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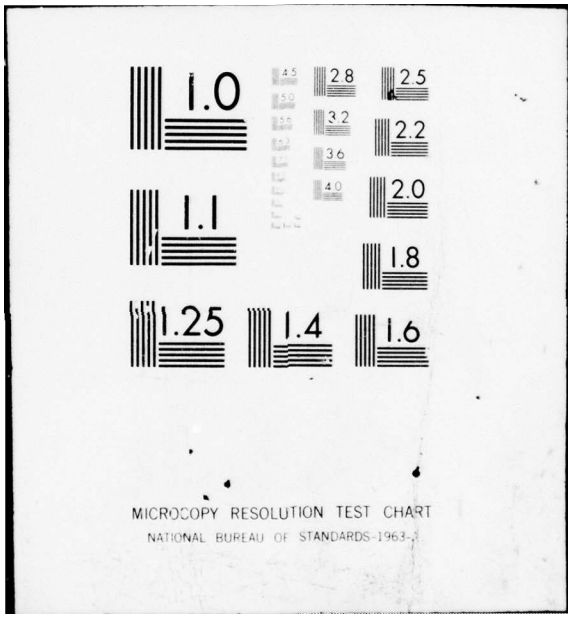
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REPORT

VOLUME I

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Methodology to Quantify the Potential Net Economic Consequences of Increased NATO Commonality, Standardization and Specialization

Prepared for:

The International Economic Affairs Directorate
Office of the Assistant Secretary of Defense
International Security Affairs

In response to:

MDA 903-78-C-0166

EXECUTIVE SUMMARY

Conclusions & Recommendations
By

Dr. William C. Pettijohn
and
Dr. Jacob A. Stockfisch

October 13, 1978

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METHODOLOGY TO QUANTIFY THE POTENTIAL NET ECONOMIC CONSEQUENCES OF INCREASED NATO COMMONALITY, STANDARDIZATION AND SPECIALIZATION

Prepared for:

The International Economic Affairs Directorate
Office of the Assistant Secretary of Defense
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This study defines and demonstrates interrelated methodologies for estimating the costs of cooperative NATO weapons systems production programs for (a) individual programs (the MICRO methodology) and (b) NATO Alliance member nations (the MACRO methodology). The MICRO methodology is based on standard cost estimating techniques and requires detailed input data concerning production factors. The MACRO methodology relies on production data from analogous industrial → (OVER)

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

(20) Abstract

cont → activities in combination with gross expected major system acquisitions to estimate gross economies available to the Alliance from utilization of least cost production option. Cost estimates derived by both MICRO and MACRO methodologies are for demonstration purposes only.

CONTENTS

CONTENTS (continued)

CHAPTER I. INTRODUCTION

BACKGROUND

In 1974 a paradigm was proposed which postulated that large economies and increased military effectiveness could be obtained through Allied co-operation leading to standardization of the equipment used by NATO armed forces.[1/] The *prima facie* evidence which support its validity are the following observations:

- NATO forces are equipped with an increasingly polyglot selection of equipments.
- This equipment mix is the product of several independent or semi-independent and nationally protected development and production systems within the Alliance.
- Warsaw Pact forces are equipped with materiel which affords many of the combat and logistic advantages of standardization. This equipment approaches or is qualitatively better than that fielded by NATO; is in greater supply; and this is done with the total resources roughly equal to those expended by the NATO Alliance.

1/Thomas A. Callaghan, US/European Economic Co-operation in Military and Civil Technology, Ex. Im Tech Inc., August 1974

This report is concerned with those aspects of the paradigm related to costs and economic efficiency. Here it is clear that its underlying assumptions are associated, (a) in the development stages of equipment with the avoidance of redundant development efforts and the selection of least cost development alternatives; (b) in the production stages with failure to achieve economies of scale and learning benefits due to less than optimum-sized production facilities, less than optimum production runs and also the loss of economies to be gained from the selection of least cost producers in a free trade context; and (c) in the operational use phase with the replacement of redundant and sub-optimal supply and maintenance systems.

Observations of apparently greater Warsaw Pact output with roughly equal inputs do not necessarily support the paradigm. This is because this apparent superiority may be due to factors other than the obvious differences between the NATO and Pact development and production systems. Specifically, this superiority may be as attributable to greater Soviet efficiency in identifying requirements, e.g. recognizing the relationships between what is technically and economically feasible and operationally useful, as to their monolithic, monopolistic development and production system. This possibility raises the exciting possibility that given the correct incentives, NATO could approach Soviet efficiencies in requirements definition and at the same time achieve, through a freer NATO military market, development production and distribution efficiencies (as it does for civilian products) which would far outdistance the Warsaw Pact.

As will be seen in subsequent discussions and analyses, there are many political and economic reasons which will make the transition from the current protected, nationally oriented development and production systems to an Alliance-wide system difficult. However, it should be emphasized that the analysis of these difficulties is not the primary problem addressed in this report. Rather, this analysis treats methods by which the economic benefits of a more rational Alliance development and production system can be estimated. In this context the authors well recognize that the "economic man", let alone the "economic nation" or "economic Alliance," does not exist. However, economic advantages, particularly when linked with a significant external threat can at some point become compelling for individuals, nations and Alliances. The value of economic analyses such as those found in the following pages lies in their ability to identify expected gains or penalties, or to define the means by which they can be realized. With respect to the NATO Alliance and world peace, there is probably no more important task at this time.

PURPOSE

The purpose of this report is to define methods by which:

- The cumulative impact of more economically rational policy for developing and producing military equipment on the NATO military budget as a whole and on individual nations can be generated and predicted, and

- the expected cost differences for individual weapons development programs utilizing two or more competing NATO-related development and production strategies can be identified and measured.

These two interrelated methodological studies have been called the "MACRO" and "MICRO" methodologies, even though these terms may not conform precisely to their usage in economic literature. For convenience, however, these designations will be retained in the balance of the report.

The output of the two methods, in addition to the differences noted above, are intended for different users. The MACRO method is intended for use primarily by those personnel responsible for evaluating U.S. materiel development and acquisition policies. The MICRO method is intended for use by those concerned with estimating the costs of individual development programs. Roughly, at the level of the Office of the Secretary of Defense, in the MACRO case, these users would be the Office of Assistant Secretary for International Security Affairs (ISA) and the Office of the Under Secretary for Research and Engineering (UDRE); and for the MICRO, the UDRE and the Services. Finally, it is hoped that, when fully developed, these methods would be used throughout the defense-oriented segments of U.S. Government, including the Congress, and industry as an essential part of the means by which weapon systems are selected for development, and the ways in which production is organized.

METHOD

The method used in this research was to employ internationally known economists with strong NATO backgrounds to investigate and define the MACRO method. These personnel relied on the concepts and techniques of economic theory in their work. In the case of the MICRO method, personnel having strong backgrounds in defense cost analysis were utilized. These personnel made use of concepts and techniques which are consistent with those currently used by DOD.

In addition to these two efforts, which have produced their own distinctive and identifiable products, a review team was constituted to provide an overview and bridge between them.

SCOPE

These analyses focus mainly on the materiel acquisitions or production process considering scale and length of production, industrial base investments, unique national capabilities, and the feasibility of various production sharing possibilities. Of secondary interest are implications for the research and development process as well as downstream economies in logistic and maintenance support. In these contexts the methodologies yield initial estimates of potential gains to be realized from production specialization, e.g. free trade and comparative production advantages, and provisionally indicate the equipment areas where such gains might be greatest. In addition, the methodology derivation process described in the report, defines areas where better data and further work is needed to make their output more meaningful and precise. Finally, the history of equipment standardization

in NATO is traced and some aspects of the political context in which standardization goals must be pursued are described.

ORGANIZATION

The report is organized into three volumes and several appendices to these volumes. Volume I is an overview and executive summary. It consists of three chapters which summarize, tie together, evaluate and demonstrate the potential use of the MACRO and MICRO methods. A fourth chapter contains the report's findings, conclusions and recommendations.

Volume II contains the MACRO methodology. It is composed of four parts and two appendices; part A contains a history of NATO standardization; Part B, an analysis of the NATO Alliance military budgets; Part C, the development of the tools for estimating production economies and Part D, their initial application. Appendix II is a review and analysis of U.S. data available concerning learning and economies of scale. Appendix I is a similar but much more extensive analysis of European, and to the extent possible, U.S. data on the same subjects. The reader's attention is specifically drawn to Appendix I as a definitive document in this area.

Volume III contains the MICRO methodology. It contains five chapters and four appendices. The chapters define terms used, layout, recommended cost formats and summarize the application of the method detailed in the appendices. The final chapter describes and defines the total MICRO method. The appendices demonstrate the retrospective application of the method to armored vehicle, aircraft and missile programs and in a final appendix, the requirements for data in future applications are discussed.

CHAPTER II. NATO ECONOMIC AND COST ANALYSIS

INTRODUCTION AND PURPOSE

The MACRO and MICRO methodologies presented in Volumes II and III are primarily concerned with economies in manufacture of weapons and other military equipment. This is done in consonance with the project's contractual Scope of Work as reflected in Chapter I. However, this is not the only area within the materiel life cycle where NATO expenditures can be reduced or made more efficient. In addition, savings and efficiency in production are related to and to some extent depend on actions taken in these other areas. As a result, the following sections deal with potential increases in research, development and logistics efficiency and lead to the consideration of efficiencies in production.

RESEARCH AND DEVELOPMENT

At one level of complexity the method for measuring and predicting increased efficiency in research and development resulting from NATO collaboration is quite straightforward. It merely involves assessing the resources saved in avoiding redundant development efforts and is illustrated by the PATRIOT cost analysis case study. Here R&D costs of $2 billion would be saved were NATO to adopt PATRIOT rather than develop

a separate European system.*

This is, however, an oversimplified example, and it is apparent that there are at least two other major areas where NATO-wide R&D can become more efficient. The first is in avoiding unsuccessful development programs and the second is in formulating and conduction research programs which result in more available technology which has greater direct and more timely military application.

Achieving greater efficiency in these three areas, e.g. avoiding unnecessary development redundancy, avoiding unsuccessful development programs and increasing the efficiency of research, poses admittedly difficult political and technical challenges. In the political arena their solution requires closer ties and greater trust among the NATO Allies than has been present in the past. The political will to make hard decisions concerning research specialization which may have unwanted or undefinable commercial and third nation military sales implications is also necessary - on both sides of the Atlantic. Finally, the need to rationalize NATO-wide military requirements and goals to a greater extent than has been possible in the past is also necessary.

In technical areas the challenge involves solving many of the same problems of R&D management that have faced the U.S. over the last two decades; and the design and implementation of a more efficient information exchange system than currently exists. With respect to the selection and management of new developments, it is quite possible that a hybred US-European system which capitalizes on demonstrated European capabilities in choosing successful development programs in conjunction with

*Volume III, Appendix A, page 116.

U.S. efficiencies in the competitive conduct of such programs could result in an R&D effectiveness far beyond that currently achieved, either in NATO or by the Warsaw-Pact. As for research, given free information exchange, the natural forces which drive efforts to attain new knowledge could quickly result in far greater rationalization than exists at present.

The reader will find that the author of the MACRO Model (Volume II, Greenwood) is very conservative concerning the possibilities and probabilities for obtaining more efficient and effective NATO-wide research and development through increased collaboration.* The Vertex Corporation believes that this assessment is unduly pessimistic. It ignores trends toward rationalization within Europe which are already apparent; fails to recognize or lend weight to the urgency imparted by the continuing increase, and recognition of the increase, in the Soviet threat; and finally, it fails to take into account the positive feedback that might be provided by the MACRO analysis itself. The extensive savings in production costs defined by the MACRO research are to a major extent dependent on increased NATO planning and R&D collaboration. But it should be recognized that that until these savings and the methods for achieving them have been defined, the economic incentives for collaboration will not be clear and compelling. Thus, there will be a positive feedback based on the MACRO results (if our initial indications are

*"...it is quite simply unimaginable that any country with proven competence in a specific military technology could give an irredeemable hostage to fortune by voluntarily abandoning its investment. Those who imagine that national defense R&D efforts are 'negotiable' within broader trans-national procurement strategies delude themselves." Volume II, Page 10.

born out by the acquisition of more definitive planning and cost data) in the NATO defense ministries, in NATO Alliance legislative bodies, and in NATO organizations themselves. Realization that NATO can provide its armed forces with state-of-the art equipment at much lower costs than with its present acquisition policies, combined with increased appreciation of the Soviet ground warfare threat, ultimately must result in major changes in the quality and quantity of cooperation within the Alliance.

OPERATIONAL ECONOMIES

It is apparent that greater equipment commonality would lead to savings in costs of supporting NATO units in the field and increase their military effectiveness in wartime. However, major logistics cost savings are not necessarily dependent on achieving high degrees of increased commonality. Modern inventory systems and supply techniques can cope efficiently with great diversity within the systems supported. The problem is adopting a systems approach to NATO logistics which will permit contemporary methods and equipment to be used. The tools necessary to investigate the savings which might accrue from the adoption of a systems approach are available and it is to be hoped that undertaking such analyses* will be a priority task for the proposed Office of the Assistant Secretary General for Logistics. It is important however, to clearly recognize that improved efficiency in this area is <u>not</u> dependent only on "...if and when commonality were to obtain more or less across the board."**

*For instance, a recent study of the US CONUS Materiel Distribution System (DODMBS) indicated that over $100 million per year could be saved through its reorganization. The problems were over-capacity and geographical mismatch of facilities with their customers. It is almost certain that like inefficiencies exist in NATO and that a similar study would reveal and quantify them.

**Volume II, Page 8.

PRODUCTION OVERVIEW

The basis of belief that NATO can benefit from weapon and system standardization resides in the expectation that resources can be more efficiently utilized in the manufacturing of new weapons, provided the diverse countries can somehow manage to procure standardized systems. Entailed in this belief is the related view that presently too many systems are procured to meet a given requirement. As a result, a smaller number of each system is produced. Consequently, there is little or no opportunity to reap the fullest gains obtainable from "economies of large scale production," "mass production," "serial production," or other similar and related phenomena that generate lower unit costs and which have been a feature of modern industrialization.

Although the evidence and benefits of scale economies and efficient production are features of everyday life in modern industrial societies, their precise nature, source, and cause are somewhat elusive. They are a function of technology, physical conditions, and especially, the social organization that defines incentives and conditions that create markets and opportunity to exchange. Efficient and large scale production has, in turn, been studied in terms of three major concepts which are not

necessarily air-tight:

(1) economies of scale,

(2) learning, and

(3) regional specialization and comparative advantage.

Although these concepts can be defined in ways that are distinct, they are usually associated or observed in similar contexts. Specifically, they are found when there is a large, if not mass, market for a product. The rate of production per unit of time must be sufficiently high as to warrant exploiting specialized machinery or installations (economies of scale). The time-length of the production run must be sufficiently long so as to be able to apply knowledge gained from experience to items successively produced (economies of learning). The presence of both sufficiently high production rates and long production runs, in turn, is conducive to the emergence of a fine-grained division-of-labor, as evidenced in specialized industrial areas.

The complexity of these production interrelationships in their necessarily social context is such that it is not readily transparant as to what is the exact set of causes for the observed efficiency of any organization, including an entire economic system. In the same vein, it is even less transparent as to how much a particular change in the social organization — as illustrated by, say, a change in tariff or trade regulations, or labor union rules — will improve (or worsen) overall productive efficiency. With respect to the "NATO problem," the relevant contemplated change in the "social organization" is the possibility that weapons and systems procurement of each of the member nations will be modified and managed in ways that will permit better exploitation of potential economies and efficiencies in the manufacture of those systems. Specifically, how might military procurement

of each of these countries be consolidated and managed so as to get maximum benefit that has been observed in the procurement by ordinary civilian consumers of countless goods manufactured for civilian demands? This question, of course, raises a further question: How great are the possible efficiency gains from consolidated or standardized procurement?

The answer to this question will not be highly precise because of subtle aspects of the subject. However, a highly precise answer is not necessary. The magnitude of possible savings is such as to make a strong case to press for some program of rationalization of system procurement.* It then becomes relevant to establish some coarse estimates of possible savings and, if it is decided to adopt some rationalization or alternative procurement schemes, to develop ways to measure and monitor the benefits and costs associated with alternative procurement strategies.

What follows summarizes the main points presented in the papers of this project that treat the nature of production economies and indicate their magnitude for the NATO countries. This is the "MACRO" phase of the study. Next, a discussion of the "MICRO" methodology is offered.

THE MACRO METHOD

Economy or efficiency of production, in a social context, is regarded in economic literature, to have three principal sources:

(1) Scale of production. These refer to production rates per unit of time of sufficient size that it is possible to take advantage of technical means and specialization that reduce physical inputs necessary to produce. Thus, an oil refinery could be of sufficient size to warrant construction of a pipeline to transport its output, rather than relying on

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* NATO programs like the Periodic Armament Planning System (PAPS) and the NATO Armaments Planning Review (NAPR) are attempts to fill this need.

tank cars. A garment plant should be of sufficient size to warrant breaking down the different tasks (cutting, sewing, etc.) so that people develop specialized skills for each of them. Different scales of production, of course, also warrant entirely different processes, as illustrated by carbon typewriter paper versus a Xerox machine.

(2) Learning. For "limited batch" production processes (as contrasted with continuous processes, like oil refining or automobile assembly), it is necessary to learn how to produce the thing. It turns out that it takes less labor effort to produce the second unit than the first, less to produce the fourth than the second, and so on. At some point--as with continuous production processes--people learn all there is to know on how to produce the thing, at which point there are no more gains from learning to be had. But for many items, especially of a major new design, gains from learning are a feature of the production process. Virtually all weapons and major military systems (as contrasted with ammunition) exhibit decreasing costs per unit due to learning.

A word is warranted with respect to the difference between scale of production economies and learning. Conceptually, these are sharply distinguished, although both are a function of the total quantity produced. Scale of production economies, on the one hand, treats the rate of production per unit of time. As this rate increases, it then pays to employ specialized machinery, or to divide the labor, and so on. Often, a larger production rate justifies a more capital-intensive process in the form of large machines, and so on. Learning on the other hand, is a function of the time length and density of a production run. Thus, if 1,000 units are produced per year, the production of 2,000 units over two years means

that people can acquire skill and discover more efficient ways to produce during the first year, and these gains are then applied over the second year. This phenomenon also says--if everything else is equal--that from the point of view of learning, it will be less costly per unit to produce 1,000 units over two years than over one year. Of course, not everything else is equal. A production rate of 500 a year, instead of 1,000, may not warrant certain specialized machines. Thus, it is possible that there can be a tradeoff between scale and learning economies. Also, availing one's self of learning economies, to the extent it means a longer run of time, can affect the time-availability of the system. In such a case, a choice must be made as to who gets the items produced during the early phase of the run.

Although the possibility of a tradeoff between scale and learning economies can exist, it should be emphasized that both kinds of economies can also be cumulative. That is, they can often be exploited simultaneously. This condition is most likely to be the prevailing one in the NATO weapons acquisition process. For example, two separate programs involving a total 1,500 units each to be produced over two years might be contemplated. Each operation thus takes place at a scale of 750 per year. But if these programs could be consolidated into one, then a rate of production of, say, 1,000 units a year over three years is feasible. In this instance, both scale and learning economies are attainable. It is suggested that this situation most likely prevails in the NATO context.

(3) Geographical Specialization. This phenomenon is often referred to as "comparative advantage," and it is sometimes associated with such public policy slogans as "free trade." The foundation of

comparative advantage as between regions or countries lies in the twin facts that certain outputs require a disportionate share of a highly specialized input for its production, and that some countries possess or own a relatively abundant supply of that particular input. The abundant supply causes relatively low price, which is responsible for lower unit production cost and hence, "comparative advantage."

How a country comes to possess a comparative advantage in its ownership of a specific factor may be a simple matter of geography, as illustrated by the textbook example of Portugal and wine production. In other instances an abundant supply of highly specialized inputs may have been acquired through time. Thus, the Swiss developed skills in watchmaking which, apparently, were readily transferable to fuze and weapons manufacturing. In these kinds of instances, both economies of scale and the gains from learning become embedded in the country's economic structure.

Given these "causes" of enhanced production efficiency, or cost saving, as a function of both larger individual programs and longer production runs, what are the potential savings obtainable in the form of lower manufacturing and, hence, procurement costs? The specialized studies (by Hartley, concentrating on economies of scale; and Klotz, concentrating on learning) suggest the following:

- On the basis of experience with a variety of civilian outputs, scale economies ranging between a 5 to 15 percent reduction in unit cost (as a function of a minimum Efficient Plant Scale concept) appear attainable. Extension of these data with respect to activities that most closely resemble manufacture

of military goods suggests that a factor of 10 percent is a reasonable weighted average that could be applied to military procurement. Learning economies, on the other hand, appear to be of the order of 20 to 30 percent, with respect to labor input. If labor input is 50 percent of value added, this works out to a 10 - 15 percent unit cost saving. Such a saving is achieved, of course, only if a doubling of production run occurs.

- These two sources of savings appear additive within the likely aggregate programs of the NATO countries. Thus, the overall savings achievable from rationalization of weapons manufacturing and procurement appear to be between 15 to 30 percent, with the ultimate outcome depending, in part, upon the relative weight of future procurement as between different kinds of systems. It appears that scale economies are most pronounced in items whose production most closely resembles civilian continuous production processes, like motor vehicles. Thus, automotive equipment, like trucks and tanks, are apt to exhibit scale economies to a greater degree than learning benefits. Aircraft construction and shipbuilding, on the other hand, display sharper learning effects, and less scale effects.

None of these estimates address any possible additional gains from comparative advantage and country specialization. These are more elusive to tie down, in part because they must be identified with respect to highly specific programs relative to the resource endowments of the

different countries, and in a context that extends the focus simultaneously to both production and development.

Volume II provides insight about the absolute magnitude of possible cost savings. It indicates some 83 major weapons or systems categories--e.g. frigates, light mortars, long-range anti-tank weapons--which are required to equip land, sir, and naval forces. Procurement of these items for developed countries (all other than Turkey and Portugal in the NATO context) run from 10 to 20 percent of the annual defense budgets. (These ratios do not include R&D expenditures, or spare parts and ammunition). Thus, 15 percent of total defense spending appears to be a good point estimate of the major system procurement share.

- What are the appropriate annual defense budgets to which these procurement savings might be applicable? Table 1 shows total military budgets for each of the NATO countries (other than Iceland and Luxembourg) for 1975. It also shows the GNP for each country and defense spending as a ratio of GNP, which provides a feeling for the relative importance of defense spending (and system procurement) for each economy. In Table 1, it is assumed that 25 percent of the U.S. military budget is attributable to strategic forces, to which any NATO rationalization scheme would not fully apply. An adjustment for this amount provides the figure of $126.49 billion shown at the bottom of the Table, which is assumed to be the total amount of resources applicable to and justified by NATO defense against conventional forces. Notice that this $126.49 amount also includes France.

- Since this $126.49 estimate applies to the year 1975, allowance must be made for increasing nominal defense spending to offset inflation. We assume an average inflation rate of ten percent per year (see Table 2 for evidence of inflation rates in major NATO countries). If the $126.49 billion shown in Table 1 is adjusted by a ten percent factor for each year through 1980, we arrive at an estimate of $203.87 billion for the total relevant NATO defense budget. If we apply the 15 percent system procurement factor to this amount, major system procurement outlay would be $30 billion annually. If procurement and its manufacturing could be rationalized to realize a 15 percent* savings, then a maximum of $4.5 billion a year savings is possible in 1980 dollars.** This amount could be revised upward to the extent that manufacturing savings extend to spare parts procurement costs.

Constraints on a Gross Overall Estimate

The $4.5 billion potential savings is based on the following assumptions:

- The NATO defense industries are operating at less than on efficient scale.

- At some point as the planning horizon is extended the NATO major systems acquisition budget in its entirety becomes available for consideration

*Using the lower bound of the savings potential defined above.

**It's interesting to note that at an annual inflation rate of 7%, this is the same figure that Callaghan's 1974 estimate of $3 billion would appreciate to.

TABLE 1. GROSS NATIONAL PRODUCT AND MILITARY SPENDING OF NATO COUNTRIES, 1975.

(Dollar Amounts are Billions)

	GNP	Military Spending	Spending As % of GNP
United States	$ 1,516	$ 90.95	6.0
Canada	152	3.07	2.0
European NATO			
Belgium	63	1.88	3.0
Denmark	36	.92	2.5
France	338	13.09	3.9
Germany	425	15.30	3.6
Greece	21	1.36	6.5
Italy	167	4.65	2.8
Netherlands	81	2.87	3.5
Norway	28	.92	3.2
Portugal	15	.78	5.2
Turkey	36	1.97	5.4
United Kingdom	229	11.47	5.0
European NATO	1,439	55.21	3.8
Total, NATO	3,107	149.23	4.8
Total, Less 25% of U.S.		126.49	

Source: SIVARD, Ruth Leger, World Military and Social Expenditures: 1978, Washington, D. C., Arms Control Association, 1978, p.21.

TABLE 2. Annual Percent Changes in Gross National Product Deflators for Selected NATO Countries, 1971 - 76.

	1971	1972	1973	1974	1975	1976
United States	4.1	5.8	9.7	9.6	5.3	5.5
Canada	5.0	9.1	14.9	11.2	9.6	6.5
Belgium	5.5	6.6	12.3	12.6	7.5	
France	6.2	7.7	11.6	12.9	10.4	8.8
Germany	13.6	5.8	6.0	13.8	10.3	8.3
Italy	6.2	11.6	17.7	17.4	17.8	NA
Netherlands	8.9	8.1	8.4	11.1	8.3	NA
United Kingdom	10.3	7.8	17.3	28.9	13.8	12.3

Source: Federal Reserve Bank of St. Louis, Rates of Change in Economic Data for Ten Industrial Countries. (June, 1978).

(Greenwood indicates that about 50% is available between now and 1982), and

- NATO nations have the political freedom to implement changes in their acquisition processes if the stakes are high enough.

At this point, we believe the above assumptions are reasonable and, in fact, conservative. Obviously, more data and analysis are needed with respect to the NATO equipment procurement mix and the extent to which production in Europe and the U.S. approaches the most efficient production rates.

THE MICRO METHOD

Given an opportunity and a motivation to reap the possible gains from rationalization of weapons procurement, the problem remains of how to go about doing it. This presents many formidable challenges, the somber quality of which is discussed at some length in Greenwood's paper. However, to make any alternative procurement scheme operational will require, at a minimum, identification of potential cost savings with respect to specific contemplated programs. Identification must further extend to components or sub-elements of a major system in such a way as to strengthen the credibility of estimates of cost savings and, simultaneously, provide a means of ascertaining how such savings might accrue to diverse members of the NATO partnership. The latter kind of knowledge may prove indispensable with respect to serving the negotiations that will be a necessary part of any rationalization scheme.

Designing an evaluation mechanism that can serve these ends is a tall order. It cannot be fully achieved in the absence or independently of specific procurement and contracting mechanisms that might have to be designed to implement a new rationalization scheme. Alternative contracting mechanisms, in particular, must have features and incentive devices that enhance the quality of the data and information supplied to decision-makers. Given the data, there is then a need for a format and related system of accounts that both displays the data in an efficient way, and permits tabulations that provide decision-makers insights.

The Management Analysis Corporation Report describes such a system and a methodology by which data might be used. Its main features are those of existing U.S. Department of Defense weapon system cost

tabulation formats and methods, but modified so as to display both separately and aggregates of NATO country requirements. It further facilitates cost comparisons as diverse procurement strategies with respect to any given system. These formats are specified in such a way as to permit laying out a fair amount of detail--e.g., learning curves as they might apply to major subsystems and components. The study then illustrates how the methodology (or costing/accounting system) might be used by means of three case studies: specifically, the main battle tank, ground-to-air missiles, and tactical aircraft.

In the course of trying to develop and specify this methodology, several points became apparent. First, it is something of a trial-and-error process to try to specify information requirements and displays relative to the kinds of decisions that are to be made in an institutional setting. This is simply a way of saying that information must be tailored to the needs of <u>specific</u> decision-makers and the kinds of decisions specific parties make must depend on whether adequate information will, in fact, be available. Second, it is apparent that existing data systems are dependent on the submissions of the military services (and their contractors). The quality of such submission is always an open question, given the fact that the submitters know that their future budgets depend, in part, upon the reaction of decision-makers to the data submitted. Within the defense establishment of a single country, senior decision-makers (and their staffs) can develop a sense by which they can apply "English" to biased submissions. What will be the counterpart of this capability in a context of NATO standardization?

Finally, it is not entirely clear how cost savings and comparisons should be best displayed and evaluated in a context where several countries may be simultaneously and jointly involved in procurement and production, and where exchange rates fluctuate. As noted previously, "comparative advantage" and regional specialization are a source (or "cause") of efficient production. In the framework of international trade, changes in exchange rates can reflect or measure changes in comparative advantage. Related to this subject is the one of precisely which countries share in what amount of any savings that might be obtained from rationalized procurement. Although the overall goal as between the aggregated NATO partners is unambiguous--i.e. to obtain maximum military capability from the total physical resources allocated--some hard thinking is necessary to find equally unambiguous measures of potential gains to each of several countries in a context of different monetary units and the diverse resources of the separate countries.

SUMMARY AND INTERRELATIONSHIPS RELEVANT TO PRODUCTION ECONOMIES

This chapter identified MACRO and MICRO aspects of rationalization of weapons production in the NATO context. It can be seen that the MACRO side deals with the social economy setting and conditions that could sustain resource savings in the manufacturing of military equipment, provided certain changes are taken by the political/military institutions by which procurement is rationalized. The MICRO side of the subject, on the other hand, treats--at a minimum--the need for and the kind of reporting and accounting system that a military decision-making organization might need if it is to be able to implement any procurement

rationalization scheme or strategy. It should be emphasized that although an accounting and data processing system is a necessary feature of any planning and decision-making apparatus, it is not a sufficient ingredient. Attention must also be given to new incentive and contracting arrangements, techniques by which data and information are evaluated if not validated, and methods by which it is decided how possible gains from rationalization are to be divided or assigned to the various partners. Consideration of these matters, in turn, may suggest modifications of the accounting system advanced in this study. Nevertheless, despite the unknowns impacting on these MICRO relationships (unknowns because they are most sensitive to matters that have a high political and bureaucratic content), the potential for real resource savings in the MACRO setting appears to have a firm foundation. It will take, however, both imagination and determination at the MICRO levels of each of the countries involved to find constructive ways to realize those possible savings.

CHAPTER III. A DEMONSTRATION

INTRODUCTION

There is no easy way to conduct economic analyses of complex international production alternatives. While Volumes II and III define methods for doing this, those methods should not be confused with the data collection and analysis which is necessary to reach firm and valid economic conclusions. Therefore it is important this chapter be regarded as exactly what it is; a demonstration of how the methods might be used. In this respect, and to sustain the interest of the reader, a topical subject has been chosen as the subject for the demonstration and insofar as possible within the scope of work of the project, real cost data and production factors have been used. Nonetheless, except for the illustration of how the MACRO and MICRO methods can be used to illuminate the interactions among the various data inputs when NATO-wide production of a major weapons system is considered, no further conclusions can or should be drawn.

PURPOSE

The purpose of this chapter is to bring forward into the summary and to demonstrate certain basic features of the MACRO and MICRO methodologies. In particular, the hypothetical MACRO construct proposed by

Greenwood in Volume II, pages 156 and 157, are combined with the treatment given comparative tank production costs by Smith in Volume III, Appendix A, pages 57-105. In addition, we have drawn rough information from newspaper accounts of the recent UK decision to develop and produce a main battle tank with a 120mm rifled gun for its main armament. These constructs, formats and data are used to demonstrate the use of the MACRO and MICRO methods.

ORGANIZATION

The chapter is organized into two parts. The first part paraphrases Greenwood's hypothetical calculation (pages 156, 157 Volume II); the second part extends this hypothetical calculation into a less hypothetical situation, main battle tank production.

A Hypothetical Calculation

Assume that five NATO nations have a requirement for 4600 hypothetical weapons to be operational in three to four years. The largest nation needs 2200, the smallest 300, with the other falling in between. One way of meeting this requirement is for each nation to build its own. Both the numbers to be built (scale) and learning to be achieved are then specified. This hypothetical situation and the assumed costs are shown in TABLE 3.

TABLE 3

Hypothetical Calculation - National Initiative

Country	Required Units	Time Years	Forecast Budgeted Cost $ (M) (Unit Cost)	Actual Annual Output		mes Annual Output*	Benchmark Cost ($B)
A	2,200	4	1.5	550	=	550	3.30
B	800	4	1.75	200	<	400	1.40
C	700	4	1.80	175	<	400	1.26
D	600	3	1.80	200	<	400	1.08
E	300	3	2.00	100	<	300	0.60
	4,600						7.64

*mes = minimum efficient scale of production

Note that due to different local conditions, mes may vary from nation to nation

Now assume that production is assigned among the five nations such that the weapons are procured in a way which permits the maximum number of countries to produce at mes. This results in the production rates and costs shown in Table 4.

TABLE 4

Hypothetical Calculation - Efficient NATO Co-Production

Country	Assigned Output	Benchmark Cost ($B) (if produced under old cost condition)	Cost Reduction Factors (CRF) Scale (S)	Learning (L)	Actual Annual Output	Procurement Option Cost
A	2,200	3.30	1.00	1.00	550	3.30
* B	1,200	2.10	0.90	0.95	300**	1.80
* C	1,200	2.16	0.80	0.90	300**	1.56
D	--	--	--	--		--
E	--	--	--	--		--
	4,600					6.66

*B & C now produce for D & E

**Still not at mes, further gains to be made by reducing production period to 3 years, say, thereby moving B & C to mes of 400.

In the assigned output situation it can be seen that several cost advantages accrue. First, there are some savings in going to lesser cost producers, countries D and E having the higher costs per unit than countries B and C. More importantly, by allocating production to B and C, these producers achieve scale economies by more closely approaching mes for their production facilities; and, in producing more units they achieve a larger learning benefit. The table shows what these cost reduction factors might be for typical kinds of weapons systems, and they result in a procurement option cost of 13% less than the national initiative option.

A Less Hypothetical Calculation

To demonstrate the use of the method in a more realistic way, data have been drawn from Appendix A, Volume III and applied to the NATO main battle tank problem. It is well recognized by the authors that sufficient data are not available to do more than provide the roughest overview of this problem and that even this must be buttressed by numerous, sometimes controversial assumptions. However, we believe that if such an illustration adds to the understanding and appreciation of the methods by our readers, it is worth the risks involved.

In the following pages the requirement numbers used are not official and the cost information is derived from unclassified sources. Table 5 shows the benchmark calculation in terms of a 120-mm gun tank fleet.

Table 5

Benchmark Main Battle Tank Calculation

Country	Total NATO Requirement	Time Years	Forecast Budget Cost/Unit ($m)*	mes**** Annual Output	Benchmark Cost (B)*
US (XM 1)	7000	10	1.2 (Vol III P.86)	720	8.4
FRG (LEO II AV)**	7000	10	.98 (Vol III P.73)	720	6.86
UK (CHIEFTAIN II)	1000	10	1.4***	300	1.4
OTHER NATIONS (?)	6000	10	?	?	?
	21000				16.66+?

* FY79 dollars based on FY76 estimates using Army inflation factor (Page 61, Vol III). The application of this factor to FRG costs may overstate them. However, the document from which LEO II AV costs are drawn may underestimate them (Page 75, Vol. III).

** For purposes of illustration we assume that the FRG produces the LEO II AV. Subsequent references to the LEO II mean the AV version.

*** UK Chieftain tank costs were about 15% more than the M60, and it is assumed that the cost of a new UK tank equal in capability to the LEO II and the XM 1 will also cost about 15% more due to the UK smaller production runs.

****mes for the US M60 tank production facility appears to be about 60/mo. When production was 1/2 that at 30/month unit costs were about 30% higher. It is assumed that the FRG mes will be in this same range. The UK obviously must design its production facility for a much lower target output and hence has a smaller mes.

It is apparent from this table that NATO has several alternatives and that a key factor is the production of tanks for nations other than the US, FRG and UK. In this respect, since both the US and FRG facilities are operating at close to mes during the ten-year period, only learning economies (which according to Hartley are likely to be quite low) are to be gained by increasing the units produced in these countries. The UK production facility on the other hand, is scheduled to operate at about 1/3 of mes. (If it operated at mes it would complete production in three years and lie idle for seven, at a cost which might not be as high as operating at 1/3 mes for ten, but a cost nonetheless.)

The Least Cost Solution

The obvious least cost NATO-wide solution would be to procure the least cost tank for its entire requirements. This option results in Table 6.

TABLE 6

Least Cost Calculation

Country	Assigned Output	Time Years	Forecast Budget Cost/Unit ($m)	Annual Output	Procurement Option Cost $B	
US (LEO II)	7,000	10	.98*	720	6.860	
FRG (LEO II)	7,000	10	.98*	720	6.860	
UK (LEO II)	7,000	10	.98*	720	.980	
OTHER NATIONS	--	10	--	--	5.880	14.7
	21,000				20.580	

*Learning and scale economies are included in these cost estimates

Here the UK produces the LEO II* rather than the Chieftain II and its mes is raised to 720 per year (at the same assumed cost as is projected to produce the LEO II in the U.S. at this mes.) Thus, the major tank-producing countries would save just under $2 billion as compared to the benchmark cost in Table 5.

Operating the UK Chieftain II Production Facility at mes

A second option is to operate the UK production facility at its current mes and procure the balance of the total NATO requirement from the next cheapest producer. This produces the results in Table 7. Forecast budget costs per unit are drawn from Table 5.

*A problem in these calculations is investments in plant capacity. Since the UK has existing plants we assume that the investment to bring the UK to the mes of the FRG and the US would not be larger than that estimated for producing the LEO II in the US. This amount was $451M (Page 73, Volume III).

TABLE 7

Main Battle Tank - Production Option Number 2

Country	Assigned Output	Benchmark Cost (B)	Cost Reduction Factors (CRF) Scale (S)	Learning (L)	NATO Procurement Option
US XM1	7,000	8.40	1.00	1.00	8.40
FRG LII	11,000	10.78	1.00	.95*	10.241
UK ChII	3,000	4.20	.90**	.95**	3.591
	21,000	23.38			22.232

It must be also recognized that UK will incur a development cost for its Chieftain II tank for about $2 billion which must be added to the total NATO cost. Although this option would fully utilize the production facilities of the three major NATO tank producers it would result in only a 5% cost savings of the benchmark cost and be more than $4 billion more expensive (including UK development costs) than the least cost solution. This also assumes that dis-economies of scale do not result from increasing FRG production by about 53% over mes*. This option provides less standardization as well as lower levels of interoperability at increased NATO-wide costs.

*Hartley makes the point on page 40, Appendix I, Volume II that minimum unit costs can extend beyond mes; i.e., the average cost incurred can be flat over an extensive range of production rates.

The Most Probable Option

The most likely action to be taken in meeting the NATO tank requirements is that the U.S., FRG, and UK will each produce its own tank design to meet its own requirements. Because it will be producing at so far below its mes, the UK will aggressively market its new tank to other NATO nations and will have some success. On the other hand, FRG will probably license the production of the LEO II in some other NATO country (Italy) and the bulk of "other nations" sales will be produced from this source. Thus, for planning purposes, the actual benchmark is likely to approximate the numbers shown in TABLE 8. Requirements and forecast budget costs per unit are drawn from TABLE 5.

TABLE 8

Probable Production Pattern

Country	Assigned Output	Time-Scale	Benchmark Cost ($B)	mes	CRF Scale ($)	CRF Learning (L)	NATO Procurement Option Cost
US (XM1)	7,000	10	8.40	720	1.00	1.00	8.40
FRG (LEO II)	8,500	10	8.33	720	1.00	.95	7.914
UK (CHII)	1,500	10	2.10	300	.95	.95	1.895*(3,895)
X (LEO II)	4,000	10	3.92	400	1.10**	1.10**	4.743
	21,000		22.75				22.952(24,952)

*development costs add another $2B to this number.
**negative learning and scale effects in country X

According to the output calculations and assumptions in Table 8, the FRG total costs would be slightly lower and U.S. total costs would remain the same as shown in Table 5. However, other nation costs would rise from the $5.8 billion shown in Table 6 for the single NATO tank option to $6.78 billion for the other nation Chieftain II (500)

FRG (1500) and X Country built (4000) LEO II mix shown in TABLE 8. The UK production facility would operate at about one half mes during the 10 years and this option would be the highest cost of those considered. Also, to this total procurement cost must be added the $2.0B Chieftain development costs for a grand total of about $25 billion.

Discussion

The tables above represent a gross estimate of the economics of NATO tank production in the next ten to twenty years. They do not include the detailed consideration of critical aspects of potential production innovations such as specialized production of engines, turrets or other major components. In this respect it is difficult to imagine a commercial multi-national vehicle manufacturer which would not at least analyze the possibility for cost savings in ventures one-tenth or one one-hundredth of the size of this; yet, there seems to be no NATO agency, or except for the proposals in this study, no accepted or common methodology for doing such analysis.

It is obvious, while one can understand the motivation, that the reported UK decision to develop its own main battle tank is a severe blow for NATO armor standardization. In the circumstances, the resulting competition between the three major tank types produced by NATO, the XM1, the LEO II, and the Chieftain II, is not likely to result in the advantages to be expected from competition, e.g., lower costs or better equipment. However, the UK does not stand alone in this respect. The adoption of the gas turbine engine by the US, and FRG lip service to its possible future adoption by them, may result in increased costs and lower

performance for a major portion of the NATO tank fleet.* Finally, the willingness by NATO to accept continued tank production under short range average cost conditions, e.g., sizing tank production facilities which are not optimized in terms of a long run average costs (or even analyzing the possibility of doing so) demonstrates the problem the Alliance has in achieving economic materiel production.

*Gas Turbine or Diesels For Tanks, R.M. Ogorkiewicz, International Defense Review, Vol. 2, No. 6/1978, Pages 913 - 916.

CHAPTER IV. FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

INTRODUCTION AND PURPOSE

This chapter summarizes the findings, conclusions and recommendations of the report.

FINDINGS

- Scale economies of up to 20% are observed in the Western European and U.S. industries which most closely resemble those producing military vehicles when production is increased from 50% of minimum efficient scale (MES) to MES.

- Learning economies of up to 20% are observed in aerospace related industries under the same circumstances.

- Free trade advantage economies in non-defense industries are observable over a wide range of manufacture and where data are available show unit cost decreases of from 25 to 50%.

- There was little directly applicable data concerning defense industries available to the study team. What data are available do not contradict the findings noted above.

- Total NATO defense expenditures, including France, should be around $200 billion by 1980. About 15% of this is devoted to major equipment procurement.

CONCLUSIONS

- It is widely believed that NATO defense industries currently operate far below minimum efficient scale. If so, the following conclusions can be drawn:

  - Scale economies are most pronounced and likely to be achieved in automotive and electronic industries

  - Learning economies are most pronounced in aerospace and missile industries.

- Comparative advantage economies are most likely in defense industries which are both protected, either intentionally or through low commonality, and where there is a mass market. An example of a candidate industry where large savings may be expected is armored vehicles. Alternatively, only small savings would be expected in industries producing common types of ammunition.

- Given a $30 billion NATO yearly major systems procurement budget, a conservative estimate of the resource savings due to economic rationalization of NATO procurement is around $4.5 billion per year. This is conservative because it is based solely on the attainment of scale and learning economies. Possible gains from comparative advantage economies are not estimated because they must be derived from highly specific

information about programs and contractors.

- Both the MACRO and MICRO methodologies require data concerning defense industries and procurement plans which were not available during their development phase.

- The estimate of the impact of economic rationalization on the NATO procurement budget as a whole, through the MACRO method, contains large uncertainties due to lack of information on the projected major equipment mix and data concerning the extent to which current and projected production approach MES.

- The reliability of MICRO methodology outputs will directly depend on valid NATO-wide cost data inputs, many of which will be proprietary to the companies and industries furnishing them.

- Further development of the MICRO methodology should be done in the context of studies of individual weapons programs where alternative procurement strategies are considered.

RECOMMENDATIONS

- Five year NATO procurement mix estimates should be defined for input to the MACRO method. These estimates should include ranges of values which reflect possible variations in projected mixes on a country-by-country basis.

- Data concerning the extent to which current and past production approaches MES in U.S. and European defense industries should be collected.

- These data should be used in the MACRO methodology to refine the initial $4.5 billion savings estimate.

- The MICRO methodology should be extended and refined through application to at least two specific family of weapons programs. One application should be in the aerospace missile industry; the other should be in automotives.

- The MACRO and MICRO methodologies and their preliminary results should be presented and discussed widely throughout DOD, with interested members of Congress and with other agencies having responsibilities for NATO affairs. Such discussion will facilitate subsequent use by these agencies.