGS

The Window Problem

The opportunities for two-way technology transfer and major standardization activities occur infrequently and depend on the conjunction (on both sides) of military requirements, political will, perceived industrial advantage, and a suitable product. If two or three major standardization programs are successfully established in the 1977-1987 period, they will represent a significant achievement.

The Sequence Problem

Governments must move in advance of industries in the negotiating process, and the MOUs must be very detailed in matters of technology transfer, performance characteristics, manufacturing and delivery schedules, as well as the more routine matters of work sharing and orders. On the other hand, industry should have a role in deciding on technology transfer matters; this will increasingly require that companies on either side of the Atlantic know intimately the capabilities of proposed partners on the other side.

The SPO as Buffer

In programs of US origin, the SPO has been indispensable; and the incorporation of senior Europeans into the US SPO management is one of the most effective practices developed to date in terms of aiding communications, facilitating technology transfer, and reducing frictions. A similar practice should be developed in collaborative programs of European origin.

Jobs and Budgets

As noted in the previous GRC study the United States must be sensitive to European concerns about employment. In the early negotiating phase, jobs are probably the paramount, even if unacknowledged, issue - especially in Britain and France. In the post-MOU phase, as the F-16 and Roland cases suggest, conformity with the budget becomes a key issue and cost overruns create extreme political hazards for a program. Consequently, the accurate estimation of program costs is critical, and the case studies suggest that US industry has failed so far to take into account the "collaboration factor" so familiar to European industry.

European Productivity and the Cost Differential

European partners will need a growing amount of latitude on production cost, due to their lower capitalization per worker, more relaxed work schedules, higher social charges, and shorter production runs. The United States can help by insisting on the concentration of work in major, well-capitalized facilities rather than fringe industries. Even so, over the life of a single program, the higher US production rates will permit learning curve benefits that may increase the cost differential.

Role of Government

Many of the issues raised in the case studies are concerned with the role of the US government in technology transfer. In the case of technology transfer to the US, there is the question as to whether the government or industry should obtain licenses for European developed equipment. On the one hand there are the arguments that if the government buys the license, European industrial organizations will be reluctant to sell. This reluctance is based on two fears: first that the government will not aggressively exploit its license as private industry would do; second that in its production source selection the government will necessarily compromise the licensor's data package.

In the case of technology transferred from the US, US industry representatives expressed reservations concerning the strong role that government now takes. It is argued that the government might achieve a smoother transfer and obtain greater benefits if industry were a more active partner in negotiating.

Importance of Government Rights in Data

One of the critical administrative factors that has facilitated US transfer of technology to Europe is that in domestic development contracts the US generally acquires full rights in technical data and requires a complete data package that would enable it to compete a production contract. European governments typically acquire only foreground rights directly associated with a development and do not require a complete technical data package and do not compete production contracts. Movement of European procurement regulations toward the American pattern would materially ease the two-way transfer of technology.

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Chapter 5

CURRENT POLICIES, REGULATIONS, AND PROCEDURES FOR RELEASING AND CONTROLLING TECHNOLOGY

GENERAL

The foregoing chapters show that there has been tension in US policy between fostering technology transfer and restricting technology transfer. Technology transfer has been fostered in broad commercial areas as part of a policy predisposition toward free trade and worldwide economic development. On the other hand, advanced technology in particular has been regarded as an important strategic asset, and certain commodities and data embodying such technology have been subject to export controls of varying stringency for particular countries since at least 1940.

As technology and its rate of advance in recent years have become more obviously important to the military balance between the US and the USSR at the strategic nuclear level and between NATO and the Warsaw Pact at the theater conventional level, this tension has increased. There now appears to be more urgent need to assure that the Soviet Union and its allies do not gain easy access to Western technology that is militarily significant while at the same time assuring that technology can be transferred smoothly enough among NATO allies to facilitate achieving timely standardization and interoperability at the best technological level available.

This tension at the national security level is complicated by a similar but different tension at another level — namely, that of industrial interests and rights. US policy has generally supported the rights of enterprise to reap the rewards of inventiveness and productivity in open competition. This is, indeed, an element of the predisposition toward free trade and the presumptive responsibility of the government to allow or even to encourage industries to sell their technologies as well as their commodities — either abroad or within the US. Because of the constrained size of the defense market and its dependence on costly advanced technology, competition can become intense and brutal to losers. Every NATO government has sought in some degree to protect its defense industries, both from invasion or domination from abroad and from loss of any technological leads (in unique know-how) from unchecked dissipation.

Thus, governmental national security interests and private commercial interests can come into conflict with repect to fostering and restricting technology transfer. It would be too simple as a generalization, but the characteristics of the worldwide commercial market and of the NATO defense market (especially as large-scale arms transfers or sales to third world countries are discouraged) suggest that — strictly from the point of view of non-governmental industrial interests — less restriction on export or import of technology in the commercial area and more restriction on export or import in the defense area might be preferred.

Clearly, harmonization of national security and alliance security interest with specific industrial interests, which also play a key long-term role in security, is not a simple process. Besides tradeoffs between these two areas of interests, tradeoffs may be necessary between policies apparently dictated by immediate, urgent needs and longer term needs in each area. Multiple national interests and multiple versions of particular interests are at stake in policies on technology transfer.

This chapter reviews some of the key US legislation, regulations, procedures and practices that currently control international technology transfer and the way national security and industrial interests are reflected in them. The purpose is to provide for adequately taking into account US interests in NATO standardization and interoperability in the current reexamination and reassessment of export (and import) controls on technology transfer that are called for by the Congress (Ref 1) and by the Bucy Report (Ref 2).

EXPORT LEGISLATION AND REGULATIONS

Two primary pieces of legislation provide the statutory and regulatory framework for US control of exports by non-governmental entities. These are the Export Administration Act of 1969 as amended, and the Mutual Security Act of 1954 as amended.

The Department of Commerce, through its Office of Export Administration in the Bureau of East-West Trade, exercises control responsibilities and functions under the Export Administration Act for "all exports from the United States, except:

1. Commodities for the official use of, or consumption by, the Armed Forces of the United States, and commodities for general consumption in occupied areas under their jurisdiction when the transport facilities of the Armed Forces are used to carry such shipments.
2. Commodities exported by the Department of Defense pursuant to Section 38 of the Arms Export Control Act.
3. Arms, ammunition, implements of war, technical data relating thereto, and certain classified information, all of which are licensed by the Department of State" (Ref 3, p 2)

and other exceptions that are licensed by Federal Departments and Agencies that have special jurisdiction over the types of commodities and data represented. These include: pennies containing bronze (Treasury); nuclear materials (Nuclear Regulatory Commission) and associated technical data (Energy Research and Development Administration); maritime vessels (Maritime Administration); natural gas and electric energy (Federal Power Commission); tobacco seed and plants (Agriculture); narcotics and dangerous drugs (Justice); endangered species (Interior). All commodities (and data) for which the Department of Commerce exercises export licensing authority are published in the Commodity Control List as part of the Export Administration Regulations (ibid, pp 2,3).

Under the Mutual Security Act of 1954 as amended, the Department of State is responsible for control of all exports of munitions by non-governmental entities - as indicated in exception No. 3 above.* Responsibilities and functions are exercised by the Office of Munitions Control in the Bureau of Politico-Military Affairs. The US Munitions List, discussed in Chapter 3 (pp 32,33), defines categories of munitions and establishes the types of products, components, parts and technical data that are subject to control (Ref 4).

Other Acts, such as the Arms Export Control Act of 1976 and the International Security Assistance Act of 1977, provide the legislative framework for governmental transfers of arms and arms-related assistance and data. The Defense Security Assistance Agency is the executive agency for the Department of Defense in establishing and supervising DOD programs of sales and assistance under such Acts in coordination with the Under Secretary of State for Security Assistance, who has primary Executive Branch policy responsibility. See exception No. 2 above.

The primary device by which control is exercised over exports by non-governmental entities is the granting or denial of a license to export (that is, governmental approval to export the item in question). All items on the US Munitions List require a formal license granted on the basis of a formal application for approval to export to virtually any foreign destination. Items on the Commodity Control List may be exported either under a "general license" or under a "validated license," whichever is applicable. A general license is a broad authorization or approval to export designated commodities or types of commodities, to designated countries, for which neither a formal application by the exporter nor the issuance of a formal license by the Department of Commerce is required. A validated license is a formal document issued by Commerce in response to a signed application by the exporter and is valid only within specific limitations spelled out in the document. The types of

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*Imports of munitions as well as virtually all other imports are controlled by the Department of the Treasury, US Customs Service.

commodities and the countries of destination for which authority to export requires a validated license are indicated in the Commodity Control List.

The fundamental purpose for requiring a formal license to export, granted either by the Office of Munitions Control or by the Office of Export Administration, is to safeguard national security. A secondary purpose in both cases is to support specific foreign policy goals that may not be directly and clearly related to national security - e.g. general or specific embargoes over exports to specific countries in support of a United Nations resolution or in support of US policies concerning human rights. A third purpose of export control reflected in the Commodity Control List, is to protect the domestic economy from excessive drain of certain scarce resources. Otherwise, the presumption is that domestic industrial interests are safeguarded by the granting of export licenses rather than by their denial: exporters have their own interests in mind when applying for export licenses.

RESTRICTING TECHNOLOGY TRANSFER

It should be noted that both the Commodity Control List and the US Munitions List control the export of technology as design and manufacturing know-how as well as the export of technology as products embodied in physical objects and in documented technical data. This is perhaps clearer in the case of munitions control than in general commodity control because of the scrutiny given to any technical assistance arrangments entered into in arms exports, whether for licensed production of US weapons designs or for operating and maintenance support.

General criteria for controlling exports of strategically significant technologies, such as advocated by the Bucy Report, are at least theoretically in effect in the policies that govern approval or denial of applications to the Office of Export Administration for exports to communist countries. "Involved in the decision to approve or reject an application for Eastern Europe are such considerations as:

a. Is the item designed or intended for military purposes? Does it have significant military use?

b. If the item has both military and civilian uses, will the transaction involve only the latter?

c. Does the item contain advanced or unique technology of significance in terms of the export control program's objectives?

d. Is there a shortage of the item in the area of destination that affects the military potential?

e. For strategically significant non-military items, can non-US sources supply a comparable item or an adequate substitute? What is the normal use here and in the free world, and probable use in the country of destination?" (Ref 5, p 6.)

Moreover, the export control program provides in general for the control of technical data whether or not directly associated with particular types of commodities. Technical data, for purposes of commercial export control "means information of any kind that can be used, or adopted for use, in the design, production, manufacture, utilization, or reconstruction of articles or materials. The data may take tangible form, such as a model, prototype, blueprint, or an operating manual; or they may take an intangible form such as technical service" (Ref 6, p 1). Under this definition and the provisions of the program limited types of technical data (general scientific and educational data and certain types of patent applications) are exportahle under a general license available to all destinations. Other types of data may be exported under a general licnese under restrictions (exclusions from specific destinations) provided the exporter has obtained written assurance from the importer prohibiting the further transfer to excluded destinations. Most technical data involving design and manufacturing technology or know-how require a validated license for export to any destination.

The Bucy Report and its follow-on argue basically for a more specific definition and discrimination of what substantive types of technologies are strategically significant, an enlarged DOD role in such definition and discrimination with industrial participation, clarification and improvement of operational criteria and policies, and improved procedures for processing applications and applying improved criteria.

FOSTERING TECHNOLOGY TRANSFER

Technology is released for transfer when an export license is granted to a non-governmental entity through the Office of Export Administration or the Office of Munitions Control, or when the government itself takes positive steps to transfer technology over which it has ownership or rights in data. For purposes of NATO standardization and interoperability, positive steps by government to transfer technology are by far the most appropriate and the most important.

Yet, since industry is the primary developer and producer of weapon systems and the medium of technological advance, the burden for effective implementation of technology transfer for NATO standardization falls heavily on industry. Moreover, government's role in controlling the export of technology in the commercial area and in general munitions control almost appears to place the initiative for all technology transfer on industry. Even when the government owns or has rights in data to a particular weapons system technology, the industrial firm that has developed the system or is the current prime contractor for production and is the potential exporter needs to go through essentially the same procedures to obtain approval to export the arms, technical data, and technical services.

US policies in support of NATO standardization and interoperability, which have progressed rapidly in the past three years, imply positive steps to facilitate technology transfer within NATO at many levels from information exchanges on military requirements to co-production agreements for developed systems — that is, at all stages of the defense systems acquisition process. The recent DOD Directive 2010.6 on standardization and interoperability issued in March 1977 specifically requires that "DOD Components will include NATO standardization and interoperability goals as fundamental considerations in their development and procurement programs for both major and minor equipment items..." (Ref 7, Section IV.D.).

Among the DOD policies established and responsibilities assigned by Directive 2010.6, principal ones affecting technology transfer include:

Policy

DOD research and development (R&D) activities will pursue a mutually cooperative and beneficial policy regarding exchange of information with NATO partners in accordance with DOD Directive 3100.3. This policy is intended to foster an early mutual exchange of technological information leading to development and adoption of standardized or interoperable weapon systems and equipment by NATO countries. This policy will be exercised within the framework of approved guidelines for assessing the impact of weapons technology transfer on US national security objectives. Bilateral agreements should be completed in those cases where required under DOD Directive 5230.1 to establish a legal basis for classified exchange, including added substantive technical arrangements to cover individual sophisticated advanced weapons and technology. (Section IV.E)

Responsibilities

The Assistant Secretary of Defense (International Security Affairs) shall be responsible for:

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Monitoring implementation of the National Disclosure Policy by DOD Components to ensure such implementation (a) fosters the mutual exchange of R&D information for the development of standardized or interoperable equipment by NATO while protecting US interests, and (b) is consistent among agencies. (Section V.A.5)

The Director of Defense Research and Engineering shall be responsible for:

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Ensuring that the Military Departments adequately consider standardization and interoperability in the defense system acquisition process --- (Section V.B.3)

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Assisting the Military Departments and other DOD Components in obtaining information on Allied systems and subsystems. (Section V.B.5)

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Providing technical positions on exchange of technology with our NATO Allies and monitoring ongoing programs. (Section V.B.7)

The Military Departments shall be responsible for:

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In coordination with ODDR&E encouraging early contacts between US development activities and NATO Allies' development organizations to consider reciprocal and mutually beneficial exchange of technology, cooperative or interdependent R&D programs, and appropriate licensed production arrangements to permit possible adoption of each other's systems. (Section V.E.3)

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Determining disclosability of sensitive information under the Department's cognizance as established in the National Disclosure Policy, advising OSD(ISA) in cases where Allied proposals for participation in cooperative programs are rejected on grounds of unacceptable technology transfer. (Section V.E.10)

IMPLEMENTATION

The success or failure of such technology transfer policies and responsibilities affecting NATO standardization and interoperability will depend heavily on the Military Departments and their relations with US industry. It is in the Military Departments' materiel development and procurement communities and, in particular, their specific Project or Program Offices that specific technology transfer and disclosure positions will first be formulated and where they will be carried out. DOD policy elements (particulalry ISA and DDR&E) will need to establish detailed interaction with and monitorship of technology transfer and disclosure positions formulated at this level as well as to provide overall policy guidance. Also, technology transfer and disclosure positions and justifications should be made a significant part of the fundamental consideration of NATO standardization and interoperability goals in the defense system acquisition process and statements concerning technology transfer should be required in all Decision Coordinating Papers.

The substance of this key DOD Directive should be given wide dissemination in the US industrial community and within NATO.

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Chapter 6

PRINCIPAL CONCLUSIONS AND RECOMMENDATIONS

The Defense Science Board Task Force report on export control of US technology (Bucy Report) and the Executive Branch study of technology transfers required by the International Security Assistance Act of 1977 portend tighter export controls that could impact on NATO standardization and interoperability policies. Despite the fact that these studies of technology transfer were stimulated by and are addressed primarily to problems of technology transfer vis a vis the Soviet Union and other communist states, there is widespread uncertainty in industry as to how new policies, criteria, and procedures of export control of US technology will affect the course of allied cooperation in defense development and production. There is an important need for clarification at the highest DOD levels of the relation between NATO standardization and the growing concern to control the export of US technology. It is recommended that, to assist in this clarification, the Office of the Assistant Secretary of Defense for International Security Affairs maintain an active role as advocate of NATO standardization in both the Bucy Report Implementation Study Program and the inter-agency Executive Branch study directed by the Congress.

New US arms transfers policies combined with the growing concern to control the export of US technology have created further uncertainties about prospects for trans-Atlantic cooperation in weapons development and production by means of licensed production and co-development. European concerns about maintaining and utilizing high-cost investments in advanced-technology industries complicate this problem. US policy needs to be especially sensitive to this issue and to seek ways to foster rationalization of European industrial capabilities and to be prepared either to purchase more systems directly from Europe to achieve standardization or to accept interoperability with European designs as an acceptable alternative.

Any means of accomplishing NATO standardization and interoperability (through common and standard technical requirements, through direct purchase, through co-development, through co-production) necessarily involves the transfer of technology either directly or indirectly. The issue of technology transfer and NATO standardization and interoperability is therefore a NATO-wide issue and not solely a US issue. Because Europeans cannot be unaware of or insensitive to US concerns with the control of advanced technology, it is especially important to solicit European views on the identification of those substantive technological areas that are most important to NATO vis a vis the Warsaw Pact and on the best means to provide for technological sharing and development in these areas across the Atlantic. The US should suggest to NATO that NATO undertake a review of technology transfer policies in parallel with current US Executive Branch studies of this subject. Both the NIAG and the AC/94 working group on protection of intellectual property could contribute materially to such a NATO study.

The case studies of technology transfer in current programs of NATO standardization showed that there exist substantial asymmetries in European and American procurement philosophies and government/industry relations that create technical and administrative difficulties for efficient technology transfer, especially from Europe to the US. The principal findings presented at the end of Chapter 4 indicate some of the measures that could be taken in NATO and on either side of the Atlantic to reduce these asymmetries and to facilitate a two-way street in technology transfer. Three principles that can be adopted immediately are:

(a) Negotiate additional general Memorandums of Understanding (MOU) like the US-UK MOU of 24 September 1975 to provide for greater bilateral or multilateral cooperation in research, development, production and procurement and harmonization of weapons acquisition processes.

(b) Negotiate MOUs prior to any licensing arrangements between industries to assure that license agreements satisfy procurement philosophies and regulations of the governments involved and reduce frictions that might arise from requirements to renegotiate.

(c) Establish a NATO Systems Project Office with authority for configuration control for any licensed production or co-production project.

DOD Directive 2010.6 of 11 March 1977 has established clear DOD policies and responsibilities for NATO standardization and interoperability. The success or failure of US technology transfer policies and responsibilities affecting NATO standardization and interoperability will depend heavily on the Military Departments and their relations with US industry.

This key DOD Directive should be widely disseminated in the US defense-industrial community and its provisions with respect to technology transfer strictly adhered to. The substance of the Directive should also be made known to NATO allies, and their Ministries of Defense should be invited to prepare similar directives for their materiel development and procurement agencies.

Appendix A

ROLAND TECHNOLOGY TRANSFER

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INTRODUCTION

Roland is a mobile, short-range, air defense missile system (SHORADS) that was originally developed for the French and German armed forces. The development and original manufacture was a joint venture of Aerospatiale of France and Messerschmitt-Boelkow-Blohm (MBB) of Germany under Euromissile, an international management and sales firm formed for the purpose. One version of Roland is a clear-weather system that will soon enter the inventory of the French Army. Roland II is an all-weather system now in its final stages of development for both the French and German armies.

In January 1975 the US Army selected Roland II to meet its requirement for an all-weather,mobile, short-range, air defense missile system. Competition included the US developed Chapparal (Ford Aeronutronic), the French developed Crotale (with Rockwell International as the US licensee), and the British developed Rapier (with United Technologies as the US licensee). Hughes Aircraft Company and the Boeing Company are co-licensees for the Roland II system, with Hughes as the prime contractor with the US Army.

Both the missile and the firing unit of the Roland system are intended to be standardized or interchangeable among the French, German, and American armed forces or any other NATO forces that may procure the system (e.g., Norway). The chassis on which the firing unit is mounted varies from country to country. The firing unit for Roland II, comprising twin missile launch tubes on a revolving turret, houses search and tracking radar, electro-optical sight, and IFF interrogation, for all-weather operations and includes various power systems, an environmental control system, and crew stations. US Roland is operated by a four man crew consisting of commander, gunner, assistant gunner, and driver. The standard load of missiles consists of the missiles on each of the launch tubes plus two magazines of four missiles each for a total of ten missiles. The Roland II missile is command-guided and has two types of tracking emitters mounted on its aft end. For clear weather operations, a flare provides the source for infrared optical tracking; for nighttime and poor weather operations, a radio beacon provides emissions for radar tracking.

According to Jane's Weapon Systems 1977, the first production Roland I fire unit, mounted on a French Army AMX30 tank chassis, was rolled out in January 1976. The French Army is expected to receive 144 Roland I and 70 Roland II firing units. In addition, they will accept 26 Roland I and 12 Roland II firing units as spares. Their total order includes 10,800 missiles. The German order includes 340 Roland II firing units to be mounted on their Marder SPZ APC chassis, with 54 spares and 12,200 missiles. The first five firing units are to be delivered to the German Army in 1977, together with 80 missiles. A further five firing units are to be delivered in 1978, with the remainder of an initial order of 143 to be turned over progressively through 1982. Two hundred Roland II systems are to go to the Luftwaffe between 1983 and 1988 for air base defense.

A hybrid version of the Roland II is being proposed jointly by Euromissile and Thomson-CSF to the Belgian Army. Designated the Roland IIS, the system is configured from a Roland II firing unit mounted in a cabin on a Berliet GBD 4x4 wheeled vehicle rather than on a tracked vehicle chassis. It may also feature a Crotale search radar in place of the standard Roland equipment, with the hope of increasing acquisition range and improving resistance to jamming. The Belgian Army requirement would be met by 22 firing units for air base defense.

The US Army's Roland program is presently in the technology transfer, fabrication and test (TTF&T) phase, which is expected to cost $265 million, only $31 million above original estimates, as compared to approximately $1 billion (by US Army estimates) to develop a domestic system of comparable complexity. In spite of this increase, the Army believes it is getting an effective air defense system by transferring the technology from Europe, at a cost that is considerably less than if it had developed an equivalent system from scratch. Any cost increases due to problems in technology transfer are considered to be more than offset by savings in research and development costs.

During the TTF&T phase the American manufacturers will build four firing units and 126 missiles. Given success at subsequent decision milestones, the US Roland is expected to enter low-rate production in FY1979 for approximately 35 firing units and 814 missiles. Full-scale production decisions will follow, and no quantities have yet been publicly discussed.

Though Hughes is the prime contractor and Boeing the principal subcontractor during initial procurement, the work division between the two US companies is essentially even. In the fire unit module, Hughes has responsibility for the major electronics including the search radar and track radar, electro-optical sight, and the IFF. Boeing has responsibility for the turret, the launch arms, the gunner and command stations, the primary power and environmental control units, and missile magazines, and for integration of all these subsystems into the fire unit module and thence into a specially modified GFE M-109R self-propelled howitzer chassis. Similarly, in the missile itself, Boeing has responsibility for the aft section and warhead, while Hughes (Tucson) has responsibility for the forward section, electronics, and integration. Both Boeing and Hughes are procuring technical assistance from various European contractors in addition to Euromissile.

The magnitude of the technology transfer problem can be gauged by the fact that more than 11,000 suppliers are participating with Hughes and Boeing in the TTF&T phase. Those with purchase orders of $100,000 or more are:

Agnew TECH TRAN	- translation services
American Electronic Laboratories	- command receiver
Bowen-McLaughlin-York	- M109R tracked vehicle
Brunswick Defense Division	- booster/sustainer igniter
Ellis & Watts Co.	- environmental control unit
Eureka Co.	- missile thermal battery
Fermont Div./Dynamics Corp. of America	- primary power unit
G & H Technology, Inc.	- umbilical
Goex, Inc.	- warhead loading
Hazeltine Corp.	- IFF interrogator
Hercules, Inc.	- solid propellant
Microwave Associates, Inc.	- beacon transmitter
Raymond Engineering, Inc.	- impact fuse
Standard Tool & Die	- reflector housing
Timex Defense Products Div.	- gyros
Thiokol Corporation	- infrared flares
Varian Associates	- magnetrons

The next two sections present discussions of various aspects of the evolution and management of the US Roland program from the point of view of the Army's Roland Project Office and from the point of view of the industrial partnership as represented by Hughes Aircraft.

PROJECT OFFICE POINT OF VIEW

Since the US Army's adoption of Roland II represents virtually the sole case of US adoption of a major European-developed weapon system to meet a requirement for the NATO environment, officials at the US Roland Project Office in Huntsville, Alabama were queried at length on procedural and technical aspects of the management of this technology transfer from Europe to the US.

Licensed Production as the Vehicle of Transfer

Officials in the Roland Project Office make it clear that they believe that contractor-to-contractor licenses for weapon systems require direct governmental supervision and intervention to be an effective approach to technology transfer for NATO standardization. US contractors may be placed in an awkward and disadvantageous position in negotiating a licensing agreement with their European counterparts, since the latter are frequently international consortia, or very closely tied in with (or even owned by) their own governments, or both. They need the US government to guide and support licensing negotiations to balance the combined strength of the European government and industry partnerships and to represent US governmental interests. This requirement also derives from the fact that there may be fundamental conflicts between the interests of the US government on the one hand and of US industry on the other.

US government interests do not always coincide with those of the US contractor. The contractor is interested in profits and in maintaining a strong market position. The government, on the other hand, wants adequate price competition, ensured inter alia by the availability of a second source. Such divergent interests can lead to misunderstanding, conflict, and cumbersome negotiations. The Roland Project Office believes that the interests of the government must be protected and the potential for friction reduced by means of a Memorandum of Understanding (MOU) between governments negotiated prior to any licensing arrangements. The company license to manufacture can then be properly structured within that framework. It has been the general practice to follow this procedure for the export of US technology, but the Roland Project Office — on the basis of their experience in requiring adjustments in the license arrangement — emphatically believes this sequence should be followed for import of technology as well. The MOU should lay out the essential conditions of technology transfer and express every interest that the government has, for example, in data, manufacturing rights, and sales rights. The contractor's license, then, would reflect these requirements and be extended by company-to-company negotiations to include royalty fees, payment schedule, and other business considerations.

The Roland Project Office recognizes, however, that while a pre-license MOU is considered to be the best approach, it is doubtful that a uniform approach that can be applied generally each time can be formulated. The climate of international relations, national politics and economics, the number of potential candidates for selection, and the existence of other major NATO procurements during the time of negotiation will affect each MOU as well as the US corporate structure and the statutory requirements for competition. What may have been best for Roland may not be best next time, depending on the atmosphere in the Alliance, in government, and in industry at that time.

In retrospect, the Roland Project Office would have preferred to have had the Roland license developed in the following sequence: first, negotiate Memoranda of Understanding with each of three nations — the United Kingdom, France and Germany; then ask the foreign governments to instruct their industries to seek US companies with whom they would negotiate licenses for the purposes of pursuing the Army's missile competition. In fact, however, as early as 1970-71 the US government signalled US industry to seek potential forms of cooperation with European designers and developers of advanced technology systems and both Hughes and Boeing approached Euromissile directly in anticipation of the US Army's Request for Proposal to meet its SHORAD requirement. The license negotiations for Rapier and Crotale as well as Roland took place without benefit of the US government's intervention through an MOU, and the US government had no opportunity to examine the licenses until the competition was well underway. Accordingly, there was no opportunity to ensure that certain essential conditions were included, in particular the right of the government to procure from a second source or to pursue third-country sales. This has since resulted in extensive subsequent negotiation of key amendments to the license for the selected system to remedy these deficiencies.

As may be expected, Euromissile was extremely reluctant to amend the original license to provide for the possibility of procuring the production version of Roland from additional sources. Second sourcing for production would mean that Euromissile may have to develop a whole new network of ties with US companies, which would face them with the threat of still further loss of control of their data.

Europeans are suspicious of the vast US industrial complex. They perceive that once their data have been released to US industry, such data will be used for purposes beyond the limits of the license. The more companies involved, the greater they see the danger to be. This concern is manifested particularly in Amendment No. 9, which gave the US government the right to use all manufacturing data to procure from a second source. Euromissile was unhappy with this requirement but acquiesced with the proviso that unsuccessful potential second-source offerors would be required to return all data with a certification that they had not and would not use such data for their own purposes. Furthermore, the US government was required to assure that every reasonable step would be taken to protect the data. It should be noted, in this context, that Euromissile rather than the governments of France and Germany owns the data, and is, therefore, privileged to place any restrictions on data release and use that it sees fit and can negotiate, subject only to export controls of the two governments.

If the program has an area of difficulty, it is that of data protection. As indicated, the Europeans have been cautious from the outset. When Hughes approached Euromissile with the RFP, they were given only enough data to permit them to respond adequately. These included drawings, parts lists, etc. for two representative items of hardware. On the basis of the data that were made available, it was assumed that Roland was a mature system, ready for production, but this was, in fact, not so. Only after Roland was selected and Euromissile freed additional data was it discovered how much was missing.

An example of some of the confusion surrounding rights in data is that of the procurement of Roland by Norway. One amendment to the license granted Hughes the right to manufacture Roland II for resale by the United States to third countries, subject to French and German government approval. The United States believed that this amendment granted unrestricted rights and offered a sale of the weapon system to Norway. The misunderstanding was compounded by the fact that the French and Germans first learned of the error when the government of Norway announced its intended procurement of the system from the United States. The compromise solution allowed the United States to sell the system to Norway, but required that the United States procure the missiles from Euromissile.

Most of the amendments were finally negotiated to the satisfaction of the US because the Europeans perceived that they ran the risk of losing the US program altogether if they did not accept statutory and other US restrictions and interests. Loss of the US program would have had a severe second-order effect on their business elsewhere in the world as well as the immediate financial loss of licensing and royalty fees. Although most problems have now been resolved, the Roland Project Office cites these types of difficulties as a principal reason for early government involvement in the licensing process. It is the government more than the contractor that must determine, early in the cycle, which data restrictions are acceptable and which are not.

Amendment No. 9, which allows the US Army to procure from a second source directly, was the most difficult to negotiate and also the most important. Data can be made available to potential second-source producers, however, only after low-rate production is first undertaken with Hughes/Boeing. The low-rate production contract for approximately two fire units per month is expected to be let in about October 1978. Approximately two years later, the decision will be taken with regard to full-rate production; and only then can the data be used for second-source procurements.

Implementation

The Project Office believes that one of the major keys to successful Roland technology transfer has been parts selection. The Office's intent is to retain the technical integrity of the system. They wish to transfer the European design intact. There was and is no desire to "Americanize" the system. In fact, during the transfer and fabrication process, Hughes had to obtain Project Office permission to use near equivalent rather than exact equivalent parts.

The linework of the original European drawings has been reproduced photographically, with only French and German legends translated into English. Even so, there have been difficulties that had to be overcome. One is that the data and drawings sent to Hughes and Boeing came from 13 different companies in France, Germany and Belgium, each with its own variation and style. Another is that European drafting practices differ from American in that European industries use first-angle projections rather than the third-angle projections in use in the United States, which are 180 degrees out of phase.

Of the 76,950 parts in the system (exclusive of vehicle and communications equipment), approximately 90% of the US Roland are the equivalent of the European parts, down through the component level. Similarly, 92% of materials and processes are exactly equivalent to those in the European system.

Of the number of parts cited, 54,800 are exactly equivalent US parts. Roughly 4,000 are nearly equivalent US parts, and 9,430 are European-purchased parts. Most of this latter group will eventually be procured from US sources. A major exception will be electrical connectors to permit interchangeability with European systems and for which it would be too costly to set up a US source. For example, it is estimated that the set-up cost for the 32 families of connectors in the system would be $1 million per family. Clearly, it would be impractical to develop US sources, particularly in view of the fact that these connectors can be stockpiled against future eventualities.

The remaining parts (US MIL STD) in the syetem, 8,720 of them, will be of US origin. These are in the prime power and environmental control units, the vehicle module, and the tracking radar transmitter. The first two subsystems are national items, unique to the US design. The vehicle module is also unique, in that it serves as a transition hull for the specially modified GFE M-109R vehicle. (The Europeans integrate the fire unit directly into their vehicles.) Finally, the tracking radar transmitter is a different design from that of the Europeans, resulting from a more stringent US assessment of the electronic countermeasures (ECM) environment posed by the Warsaw Pact. The US track radar transmitter has higher power and resultant cooling requirements than the European. The French and German armies have expressed interest in this higher-powered version being developed in the United States.

There will be one further change in the system from the original European design that has led to allegations of "Americanizing" the system. When the US Army conducted a preliminary evaluation of Roland and other foreign systems in 1973, it recommended to the developers that the analog command computer be replaced by a digital computer. The developers concurred in this evaluation, and Roland II will eventually have a digital command computer designed by MBB. In the meantime, the US Army selected Roland with a caveat on the computer and will accept the first four test units with the analog computer supplied by Euromissile. American production of the digital computer will await completion of the MBB-designed digital computer. Such history has led some partially informed French and German officials to complain to the authors that American engineers have redesigned the computer system for Roland.

The very high proportion of exactly equivalent parts in the US and European systems provides for interchangeability well into the subassembly level. The optimum level chosen for interchangeability is the level of the field-replaceable units (FRU), and more than 600 FRUs in the system have been identified as candidates for interchangeability between the US and European systems. Once these have been negotiated as a common list of FRUs, neither party will make a change in any item on this list without full coordination with the other. In wartime, this approach will ensure that - with few exceptions - a failed FRU in the system of any national force can be replaced with an FRU from an ally's stockage of parts.

Peacetime maintenance and repair are a slightly different matter, however, due to the US Army's stringent requirements for high-reliability components. Because of these requirements, the US FRUs may be expected to have better reliability also. For immediate operational and readiness purposes a US Roland may accept temporarily a European FRU, to be replaced later by the repaired US FRU or with another US FRU. The logistics of this approach are under review jointly by both parties. The candidate list of FRUs will also indicate which units are exact equivalents to assist the logistics groups in establishing their system.

In general, the Roland Project Office believes that the Roland program provides a reasonable and workable model of technology transfer to realize the objective of NATO standardization in weapon systems. The evolution of the weapon system from its present TTF&T phase to full field operability is under the control of the three industrial participants, Euromissile, Hughes, and Boeing. Under these circumstances, interchangeability may be difficult to maintain without tight configuration control. The situation is compounded by the fact that any improvements made by the US participants cannot be conveyed to the Europeans without State Department export license approval. This initial program nevertheless is helping to establish a framework in which any subsequent weapon system of any kind can be transferred and further developed. Approaches to operations, logistics, maintenance and repair, etc., can all be adapted for future systems which will have as the ultimate objective an improved NATO fighting capability.

After an initial period of caution and wariness regarding being over-powered by the US industrial behemoth, the Europeans have relaxed considerably, and relations between the parties continue to improve. The Joint Roland Control Committee, of which there are six subcommittees, and the obvious US commitment to commonality and interchangeability have given the needed reassurance to the Europeans.

THE INDUSTRIAL CONTRACTOR'S PERSPECTIVE

The prime US contractor and co-licensee with Boeing for the manufacture of the Roland air defense missile system, Hughes Aircraft Company, has a history of interest and participation in the program that predates the formal US Army requirement. As early as 1970, Hughes foresaw a future US Army requirement for a short-range air defense missile and possible US interest in several European systems then under development. With the limited data they were able to obtain at that time, the Company made performance and cost effectiveness comparisons of various US and European weapon system designs. The issuance on 1 November 1971 of the Memorandum titled "Licensing Agreements between U.S. and Foreign Companies on Foreign-Developed Items" by then Deputy Secretary of Defense Packard gave impetus to the Hughes investigations.

The Company took the Memorandum seriously and placed high value on its intent. They recognized that to satisfy the future US Army requirement for an air defense missile, a choice would have to be made between procurement of an existing European system and the design, development and engineering of a totally new US system. The situation was unique. For no other US weapon systems requirement did there exist several strong foreign options that appeared the equal of or superior to the one US counterpart. The choice, therefore, between procurement of a foreign system and a new US development would in the end have to be made on the basis of significant, major cost savings to overcome the domestic military/political view of the superiority of American weapon systems. The Packard Memorandum was perceived as laying the groundwork for such a possibility. Hughes' decision to seek a license to produce Roland for the US Army SHORADS competition was not at the outset an obvious choice. In the early 1970s, Hughes had enjoyed (and still enjoys) excellent long-term relations with both Thomson CSF in France and British Aircraft Corporation (BAC), both of whom were well into development of battlefield air-defense missile systems, namely Crotale and Rapier. At the same time, Hughes and Euromissile, Roland's developer, were head-to-head competitors in the NATO and world anti-tank missile market: Hughes' TOW versus Euromissile's HOT and MILAN.

On the surface, then, it would have appeared that business agreements would have been pursued with Thomson CSF or BAC for the forthcoming SHORADS competition. Hughes' relationships with the two European companies had included not only extensive work together on the NADGE program, but had also encompassed a joint-venture company with Thomson CSF called TVT. It was natural, therefore, that both Thomson CSF and BAC should invite Hughes to represent them in the expected competition. Thomson

CSF approached Hughes both directly and through its US agents, DGA International, Inc., to promote Crotale in the competition. BAC took an even more vigorous approach. Even as BAC was coming to an agreement with United Aircraft Corp. (UAC), now United Technologies, on Rapier, both parties recognized that an experienced manufacturer of missiles was required, and UAC pressed Hughes to join with them in the Rapier system. In assessing Rapier's cost and performance, Hughes had the benefit both of a number of simulations that UAC had run as well as extensive conversations with BAC's chief engineer. Based on its studies of the Thomson CSF and BAC data in comparison with its earlier investigations of Roland, Hughes concluded that, of the three, Roland was the most cost-effective system. Accordingly Hughes made a decision to seek to negotiate a license for Roland.

It is important to keep a chronological perspective on the licensing activities. The Hughes decision to seek a license for Roland was taken in 1972. The Army requirement for SHORADS had not then been validated, and in fact was not until after the findings of a special task force in the summer of 1973. Even then, a question remained as to whether the procurement would be forthcoming. The RFP was issued, however, in August 1974, responded to in September, and the Army made its choice in January 1975.

Having made their decision on Roland, Hughes sought a meeting with Aerospatiale. The meeting was arranged in France as a result of a personal relationship between Hughes' marketing manager and General of the Army Jean Crepin, then Vice President of Aerospatiale and President of Euromissile. At this meeting Hughes conveyed its conviction that Roland was superior to the competitors. Hughes spokesman also expressed their sensitivity to the fact that the two parties were strong competitors in the anti-tank field, which might affect Hughes' eligibility to represent Aerospatiale in the latter's view. General Crepin responded to the effect that, "In business as in war occasionally people are friends, occasionally enemies." The outcome of this first meeting was that Euromissile welcomed Hughes to compete for the US license.

Several other US companies were, at the same time, invited by Euromissile to express interest in representing them with Roland in the expected Army procurement. Several companies, Boeing among them, responded to this invitation with oral presentations on their capabilities. Boeing had independently come to the same conclusion regarding Roland's superiority, and had approached Hughes to explore their mutuality of interest in the system. Following the verbal presentations, Euromissile then invited written proposals which were to include proposed royalty schedules. Although Boeing and Hughes had continued their discussions, each submitted a proposal independently, since no agreements or understandings had yet been formally reached.

In all, about ten written proposals were submitted to Euromissile. This number was reduced to four or five contenders who were invited to participate in a final round of discussions and negotiations. It was at this point that Hughes and Boeing joined together in a team, since their marketing intelligence suggested that they were the leading contenders among the finalists. The Hughes/Boeing agreements specified that Hughes would take the lead in negotiations and would represent the team to the US Army, although the license from Euromissile would be issued jointly to both companies. The specifics of the contractual relationship between the two US companies were deliberately kept open until the RFP was issued. A general agreement was reached between the Hughes/Boeing team and Euronmissile in October 1972, still some nine months before the SHORADS requirement was to be validated. This general agreement laid the framework for subsequent more detailed agreements and for the license itself. Such agreements were signed by all competitors for the Roland license.

Finally, Euromissile made their choice of the Hughes/Boeing team to represent them, and issued a license for the manufacture of Roland in November 1973, to be effective on the date of contract award by the US Army. Upon issuance of this license agreement, Euromissile became much more liberal in their release of technical data on Roland to the US team than they had been earlier. While still more disclosure had to await contract award, Euromissile made sufficient data available for Hughes and Boeing to write what became the winning proposal. At the time of the RFP, Hughes and Boeing entered into firm agreements which designated Hughes the prime contractor and Boeing the sub-contractor, although each is a co-licensee from Euromissile. In the latter respect, each participates equally in all licensing and amendment negotiations.

During the license negotiations, Hughes had little guidance from US government sources as to what elements the license should contain. It is, of course, true that there was no validated Army requirement at that time for the system. No one in the Army, moreover, appeared to be in favor of procuring an off-shore development. Hughes was looking for inputs relative to hard requirements, special arrangements or other matters that the government considered essential, together with ideas on financial considerations such as down payment, fees and royalties. Royalties and fees, in particular, would bear heavily on the overall cost effectiveness of the system, but were also recognized to be an important subjective issue. No real guidance was forthcoming, however. For future licensed production in the United States, Hughes believes the DoD should provide clear guidelines for the license arrangement setting forth guidance on fees and royalities, second sourcing, third-country sales, and the extent of the data package, and with provision for a technical support contractor. Had this groundwork been laid initially, the necessity for subsequent amendment of the license to embrace some of these matters would have been significantly reduced.

Of the nine times the license has been amended, eight were at the request of the US parties, with attendant yielding of rights in most instances. (The one amendment requested by Euromissile dealt with changing the bank to which payments are made.) The license, as originally issued, was quite restrictive. It allowed for manufacture of Roland by a single contractor in the United States for sale only to the US government and for use only by the US armed forces. Very early, the Army requested that the license be amended to provide for second sourcing, and this amendment was negotiated prior to contract award.* Subsequent amendments have dealt with critical issues referred to above, for example, third-country sales, data package, and support contractor.

Amendment 8 allowed second sourcing only after low-rate initial production had been completed. It restricted the use by second-source bidders to the limited data made available to the prime contractor for his original proposal. The Army later recognized that such data restrictions would place limitations on their procurement process: limited data for the RFP, then full data to the second-source winner. Accordingly, in August 1976 they requested that the contract be amended again to allow the Army to use, with appropriate legal restraints, the data then in its possession for second-source procurement.

While Amendment 9 permits any qualified US company access to the data for bidding purposes, the data cannot be released until the US government notifies the French and German governments of its intent to proceed with full-scale serial production of Roland. This production will not be undertaken before 1980, and Hughes does not expect to have a US production data package before 1980. A successful second-source bidder would receive a sub-license from Hughes for manufacture of Roland. Amendment 9 also permits the Army to procure spares from multiple sources, once full-scale production is established. The primary obligation for protecting Euromissile's data rights through these subsequent bidding cycles has fallen upon Hughes. They believe that the US government should assume greater responsibility in this regard.

Each of the license amendments — e.g., privileges, money, etc. — has required that the licensees make payments in some form as a quid pro quo. In certain instances, this has resulted in Hughes and Boeing yielding a right in order to obtain a right demanded by the government. The

*The Europeans had originally (1974) offered unlimited rights in data for compensation of approximately $300 million, and limited rights (which were accepted) for US consumption only for $100 million.

government has not yielded rights. An example is the amendment which gives the government's support contractor, Sperry Rand, access to the same data as the Roland licensees. As always, data dissemination is a matter of tension with the Europeans. In order to obtain this amendment on behalf of the government, therefore, Hughes and Boeing yielded the right of approval on changes and improvements to the system to be transmitted to Euromissile. Originally, Hughes and Boeing had the right, together with the US government of approving changes. Now the industrial parties have been eliminated from the approval chain. This makes the US procedures symmetrical with the Europeans, in that changes in Europe flow directly with approval of the French and German governments, and do not call for Euromissile approval.

Hughes believes that many difficulties could have been avoided had the matters been recognized as government requirements before the license was issued. Hughes officials note that while the Europeans may not have had formal guidelines from their governments, they enjoyed far better communications in the pre-license stage.

There is a strong concern at Hughes that a trend may be developing within certain DoD circles to back away from the principles of the Packard Memorandum in the future, and have the government assume the foreign license directly. Hughes sees some major dangers in this approach. In the first instance, the government would place itself in the position of itself evaluating each foreign system that it may wish to consider for a given military requirement. Once that process is completed and a system chosen, the government would then negotiate a company-to-government license with the successful foreign manufacturer.

In order, next, for the government to offer the system for competitive manufacture among US industrial organizations, it would be required to broadcast the complete data package to many firms - certainly, at least three. Here is the point where Hughes believes the Europeans would balk. The Europeans' perceptions are that they would run a grave risk if their company-developed data were distributed widely throughout US industry. They believe that the data would be used to educate US industry with the risk that there may never be production payoff by fees and royalties. The US would then utilize the data to upgrade its own technology to leapfrog the European systems, and wipe them out competitively in world markets. This scenario may not in fact develop, but it is one the Europeans fear. Further, for a European company there is the legitimate fear of inexperience, lack of knowledge and inability to deal on an equal basis with the US government in adjudicating misunderstandings or in the event of a breach of contract dispute. Moreover, a major disadvantage to DoD would be that the selected US contractor could claim that any problems arising during the technology transfer process were the result of a deficient data package supplied by the US government.

Turning to other programmatic management matters, Hughes believes that, in spite of the difficulties attendant upon the license, the program has come together very well, and that they now enjoy excellent relations with Euromissile. A strong cadre of subcontractors has been assembled. The license gave Hughes and Boeing full freedom to subcontract in the conventional manner. Normal bid and procurement procedures are employed, again with the familiar legal restraint that the data not be used for any other purpose. Concerns regarding data extend down the European subcontractor chain as well. On certain items the European subcontractor to Euromissile will not release data for manufacturing purposes because of patent considerations and the availability of items from US sources. This type of problem is expected to be resolved, but in some cases it may require that Hughes and Boeing write their own performance specification for the subsystem for US procurement.

The people close to the program on both sides of the Atlantic are not concerned about the "Americanization" issue. They point out that there have been only two design changes made, and these occurred in the proposal phase. One was in the size of the detonator squibs to meet more stringent US safety requirements. The other was a higher-powered transmitter in the tracking radar. Hughes exercises strict management control to forestall the natural engineering-department propensity to make improvements in the system.

One curious development of standardization and interoperability results from the fact that the French and German military are integrating Roland into different vehicles. Each European version thus has a different prime power and environmental control requirements. As a result of original US requirements, Boeing designed an interface module to permit universal vehicle integration. This has resulted in the US system being more attractive to additional countries, since they can integrate it into the vehicle of their choice and not be forced to buy either the French AMX30 tank chassis or the German Marder APC chassis. This prospect is of concern to the Europeans.

Overall, Hughes believes that their participation in the program has satisfied their original objectives. These were: to accept the challenge for its own sake; to serve as a catalyst in strengthening relationships with the NATO allies; to establish a foundation for future similar ventures; to diversify its sales in the field army; and to make a profit.

Hughes would like to see programs of this nature continue to be developed in the future. They are also supportive of co-development/co-production programs. They think it highly unlikely that the US government would procure a major weapon system directly from a foreign manufacturer. Hughes advocates that the next generation weapon system be a NATO design, that is, jointly developed by a US and a European manufacturer or consortium of manufacturers. The ever-present necessity, however, for the US government to use competitive procedures for the selection of their contractors might make this approach insurmountably difficult.

Appendix B

SIDEWINDER AND SPARROW TECHNOLOGY TRANSFER

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INTRODUCTION

The Sidewinder and Sparrow air-to-air missiles are only two examples of numerous American-developed systems that have been or are being licensed for production by NATO allies. From the US point of view, the technology transfer they represent — i.e., exportation — is far more typical than the importation represented by Roland.

Both missiles have been highly successful and have gone through several versions since their original designs; Sparrow has also been adapted to surface-to-air use for both land-launched and shipborne operations. The latest air-to-air versions of Sidewinder and Sparrow are the AIM-9L and the AIM-7F, respectively. The Raytheon Company, Missile Systems Division of Bedford, Massachusetts is the current prime contractor for the manufacture of both missiles, for which the US Navy has project responsibility. General Dynamics/Pamona is presently being qualified under a second-source contract for the AIM-7F. Philco-Ford Aeronutronics is intended to be qualified to produce the AIM-9L for future US production competition.

Sidewinder was designed and developed at the Naval Weapons Center, China Lake, California, and in earlier versions has been manufactured in the US by Aeronutronic Ford Corporation Communications and Electronics Division in Philadelphia; Aeronutronic Ford Corporation in Newport Beach, California; and Motorola Government Electronics Division in Scottsdale, Arizona; as well as by Raytheon. Sparrow was designed and developed by Raytheon. Both, in earlier versions, have been licensed for production abroad: the

AIM-9B Sidewinder to Bodenseewerk Geratetechnik GmbH (BGT) in West Germany; the AIM-7E Sparrow to Mitsubishi in Japan, to Selenia in Italy, and to Hawker Siddeley Dynamics in Great Britain.

During April and May of 1977, negotiations were underway between the US government and the Federal Republic of Germany on a Memorandum of Understanding (MOU) for licensed production of the AIM-9L Sidewinder in West Germany with BGT as the chosen prime contractor again. This provides the primary focus for analysis of industrial interests in technology transfer. The current licensed production of the AIM-7E Sparrow by Hawker Siddeley Dynamics (HSD) and the evolution of Sparrow into the US AIM-7F and the British Skyflash provides a second focus, relating technology flowback and technology transfer.

BACKGROUND DATA

AIM-9L Sidewinder

The Sidewinder is the most widely adopted air-to-air missile among the world's air forces. It has been fitted to the A-4, F-4, F-8, F-86, F-100, F-104, F-14, F-15, F-16, AV-8, OV-10, Mirage, Draken and Viggen aircraft among others. First introduced operationally in the 1950s, Sidewinder has been developed through ten variants in the last two decades. The AIM-9L is a third-generation development that provides dogfight attack capability from all aspects against rapidly maneuvering targets, featuring a low-cost infrared target acquisition system. Aerodynamically the missile has two sets of cruciform wings, fore and aft on its cylindrical body, with the forward set acting as canard controls.

The principal features of the ten variants of Sidewinder are:

AIM-9A	Original variant.
AIM-9B	First production variant with more than 80,000 built.
AIM-9C	Infrared homing replaced by semi-active radar guidance.
AIM-9D	Developed from 9B by USN. Intended for USAF F-4, but delayed.

AIM-9E	Improved low-altitude performance.
AIM-9F	9B fitted with Bodenseewerk FGW Mod 2 improved guidance and control.
AIM-9G	Has Sidewinder expanded acquisition mode (SEAM) for improved guidance.
AIM-9H	Solid-state version of 9G. Improved reliability and performance.
AIM-9J	Upgraded 9B for USAF.
AIM-9L	Latest USN and USAF version, improved over all others.

Raytheon has been a manufacturer of the Sidewinder guidance and control section for approximately ten years. The company entered the program as second-source producer of the AIM-9D, and has since produced the AIM-9G and AIM-9H, all for the US Navy. While the missile was originally designed by, and its continued development remains under the control of, the US Navy/China Lake, product improvements have been introduced by the production contractors as well as by the Navy. Except for the original production version of the Sidewinder, AIM-9B, all foreign sales have been by direct procurement of US manufactured missiles.

As noted above, a government-to-government Memorandum of Understanding will provide a basis for company-to-company licensing agreements for future production of AIM-9L in Germany. The MOU will establish many critical features of the proposed European production of AIM-9L, including the nature and extent of the technology to be transferred and the US contractor's role in facilitating that transfer. In many cases, an MOU would define minimum requirements for procurement from the prime US contractor of a specified amount of hardware and technical assistance in addition to technical data.

As discussed in greater detail below, officials at Raytheon expressed concern to the authors that there was not more opportunity for industry to participate in the development of the MOU. Presumably due to the planned US competitive procurement of AIM-9L, the Navy has solicited no comment from

Raytheon during the conduct of MOU negotiations. Moreover, Raytheon cannot, on its own initiative, engage in technical discussions with the prospective German prime contractor until an export license has been approved, which is not expected to occur until the government-to-government MOU is executed.

Following completion of the MOU, licenses are expected to be negotiated between US and European contractors for the various elements of the missile system. It is expected that BGT will subcontract within the European consortium, but the extent of this subcontracting will be limited first by the terms of the MOU and second by the terms of the contractor-to-contractor license. This point is critical because it will bear directly on any third party sales rights that BGT may gain. Under these arrangements the drawing package will be furnished to the German government (and thence to BGT) by the US government. US industry will then provide technical assistance to the extent needed to provide know-how and support satisfactory production. Technical assistance normally covers a broad spectrum of activities including in-plant training courses, supplying items of hardware for purposes of demonstration and training, and conveying manufacturing methods and processes. Raytheon considers that BGT, having had prior licensing experience with the 9B version of Sidewinder in 1959-60, will have sound judgment in knowing the magnitude of the technical assistance program required for 9L.

AIM-7F Sparrow

Sparrow has been almost as popular as Sidewinder among allied air forces. The current standard operational version, AIM-7E, which saw extensive service in the Vietnam War, is employed on the F-4 aircraft of the US Air Force, Navy and Marine Corps; the UK Royal Air Force and Royal Navy; the German, Turkish, Greek, Israeli, Korean and Imperial Iranian Air Forces; and the Japanese Air Self-Defense Forces. It is also operational aboard the F-104 aircraft of the Italian and Turkish Air Forces. The AIM-7E has double cruciform wings on a 20cm-diameter body, approximately 3.65 meters long. It weighs 200kg of which 30kg is the high-explosive warhead. Guided by semi-active continuous-wave radar, it has a range of approximately 25km. Proximity or contact fusing is employed. The AIM-7F, currently in production, has all solid-state electronics for its improved semi-active radar guidance. It also has a larger solid-propellant rocket, doubling its range. Its lethality and reliability are also improved over the AIM-7E, and it has significantly improved performance making it effective against highly maneuverable targets.

Another derivative of the AIM-7E is the Skyflash, developed by Hawker Siddeley Dynamics from the basic Raytheon missile. This version features a semi-active radar seeker, developed by Marconi Space and Defence Sytsems, and an EMI fuse. Its airframe, rocket motor and warhead are the same as the AIM-7E.

The AIM-7E is also used in the NATO Seasparrow surface-to-air system and is designated the RIM-7H. It has folding fins to accommodate to the NATO deck launcher/containers. An earlier version, the AIM-7D, is used in the US Navy's Basic Point Defense Missile System. Sparrow is also employed as the vehicle for the US Air Force/Navy Brazo/Pave Army system, in which a laser homing head will be used.

As noted previously, Sparrow has been, and presently is, licensed for co-production in Italy and Japan. Raytheon considers both licenses to be satisfactory. Neither provides for full technology transfer (as the Roland license does in the opposite direction across the Atlantic), and Raytheon considers information concerning what portions of Sparrow these two licensees manufacture to be proprietary.

The largest foreign user of Sparrow is Great Britain and until recently all the British units were Raytheon-manufactured AIM-7E missiles. At the beginning of this decade, the British sought to increase their procurement of follow-on Sparrow-type missiles. The Ministry of Defence studied three candidate missiles to satisfy their future air-to-air radar missile requirements. The candidates studied were the latest US model, the AIM-7F, and both the AIM-7E and AIM-7F modified by a

British-designed seeker and fuse, both of which had been in basic development for some time. Raytheon's commercial interest argued, of course, for direct sale of the AIM-7F. Because it was then still in the development phase, the US Navy did not have the final AIM-7F data required by the UK to evaluate the missile properly. For this reason, together with political, economic and other factors, the United Kingdom found it necessary to pursue other avenues for procurement of advanced Sparrow missiles, and in 1973 Raytheon completed cross-license agreements with three British companies for the manufacture of each other's subsystems.

The project definition phase of the UK procurement program concluded that the missile of choice was the AIM-7E with a British (Marconi) seeker and British (EMI) fuse. This missile was designated as the XJ-521 Skyflash. Hawker Siddeley Dynamics, as the prime contractor, was licensed by Raytheon for the AIM-7E missile. As part of this program, Marconi and EMI granted Raytheon cross licenses for the seeker and fuse respectively. The terms of the various licenses in this arrangement are considered by Raytheon to be proprietary. Basically, however, sales rights for the XJ-521 are exclusive to Raytheon in the United States, to HSD in the United Kingdom, and to both Raytheon and HSD on a non-exclusive basis elsewhere in the world.

Raytheon is cautious in their evaluation of the results of these license agreements, partly because specific expressions may reveal their competitive posture in future business development plans. On the whole however, they conclude that the results are generally what were expected, including the observation that any license inevitably leads to competition. An example of this latter point is the Swedish choice of Skyflash for the JA-37 Viggen. Initially Sweden bought a systems-integration program from Raytheon to incorporate the AIM-7E in their front-line aircraft. They did not, however, commit to the AIM-7E since they subsequently decided that they preferred a more up-to-date missile. They considered various missiles, including Raytheon's AIM-7F and HSD's Skyflash. Raytheon's competitive position in this procurement was made difficult by the limited release of data on the AIM-7F, and, in the end, Sweden chose Skyflash.

CONTRACTOR'S OVERALL PERSPECTIVE

In addition to being the current prime contractor for the AIM-9L Sidewinder and the AIM-7F Sparrow, Raytheon has had two decades of experience in selling and in licensing a wide number of defense systems for production or assembly overseas. This section presents some of Raytheon's views on overseas sales, co-production, and co-development, and attendant issues of technology transfer and NATO standardization.

In general, the company sees three broad avenues available for selling missiles, such as Sidewinder and Sparrow, overseas. These are:

1. Sales of the complete product with its supporting software and services, either through the US government as a Foreign Military Sales (FMS) case, or by direct commercial sale to the foreign customer. (Technology is transferred only in the end product and would require reverse engineering for effective absorption — a difficult process.)

2. Co-production with overseas companies, in which each participant (including the US) makes a portion of the missile, but it is generally integrated and sold off in the using country. (Licensing to produce components with their technologies abroad is involved, but the characteristic of this approach is that critical components may be produced in the US, thereby reserving control of their technologies to a much greater degree than in the next case.)

3. Direct license to a foreign country with full production overseas, the US licensor furnishing the technical package and technical assistance and only a few production models and components for start-up. (Technology is transferred to the highest degree in this case.)

Of these three, Raytheon clearly prefers direct sales to the other two, and co-production to licensing. The principal reason is to keep work in its own factories, thereby increasing its sales and enhancing its competitive position. In a pure licensing program, the licensor normally receives a royalty for each missile produced and payment for technical assistance; but these returns alone, in Raytheon's view, do not fully compensate for the lost advantages associated with US manufacture of the complete system. Logically, and for the same reason, the company reverses its order of preference for products and technologies that might be transferred from overseas to this country.

With respect to technology transfer, Raytheon believes a licensed sale may compromise some long term objectives of the US government and of the US company. The government owns certain rights in data for any program that it has supported in development. The objective of these rights is to permit the government to procure the weapon readily from a second source in open price competition. For this reason, the data package is generally as complete as the US government can specify it. This means that when the complete data package is provided to a foreign government, detailed manufacturing technology is being transferred overseas with a minimal amount of US industry support and remuneration being negotiated. Raytheon believes that the compensation to the US government and to US industry is rarely adequate and that the transfer of US technology can have deleterious long term competitive results.

The other side of this coin, however, is that no matter how complete the data package, technical assistance will always be required by a foreign company to get its licensed production underway. Raytheon's experience has taught them that there may be lack of agreement as to how much technical assistance is needed. Licensees frequently underestimate the accrued benefits from such technical assistance. They will additionally be motivated to limit their procurement of technical assistance by financial considerations.

Realizing the need to promote NATO standardization and interoperability, Raytheon will enter into and consummate negotiations for licensing production of its tactical missiles by US NATO allies. But even in this event, the company expresses two serious concerns. One relates to the general licensing policies of the US government, the other to the nature of the relationship between government and industry in the licensing process.

Raytheon sees no established overall policy for licensing and technology transfer. Within the State and Defense Departments, there are many organizations that contribute to the policies to be followed for any particular overseas program. The individual military branch that has the responsibility for the particular system being licensed or sold has little guidance to follow. This inevitably leads to policies and judgments based on subjective views of the benefits to be gained or lost in any particular overseas program. Raytheon recognizes that steps are being taken at high levels to develop overall policies with respect to arms sales and technology transfer, but it feels that the policies must be clearly understood at the working levels of the government if they are to be useful. Raytheon urges that a single set of guidelines be generated and implemented to be uniformly applied by all services in dealing with technology transfer and licensing to foreign countries.

The second concern that Raytheon expresses is that the US government does not involve industry early enough in the government-to-government negotiations that ultimately lead to company-to-company licenses. This problem results in part from government's desire to satisfy the need for impartiality in dealing with potentially competing US companies. But this effort to avoid unfair advantage may work in both parties' detriment by denying industry its prerogatives in dealing with foreign manufacturers and denying government the benefit of industry's experience. Unlike the US government, moreover, foreign governments and their industries always work closely together from the outset in any licensing negotiation. This puts the US at an obvious further disadvantage. Normally US industry is not introduced into the negotiation cycle until a government-to-government Memorandum of Understanding is promulgated. By that time it may be too late for industry's perspective to influence the nature of the agreement.

The Arms Export Control Act of 1976 prescribes what major programs will be conducted on a government-to-government basis in lieu of direct commercial sales. Raytheon believes the effect of this legislation is further to cast the US government in the role of primary negotiator and decision maker relative to the definition of licensed programs.

With respect to technology transfer, government and industry must work very closely together to decide what the impact of technology transfer will be in any given program. Government must, with industry's inputs, decide which basic technologies can and cannot be transferred to each country, based on the interests of national security and national policy. In Raytheon's view, industry is in the best position to judge what its overseas counterparts can do, and is, therefore, in a better position to know how long it would take foreign industry to develop the design or manufacturing expertise involved in the particular program in question.

In Raytheon's view, programs that are negotiated and contracted for solely on a government-to-government basis are especially subject to significant price uncertainties. In direct arrangements with the US government, foreign governments have experienced difficulty in measuring the final costs of their programs. Industry has wide flexibility in financing arrangements, whereas the government is almost completely inflexible by the procedures it must follow. Government controlled (i.e., FMS) sales are generally satisfactory for sales of complete equipments, but even in these cases may encounter serious problems depending on the ability of the procuring country to identify and procure the necessary items of logistics equipment and technical support. It is anticipated that this problem will be compounded by the recent down-grading of Military Assistance Advisory Groups and Missions.

In summary, then, Raytheon prefers direct sales to licenses; believes that direct company-to-company negotiations are necessary in support of government-to-government agreements; would like to see industry involved in the latter case at a much earlier date (competitive issues notwithstanding); and sees an urgent need for uniform licensing and technology transfer policies, buttressed by adequate procedures and guidelines, for all services and the State Department. They are concerned that technology and the results of research and development programs could be transferred to foreign companies with inadequate compensation and that the nature and extent of technical assistance to be transferred to a foreign company may not be properly judged by all the parties.

Appendix C

F-16 TECHNOLOGY TRANSFER

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F-16 TECHNOLOGY TRANSFER

INTRODUCTION

On June 7, 1975, the governments of Belgium, Denmark, Norway, and the Netherlands selected the General Dynamics F-16 as the replacement aircraft for the F-104G and other obsolescent fighter aircraft in their inventories. In order to promote greater standardization of equipment within the North Atlantic Treaty Organization, the four nations had earlier agreed in principle to procure the same type of aircraft. An informal ad hoc consortium was formed under the particular leadership of the Dutch, who had defected from the MRCA consortium several years earlier to find a lighter and cheaper aircraft than the MRCA program offered. The F-16 was chosen after an intensive international sales competition which included the Northrop YF-17, an improved Dassault-Breguet Mirage F-1, and the Saab-Scania Viggen. Widely heralded as the "arms deal of the century," the selection of this low-cost supersonic aircraft will lead, according to conservative estimates, to total sales in excess of $15 billion over the next twenty years.

The European consortium's procurements are based on co-production agreements which could eventually offset the entire cost of procurement by the European participants. Industries in the four European member nations are scheduled to produce 10% of the value of the F-16s to be procured by the United States (currently a minimum of 650 but more likely to run as high as 1,338); 40% of the value of the aircraft to be purchased by the Belgian, Danish, Norwegian, and Dutch air forces (at least 306); and 15% of the value of the sales of the aircraft to all other nations. General Dynamics and its major subcontractors (the most important of which are United Technologies Corporation and Westinghouse) will transfer substantial portions of the technology required to produce F-16 components in Europe. According to the official US policy, no profits may be earned on the licensing agreements established for this purpose. US national security considerations require that the transfers be restricted, in the near term, to exclude such items as the aircraft's electronic countermeasure (ECM) devices and the most strategically sensitive parts of its Pratt and Whitney (United Technologies) F100-PW-100 after-burning turbofan engine. In addition there are some corporate proprietary restrictions involved, especially with regard to the Westinghouse radar.

One of the most remarkable aspects of this program is its complicated co-production schedule, which is superficially reminiscent of the program established by Lockheed in the 1960s for European production of nearly 1000 F-104G aircraft but is, in fact, more intricate because of concurrent US development and production. In most previous (but not all) defense-related agreements, delivery to the US weapons inventory has occurred several years ahead of foreign sales. In the F-16 program full-scale US production will begin in 1979, to be followed within twelve months by European series production. Thus, the technology transferred to firms in the consortium countries will not be fully "proven" by series production before it is implanted. In this and other regards, the transfers of production technology will be virtually at the state-of-the-art in many instances.

The unit price has been specified, in the Memoranda of Understanding, at a maximum of $6.09 million for the European version. This figure includes roughly 54% for the airframe, 23% for the engine, 13% for US Department of Defense research and development recoupment, 7% for the target detection systems, and 3% for US government-supplied equipment.

The F-16 is a multimission aircraft, providing more advanced technology and lower cost than current European fighter aircraft. The F-16 incorporates such advanced-technology features as fore-body strakes, wing-body blending, fly-by-wire electronic flight controls, and variable wing camber. The F-100 engine has a higher thrust-to-weight ratio than any engine now available in Europe. The technologies incorporated in the F-16 were selected and integrated so as to lessen the vehicle's weight, cost and difficulty of manufacture, and fuel consumption. The F-16's combat capability has been described as far superior to most other fighters, certainly those in development in Europe.

US subcontractors on the project include — in addition to United Technologies and Westinghouse — General Electric, Singer Kearfott, Bendix, Hughes Aircraft, AirResearch Manufacturing, TRW Systems, Teledyne Electronics, Sperry Rand, Sylvania Electronic Products, and Brunswick Corporation. Each of these companies is required to arrange for co-production in at least one of the four consortium countries. Ultimately, many of the components of the F-16 will be produced both in the US and in the consortium nations, thus involving several hundred corporations in the two areas. Although final authority for these arrangements resides with the Department of Defense, General Dynamics is responsible for their coordination and for verification that each nation receives at least its promised share of shared production. General Dynamics has sought to utilize existing industrial capabilities in the European member countries, contributing to the technological upgrading of the industrial base in these countries, supporting local employment for extended production runs, and providing the basis for in-country support of the aircraft during its life cycle.

The minimum levels of shared production were established through inter-governmental negotiation. Based on the expectation that at least 1,500 aircraft will eventually be produced, the result will be to return approximately $750 million worth of business to Belgium (92.99% of its F-16 purchase), $328 million to Denmark (80% of the cost of its procurement), $406 million to Norway (80%), and $697 million to the Netherlands (98.3%). The resulting overall offset will be 88% when 1,500 F-16s are purchased. After more than 2,000 planes have been sold, the four countries should obtain more than a 100% offset. Parenthetically, when 850 planes are sold outside the US, a $3 billion positive impact on the US balance of payments is anticipated. The potential world market for this aircraft has been estimated at nearly 5,000.

Two final assembly lines will be set up in Europe, one in Belgium and one in the Netherlands. The Belgian assembly operations will be carried out by Fairey and SABCA, and the Dutch by Fokker VFW. These firms had extensive experience in the F-104G program. In addition, the Belgian firms were co-producers of the Dassault-Breguet Mirage V, and Fokker of the Northrop F-5.

Although the United Technologies F-100 engine co-production program calls for Fabrique Nationale (FN), a Belgian company, to handle the final assembly and testing of the engine, the production of various components has been sub-contracted to firms in each of the four countries. FN will build the inlet fan and core engine modules. Belgium has been assigned the largest share of engine work — about $190.2 million worth of business, resulting in the temporary creation of at least 3,000 jobs. The estimated dollar volume and job impact of the engine program in the other nations is as follows: the Netherlands, $149.5 million and 1,400 to 1,600 jobs; Norway, about 500 jobs; Denmark, $13.3 million and up to 1,000 jobs. These levels of employment will taper off after 1982, as F-16 production diminishes.

Sales of the F-16 outside the United States and the other four nations are subject to the approval of the US Departments of Defense and State. The governments of Israel, Iran, and South Korea have already discussed the aircraft and have suggested establishing co-production arrangements. Whether the Defense Security Assistance Agency will recommend additional co-production arrangements is uncertain. The present European co-producers will probably resist the addition of co-production partners.

The direct economic consequences of the F-16 co-production program are generally favorable both to the United States and to the European participants. The principal potentially negative economic aspect of this program for the US relates to the effect of the technologies transferred on the international commercial environment. If it were postulated that the transferred technology greatly strengthened the competitive position of European aircraft component manufacturers, this could result in a potential loss of future business for specific US companies. However, as this appendix indicates below, there is virtually no such risk. On the other hand, there are some political penalties involved in the F-16 program, especially with respect to US industrial relationships with Britain and France. These are also discussed later in this appendix.

PROGRAM CHARACTERISTICS

Milestones and Budgets

The original Memorandum of Understanding was signed in June 1975, immediately following an announcement made at the time of the Paris Air Show. The preliminary contracts authorizing work to begin were issued in July 1976. These preliminary contracts gave General Dynamics an umbrella under which to start issuing work to the European partners. By April of 1977, the preliminary contracts already totaled $1.5 billion out of an ultimate total of about $1.9 billion, not counting potential future third-country business. Letters of Agreement (LOA) between governments will specify unit numbers and prices. The LOAs were to be signed by 15 April 1977, but delays were encountered in Belgium and Denmark, caused by internal fiscal and monetary problems.

Through the first quarter of 1977, there were, in fact, various delays and disagreements among the European partners over actual work-share. In April, for example, the Danish Defense Ministry asked for a postponement in signing of the LOA for the purchase of 58 F-16 aircraft. Concern was expressed about increasing program costs and the short-fall in promised F-16 offset work in Denmark. In fact, however, a key issue appears to be the rate of inflation in Denmark and its impact on the Danish share of the work.

One US bargaining chip in keeping the project on schedule is the likelihood that USAF will increase its order from the original 650 aircraft up to a possible 1,388 aircraft. There is some ambiguity in the existing agreement about whether 10% of the value of an entire run of this kind, over and above the initial 650 units, would be allocated to the European partners. It seems likely that the US allowed this ambiguity to persist as a means of maintaining bargaining power during the early industrial negotiations.

Even in the United States, the F-16 has encountered budgetary resistance, due in large part to the fact that the Congress was originally told that F-16 RDT&E costs would be $4 billion and is now being asked for an additional $1.4 billion in funding. The explanation of the Air Force is that the R&D cost of support equipment, rather than of the aircraft itself, was grossly underestimated. On April 1, 1977, the General Accounting Office (GAO) released a report, the first of two, entitled "Status of the F-16 Aircraft Program," which was critical, in some regards, of the aircraft and the program as a whole. The second report was to deal with the international collaborative aspects of the project. One of the most critical comments in the first report was technical rather than budgetary — that the F-16 is highly vulnerable both from air-to-air and ground-to-air weapons. For purposes of the present study, the important point is that the European partners were very concerned by the GAO report. In the European partner countries there is no exact counterpart to the Office of the Controller General of the United States. The prospect of issuance of the second report, dealing with international aspects of the program, has been even more disturbing.

The F-16 System Project Office (SPO) has gone to considerable lengths to reassure the European partners that the GAO report does not augur a change in policy on the part of the US government as a whole and does not presage a reduction in commitment to the program. In fact, all of the agencies involved, especially the Air Force and the State Department, took rapid steps to reduce the negative impact of the GAO report. The report received very wide press coverage in Europe, and General Dynamics stock dropped five points on the New York Stock Exchange as a result of the report. Even the GAO finally issued corrective statements indicating that the report had been "misinterpreted."

Two development aircraft out of a total of eight had been delivered to Edwards Air Force Base by April 1977. A third aircraft, the avionics test bed, was scheduled to be delivered during the summer of 1977. It seems likely that a full-scale production decision in the US will be made in September 1977.

Overall Co-Production Arrangements

The initial European order covers 306 aircraft, with options for 42 more. Total orders and options are as follows:

Belgium	116
Denmark	58
Netherlands	102
Norway	72

The main preliminary contract arrangements set up under the program, pending final contracts and government-to-government letters of authorization, are the following:

> General Dynamics to Fokker-VFW in the Netherlands for production of center fuselage sections, control surfaces, main landing gear door sets, main landing gear buildup, and final assembly and delivery of 102 aircraft to the Royal Netherlands Air Force as well as the 72 aircraft to the Royal Norwegian Air Force. Thus, although final assembly work is being performed only for the Dutch and Norwegian aircraft, all of the component manufacture applies to the total production run for Europe, as well as some for the United States and third countries.
>
> General Dynamics to Per Udsen in Denmark for production of vertical fin boxes and wing and fuselage pylon-fuel and ordnance assemblies. There is also a contract to Standard Electric A/S in Denmark for assembly of flight control panels, electronic components, and manual trim panels. These components apply to the entire production program in both the United States and Europe.
>
> From General Dynamics to Fairey S/A in Belgium for production of vertical stabilizer detail parts, assembled aft fuselages, nose landing gear buildup, and engine buildup; and to SABCA for final assembly and delivery of

up to 116 completed aircraft for the Belgian Air Force and up to 58 completed aircraft for the Royal Danish Air Force. In this case, nose landing gear buildup, engine buildup, and final assembly are for the Belgian and Danish orders only, while the remaining work will be for the production runs on both continents.

In Norway, a contract to Kongsberg Vapenfabrikk from Pratt & Whitney for production of fan drive turbine modules on the United Technologies F-100 engines.

See Figure 1 for a schematic of the F-16 airframe component manufacturing and final assembly. This figure does not include the engine and avionics. Tables 1 through 4 show the industrial participants for the basic co-production jobs to be performed in the Netherlands, Belgium, Denmark, and Norway, respectively.

With regard to the production schedule, the delivery of the first components made in the Netherlands is now set for early 1978; and the first Dutch-assembled F-16 will be rolled out in mid-1979. The normal production rate at Fokker-VFW will be three aircraft per month, and work will be assigned to four of the company's plants in the Netherlands. Component production at Fokker-VFW now calls for eleven complete sets per month, which could be increased to fifteen sets to accommodate third country sales.

SABCA is scheduled to complete its first F-16 wing from mostly US supplied components in February 1978. Thereafter, the firm will deliver wings manufactured entirely in Europe for the 116 aircraft for the Belgium air force and 58 aircraft for the Danish air force. SABCA's wing box production and wing integration line will start in September 1977 and is expected to be fully operational in May 1978. About 15 wings should be in production by the end of 1977. SABCA and its neighboring firm, Fairey, S.A., will perform final assembly of all 174 aircraft for the Belgian and Danish air forces. In addition, SABCA is producing integrated servo actuators for European F-16s and will have responsibility for systems integration and flight testing of aircraft for the two air forces prior to delivery.

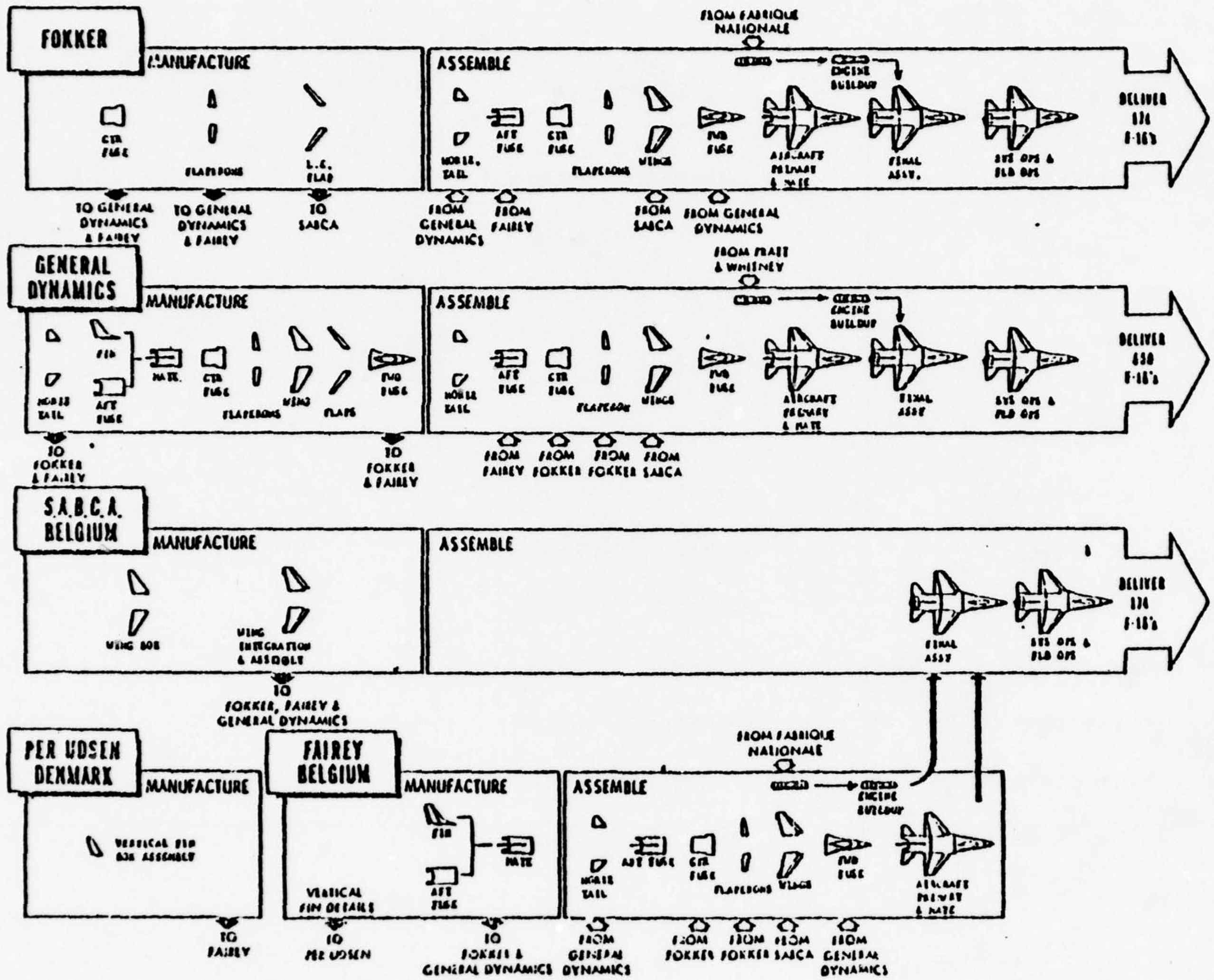

Fig. 1 Breakdown of F-16 Manufacturing and Assembly

Table 1

Dutch Industry F-16 Participation

Job	Prime Supplier	Co-Producer
Flaps, final assembly, flight test	General Dynamics	Fokker-VFW
Assembly	General Dynamics	Fokker-VFW
Centre fuselage	General Dynamics	Fokker-VFW
Undercarriage door	General Dynamics	Fokker-VFW
Centre-fuselage structure	General Dynamics	Fokker-VFW
Sheet metal	General Dynamics	Fokker-VFW
Fule gauging	Simmonds (USA)	Simmonds
HUD display unit	Marconi-Elliott	De Oude Delft
Fire-control radar aerial and transmitter	Westinghouse	Signaal
Undercarriage	Menasco	DAF
Ride-quality study	General Dynamics	National Aerospace Laboratory
5kVA generator control unit	AirResearch	In competition

Table 2

Belgian Industry F-16 Participation

Job	Prime Supplier	Co-Producer
Wings	General Dynamics	SABCA
Integrated servo actuator	National Waterlift	SABCA
Flight testing	General Dynamics	SABCA
Fuselage assembly	General Dynamics	Fairey
40kVA generator	Westinghouse	ACEC
Radar low-power RF	Westinghouse	ACEC
Radar power supplies	Westinghouse	Siemens
Radar digital signal processor	Westinghouse	MBLE

Table 3

Danish Industry F-16 Participation

Job	Prime Supplier	Co-Producer
Manual trim panel, ECA	General Dynamics	Standard Electric
Flight control panel	General Dynamics	Standard Electric
Vertical fin box, pylons	General Dynamics	Per Udson
Chaff and flare dispenser	Tracor	DISA
Airbrake actuator	Arkwin	DISA
Pneumatic sensor	AirResearch	DISA
Starter gearbox	Sundstrand	DISA
Emergency power unit	AirResearch	DISA
Fire-control computer	Delco	DIG-I*
Heat-exchangers	Hamilton Standard	Quitzau
Leading edge flap drive	AirResearch	J. Hoyer
40kVA generator control unit channel frequency indicator	Westinghouse	Radartronics
Flight control	Lear-Siegler	Dannerborg (formerly Terma)
Radar electro-optical display	Kaiser	Nea-Lindberg
Inverter	Aerospace Avionics	Silcon

* DIG-I is a Danish consortium led by Christian Rovsing and including Neselco.

Table 4

Norwegian Industry F-16 Participation

Job	Prime Supplier	Co-Producer
Stores management system	General Dynamics	Kongsberg
Air conditioning turbine compressor	Hamilton Standard	Kongsberg
HUD (rate gyro and electronics unit)	Marconi-Elliott	Kongsberg
Inertial system	Kearfott	Kongsberg
Brakes and anti-skid	Goodyear	Kongsberg
Rate gyros	Northrop	Kongsberg
Central air data computer	Sperry	STK
Air-ground IFF	Teledyne	STK
Interference blanker	Novatronics	GA Ring
Ammunition-handling Hydraulics	General Electric	Sperry-Vickers
Wheels	Goodyear	Raufoss
Constant speed drive	Sundstrand	Raufoss
Ammunition handling drum drive	General Electric	Raufoss
Jet-fuel starter	AirResearch	Raufoss
Ammunition handling inner drum	General Electric	Norcem Plast
370 gal fuel tank	Sargent-Fletcher	Nordisk Aluminium
Ammunition handling scoop disc	General Electric	NTP

Specific Patterns for Radar, Engine, and Other Components

In practice the problem of placing enough contracts in each of the participating countries to reach the specified national shares has been complicated by the scarcity of competent bidders in the principal categories.

While General Dynamics negotiates directly with the airframe co-producers in Europe, its American subcontractors must also establish their own operating networks with European partners and this has led to some unusual arrangements. For example, Menasco Manufacturing Co., the landing-gear vendor, could find no direct equivalent in any of the four partner countries since European landing-gear production is concentrated mainly in Britain and France. Consequently, they had to establish a license with a Dutch truck manufacturer, DAF. This kind of situation is, of course, objectionable to the major European aircraft manufacturers, who are already well-equipped and thoroughly capitalized for such production and also under utilized. The view at DAF now is that the F-16 contract has opened the way for them to enter the landing gear business, a view which almost certainly underestimates the market constraints to such a course. As a result, DAF is building a new wing on its main factory and is filling it with $6 million worth of new production equipment. Furthermore, Menasco must maintain a staff of six technicians in the DAF plant due to their lack of experience.

Hamilton Standard Division of United Technologies Corporation had to find a co-producer of heat exchangers. In Denmark it established a relationship with a small firm of just 80 employees, Quitzau of Sonderborg, a manufacturer of industrial cooling equipment and truck radiators. Although this firm has never performed any aerospace work, it won a $4 million contract from Hamilton Standard.

Negotiation of the radar co-production has been one of the most difficult elements in the program. When General Dynamics originally requested bids from Westinghouse and Hughes in mid-1975, while the two were engaged in a flyoff, the companies were asked to submit prices based on manufacturing 25% of the combined total of 998 F-16 radars in

Europe, and an alternative price for 50% co-production. The original requests for proposal had envisioned that the radar antenna and transmitter would be built in the Netherlands, while the radar computer, signal processor and low-power radio-frequency units would be built in Belgium. The cockpit display scan converter, then planned as a separate unit, was to be built in Norway. Westinghouse submitted fixed-price quotations, and it sought the same type of bid from prospective European co-producers. However, at that stage in the radar program, the companies could make estimates based only on the flight test demonstration hardware and a modest amount of descriptive material. Therefore, the prospective European co-producers found it necessary to use very conservative estimating procedures, padded to provide for unknown contingencies.

It soon became evident that if even 25% of the total radar systems were built in Europe, the price of the European F-16s would be pushed beyond acceptable limits. With reduced quantities built there, the cost of manufacturing setup and special test equipment had to be allocated against fewer systems, adding further to the unit cost. During early negotiations, Westinghouse had been dealing with five prospective co-producers in Belgium, but by mid-1976 the US company had concluded that the number had to be reduced to three to minimize overhead costs, especially since it was then planned to produce three different types of radar subassemblies in that country. Meanwhile, Westinghouse decided that it could save cost and weight by including the scan-converter function within the radar computer, eliminating the separate element that was to have been built in Norway. During the late summer of 1976, engineers and manufacturing specialists from the three Belgian companies and from Netherlands' Hollandse Signaal Apparaten visited Westinghouse to familiarize themselves with the emerging production design, preparatory to submitting new cost estimates. When these new prices were received in October 1976, they were still too high.

By the fall of 1976, with many of the other portions of the airframe and engine co-production arrangements having been worked out, Norway and Denmark were complaining that their industries were not receiving a large enough share. This meant that companies in those two countries would have to be brought in on radar co-production, receiving a larger share of the latter to make up for short-falls in other parts of the F-16 program. An additional obstacle was that total production of each radar subassembly had to be prorated between Westinghouse, which would build at least some of all elements in order to work out production problems, and a European co-producer in such manner that the cost of the radar for the USAF F-16s would not be significantly higher than if all USAF radars were produced by Westinghouse.

By late 1976, Westinghouse and the Belgian government agreed to select a single avionics manufacturer in that country to produce the radar computer: Manufacture Belge de Lampes et de Materiel Electronique (MBLE). Hollandse Signaal Apparaten remained as the manufacturer of the radar antenna, based on its extensive experience in the field. Denmark's Dannebrog Electronics was selected to build the radar control panels for the F-16 cockpit, which Westinghouse had planned to build in the US. Norway's NERA was selected to build the radar rack, into which all major elements are plugged or attached, as well as the associated cabling and cooling air plenum.

After bids were sought on a number of different production quantity options, compared with the cost of producing the subassembly in Baltimore, and after USAF aircraft production schedules and European start-up time were taken into account, the following sharing ratio was established:

Radar computer	-	Belgium's MBLE will build 800, Westinghouse will build 198.
Antenna	-	Signaal Apparaten will make 500, Westinghouse 498.
Rack and cabling	-	NERA will produce 800, Westinghouse 198.
Radar control panel	-	Dannebrog will build 800, Westinghouse 198.

Westinghouse will build all 998 of the radar transmitters, digital data processors and low-power RF units. It also will be ready to back up its European partners for all units in the event that problems develop there.

First production units from European co-producers are scheduled for delivery in February 1979, approximately a year after delivery of the first Westinghouse-built units. Initially all co-produced units will be shipped to Westinghouse for final verification tests before being delivered to General Dynamics for installation in the F-16 nose-cockpit sections being built there. General Dynamics will also integrate the radar with the rest of the fire control system. Eventually the European co-production units may be shipped directly to General Dynamics. On this basis, the cost of F-16 radars to the USAF should be no higher because of co-production, and may run slightly less because of the increased peak radar production rate resulting from the larger total procurement.

Because of its vast European experience, Westinghouse saw the importance of preventing price escalation. It is interesting, in this regard, that the MBLE bid was initially as much as 50% higher than Westinghouse's prices for similar equipment. Because the multi-national agreement requires European co-producers to be "reasonably competitive," some of the early Belgian bids were rejected.

Co-production of the radar system is particularly interesting because it involves the transfer of advanced technology. For this reason, each of the member countries focused on participation in radar manufacture. At the same time, Westinghouse, jealous of its proprietary knowledge, has been very cautious in the structuring of co-production arrangements, trying to protect its technology as much as possible.

Although the radar co-production was originally to be assigned only to Belgium and the Netherlands, the two Scandinavian participants complained sufficiently to win a concession that all four member countries will now participate in the radar co-production. According to the F-16 SPO, Denmark and Norway have apparently been able to fill some of the clean-room requirements better than the larger partners, the Netherlands and Belgium.

United Technologies' Pratt & Whitney F100-PW-100 engine, a military turbofan with afterburner for supersonic operations and also for high performance across a broad performance envelope, powers the USAF F-15 aircraft and has been adopted for the single-engine General Dynamics F-16. As part of the total European production package for the F-16, Pratt & Whitney Division of United Technologies Corp. has granted the principal license for manufacture of engine parts and final assembly to Fabrique Nationale (FN) in Belgium. The cost of each engine is about $2 million. FN will also produce components for USAF F-16s under a separate $100 million contract.

Fabrique Nationale is going into F-100 production in three phases, manufacturing more of the engine components itself in each phase. Those components that it is not manufacturing will be supplied either from Pratt & Whitney in the US, Philips in the Netherlands (afterburner and nozzle module), DISA A/S in Denmark (gearbox module), and Kongsberg Vapenfabrikk in Norway (fan drive turbine module). Tool design for Phase 1 has been completed, and the first FN-produced F-100 components are scheduled for delivery to Pratt & Whitney in April 1978. The first engine under this phase is due for completion in September 1978 for installation on a European F-16. The first complete engine under Phase 2 is due for delivery in February 1979, and the first complete engine in the fully operational Phase 3 should be finished in January 1980.

Fabrique Nationale is one of the few European participants that operates on a two-shift day. One result of this is that estimated tooling costs are close to those of Pratt & Whitney.

Under the Memorandum of Understanding between the US government and the European participating governments, Pratt & Whitney selected the European contractors after surveying forty companies in the four nations. The selected European contractors are individually responsible to P&W, which in turn is responsible to the US government for the program. This tends to preclude friction between the European companies and governments, since the European governments address the contractors through Washington and West Palm Beach.

Early in the co-production negotiations, Pratt & Whitney told the European participating governments that there was no efficient way to distribute equally the engine work among the four nations, particularly given Fabrique Nationale's strong gas turbine capabilities. The Europeans were guaranteed a nominal share of about 43% of the value of the 438 engines for the 348 F-16s that the European consortium is to build. Pratt & Whitney would make the rest. In actuality, the Europeans are allowed their own make-or-buy decisions for their components, according to the amount of capital investment they believe it prudent to make. As a consequence, the European engine partners will make only about 25% of the value of their engines, and will purchase the remainder from Pratt & Whitney.

The contracts with the four European engine partners are fixed-price with inflation escalator provisions. This type was chosen as the simplest way to bridge the gap between the accounting systems used in Europe and the one used by Pratt & Whitney. The Europeans did not want to change their accounting systems to track costs all the way through, as would be required for cost-plus-fixed-fee contracts. Also, European companies generally tend to be more reluctant to release financial data than are US firms. Table 5 presents a display of the division of work among the European co-production partners for the F-100 engine.

The methods of subcontractor selection have varied from country to country. For example, in Denmark the issue of which companies would participate was permitted to be worked out on a fairly open competitive basis, as it might be in the United States, even though there were relatively few qualified firms. In Norway, it was the central government which selected those companies that would bid for the F-16 work, the most important of which was the state-owned company, Kongsberg Vapenfabrikk. In Belgium, there was no question that the principal subcontractor would be SABCA (Societe Anonyme Belge de Constructions Aeronautiques). SABCA (which is partially owned by Dassault) had already engaged in subcontract production of airframe components in the Lockheed F-104 program and also manufactures wings for the Mirage fighters. Fairey got the assignment of aft fuselage sections, the same element it had manufactured both in the F-104G program and in work for Dassault. Finally, much of the engine subcontracting was assigned to Fabrique Nationale. In the Netherlands,

Table 5

F-100 Co-Production Partners in Europe

Contractor	Portion	\$ Million Contract Value	\$ Million Tooling Capital Cost
Fabrique Nationale (Belgium)	Inlet and fan module, core engine module, engine assembly & test	290	19.9
N.V. Philips (Netherlands)	Afterburner & exhaust, nozzle module	142	1.6
DISA A/S (Denmark)	Main gearbox module	38	7.7
Kongsberg Vapenfabrikk	Fan-drive low-pressure turbine and shaft module	163	40.1

Fokker-VFW was the obvious subcontractor; but it, in turn, spread out its portion of the production among six plants, in order to distribute economic benefits as widely as possible.

Pratt & Whitney is responsible for training, management systems update for the engine co-producers, and for technology transfer. In regard to technology transfer, the US Air Force is restricting the transfer to the Europeans of certain advanced manufacturing technologies. Foremost among these is the directionally-solidified, nickel-based superalloy blades for the two-stage high pressure turbine. Directional solidification is a state-of-the-art technique for longitudinally aligning the metal grains by gradual withdrawal of a casting from a furnace. Pratt & Whitney will supply the directionally solidified turbine blade castings to Fabrique Nationale, which will then perform the detailed machining.

Another restricted technology is in what P&W calls "gatorizing," an isothermal pressing technique for superalloy powder to form superalloy billets of materials such as IN 100 nickel alloy that are virtually unforgeable. The firm will supply gatorized turbine disk billets to its European partners for machining.

One example of a management system update is the computerized online real-time, job-control, material-flow scheduling system being developed with Fabrique Nationale. Data from the computer at FN's Herstal plant will be transmitted to the F-100 office in Brussels and then via satellite link to Pratt & Whitney's Manufacturing Division in East Hartford, Conn. This will permit the managers in East Hartford to know where all the components are and their state of fabrication as they pass through the Belgian shops, from raw materials inventory to finished goods inventory. The same is done with the assembly process. Similarly, data from Fabrique Nationale's engine test cells are linked to East Hartford and thence to the West Palm Beach for monitoring by the engineers there. The intra-US segment of the link is the same that is used to transmit data in the same format from the East Hartford test cells to West Palm Beach.

Also, to keep the US and European F-100 management in step, there are identical "command posts," planning/chart rooms, in the US and in the F-100 office in Brussels. The actual planning work is done in Brussels, and the changes are sent by teleprinter to West Palm Beach to update the charts in the US. Coordination is further ensured by Pratt & Whitney's stationing of people at Kongsberg and DISA to track scheduling and manufacturing control. Altogether, P&W now has about 30 persons in Europe, including 12 in Brussels and 13 at Fabrique Nationale, for the F-100 program, and plans to add a dozen more quality control experts by the year's end. In addition, there are Pratt & Whitney personnel who shuttle to Europe for special short-term tasks on United Technologies' corporate Boeing 727.

The current schedule calls for the first European-made set of parts for a USAF F-100 engine to be delivered in June 1978.

THE F-16 SPO AND GENERAL DYNAMICS

The F-16 program is run by a USAF System Program Office (SPO) at Wright Patterson Air Force Base in Ohio and a subsidiary European SPO in Brussels. This is a highly effective organization in which the European partners have direct participation. In addition to a fully-staffed office in Brussels, there are currently about 20 European government program officers stationed at the main SPO at Wright Field, four of whom are Senior National Representatives. The European partners have full participation in the entire program and full place in all staff meetings whether they deal with logistics, configuration management, engineering, or other functions.

At the present time, there are 302 military and civilian employees in the SPO, of whom 48 are assigned to international aspects of the program. These are paid for by a 2% surcharge to each country, based on the value of the LOA. The SPO has been an extremely effective means of maintaining close coordination and communication among all the partners. One of the problems in the early stages of the F-16 program was a lack of prior experience at General Dynamics in international operations.

Senior and middle management were not adequately prepared for the complexities of dealing with European governments and industries and were, on occasion, insensitive to the political environment. On one occasion, the public relations office of General Dynamics started to issue public announcements at the time of the signing of the first preliminary contract, without any consultation among the European partners. Only a last minute effort by the F-16 SPO at Wright Field forestalled this occurrence which would have angered the other partners. Of the two US light weight fighter competitors, it was Northrop which had had the greater experience in managing collaborative international programs. Northrop had already developed international proposals for the P-530 Cobra as a strictly private venture in which a great deal of co-production could be transferred to the purchasing country. General Dynamics, on the other hand, lacked any similar experience and had devoted its entire effort to selling the F-16 to the US Air Force.

The General Dynamics' management now indicates that, when they were still competing for the final award in the US light weight fighter competition, they were not able to get frank and open information from the European manufacturers on all of their operating procedures. Consequently, their original cost estimates were based on incomplete information, especially of European working conditions. For example, General Dynamics had worked out an integrated schedule for the first year which was totally predicated on multiple shifts, which the European partners are unwilling to adopt. The European countries specified a guaranteed maximum price of $6.091 million in 1975 dollars, including the cost of tooling for European production, a price that was based on the multiple shift operation at Fort Worth. For a single shift, nearly twice as much special tooling was required. Consequently, special arrangements have been necessary for the European governments to pick up the extra tooling costs. The one-shift procedure also creates greater lead times in Europe. General Dynamics has a 26-month lead time for production of an F-16 at Fort Worth. The comparable figure is 10 months longer in Europe.

It seems possible, in retrospect, that contract negotiations would have collapsed very early in the program if it had been left strictly to General Dynamics to convince the European companies they should conform to standard boiler plate in US defense contracts. If it had not been for the F-16 SPO, and particularly for the Business Director of the SPO at Wright Field, Fred Wood, it is reasonable to doubt that the program could have moved ahead. Under Wood's guidance, the US government surrendered some of its usual contract prerogatives, such as the right to audit directly the books of European contractors. It has also delegated to European officials the responsibility normally held by in-plant quality control inspectors.

Another compromise had to be made in the usual practice of reimbursing the contractor only 80% of the costs each month and disallowing the cost of borrowing. The Department of Defense agreed to allow General Dynamics to pay its European co-producers 90% of their cost twice a month, within ten days of billing. Finally, a further stumbling block was the US approach of annual purchase decisions rather than a commitment for the life of the program. This was never fully resolved, but the European governments ameliorated the problem somewhat by guaranteeing virtually their entire order of aircraft.

In 1976 and 1977, General Dynamics has rapidly gained experience in managing the program. However, it is the USAF SPO that remains the driving force of the program, indicating the importance of strong leadership at the governmental level. This strength extends to technical issues. For example, there has been a major effort within the SPO to prevent the build up of complexity in the aircraft. It is a small airplane, which now has only about nine cubic feet of remaining unused space. Many different bidders have made unsolicited efforts to get their equipment on the aircraft; but there is a strong will on the part of the SPO to discourage additional components.

Whatever its lack of international negotiating experience, General Dynamics is in an extremely powerful financial and technical position in the United States, a fact which is bound to aid the project as a whole.

General Dynamics has been less severely affected than other firms in the industry by the recent decline in government defense procurements and civilian aircraft sales. The company has continued to be awarded a number of large US government contracts. Besides being the prime contractor for the F-16, General Dynamics produces the F-111, Trident ballistic missile submarines, sea-launched Tomahawk cruise missiles, and the Atlas and Centaur rockets used by the US space program. Among other items, the company also manufactures fuselages for the McDonnell Douglas DC-10 wide-bodied jet transport and 125,000 cubic meter liquified natural gas tankers.

In 1975, General Dynamics earned $84.5 million on sales of approximately $2.2 billion. Aerospace sales contributed 30.4% of these revenues and 37.8% of corporate net income. Although the company operates plants and offices in ten countries, it earned less than 10% of its 1975 revenues from foreign sales. The principal beneficiary of General Dynamics' F-16 contract is its plant in Fort Worth, Texas, the size of whose work force is expected to double during the program.

SOME FURTHER INDUSTRIAL ISSUES

All of the European partners are motivated by the same kinds of constraints, in particular, by tight budgets and the need to maintain stable employment. The US, especially the SPO, has been very sensitive to these needs. In addition, the F-16 SPO, under orders from Aeronautical Systems Division (ASD) of the USAF, has provided virtually unique access to decision-making processes. In fact, the turning point in Europe came, in the view of SPO officials, when General James Stewart, then Commander of ASD, invited the potential European partners to take part in the source selection process among the light weight fighter candidates. As a result, representatives of the European air forces had virtually full access to all data even before the General Dynamics aircraft was selected and were vested with a great deal of credibility within their own governments. The competing French and Swedish aircraft were presented in more conventional marketeering terms.

The F-16 project has had a considerable impact throughout Europe, both politically and economically. Despite its success as a cost-effective solution to meeting the requirements of smaller NATO air forces, one probable economic affect of the F-16 program on the European aircraft industry as a whole is to lower its productivity. This effect can be created in two ways: first, by requiring capital investment in countries where there is little long-term prospect for sustained aviation production, resulting eventually in under-utilization of capital resources; and second, by depriving the major, well-capitalized industries in Britain, France, and Germany of work that would lead to fuller utilization of their own resources. One example of major capital investment is the construction of an engine test cell at Fabrique Nationale in Herstal, duplicating similar facilities in Britain, France, and Germany.

Partly mitigating the previous point, the Fokker-VFW complex (a Dutch-German international firm) offers an avenue to Germany for the F-16. The company management has already attempted, unsuccessfully, to place some of the work in north German industrial facilities. If the Luftwaffe concludes, at some point, that it should have a less expensive aircraft than the Panavia Tornado to fill out its inventory, the F-16 would be an obvious choice both in a military and industrial sense. The F-16 probably has a promising future in Europe. In addition to the German prospect, Spain and possible Italy are markets for the aircraft.

There is an important difference in the scale of production on the two sides of the Atlantic: a difference that will grow more pronounced and possibly affect the capability of the European partners to participate in growing third-country sales. The initial rate of production at Fort Worth will be 12 per month, possibly rising to 45 per month in the 1980s, depending on additional orders. The European lines will start at six per month, and, based on past experience in Europe, this number is likely to remain constant. The difference in scale will undoubtedly affect the third-country issue in terms of delivery schedules, cost, and work sharing. Potential purchasers of such importance as Japan, Israel, and Iran will press both for work sharing and for early delivery positions.

It is already clear to the European partners that they will have to fight hard to retain their 15% share of third-country sales.

Cost differences have brought to light once again the differences in US and European industrial productivity, generally calculated on a ratio of 1.5:1 or 2:1 in favor of the United States. However, the European partners claim that part of the apparent difference in productivity is probably due to US contract loading practices, in which a US subcontractor may add a handling charge when he first ships a part to a European partner and again when the finished item comes back through his facility on its way to the prime. The European companies have vigorously protested this practice. The European industry partners have also complained about the large volume of paperwork involved in the program, which SABCA officials estimate to account for up to 30% of total system cost in Europe.

Regarding technology transfer, the impression of the US participants is that the European partners are very interested in acquiring management and manufacturing know-how, ranging from management procedures to advanced machine tool methods, that will improve their general operations. They apparently have much less interest in specific areas of weapons technology. In the sensitive area of electronic warfare equipment, some differences of opinion have emerged. The United States is reluctant to enter into coproduction agreements for such systems. The US proposed final version of the F-16 will carry an ALQ-131 jamming pod. The Belgians are pressing for acceptance of an internally mounted jammer which is already being built under US license in Belgian for use on the Dassault Mirage V.

Appendix D

REFERENCE BIBLIOGRAPHY ON NATO STANDARDIZATION AND TECHNOLOGY TRANSFER

Appendix D

REFERENCE BIBLIOGRAPHY ON NATO STANDARDIZATION AND TECHNOLOGY TRANSFER

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