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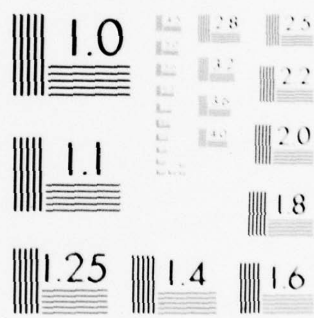

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THESIS

A SYSTEMS ENGINEERING APPROACH
TO NATO STANDARDIZATION

by

Douglas M. Turner

March 1979

Thesis Advisor: M. B. Kline

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A Systems Engineering Approach to NATO Standardization

by

Douglas Turner
B.S. California State Polytechnic University, 1963

Submitted in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE IN MANAGEMENT

from the

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March 1979

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ABSTRACT

The increased threat from Warsaw Pact forces combined with recognition of the inability of NATO forces to cooperate fully in combat has caused emphasis to be placed on standardization of equipment, procedures, and tactics. The Conference of National Armaments Directors (CNAD) and the Military Agency for Standardization (MAS) are the NATO organizations tasked with implementation of standardization. The CNAD concerns itself primarily with requirements determination. The MAS develops NATO-wide agreements at a low system level. Neither organization is concerned with the total system life cycle nor does an effective user-producer dialogue exist. A systems approach is presented as a rational way of making standardization decisions. A hierarchy of standardization and a system design model are described as methodologies for decision-making. Alternative ways of implementing the systems approach are examined using the system design model. A recommendation is made to establish a systems engineering activity, within CNAD, to direct and coordinate all standardization activities.

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I. INTRODUCTION

A. BACKGROUND

> "It is the policy of the United States that equipment procured for the use of personnel of the Armed Forces of the United States stationed in Europe under the terms of the North Atlantic Treaty should be standardized or at least interoperable with equipment of other members of the North Atlantic Treaty Organization [Ref. 1]."

This statement, made by Congress as a part of the 1976 Defense Appropriation Act, set the stage leading to the current emphasis by the U.S. and NATO on standardization of equipment, weapons, procedures, tactics, and doctrine.

Standardization is not a new concept. It has been a NATO objective since NATO was formed. Even so, the NATO nations have had a history of going their separate ways with regard to equipping their forces and working out tactics and procedures. This has caused the combat capability of the combined forces to be less than it should be. According to General Andrew Goodpaster (ret.), former Supreme Allied Commander Europe (SACEUR):

> "We are not getting a satisfactory return on our investment for our vast expenditures; we are losing at least 30 percent and in some areas 50 percent of our capability due to lack of standardization [Ref. 2, p. 212]."

It has been determined that the NATO allied combat forces employ [Ref. 3, p. 6]:

.23 different types of combat aircraft

.7 different types of main battle tanks

.8 different types of armored personnel carriers

.22 different types of anti-tank weapons

Even the Allied Mobile Force, a quick-reaction, highly maneuverable combat force composed of troops and equipment of seven nations uses:

.7 different types of combat aircraft

.6 different types of recoiless rifles

.4 different types of wire guided missiles

.3 different types each of mortars, rifles, and machine guns

The net effect of this is higher acquisition costs, duplication of logistics support, and reduced ability of forces to support each other.

Only within the last several years has there been a growing alliance-wide recognition that the need to achieve standardization is urgent. Indeed, the policy of achieving standardization within the NATO forces is receiving the highest level support within the U.S. This is evidenced by statements made by President Carter to a meeting of NATO Defense Ministers in London on May 10, 1977:

> "....I hope that European and the North American members of the Alliance will join in exploring ways to improve cooperation in the development, production, and procurement of defense equipment.... Together we should look for ways to standardize our equipment and make sure it can be used by all allied forces [Ref. 4]."

Standardization of weapons and related support procedures and tactics is clearly the policy of the United States as well as the rest of NATO.

Over the last several years much has been said about how the NATO nations should collaborate in the standardization of arms and related systems. Very little has been done to achieve specific means of implementation of the guiding principles or policy. Many people throughout NATO say, "What we should do," but few are saying, "How we should do it."

Establishing policy has been a necessary step in the evolution of increasing standardization. Without high level guidance, those charged with the responsibility for implementation are forced to set their own goals and objectives. It is not very likely, under those circumstances, that everyone would be moving in the same direction. However, the policy has been well established and most of the concerned organizations and individuals have accepted increased NATO standardization as a goal worth spending time and effort on. The next step in the process is to implement the policy with specific standardization plans and programs.

B. PURPOSE OF THE THESIS

There are many ways to establish plans and programs. Some ways are certainly more effective than others. The NATO organizations have not taken a well organized approach to making standardization decisions. Implementation, where it even exists, has tended to react to some of the most critical armament standardization deficiencies without looking to the overall system life cycle.

It is the purpose of this thesis to develop and present a rational systems approach to making standardization decisions over the entire system life cycle. This approach is then compared with current methods used for standardization. Problem areas are defined, alternative solutions are presented, and recommendations are offered.

C. RESEARCH METHOD

The research method used in this thesis is illustrated in Figure 1. Four basic tasks were conducted as described below:

.Task 1 - A study was conducted to determine the basic definitions of the systems approach including detailed methodologies suitable to aid in making standardization decisions. Definitions of standardization terms, used throughout NATO, were examined and a classification scheme was developed to relate the terms to each other.

.Task 2 - Current NATO approaches to standardization decision-making were reviewed in detail. A brief history of past approaches and reasons for their failures was included in this review.

.Task 3 - The results of tasks 1 and 2 were compared to determine those areas in which the current NATO methods matched the systems approach and those areas where they did not. The latter areas were identified as deficiencies which need to be resolved in order to most effectively achieve standardization at the least cost.

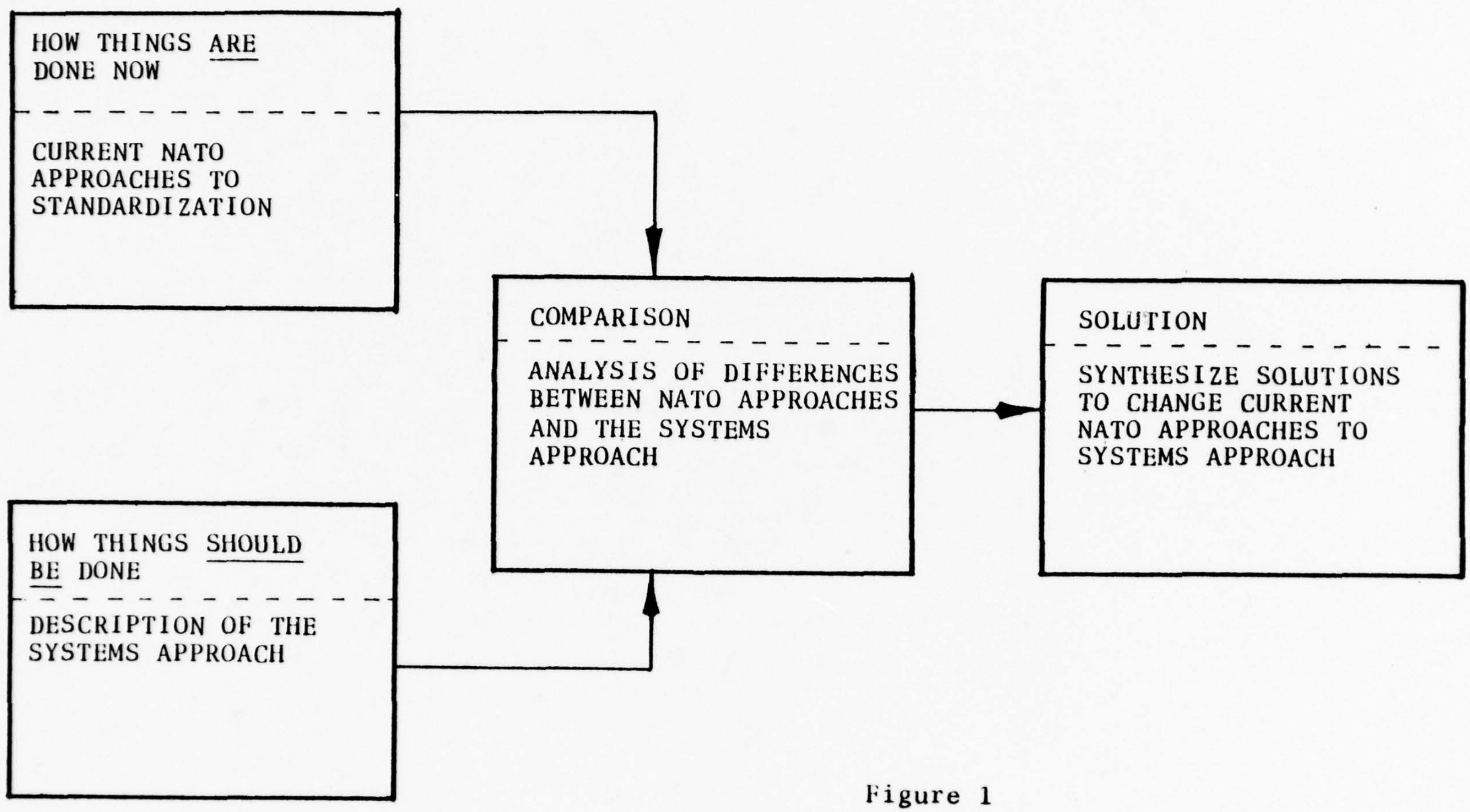

Figure 1

RESEARCH METHODOLOGY

.Task 4 - Task 4 was a synthesis of alternative possible solutions to the deficiencies in current approaches identified in task 3. Development of the alternative solutions was accomplished using the systems approach described in task 1.

A number of different sources of information were used in developing this thesis. In brief summary, they consisted of books and articles in the open literature, terms of reference and other NATO documents, Department of Defense directives and reports (formal and informal), and discussions with a number of persons involved in NATO standardization, both in Department of Defense and U.S. Congress. The list of references cites some of the most important documents used. A review of the documents will give the reader a more complete background on the problems and future of NATO standardization and will be a valuable supplement to this thesis. Most of these documents are available from the various agencies as identified in the list of references.

II. THE SYSTEMS ENGINEERING APPROACH

A. INTRODUCTION

This chapter presents the systems engineering approach and its applications to NATO standardization. A definition of related terms is made. These terms are structured in a standardization hierarchy model. The general definition of a systems approach is then made along with applications to the standardization issue. Tactical aircraft (TACAIR) systems are presented throughout this chapter to demonstrate definitions and concepts.

B. STANDARDIZATION DEFINITIONS

One of the principal difficulties in establishing a common baseline is the understanding of the terms and expressions used in defining the standardization issues. In some cases, terms have tended to be used interchangeably to define the same thing. In other cases, the meaning of certain expressions is vague and subject to differences in interpretation. It is the purpose of this section to sort out these definitions and to establish a common basis for their application. Most of the definitions given here have been approved by the Department of Defense Steering Group on Rationalization and Standardization within NATO [Ref. 5, p. 128].

Rationalization and standardization are general expressions which, in slightly different ways, describe the unification of NATO forces. Compatibility, interoperability, interchange-ability, and commonality are expressions which refer to varying degrees of standardization. Rationalization is a high level policy term which will be described here for the sake of completeness but will not be discussed further. Those terms marked by an asterisk have also been approved by NATO and are included in the NATO Glossary of Terms and Definitions for Military Use [Ref. 5, p. 129]. The approved definition is given first and is followed by amplifying remarks.

1. Rationalization

> Any action that increases the effectiveness of Allied forces through more efficient or effective use of defense resources committed to the Alliance needs, standardization, specialization, mutual support, improved interoperability or greater cooperation. Rationalization applies to both weapons/materiel resources and nonweapons military matters [Ref. 6].

This is a general definition which provides a basis for all policies relating to standardization. In effect, it says that anything the NATO members do to enhance military effectiveness and/or the economic condition of the collective countries is a desirable goal. Rationalization may, in fact, result in some nations giving up some degree of supremacy in political, economic, or military matters for the common good.

2. Standardization*

> The process by which member nations achieve the closest practicable cooperation among forces; the most efficient use of research, development, and production resources; and agree to adopt on the broadest possible basis the use of (a) common or compatible operational, administrative, and logistics procedures; (b) common or compatible technical procedures and criteria; (c) common, compatible, or interchangeable supplies, components, weapons, or equipment; and (d) common or compatible tactical doctrine with corresponding organizational compatibility [Ref. 6].

This definition also is very general in that it does not specify the degree to which systems will be made "alike."[1] It merely states that movement towards some degree of "alikeness" is desirable. This definition forms one of the principal bases for development of a hierarchy of standardization which is presented later in the chapter.

3. Interoperability*

> The ability of systems, units, or forces to provide services to and accept services from other systems, units or forces and to use the services so exchanged to enable them to operate effectively together [Ref. 6].

The definition of interoperability implies that the overall military effectiveness of multinational forces will be enhanced. Standardization and interoperability are the

---

[1]The term "systems" must be interpreted in the broadest sense. A system can be a physical entity such as a ship, aircraft or set of electronic equipment. It can also be a set of administrative procedures or tactical doctrines. Most important, a system can be (and usually is) a mix of all of the above. For purposes of brevity the expression "system" will be considered to encompass all of the above.

expressions most frequently used to define the implementation methods used to achieve highest rationalization. It is important to understand the distinction between them as seen by DoD and NATO members. Standardization focuses on efforts to make future systems common (as much as possible). Interoperability attempts to make all systems work well together, regardless of whether they are common or not [Ref. 3, p. 5]. A TACAIR example is the Identification Friend or Foe equipment (IFF). If two or more NATO nations' aircraft have different designs of IFF equipment they will probably not be interchangeable or common. However, if they can still function together in an operating environment to mutually identify each other, they are considered to be interoperable.

4. Compatibility*

> Capability of two or more items or components of equipment or materiel to exist or function in the same system or environment without mutual interference [Ref. 5, p. 128].

This definition does not imply any degree of functional relationship. All it says is that one system will not cause any degradation of other separate systems.

5. Interchangeability*

> A Condition which exists when two or more items possess such functional and physical characteristics as to be equivalent in performance and durability, and are capable of being exchanged one for the other without alteration of the items themselves or of adjoining items, except for adjustment, and without selection for fit and performance [Ref. 5, p. 128].

This definition implies that the items do not have to be identical as to their internal design. However, the items must be equivalent one to another. This implies that form, fit, and function must be similar enough to the rest of the system as to cause no significant change in performance. Adaptors and other forms of compensation may be required. Once again in the TACAIR case, rearmament of one nation's aircraft with weapons or stores from another nation's air-base is a good example. U.S. aircraft, for instance, will normally carry U.S. weapons. However, if the circumstances warrant doing so and the weapons are designed to be inter-changeable, that same aircraft may also carry United Kingdom weapons, Italian weapons, and so on.

6. Commonality

> A quality which applies to materiel or systems possessing like and interchangeable characteristics enabling each to be utilized or operated and maintained by personnel trained on the others without additional specialized training; and/or having interchangeable repair parts and/or components; and applying to consumable items interchangeably equivalent without adjustment [Ref. 6].

Commonality suggests that there are no significant external differences between items. That is, the "form, fit, and function" are identical. The internal composition, however, may be different. Thus, the systems need not be identical. They just need to function in all respects as if they are. A TACAIR case is 20 mm ammunition. External form, fit, and function is identical from one country to another (in most cases). The internal design may or may not be identical but gun operation will still be possible.

C. HIERARCHY OF STANDARDIZATION

It is apparent that there are a significant number of terms related to standardization and interoperability within NATO. Although all terms have been officially accepted and agreed to by DoD, NATO, or both, there has not been an adequate attempt to depict the relationships among them. Nor has there been an organized attempt to use the definitions or an organized standardization program as an aid in planning the acquisition of systems and materials within NATO or in unifying NATO-wide procedures and doctrines. There is a tendency to consider standardization as a discrete concept, i.e., "We either have it or we don't." The real life situation is that standardization exists at a number of definable levels.

Figure 2 illustrates the relationships among the previously defined standardization terms and shows how these represent increasingly greater degrees of standardization.

The hierarchy of standardization is presented for two purposes. The first purpose is to provide the reader with a way of understanding the meaning of standardization within the NATO context. The second purpose is to develop a tool which can be used to aid in making decisions with regard to a desired level of standardization for any system.

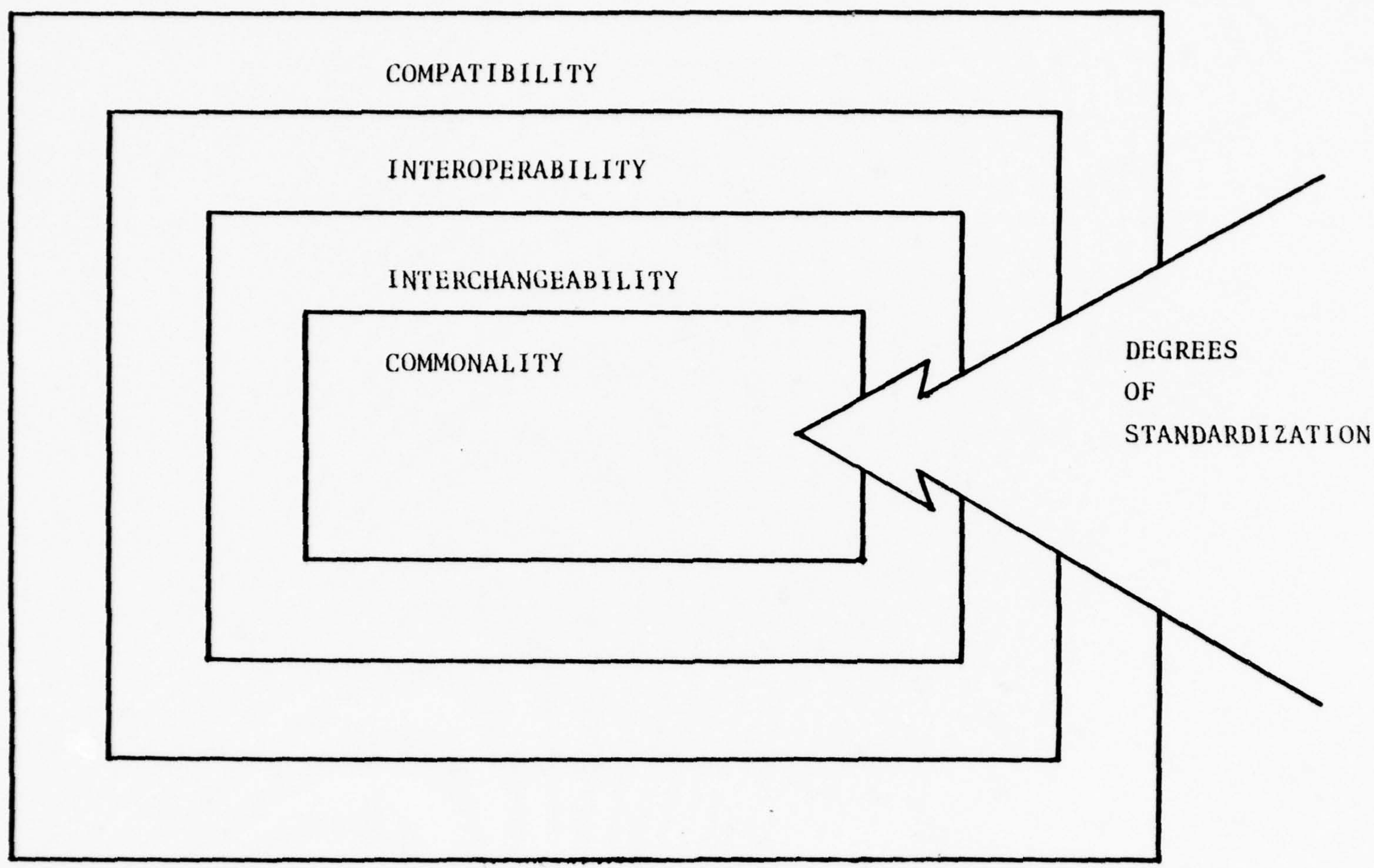

Figure 2
HIERARCHY OF STANDARDIZATION

Standardization, as used here and throughout the remainder of this thesis, should be considered as encompassing the entire spectrum from total dissimilarity to identicality. The degree of standardization is greatest at the center of the figure and each level becomes a subset of the one preceding it.

TACAIR will be used again as an example to illustrate the hierarchy of standardization. Specifically, aircraft launched precision guided munitions (PGM) will be assumed using laser seekers. Designation of targets will be by either airborne or ground-based lasers.

Compatible systems reflect a degree of standardization wherein there is no mutual or unilateral degradation in performance or function among them. This lowest degree merely indicates peaceful coexistence in the same environment but no mutual support. According to the definition of compatibility, the PGM's and target designators of different nations cannot help each other but at least they do not interfere. There is essentially no interoperability in this degree.

Interoperability takes a step forward towards standardization. At this level, two or more systems are not only compatible but are able to function together in a cooperative sense. They mutually aid and support each other to the benefit of both. In this sense interoperability becomes a subset of compatibility. Several case examples come to mind. A

U.S. PGM might be used with a target designator from another country. They mutually support one another. Another example, currently being implemented, is cross-servicing of aircraft Aircraft from one nation may land, refuel, and rearm at the airbase of another nation.

The next degree of increased standardization is interchangeability. This represents a considerable advance in that the systems are not only interoperable but can be exchanged one for another should the need arise. The condition is that the exchange should be able to be accomplished with only minor adjustments and realignments. At this level, the NATO members may go their own ways in design and production of equipment and materials, but it is important to maintain such close coordination of functions, performance, and interfaces that the system or equipments may still be substituted one for another. The internal design and composition, however, may still be entirely different. Continuing with the tactical aircraft example, a U.S. aircraft would rearm at an FRG airfield using PGM weapons of FRG design instead of U.S. weapons. This might involve the use of special adaptors, rigging and different procedures but would result in a fully combat ready aircraft.

Commonality is the next higher degree of standardization and reflects a relatively small but potentially important advance over interchangeability. Commonality allows complete interchange of systems with no need for adjustments, realignments or any other form of compensation in other system components. To all extents and purposes the form, fit and function are exactly the same even though the internal design and composition may still be different. Obviously control of interfaces becomes critical at this level. Once again using the tactical aircraft example, the FRG weapon would be to all intents and purposes the same as an equivalent U.S. weapon. This "alikeness" would extend beyond physical characteristics such as length, weight and form to include handling/safety procedures, maintenance procedures, etc. The only external differences allowable would be in minor areas such as color and markings which do not affect form, fit, and function. The difference between this degree of standardization and interchangeability is in the elimination of adaptors or other forms of external compensation.

One additional comment should be made regarding the hierarchy of standardization. It may be difficult to fit a particular system into just one of the degrees of standardization described. In fact, it is likely that decomposition into system components, procedures, tasks, or doctrines and policies may reveal that each exists at a different place in the hierarchy from the others.

D. THE SYSTEMS APPROACH

The systems approach is a generalized framework by which decision making may take place in a logical and coherent manner. Churchman provides a succinct definition,

> "Systems are made up of sets of components that work together for the overall objective of the whole. The systems approach is simply a way of thinking about these systems and their components [Ref. 7, p. 11]."

It is the intent here to firmly establish a systems approach framework by which NATO standardization decisions may be made.

A reasonable first step is to define the term "system." According to Kline:

> "A system is a set of elements organized to perform a set of designated functions in order to achieve desired results. An element is a set of resources organized to perform some highly interrelated subset of the desired system functions. The resources which comprise a system include personnel, materiel, equipment, facilities, and information [Ref. 8, p. 1-14]."

The above definition is generally applicable in that it includes doctrines, principles, and procedures as well as physical hardware. It is in this broad view that the word "system" must be defined. Standardization in the NATO context must include not only physical equipment and materials but administrative procedures, logistics philosophies, tactical doctrines, and even broad economic and political relationships between the nations. The importance of thinking of systems on a total view cannot be overemphasized. It is with this kind of view that decision-making with regard to standardization must begin. This idea is discussed more fully in the next section.

The systems approach is simply a way of planning, analyzing, and making rational, informed decisions with regard to systems. According to Ramo:

> "The systems approach applies logic, wisdom, and imagination on a sophisticated technological level. It is often quantitative and always objective. It makes possible the consideration of vast amounts of data and of numerous, often conflicting, considerations. It spells out the interactions among the elements of complex real-life problems, recognizing the need for careful compromises, for 'tradeoffs' among competing factors such as time versus cost. It uses simulation and mathematical modeling, when applicable, to predict performance before the entire system is brought into being. By insisting on an examination of the total problem -- the goals, the criteria, the costs, the benefits, and the penalties -- it seeks to disclose what we can expect to get and what it will cost us, and it makes feasible the selection of the best from among many alternatives."

Ramo goes on to say,

> "It (the systems engineering approach) concentrates on the analysis and design of the whole, as distinct from the components or the parts. It insists upon looking at a problem in its entirety, taking into account all the facets and all the variables, and relating the social to the technological aspects [Ref. 9, p. 15]."

Kline provides an excellent foundation for applying the systems approach to decision-making for NATO standardization:

> "The systems approach recognizes the interrelationships which tie a system together; it recognizes that factoring out a part of a problem by neglecting the interactions among subsystems and components increases significantly the probability that a solution to the problem will not be found; it requires that the boundaries of the system be extended outward as far as is required to determine which interrelationships are significant to the solution of the problem [Ref. 18, p. 1-12]."

Thus it is apparent that any attempt to standardize systems, procedures or doctrines on a piecemeal basis without consideration for overall impact may not succeed in achieving desired standardization results.

A general overview of the systems approach is not complete without some discussion concerning the system life cycle. As seen in Figure 3, Kline [Ref. 8, p. 2-3] breaks the system life cycle into separate and distinct phases. These phases match quite well with the DoD acquisition cycle as well as the actual events which occur throughout a system's life. The four factors at the top of the figure represent the primary inputs to problem formulation discussed in the next section. While the issue of standardization may come up at any phase of the system life cycle, the planning period decisions are of most critical importance. It is this period, consisting of the concept formulation and system definition phases, for which the approach and recommendations of this thesis are focused.

E. APPLICATION OF THE SYSTEMS APPROACH TO STANDARDIZATION

An important objective of this thesis is to present an analytic methodology based on systems approach principles. This methodology should result in more effective and rational standardization decisions. Figure 4 is a slight modification of the system design process definition by Kline [Ref. 8, p. 3-2]. This figure illustrates the systems approach principles as applied to the issue of

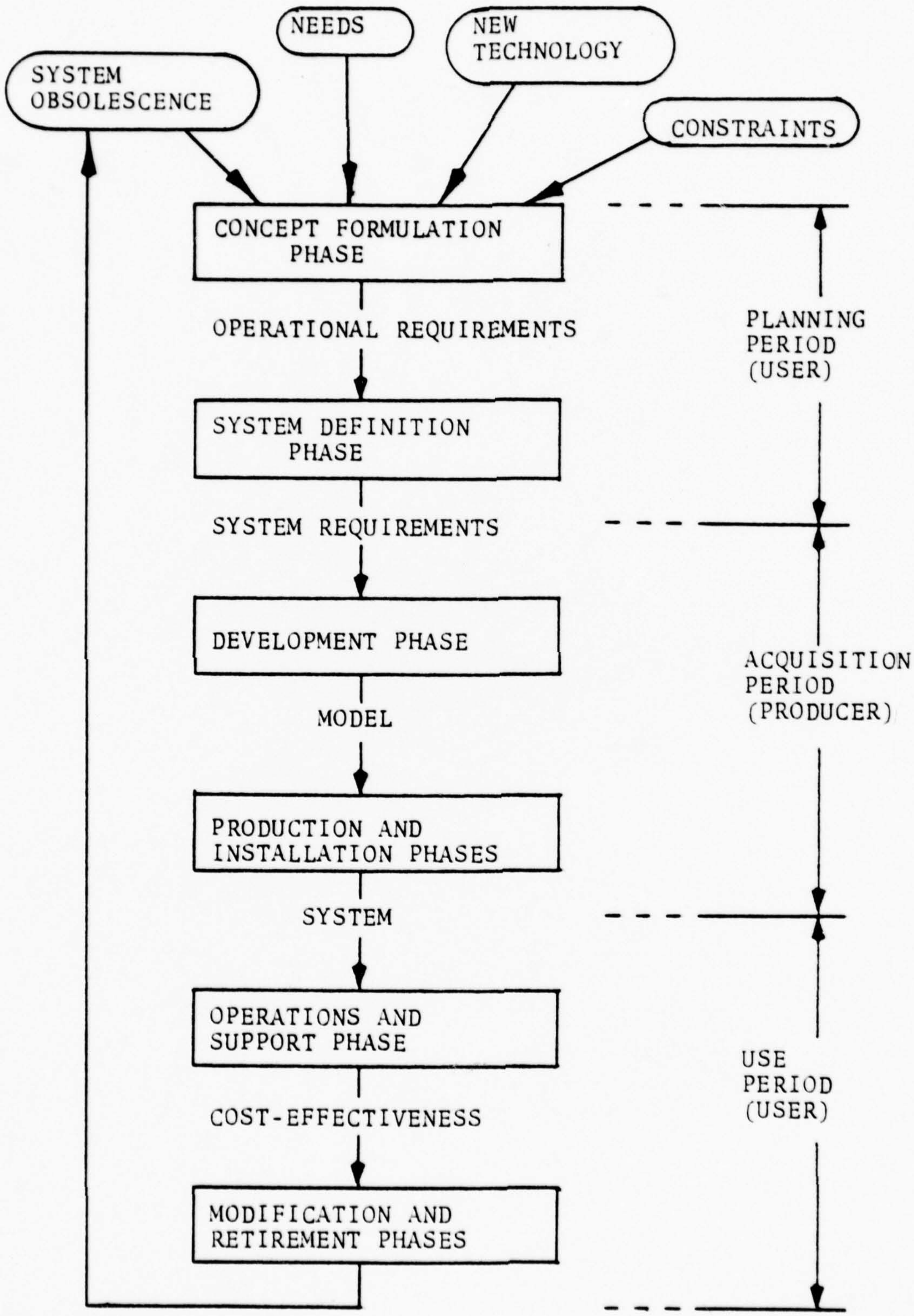

Figure 3
SYSTEM LIFE CYCLE

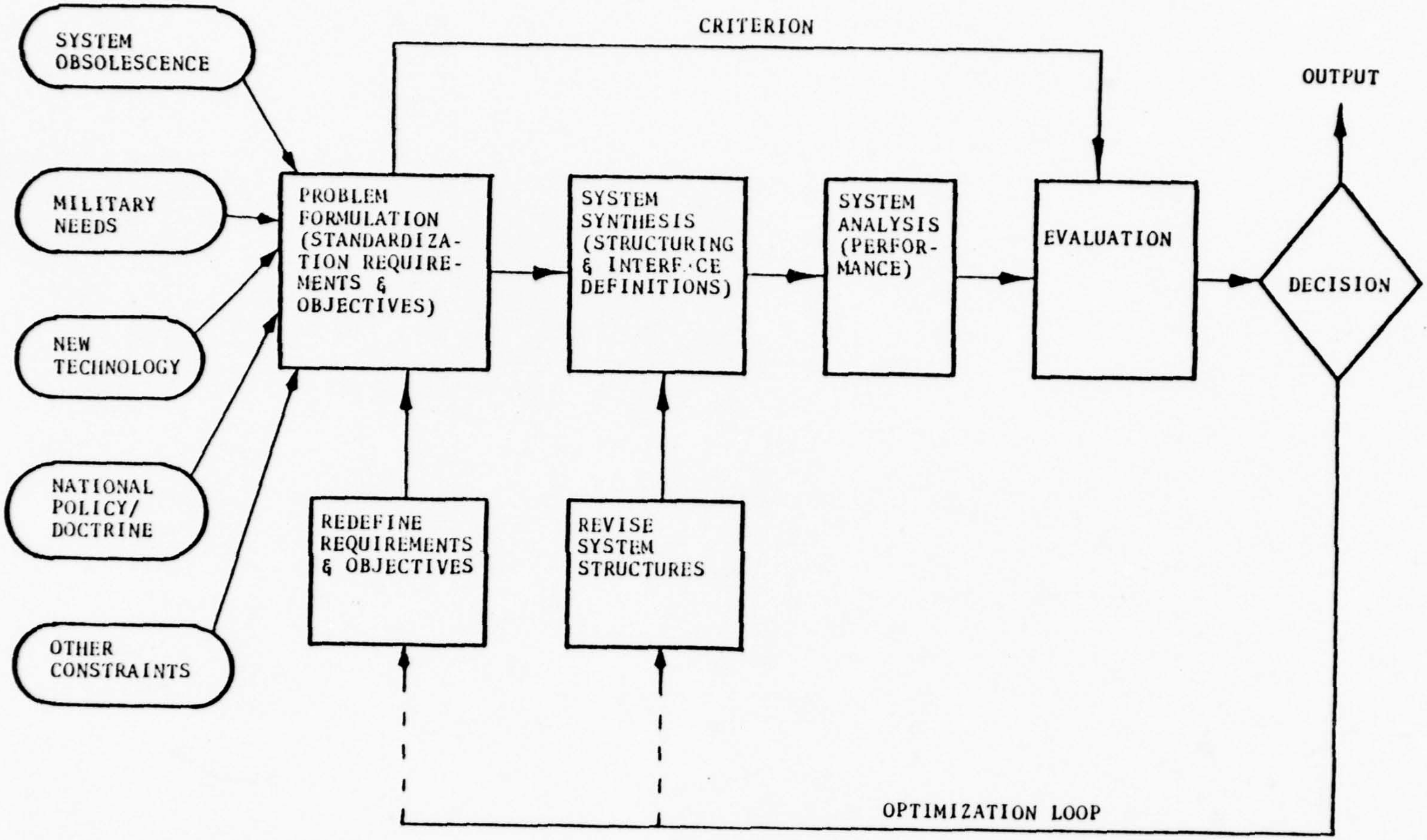

Figure 4
SYSTEM DESIGN MODEL

NATO standardization and will be referred to throughout the following discussion.

1. System Design Model

The model for system design, shown in Figure 4, illustrates a basic decision model.

It begins with formulation of the problem to be solved in terms of requirements and objectives to be reached. It then proceeds with the synthesis of possible (and reasonable) solutions to the problem. These system alternatives are analyzed to obtain data on system characteristics and performance. A comparative evaluation is made, i.e., how does each system solution compare to the original objectives and criteria established during formulation? When a satisfactory and reasonably optimum solution has been reached, a decision should be made to implement that solution. If evaluation indicates that none of the system alternatives meets the criteria then the alternatives must be revised, the requirements and objectives redefined or both. This last step represents the iterative nature of the process. Thus, the system design process provides a means whereby the problem and its possible solutions may be matched in an optimal way. Each step of the process is now discussed in more detail with particular emphasis on application to issues of NATO standardization.

a. Model Inputs

Many different factors influence a decision on whether or not a system should be standardized throughout NATO. These factors provide the input information which is used to establish standardization requirements and objectives during the formulation process. Consideration should be given to such factors as:

.Basic military requirement

.Degree of current system obsolescence

.Degree of current system standardization

.Extent of NATO-wide usage

.Impact of new technology

.Environmental and doctrinal constraints

.Increase in threat resulting from standardization

These factors are representative of the kinds of information needed to formulate requirements and objectives. Some of the information will be subjective, at least initially. Other information will be more specific and objective.

A potential problem which has occurred many times within NATO is the existence of conflicts in the input information. These conflicts may have military or political overtones (such as giving up a technological capability in order to achieve standardization) or just basic disagreement as to the need for standardization for a particular system. Whatever the cause, it is apparent that such conflicts between nations have always existed and will continue to exist in the future. The important thing is to make sure that the process continues and is not stymied by early disagreements.

b. Problem Formulation

Problem formulation consists of combining all the input information in such a way as to arrive at requirements and objectives for standardization. The importance of doing a good job in this step cannot be emphasized too strongly. This is the point in the system design process which sets the direction for all subsequent efforts. Hall [Ref. 10, p. 105] makes the statement,

> "It is much more important to choose the 'right' objectives than the 'right' system. To choose the wrong objective is to solve the wrong problem; to choose the wrong system is merely to choose an unoptimized system,"

It is at this point that the desired degree of standardization should be determined. It should be recognized that this objective is established initially with concern only for the degree of desired standardization. Later steps will determine whether or not the selected degree of standardization is feasible.

Requirements and objectives should be stated in specific terms. They should be precise and unambiguous so that they can be used to measure effectiveness of later decisions. Requirements and objectives should be consistent and mutually supporting. If inconsistencies or conflicts exist, that should be a strong indicator that further tradeoffs and compromise are needed before proceeding to the next phase.

In the case of TACAIR, a decision might be made to have interoperability of aircraft, certain weapons/stores, communications/nav aids, and airbase support as a minimum degree of standardization. The degree to which these equipments and systems can be standardized and made interoperable is determined during the following phases of the system design process. Constraints may be placed on the requirements and objectives. For example, several nations may be unwilling to accept common weapons/stores. They may be more interested in producing their own weapons/stores because of possible sales to non-NATO nations. Other nations may have difficulty reconciling differences in tactical doctrines and this can have a strong effect on interoperability. These constraints are important and must be considered.

c. Synthesis of System Structures

The next phase in the system design process is synthesis of system structures, i.e., develop a system (or alternative systems) which may be capable of satisfying the desired standardization requirements and objectives. This phase should be undertaken without an assessment at this time as to whether standardization of the system between NATO members is feasible. Indeed, it may be detrimental to achieving an optimum system if some of the possible structures are discarded at this point before analysis and evaluation. Structuring of alternative systems may take several forms depending on the nature of the standardization requirement. If different NATO systems already exist, the process may be one of describing them separately with the intent of identifying those areas where various levels of standardization apply. Also implicit in this is identification of those system elements in which modifications may allow standardization to be achieved. If a new requirement is determined for which no system is in existence, then alternative structures may be developed to suit that requirement.

It is necessary to understand the meaning of the expression "system structure" before proceeding further. Chestnut [Ref. 11, p. 98] gives a definition.

> "Structure is the form, the arrangement of parts, the interrelationship of parts as dominated by the general character of the whole."

Chestnut expands this definition in more detail,

> "....structuring is a way of subdividing or partitioning a large problem into a number of smaller problems which presumably can be handled separately and therefore more easily. Thus, structuring provides a method for reducing the apparent dimensionality of large system problems by decoupling the interaction between the different parts through the mechanism of organized separation. Although this subdivision or structuring is performed to provide a first approximation to the solution of the whole problem, the interaction of the parts must be considered later once an apparently satisfactory first-order solution has been developed. The structuring assists in the more rapid realization of the first-order solution to the overall problem."

What Chestnut is saying is that structuring is a way of thinking about and understanding systems by breaking them down into smaller, more manageable elements.

An example of system structuring is shown in Figures 5 and 6 and typifies the approach described by Chestnut. In this case, existing tactical air forces are considered to be the system, with one such force in existence in each NATO nation as indicated.[1] In Figure 5, it is shown that each NATO member concerned has essentially the same type of system. Each nation's TACAIR may be broken down into aircraft, weapons/stores and operational support. These three items may be broken down again into progresssively greater detail as displayed in Figure 6 for the aircraft element. This decomposition process will continue as long as required to reduce to the lowest meaningful system level. It is apparent that the system could be decomposed into several different types of structure depending on the nature of the standardization decision to be made. The first level might very well be structured according to function rather than NATO member TACAIR. The first level would then contain elements such as fighter/intercept, strike, and patrol aircraft with the different nations split off as smaller elements under the major headings.

Close examination of the characteristics of each NATO member's TACAIR will reveal that they do not always have

[1]Not all NATO nations have a significant tactical air capability; Luxemborg and Iceland are examples. Only those nations which contribute to the total NATO tactical air capability need be involved in standardization decisions. Determination of involved nations must, of course, occur at highest levels in NATO.

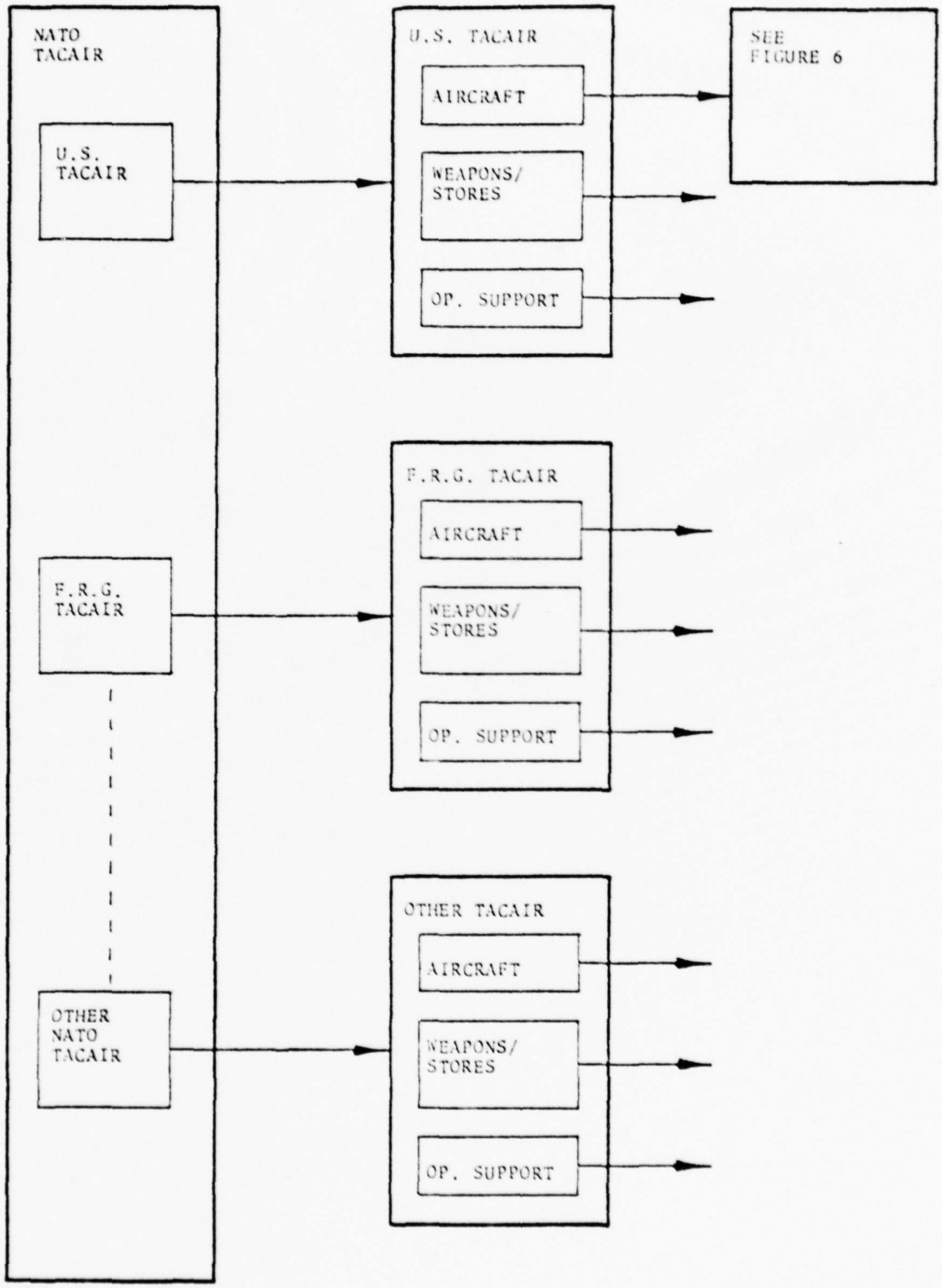

Figure 5
TACAIR SYSTEM STRUCTURE

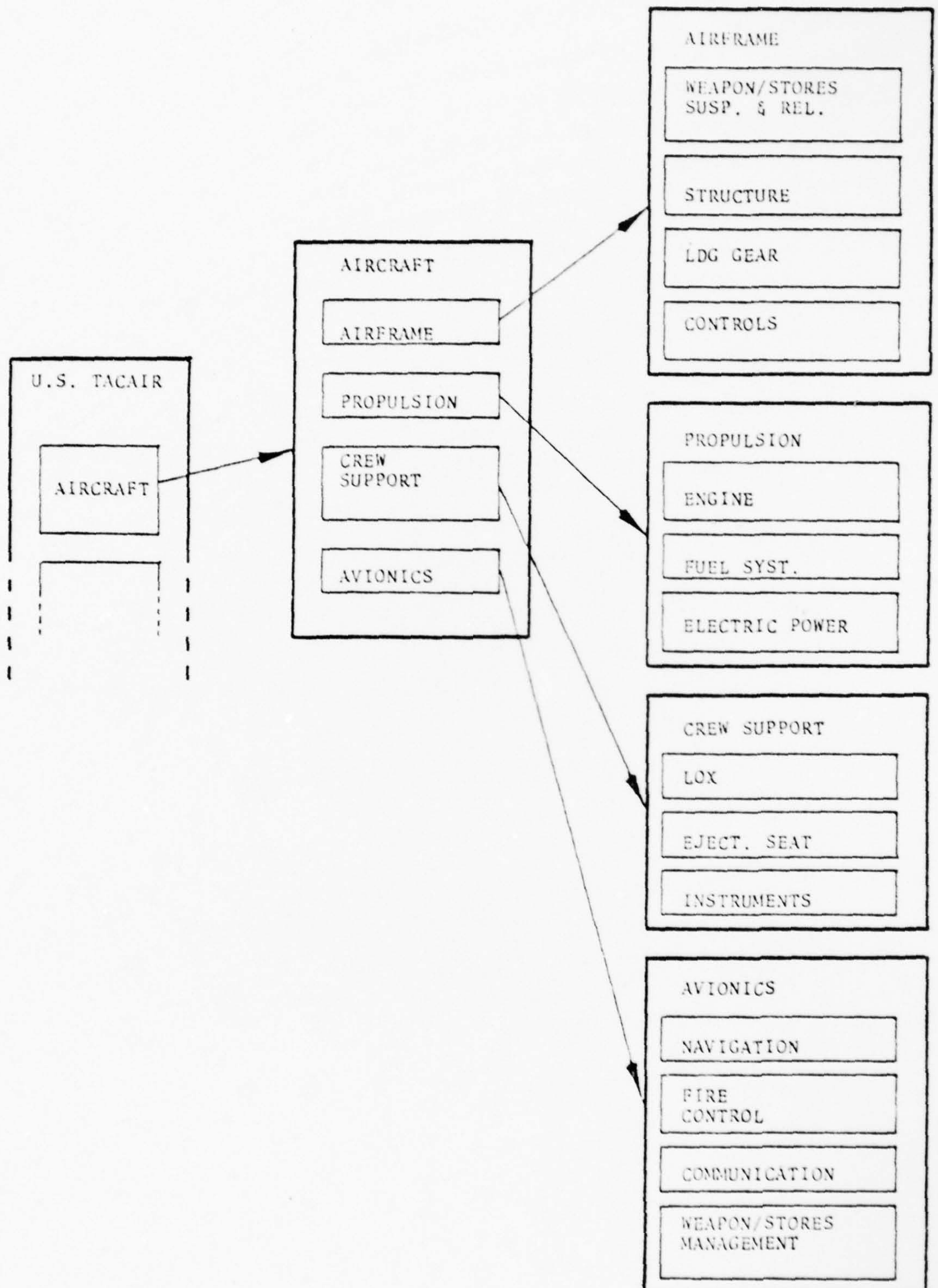

Figure 6
TACAIR SYSTEM STRUCTURE

the same system structures and element classifications. One nation may have only simple weapons without target sensors and signal processing whereas another nation may have very sophisticated weapons. Emphasis on certain areas may be different also. In one nation, the aircraft avionics may be very complex and capable of performing many functions. Another nation may have tactical aircraft with very simple navigation, communication, and fire control equipment. Nevertheless, the basic elements of TACAIR should be the same in all cases. The main point is that the systems, whether existing or to be developed to meet new needs, must be broken down into a common structural framework prior to analysis of standardization possibilities. This is the essence of system structuring.

The interaction and interrelationships between elements of a structure form the system interfaces. These interfaces are best established after the structure has been initially completed. First, each element of the structure, at any particular level, is compared with all other elements at the same level to determine if any interaction is present. An interface point is defined as existing between these elements if the analysis shows one or more relationships. The ease with which system elements work together or mesh with other systems is determined by the interfaces. Interfaces may take many forms. They may range from meshing tactical procedures in a coordinated multinational air strike down to making refuel nozzles identical on all aicraft. It depends entirely on the level of the system structure.

An understanding of the system interfaces is critical in making standardization decisions. Because of its importance the topic of interfaces and their impact on standardization is discussed separately in section F in this chapter. For now it is sufficient to understand that they exist and must be fully accounted for.

d. Analysis of System Structures

In the analysis step of the system design process, the impact of the system structure and the hierarchy of standardization are determined. The purpose is to establish a specific degree of standardization for each element at each level of the system structure. The requirements and objectives which were set during problem formulation are used throughout this analysis as evaluation criteria for setting the degrees of standardization.

Figures 5 and 6 will be used as an example system structure to illustrate the procedure. The first breakdown of TACAIR into elements yields forces for each of the NATO members. The rapid expansion of system elements precludes showing the structure for each nation. Suffice it to assume they are pretty much the same.

Figure 7 demonstrates the analysis process in simplified flow chart format. The first step is to determine whether the complete TACAIR forces of each NATO nation

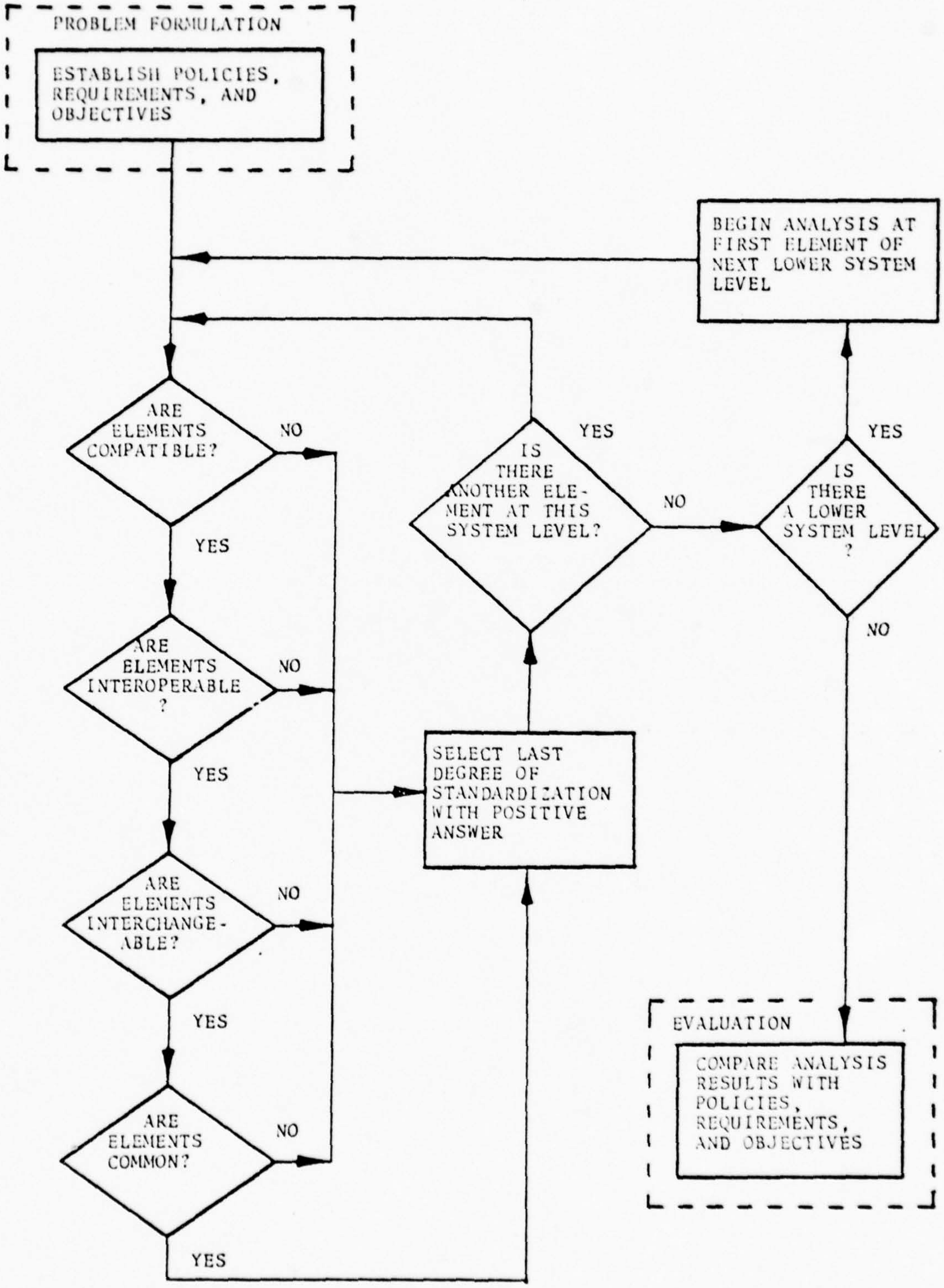

Figure 7
ANALYSIS FLOW CHART

are or should be compatible according to the minimum degree of standardization shown in the hierarchy of standardization. If the answer is negative it must be determined whether the analysis should proceed to the next element. In some cases it may be necessary to re-evaluate the requirements and objectives very early in the analysis.

The process continues by comparing the increasing degrees of standardization, as shown in the hierarchy of standardization, with the system element under analysis. The next question is, "Should TACAIR be interoperable?" If the decision is yes then the question is asked again with regard to interchangeability. This process extends on until the question receives a negative answer. The last degree of standardization which received a positive answer is then selected, tentatively for TACAIR.

The next step is to move to the next lower level of the system structure and repeat the above process for each element at that level. This analysis is repeated again until a decision is reached as to the highest degree of standardization for aircraft. Table I presents an example of the implementation of various degrees of standardization for an aircraft element. The next element is weapons/stores and it is examined in the same way. The process is continued at this structure level until completed at which time the next lower level is addressed.

ELEMENT	DEGREE OF STANDARDIZATION	INTERPRETATION
AIRCRAFT	COMPATIBLE	Indicates that aircraft of each NATO nation will not cause degradation in performance or operation of other NATO aircraft or elements. Incompatibilities could exist in such areas as electromagnetic radiation from airborne radar and communication equipment
	INTEROPERABILITY	Indicates that NATO aircraft not only are compatible but also aid each other. Weapons/stores of one NATO nation are capable of being carried and used by another NATO nation aircraft. Partial or full cross-service of aircraft is a reality.
	INTER-CHANGEABILITY	Indicates that NATO nations could exchange aircraft between one another with few problems. Aircraft designs would be different but have no significant effect on combat or mission performance. Pilots would have little difficulty transitioning from one aircraft to another.
	COMMONALITY	Indicates that NATO nations use the same aircraft with virtually the same engines, avionics, etc.

TABLE I

EXAMPLES OF DEGREES OF STANDARDIZATION

The result of this analysis is a well defined system structure with a reasonably thorough understanding of the degree to which it may be standardized throughout NATO.

A decision to have a given degree of standardization at one level of a system does not mean that all lower levels will have to have the same degree or greater. For example, a decision might be made throughout NATO to have interchangeable avionics system elements on tactical aircraft.[1] This decision, however, applies only to the entire avionics element taken as a whole. It does not necessarily follow that lower level elements, such as communications equipment, can be interchanged from one nation's aircraft to another. The ability to be interchangeable at the next lower level must be based on a deliberate decision made concerning that level.

The flow chart format makes it all look easy. In reality, each decision point may require long, difficult trade-off studies and compromises. The process described above simply sets the entire effort into a logical,

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[1]It is reasonable to consider standardization of less than the complete element. In the case of avionics it might be decided to standardize on navigation and communication equipment, for example, and leave radar and fire control equipment up to the individual nations. The approach taken in these cases must be based on guidance contained in the requirements and objectives.

step-by-step framework. It provides a means for making decisions in a systematic, optimal way rather than in random fashion. Even so careful reasoning must still be an integral part of this process.

e. Evaluation, Decision and Optimization

The final three steps are reasonably straightforward. Evaluation consists of comparing the standardization analysis with the requirements and objectives criteria as shown in Figure 4. If the standardization decisions match the original requirements and objectives (assuming they have not changed), then a decision to implement the defined degrees of standardization can be made. If there is a mismatch, it is necessary to iterate the process via the optimization loop shown in Figure 4. This involves revising the system structures, or redefining requirements and objectives, or both. Of course, it will be necessary to go through the analysis phase again but it should be considerably easier since the basic system structure and general fit of the degrees of standardization are usually much better understood after the first pass through. This is probably true even though optimization may have caused some changes in the structure or requirements and objectives. The iterative process will continue as necessary until an acceptable level of agreement between the standardization solution and the requirements and objectives has been reached.

In the case of TACAIR, assume a requirement is to have interchangeability between aircraft and weapons/stores of the NATO nations. If, after the analysis and evaluation steps, it is determined that interchangeability is feasible and agreeable between the nations, then the system design process is complete and implementation may take place. If, on the other hand, agreement or technical feasibility is not achieved then both the requirements and system structures must be reviewed. In the case of requirements it would be wise to ask if the standardization requirements were set too stringent and whether interoperability might be a better goal. Also, one or more nations may have technical difficulty adapting their aircraft to accept the entire list of weapons/stores. In this case the list should be reassessed. On the system structure side, the same technical difficulties might be resolved by careful analysis and evaluation of problem areas.

The system design model has been presented as a practical aid in determining degrees of standardization of systems between NATO nations. In actual use some of the steps may be accomplished quickly and easily. For example, the problem formulation phase could define requirements and objectives well enough to cause the structuring and analysis phases to converge quite rapidly on a solution. This does not mean that any steps should be left out but rather that optimization can be accomplished rather easily if problem formulation is done well.

F. INTERFACE CONSIDERATIONS

The impact of interfaces between systems and system elements is of critical concern. Success or failure of efforts to achieve standardization of systems and/or their elements depends on careful consideration and understanding of interfaces. It is the intent of this section to present a definition of system interfaces along with some of their characteristics as related to standardization.

1. Definitions

Webster [Ref. 12] defines interface in two ways.

> "A surface regarded as the common boundary of two bodies of space."

> "The facts, problems, considerations, theories, practices, etc. shared by two or more disciplines, procedures, or fields of study."

Although technically correct, these definitions are general and do not reflect the exact meaning and impact of system interfaces to system standardization. An alternate definition is offered for consideration. This definition more accurately reflects the strong system-oriented nature of interfaces.

> Interfaces are those interrelationships which exist between systems and between various identifiable elements of a system and which, when properly matched, allow the system to function at maximum efficiency and effectiveness.

Maximum efficiency and effectiveness as used in the above definition does not mean the system is of optimal design to meet established requirements. It simply means that the interfaces have been matched so as to permit the systems to perform together as well as possible for any given design.

All the interfaces should be considered to understand the complete functioning of the system, both internally as well as relative to other systems. The properties of the interfaces may take many forms. Several of these are:

- .Physical
- .Functional
- .Performance
- .Environmental
- .Operational

Some of the interfaces are obvious, such as the mating of connectors between a weapon and an aircraft. Others are not as obvious. For example, the interaction between a missile radar guidance unit and a shipboard electromagnetic radiation pattern is an environmental interface which is less well defined. It might even be ignored until a problem develops.

2. Interface Characteristics

The maximum number of interfaces among elements of a system (or when comparing elements among several systems) can become very large. It is partially dependent on a number of elements and levels which are defined during system structuring. The larger the number of elements, the larger the number of potential interfaces. Figure 8 is a simplified example which could represent a comparison between two

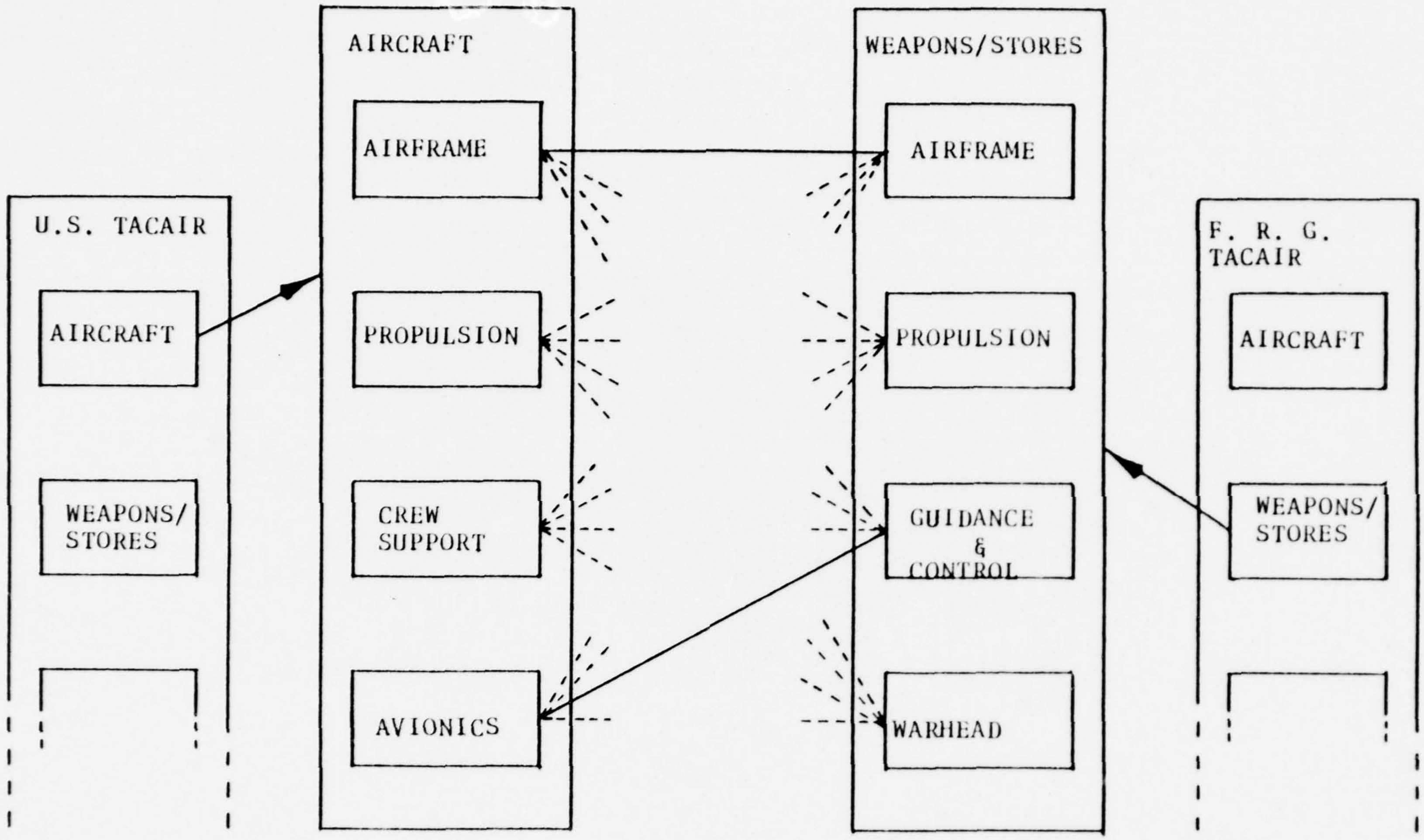


Figure 8
EXAMPLE OF INTERFACES BETWEEN U.S. TACAIR
AIRCRAFT AND F.R.G. WEAPONS/STORES

different but similarly constructed NATO TACAIR systems, one from the U.S. and one from F.R.G. The issue is to determine if a degree of standardization can be established to allow U.S. and F.R.G. aircraft and weapons/stores to be interoperable. Figure 8 shows the case of U.S. aircraft and F.R.G. weapons/ stores. An identical diagram (not shown) needs to be drawn showing U.S. weapons/stores and F.R.G. aircraft. The dotted lines show potential interfaces between aircraft and weapons/ stores. A more detailed analysis, however, shows only two interfaces which have any meaning or impact on interoperability. These interfaces are:

.Aircraft airframe to weapons/stores airframe mechanical interface associated with suspension equipment, pylons, and release-jettison equipment.

.Aircraft avionics to weapons/stores guidance and control electrical interfaces associated with transfer of target data, command/control signals, status information, and pre-launch power.

It is important when analyzing and comparing different systems to try to bring their structures into a common framework. This is because different framework structures may have different interfaces between elements. Comparing interfaces between dissimilar structure frameworks is like comparing apples and oranges. They are not the same thing. The results, if obtainable, will not necessarily reflect the actual case.

There is a need to have well defined interfaces. Lack of knowledge about interfaces between elements leaves room for uncertainty as to whether the degrees of standardization selected are achievable. Interfaces must be well defined and understood, whether they are part of existing systems or created as part of a new system structure. Assume, for example, a weapon/store produced by one nation is to be made interoperable with an aircraft produced by another nation. If pre-launch electrical power from the aircraft to the weapon is defined simply in terms of primary voltage and current requirements and secondary parameters such as ripple voltage, regulation, and transient recovery are neglected, then the interface is not well defined. The weapon may not be able to function properly if the secondary parameters are outside of acceptable limits. This is a simple example but, nevertheless, represents the level of detail which is needed to have a well defined interface.

Identification of the interfaces occurs during the system synthesis phase after structuring has been completed. It is important to note that not all elements will have interfaces with all other elements. Although the number of actual interfaces in a real system will be less than the theoretical maximum, it is still important to examine each potential one to see if it is significant.

It is very important to establish interface standards and specifications. There are three main advantages to doing this:

(1) Agreement on significant interfaces at all levels of a system will allow early achievement of the lower degrees of standardization. Systems will then be at least compatible or interoperable. This will facilitate an early NATO-wide solution of the problems of decreasing military effectiveness.

(2) If the NATO nations decide on acquisition of common systems the interfaces between the new common systems and existing systems will already have been standardized. A significant part of the system engineering task will be reduced.

(3) If the NATO nations are not unanimous in selection of a common or interchangeable system then those who go their own way will at least be interoperable.

Identification and analysis of the important interfaces is basic to the entire process of standardization. If improperly done the end result may actually degrade overall system performance. In the NATO context it is vitally important that all nations be aware of the need for careful definition and understanding of interfaces between systems and their respective elements.

III. THE NATO ORGANIZATION FOR STANDARDIZATION

A. INTRODUCTION

It is the intent of this chapter to present a detailed description of the primary organizations and activities currently tasked to achieve within NATO. The overall NATO organization is presented first followed by descriptions of the Military Agency for Standardization (MAS) and the Conference of National Armaments Directors (CNAD). The MAS and the CNAD organizations represent the bodies within NATO in which standardization efforts are being carried out.

B. THE NATO ORGANIZATION

It is important to have an overall understanding of the NATO organizational structure before attempting to analyze the activities of those groups most responsible for the implementation of standardization.

NATO Facts and Figures, an official publication of the NATO Information Service, provides the following description:

> "The North Atlantic Council, the highest authority in NATO, provides a forum for wide political consultation and co-ordination between the allies. Military policy is discussed in the Defense Planning Committee (DPC) composed of member countries participating in NATO's integrated defense system.... The Secretary General of NATO is chairman of the Council and the DPC and also heads the International Staff. In support of their roles, the Council and the DPC have established a number of Committees, the most important of which are shown in [Figure 9]. These Committees cover the whole range of NATO's activities and meet under the chairmanship of a member of the International Staff.

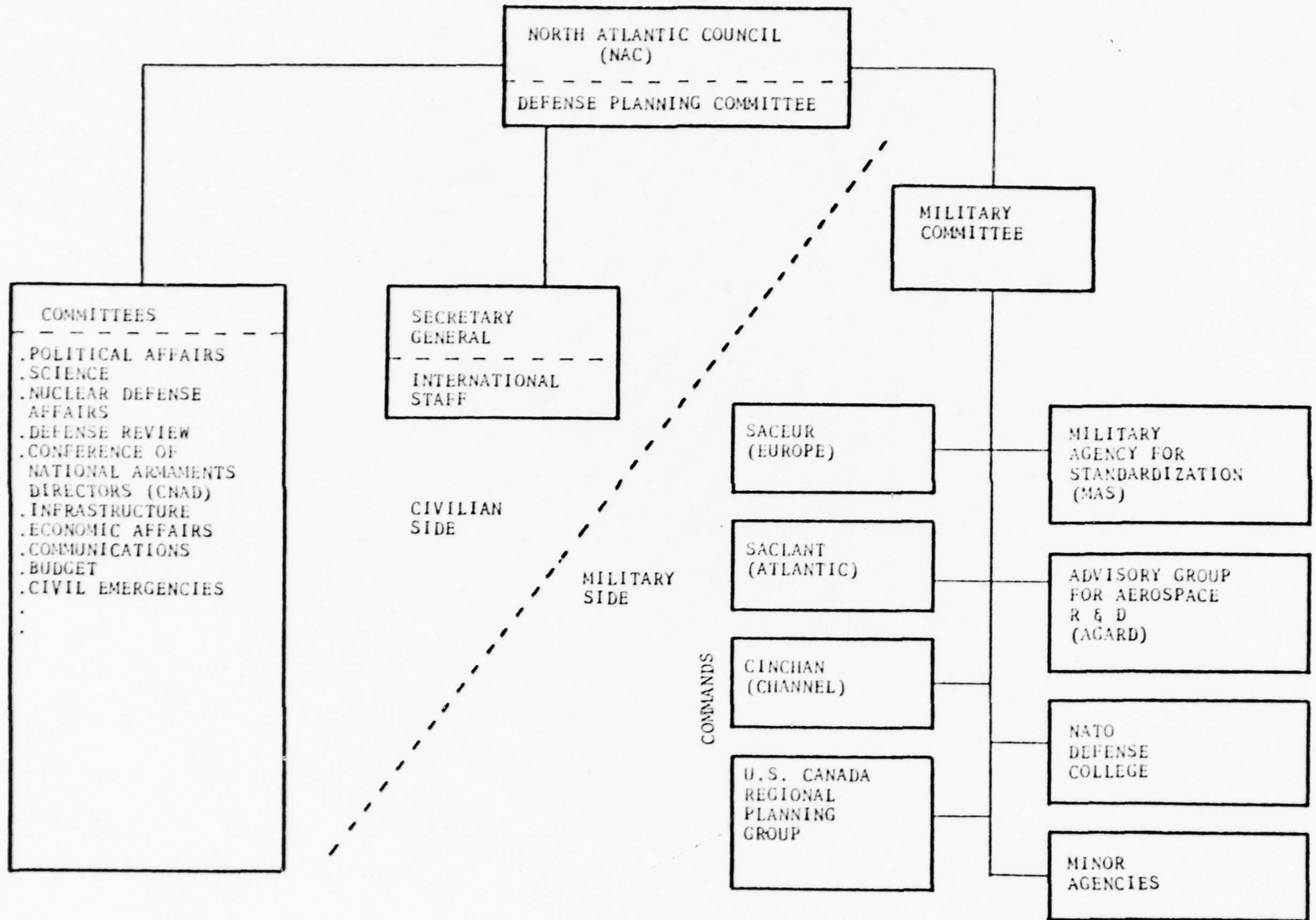


Figure 9

NATO ORGANIZATION

The Military Committee, composed of the Chiefs-of-Staff of the member countries taking part in the NATO integrated military structure, is the senior military authority in the Alliance. It provides advice to the Council/DPC on military matters and gives guidance to the major NATO Commanders.... Implementation of the policies and decisions of the Military Committee is ensured by the International Military Staff (IMS) acting as executive agency. The NATO defense area is divided into three separate regional Commands -- the Atlantic Ocean Command, the European Command and the Channel Command -- and a Regional Planning Group for the North American area. Under the general guidance of the Military Committee the major NATO Commanders are responsible for planning the defense of their areas and for conducting NATO's land, sea and air exercises." [Ref. 13, p. 204]

The NATO organization consists of a civilian side and a military side with the military side reporting to top-level civilian policy groups (the North Atlantic Council and Defense Planning Committee). This overall civilian/military split has been extended to include a split in standardization efforts and approaches as well. The military side attempts to achieve standardization goals through the Military Agency for Standardization (MAS). The civil side has the same overall goal and conducts its activities through the Conference of National Armaments Directors (CNAD). The methods of achieving standardization, however, are different and this is explained in sections III.C and III.D.

C. THE MILITARY AGENCY FOR STANDARDIZATION (MAS)

The MAS was formed in 1951 under the direction of the Military Committee as the principal agency concerned with standardization. The Military Committee provided policy-level direction to the MAS. This policy document states:

> "NATO military standardization is the process by which member nations achieve the closest practicable cooperation among forces, the most efficient use of research, development and production resources, and agree to adopt on the broadest possible basis the use of:
> (a) Common or compatible operational, administrative and logistics procedures.
> (b) Common or compatible technical procedures and criteria.
> (c) Common, compatible or interchangeable supplies, components, weapons or equipment.
> (d) Common or compatible tactical doctrine with corresponding organizational capability." [Ref. 14]

The Military Committee realized very early that trying to get all NATO members to agree to standardization of all equipments, systems, procedures, tactics, etc., would be a task with little payoff for the effort expended. The Military Committee therefore adopted a basic policy in which it was recognized that each NATO member would be responsible for equipping its own forces. It was further recognized that the various nations were likely to have widely varying military requirements which would further complicate attempts to standardize. An example of this is the difference between U.S. forces, which are only partly committed to a European-type conflict, as opposed to a nation such as the Federal Republic of Germany (FRG) which is fully committed to Western Europe defense. The U.S. must procure weapons/equipment and develop tactics and logistics procedures to engage in any type of conflict in any part of the world. The FRG, on the other hand, need concentrate solely on defending against front-line assault by Warsaw Pact forces.

The U.S. would obviously prefer to develop its forces to handle all situations and not be forced to provide extensive "theatre-specialized" forces and equipment. The FRG, understandably, does not want to pay for capabilities which are beyond its needs and means. Extend this situation to the thirteen armed NATO members and it is readily seen that disagreement over specific requirements is likely to always exist.

As a result of this state of affairs the Military Committee realized that since standardization would be difficult to achieve amongst all the NATO nations, it must be accomplished on a voluntary basis. This policy was given a small degree of influence by emphasizing the essential need for standardization where effective implementation of operational plans depends on it.

This has tended to become submerged in the daily affairs of the MAS. Additional instructions to the MAS include the need to give priority to (not in order of importance):

1. Standardization of components
2. Standardization of stores in large consumption
3. Interchangeability of ammunition
4. The development of adaptors
5. Joint development of future equipment

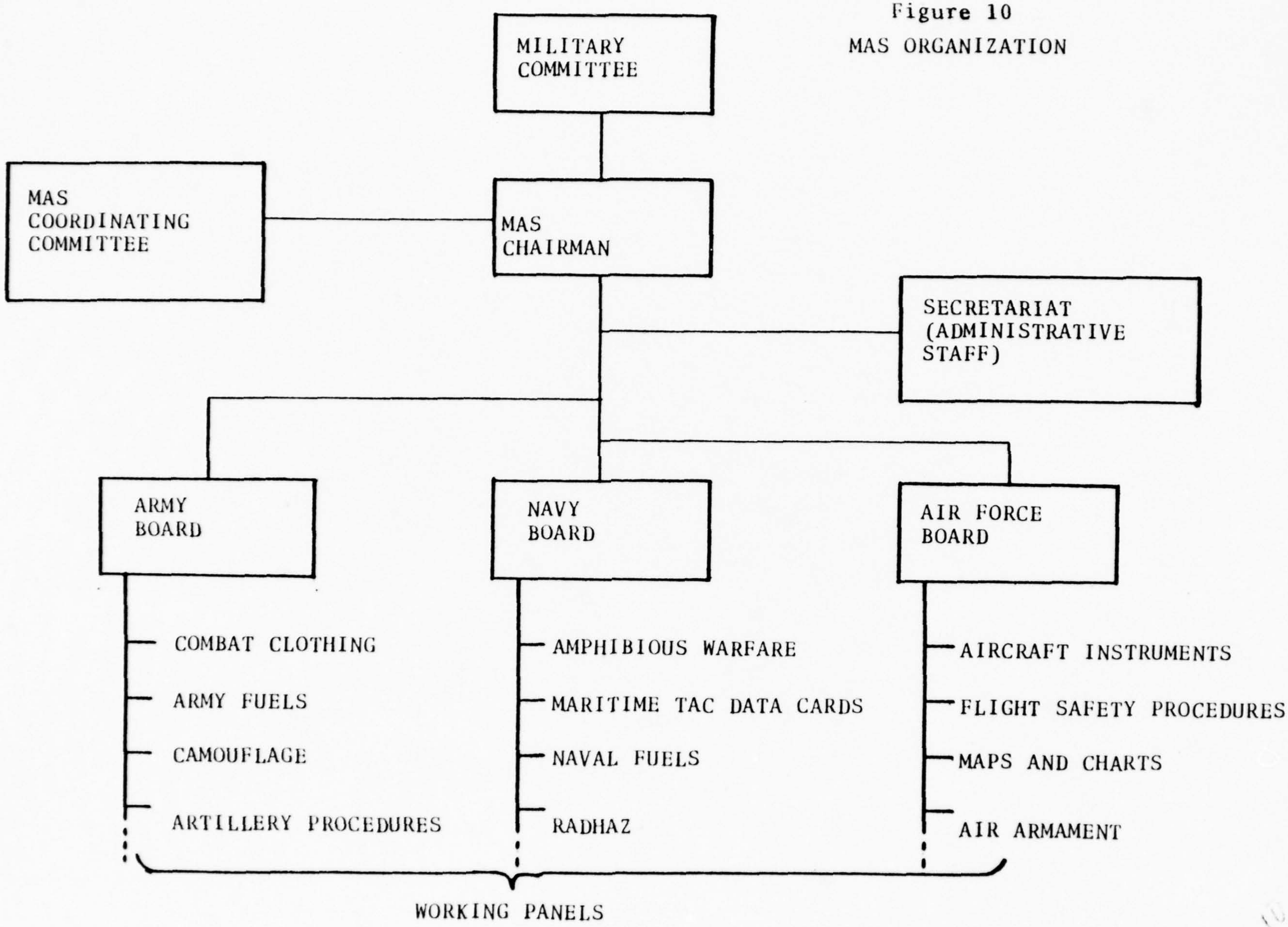
The practical result of this is that the MAS has tended to achieve NATO-wide standardization on a number of smaller issues in which agreement is possible but has had little impact on the requirements of the forces and major systems acquisitions.

The MAS organization is shown in Figure 10. The basic MAS Committee consists of the MAS Chairman and three Service Board Chairmen. These chairmen, as well as the secretariat staff, are all "international"; that is, they serve the interests of the MAS organization rather than their respective nations. Each Service Board is organized along traditional Army, Navy, and Air Force lines. A standardization task is assigned to one of the Service Boards by the MAS Chairman with Military Committee agreement. Assignment is usually based on which service function is likely to be most impacted by the particular standardization issue. The actual effort is carried on by separate Working Panels.

These lower-tier groups are composed of military and civilian experts in the particular area which the Working Panel had been tasked to address. These are the people who actually accomplish the studies, analyses, tests, and preparation of draft standards. The Working Panel members are "national" in character; that is, they represent the opinions and positions of their respective nations. Many of the Working Panels are ad hoc in nature in that they are formed and disbanded as the need arises. The organization, as shown in Figure 10, will quite likely be different at the Working Panel level by the time this thesis is published.

Figure 10

MAS ORGANIZATION



However, the nature of the panels should still be evident from their titles as shown in Figure 10.

In general, standardization efforts in the Navy and Army Boards and Panels have been more concerned with standardization of procedures and tactics. The Air panels have extended their efforts to include a selected set of equipment, systems and components. There is no organization within the MAS to ensure that the Working Panels coordinate their efforts with one another except for fairly broad administrative direction given by the Service Board Chairman. Unlike the CNAD, the MAS has no direct, visible link to the authority vested in the various national defense ministers. The MAS is a relatively low-level organization with several layers of management before reaching the North Atlantic Council. Thus, the MAS lacks power.

The function of the MAS is to promulgate standardization proposals in conformity with Military Committee policy. In general these proposals should be processed through the MAS organization if they have NATO-wide application although this policy has been relaxed considerably over the past several years. Proposals for standardization may be initiated by the North Atlantic Council, the Defense Planning Committee, Military Committee, various national staffs, operational commanders or from within MAS itself.

The end products of the MAS are NATO Standardization Agreements (STANAGS) or Allied Publications (AP). A STANAG is a record of agreement among several or all of the member nations to accept a standardization proposal for like or similar military equipment, ammunition, supplies and stores, and operational, logistic and administrative procedures. It is negotiated with nations, discussed with NATO commands, ratified by some or all nations, promulgated by MAS, and issued to the various Ministries of Defense and NATO commands. An AP may be an informative document not requiring ratification by NATO members or it may require approval action by the nations involved. The latter is ratified through the processes in which the NATO members agree to accept and use the manual.

The procedure whereby the MAS promulgates a STANAG begins with the receipt of a standardization proposal from one of the sources previously mentioned. The responsible Service Board assigns the proposal to a working panel (or creates a new one) for direct action. The Working Panel then studies the proposal itself or reassigns it to a custodian. A custodian may be any particular group or individual representing a particular national interest. The proposal is then studied and a draft STANAG is prepared. The draft STANAG is reviewed by all interested NATO members, comments are received and incorporated, and a final STANAG is issued. The final STANAG is then sent on to the nations for formal ratification. Acceptance occurs and is implemented by incorporating the contents of the STANAG into the various military specifications and tactical doctrines of the respective nations. Once a STANAG has been accepted and incorporated into the NATO structure (in whatever fashion is appropriate), it is the responsibility of the NATO commands to provide feedback to the MAS. This feedback should provide specific information as to the effectiveness of the STANAGS as disclosed by direct experience in training, operations, exercises or any other source. It is intended to lead to proposals for new STANAGS and improvements in existing ones.

D. THE CONFERENCE OF NATIONAL ARMAMENTS DIRECTORS (CNAD)

The CNAD, shown in Figure 11, was chartered in 1966 and was an outgrowth of the older Armaments Committee (AC). During the 1950's and early 1960's the Armaments Committee attempted to standardize by first gaining agreement on common or standard military requirements. This approach was based on a policy of rigid, inflexible adherence to single NATO-wide policies without recognizing the inherent differences in character and needs of the various national forces. The predictable result was that the NATO members never did agree fully on basic military requirements. Even in areas where partial agreement was reached, it tended to be ignored at the national levels. The CNAD recognized the diversity of requirements coupled with the fact that weapons development and procurement, at least in Europe, is more of a political/economic issue and less of a military matter [Ref. 15, p. 12]. Because of its civilian base the CNAD was considered the

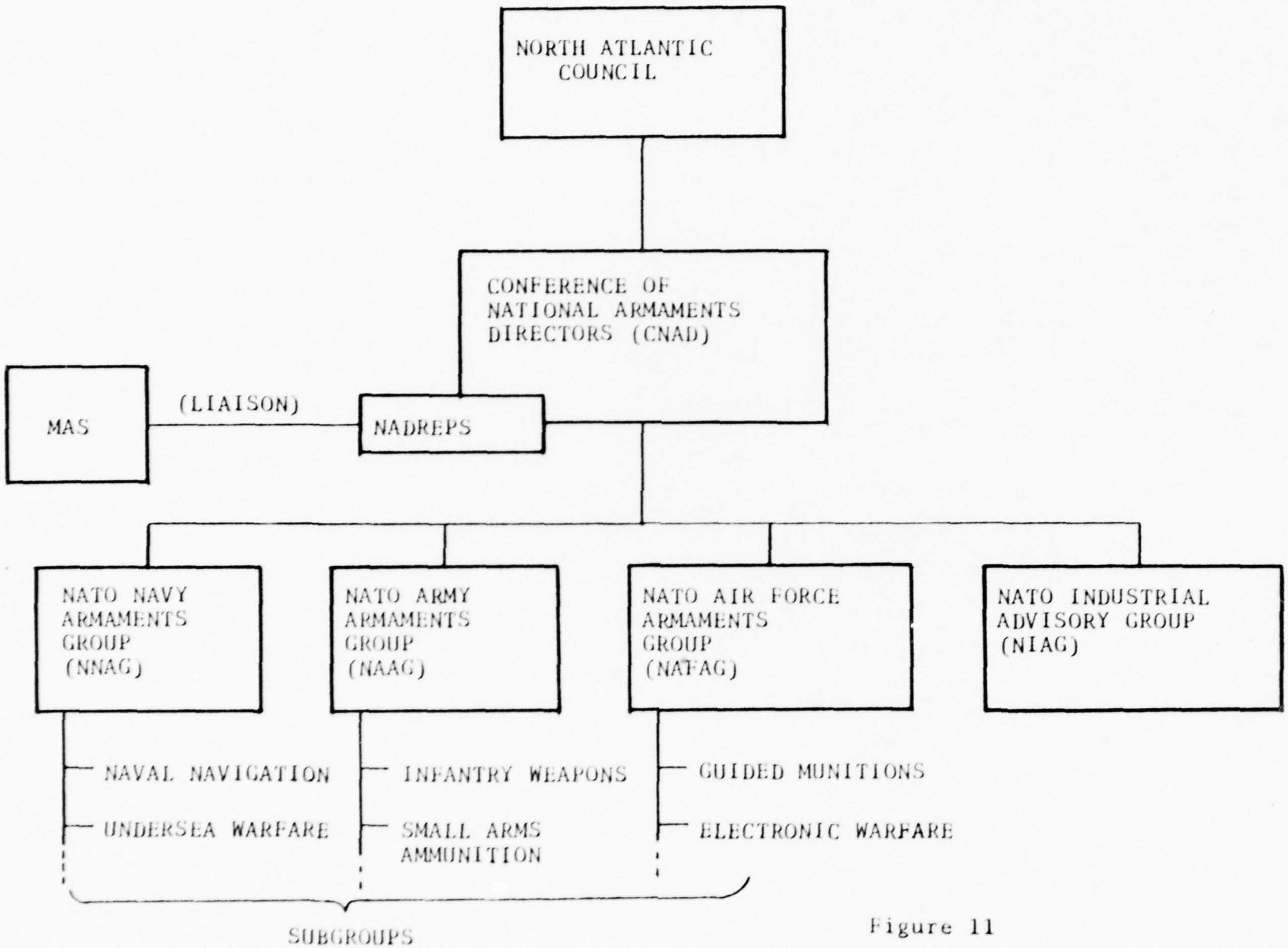


Figure 11
CNAD ORGANIZATION

CNAD was considered the logical place to work out these broader issues. Thus the burden of system and major equipment level standardization shifted from the MAS to the CNAD. The CNAD is kept up to date on military requirements by having a Military Committee representative and advisor included in all Armament Groups and Subgroups.

The new approach is to use the CNAD as a formal medium of voluntary exchange of research, development, and procurement information. Coupled with this is the CNAD task of identifying priority tasks and requirements through ties to the Military Committee. From this information, priorities relative to standardization needs are determined. These matters are summarized in the four basic principles by which CNAD conducts business [Ref. 16]:

(1) Each country is responsible for equipping its own forces.

(2) NATO Military Authorities (NMA) should be able to give opinions as to requirements of the NATO forces as a whole.

(3) Cooperation in R&D and production between two or more members is to be encouraged and supported by NATO but not mandated or directed.

(4) Countries are encouraged to present their respective national military requirements and procurement plans.

The main standardization thrust by CNAD is to create a forum of exchange between all NATO members. As a result of this exchange, if two or more nations can agree to harmonize requirements and share the burden of weapons acquisition, then they are encouraged to do so. While this approach does not guarantee broad-scale standardization it is still considered to be better than nothing. The emphasis in CNAD is to address those equipments, systems, and material which are currently in production or development. CNAD does not, as a rule, establish broad-scale standards or specifications on which future acquisitions are based. The latter falls under the MAS area of responsibility.

The CNAD leadership is composed of senior government officials responsible for acquisition of defense systems for each of the NATO members. The current U.S. representative is Dr. William Perry, Under Secretary of Defense for Research and Engineering. In addition, the CNAD has a direct organizational link to the North Atlantic Council whereas the MAS must work through the Military Committee. These factors tend to lend considerable weight to the CNAD.

Several groups and committees have been deleted from Figure 11 in order to preserve clarity. The CNAD Council, as indicated earlier, consists of the respective governmental Ministries of Defense or their appointed representatives. The National Armaments Directors Representatives (NADREPS) are the senior members of national delegations and are attached to the CNAD on a full-time basis. In addition to carrying out the routine managerial tasks of CNAD, NADREPS also comprises the only formal tie to the MAS for exchange of information.

The main bodies responsible for promoting cooperative ventures are the three Armaments Groups. These groups, like the MAS Service Boards, are organized along service functional lines, i.e., Navy, Army and Air Force. The NATO Industry Advisory Group (NIAG) provides information regarding current technology and developments in the private sector. It is imperative that the members of the Armament Groups be able to speak with authority regarding national operational concepts and material requirements. Each Armament Group includes a number of Subgroups each of which deals with a particular armament related topic. The Subgroups are analogous to the MAS Working Panels in terms of function and charter.

The method by which CNAD conducts business begins with a proposal for cooperative action based on common requirements and material needs. The proposal may be made by any representative within the CNAD organization or by the NATO Military Authorities. If two or more countries are interested in a cooperative venture a subgroup will be formed to study the proposal further. The nature of the proposals may range from common procurement of a specific piece of equipment to a much more general approach looking at such things as interoperability of multi-nation communication systems. If the studies indicate that a cooperative approach is desirable and possible the Subgroup may petition the CNAD Committee to designate the program as a "NATO Project." If accepted by the CNAD the project then continues with details as to licensing, coproduction, delivery schedules and priorities, etc., to be worked out between the participating NATO members.

In 1971 NATO attempted to strengthen the CNAD role even further by directing the organization to work more closely to define critical areas and needs for standardization. Inputs as to operational field problems and requirements were given more importance than before so that political, economic and military were all placed at relatively equal priority.

E. CURRENT NATO STANDARDIZATION ACTIVITIES

1. Periodic Armaments Planning System

Recent initiatives on the part of NATO have resulted in further strengthening of the CNAD through formation of a Periodic Armaments Planning System (PAPS). This is the title given to the administrative procedure designed to aid the CNAD in acquisition of NATO-wide systems and standardization decisions. This new procedure operates entirely within the policy framework of CNAD [Ref. 17].

Figure 12 illustrates the system life cycle as defined for NATO projects. The ordering of NATO life cycle phases has been adjusted to be compatible with the life cycle phases of the different NATO nations. As shown on Figure 12,

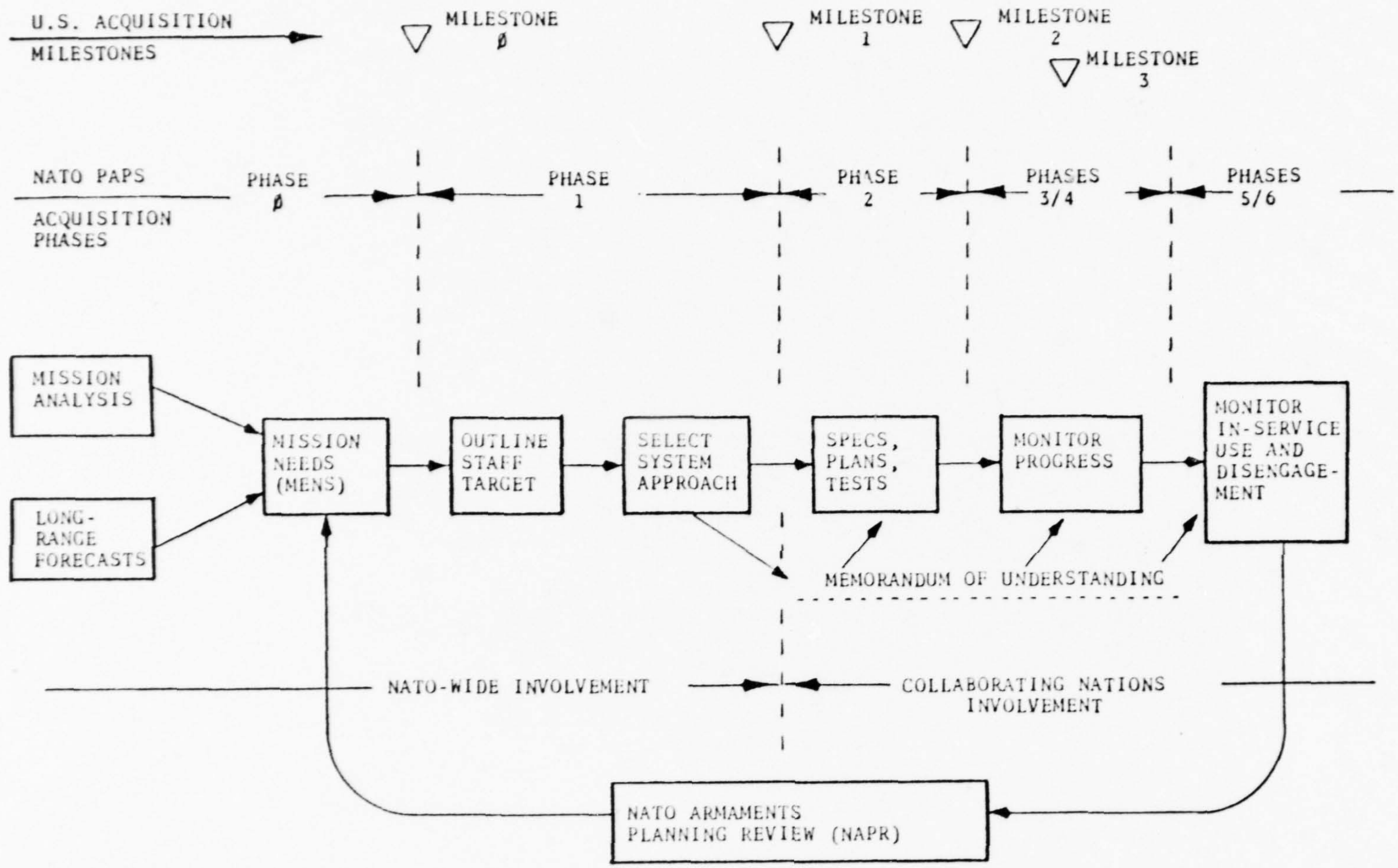


Figure 12
PERIODIC ARMAMENTS PLANNING SYSTEM FLOW CHART

the U.S. decision milestones are superimposed on the NATO phases to show the general relationship. Phase 0 consists of preliminary work in terms of long-range forecasting (technology trends, political and economic affairs) and mission analysis (operational threat, mission deficiencies). The information gathered is combined with field experience and replacement schedules for equipment to generate a document equivalent to the U.S. Mission Element Needs Statement (MENS).

This document supports phase 1 which is the Staff Target Development. The First step in this phase is to transform this MENS-like document into a detailed set of functional requirements and objectives. At this point all NATO nations participate and help formulate the requirements. Also, at this point, some nations may decide they are no longer affected by, or interested in, the particular requirements and will play a lesser role, such as monitoring the other nation's efforts. The set of functional requirements includes mission needs (as stated in the document), initial cost estimates, schedules, and operational considerations in such areas as support and training. These requirements and objectives are contained in a document called the "Outline Staff Target." This document, in turn, guides the second part of phase 1 which consists of pre-feasibility studies, alternate systems concept development, and evaluation. The output of this phase consists of a selected system approach and sufficient planning data to allow continuation into phase 2. Also at the conclusion of phase 1, those nations wishing to continue cooperation prepare a Memorandum of Understanding (MOU) to act as a statement of agreement among nations. Those nations which elect not to participate will continue monitoring the effort with possibility of involvement at a later date. At this point in the life cycle, the project begins to lose its NATO-wide character and begins to assume the nature of a group of collaborating nations. Even though the project may be designated a NATO project, NATO does not fill a management role but, rather, performs a monitoring function. The group of collaborating nations work out the project organization and management roles among themselves. The CNAD has little direct involvement after phase 1.

The remainder of the NATO acquisition phases coincide closely with U.S. practice and will not be discussed further.

2. NATO Armanents Planning Review

A description of current activities would not be complete without a brief mention of the NATO Armaments Planning Review (NAPR). This administrative process, illustrated in Figure 12, provides a heretofore missing link which gives operational feedback information in the form of field experience, problems, opportunities, and armaments re-equipment schedules. This information is combined with long-range forecasts and mission analysis to generate the MENS-like document. NAPR is generally thought of as an element of the Periodic Armaments Planning System.

It is interesting to note that phase 1 efforts closely follow the system design process described in section II.E. This is a significant fact and is discussed further in section IV.B. The PAPS procedure formalizes the process. Unlike past abortive efforts to generate common NATO military needs and requirements, the PAPS procedure attempts to bring the nations together at the beginning of the system life cycle before irrevocable national decisions are made. Finally, a positive method of providing user feedback to the planning process exists in the NAPR. This is a new approach for NATO and has yet to be proven.

IV. ANALYSIS OF NATO ACTIVITIES

A. INTRODUCTION

The systems approach described in Chapter III shows how decision-making can be accomplished to achieve standardization in a logical way through superimposing the Hierarchy of Standardization on system structures. It is the purpose of this chapter to examine the activities of the CNAD and the MAS to determine to what extent they are following the system approach to achieve standardization. Special attention is devoted to system interfaces and the manner in which they are being addressed within the NATO organizations.

B. ANALYSIS OF CURRENT ACTIVITIES

1. Conference of National Armaments Directors (CNAD)

The objective of the current CNAD efforts is to establish a framework in which it is easy for allies to collaborate in system acquisition and standardization. The CNAD has been working very hard to improve its procedures. This is accomplished through the Periodic Armaments Planning System (PAPS). Secretary of Defense Harold Brown has stated that, when fully implemented, the PAPS and related NATO planning systems should include:

"(1) Timely development of NATO military requirements documents which will guide the activities of the CNAD and influence national weapons acquisition plans at an early stage of their formulation.

(2) A means to systematically prepare NATO acquisition strategies which form the basis for both national and multinational programs to satisfy these NATO needs.

(3) Management review procedures to assess progress on cooperative programs at critical milestones and monitor the degree to which harmonization is being achieved Alliance-wide." [Ref. 5, p. 91]

In attempting to achieve standardization, the primary focus of the CNAD is in three areas:

(1) For participating NATO nations to reach an agreement on military requirements. This, ideally, should include all NATO nations but less than unanimous agreement is still satisfactory.

(2) For participating NATO nations to acquire common systems to satisfy the needs and requirements of the individual nations as well as NATO.

(3) For participating NATO nations to reach interoperability agreements in selected, high-priority areas.

In the area of establishing common military requirements the emphasis is on early communication of those requirements among the NATO Allies. Even so, differences in tactical doctrine, technical capabilities and other factors may preclude the NATO nations from being in close agreement on either military requirements or system solutions. This can lead to several difficulties.

If the nations find themselves unable to agree on basic military requirements, then collaboration on systems acquisition will be difficult to achieve and possibly not worth the effort. Any system obtained under this condition may fail to meet the requirements of one or more nations while possibly exceeding the requirements of others. Even when agreement is reached on military needs there is no assurance that the allies will be able to agree on which system is optimum. Nor will they necessarily be able to work out joint management responsibilities, funding, and acquisition strategies. In addition, those nations which drop out of active participation may elect to proceed on their own or in a coalition with other nations.

Even with the potential difficulties listed above some measure of success in acquisition of common systems has been achieved. The Airborne Warning and Control System (AWACS) program is a good example. According to Aviation Week and Space Technology [Ref. 18, p. 89],

> "The AWACS program is completely unique.... It is the first time NATO as an organization has tried to define, develop, and purchase a complex system, rather than having each member nation buy the system and then assign it to NATO.
>
> "In theory, the process was not complicated. The NATO military staff, having decided that an airborne early warning system was required to detect low-flying aircraft that might try to penetrate the airspace of NATO nations, was to have agreed on a common system that then was to be funded by the member nations on the basis of an agreed ratio."

Several problems have recently stalled the progress on acquisition of AWACS as a NATO system. Nevertheless it shows that common requirements and common acquisitition processes are indeed possible to achieve.

In addition to coordinating common military requirements and collaboration of systems acquisitions, the CNAD is also active in achieving interoperability in selected, high-priority areas. One example of this is the NATO Air Armament Subgroup 16 on Aircraft Cross-servicing. Subgroup 16 is pursuing a course which leads to progressively greater degrees of interoperability of NATO TACAIR. Stage A cross-servicing essentially allows an aircraft to refuel and replenish other consumables (not weapons/stores) at another NATO nation's airbase in order to get back to its own base. Stage B carries the cross-servicing a significant step further by providing for rearming of a limited selection of weapons/stores. Stage B allows the aircraft of one NATO nation to land at a different NATO nation's airbase and replenish to a combat-ready status. Both stages A and B have been implemented and have had considerable success. Stage C is the final stage and involves not only refueling and rearming but organizational level maintenance as well.

Subgroup 16 has been responsible for coordinating all the activities leading to achievement of greater interoperability of aircraft, weapons/stores, and airbases between the NATO nations. In so doing, it has been more concerned with working out the interface problems with today's systems and system elements and less concerned with establishing a standardization framework for tomorrow's systems.

Subgroup 9 on air-to-surface weapons and Subgroup 13 on air-to-air weapons are attempting to arrive at common military requirements for the 1980's. Both subgroups are looking to the MAS to establish standards for system elements and interfaces to support acquisition of common systems [Ref. 19].

In summary, the CNAD is actively attempting to promote common acquisition of systems among the NATO nations and interoperability in those systems where common acquisition is not feasible. The Periodic Armaments Planning System provides an excellent framework within which the system design model, described in section II.E, may function. However, the CNAD does not have a strong systems engineering group to pull together all of the diverse system elements and interfaces. Partly because of the lack of a systems engineering organization, the CNAD does not take a systems approach in solving its standardization problems.

2. Military Agency for Standardization (MAS)

The objective of the MAS currently is to establish common tactics, procedures, materials and interfaces between systems and their elements. This objective is essentially the same as when the organization was formed in 1951. The Standardization Agreement (STANAG) also continues as the means by which the common agreements are documented. The primary emphasis has been on setting standards for future systems with a "no retrofit" clause written into each

STANAG. This meant that all future systems would abide by the agreement but existing systems did not have to be changed to comply. Recent concern over the lack of standardization in NATO has resulted in elimination of the "no retrofit" clause. The door is now open to standardize existing systems at least to the degree of interoperability with new systems.

The MAS has come under considerable criticism over the past several years. Even the official NATO publication, NATO Facts and Figures, makes the statement:

> "Consequently, although the Standardization Agreement (STANAG) method is still used when need arises, it no longer represents a major part of cooperative efforts in the equipment field." [Ref. 13, p. 132]

The concern is that the MAS has not been effective in achieving NATO-wide standardization. There are several reasons for this apparent lack of effectiveness. The MAS has achieved some low-level standardization in parts and materials. However, no major system has ever been acquired based on specifications derived from STANAGS [Ref. 15, p. 11]. There has been very little emphasis on standardization at the higher system levels. In addition, the MAS, operating within its charter, has no enforcement power. The NATO nations accept and ratify or reject STANAGS on a strictly voluntary basis [Ref. 20, p. 327]. In addition, compliance after ratification has often been inconsistent, especially if the STANAGS are not incorporated into military specifications and standards of the NATO nations. As a result, few agreements are unanimous throughout NATO. In some cases, STANAGS are not ratified by the nations even after agreement is reached in MAS sessions [Ref. 21, p. 27].

The future of the MAS and the STANAG process is not as bleak as the above discussion might indicate. Substantial progress is being made in giving some authority to the STANAG process. Recognizing the lack of authority and enforcement power, the NATO nations have agreed to test a new process for monitoring STANAG implementation. This process is intended to provide NATO and the national authorties with feedback on the status of STANAG ratification and implementation by each nation [Ref. 5, p. 83]. This should certainly help strengthen the MAS and will aid considerably in achieving standardization.

Even though the MAS is being given additional support, this is occurring mainly in its administrative processes and not so much in the substance and form of the standardization tasks. It is in this area that more attention is needed. In particular, the MAS continues to reach standardization agreements at a low level. There is very little higher system level coordination of the STANAGS.

There is one encouraging example of how an organization within the MAS has broadened its view to include higher system level considerations. The Air Force Board has been very much concerned with the problem of interoperability of aircraft and weapons/stores among those nations possessing a significant TACAIR capability. The Air Force Board originally chartered the Air Armament Working Panel to work out technical interface problems in connection with the cross-servicing of aircraft and weapons/stores. Table II is a representative list of the type of STANAGS which resulted from this early effort [Ref. 22, pp. A1-A8]. The primary emphasis is on mechanical characteristics relative to the carriage and release of conventional, non-guided weapons. Some STANAGS exist for 20 mm and 30 mm aircraft guns and bomb fuze safety requirements. There was no emphasis or concern with the newer, more effective weapons. Stores such as Maverick television-guided close support missile, Harpoon anti-ship missile or any of the complex electronic warfare pods and target designator pods were not addressed.

Within the last year, efforts have led to consideration of interoperability of a broader range of weapons/stores than just conventional bombs and 20 mm/30 mm ammunition. Table III shows expansions into areas involving a much higher degree of integration of complex weapons/stores with the aircraft systems which must support them [Ref. 22, pp. A1-A8]. It is of interest to note that the Air Armament Working Panel was expanded into a new working panel which included the Aircraft Instrumentation and Aircraft Electrical Working Panels. This new panel has recently recommended formation of a higher system level organization to be known

TABLE II

SAMPLE OF EARLY STANAGS
OF THE AIR ARMAMENT WORKING PANEL

STANAG NO.	TITLE
3231 AA	ADEN and DEFA 30 mm Gun Barrel Chambers
3232 AA	30 mm Link for ADEN and DEFA Guns
3420 AA	Photoflash Cartridges for Low-Altitude Photography
3525 AA	Design Safety Principles and General Design Criteria for Airborne Fuzes
3556 AA	Bomb Ejection Cartridges
3575 AA	Requirements for Bomb Ejection Racks
3585 AA	20 mm Ammunition for Airborne Weapons
3605 AA	Compatibility of Mechanical Fuzing Systems and Arming Devices for Droppable Stores
3635 AA	Suspension Units with Release Capability for Helicopters
3726 AA	Bail Lugs for Suspension of Airborne Stores
3727 AA	Saddle Lugs for Suspension of Airborne Stores

TABLE III

SAMPLE OF RECENT STANAGS OF THE AIR ARMAMENT WORKING PANEL

STANAG or STUDY NO.*	TITLE
3841 AA	Safety Aspects Arising from the Application of Digital Data Bus Techniques to Stores Management
3845 AA	Display and Control Requirements Arising from the Management of Aircraft Stores, Internal Guns, and Dispensers
3839 AA	Design Measures Required to Achieve Flexible Organization of Software
3350 AA	Standardized Video System for Electro-optically Guided Weapons
3840 AA	Automatic Store Identification
3843 AA	Size and Weight Standards for Aircraft Stores Used on Fixed Wing Aircraft
3791 AA	Selection of NATO Common Use Weapons
3785 AA	Air-Ground Guided Weapon Interface (Electrical and Mechanical)

*Study Number indicates that the item has not been approved yet but is under consideration.

as the Avionics Systems Integration and Architecture Working Panel [Ref. 22, Annex F].

Even this broader view of the aircraft and weapons/ stores interoperability task has not yet included consideration of such necessary elements as maintainability, logistic support, tactical training, and more. It is, however, a start in the right direction. An important observation is that the expansion of Air Armament Panel task areas occurred solely as the result of the realization by the panel members of the need to do so. There was no initial direction by higher authorities to move into higher level considerations. There is no reason to believe that other working parties will be so fortunate as to recognize their limitations and the need to expand their efforts and their thinking. Herein lies the basic problem with the MAS. As in the CNAD, the MAS does not have a systems engineering organization to aid in structuring systems to help make decisions or to advise the different working panels. There is no deliberate emphasis on taking a systems approach to achieving standardization.

The importance of the MAS activities was underscored by Deputy Secretary of Defense Charles W. Duncan in testimony before the House Subcommittee on Problems in the Standardization and Interoperability of NATO Military Equipment:

> "Our Proposal will call for NATO mission element need statements -- to pave the way for cooperative

development and standardization agreements (Stanags) governing equipment designs to insure needed interoperability." [Ref. 23, p. 8]

3. CNAD and MAS Coordination

The only formal communication link between the CNAD and the MAS is through the National Armaments Directors Representatives (NADREPS). The NADREPS, which consists of senior CNAD staff members, handles all the routine exchange of information on activities status and decisions reached. However, discussions with members of CNAD subgroups and MAS working panels give indication that the exchange of information is not as effective as needed to accomplish standardization goals. There is some evidence, based on these discussions, that the difficulty may be the fact that the CNAD is a civilian organization whereas the MAS is a military organization. There is a natural and usually healthy gap between military and civilian sides of defense-oriented organizations. This helps keep a checks and balances arrangement between the two. Unfortunately the gap can sometimes be detrimental to good communications. Regardless of its effectiveness, it is safe to say that good exchange of information between CNAD and MAS is essential to achievement of standardization

C. SUMMARY OF ANALYSIS

The basic problem of both the CNAD and the MAS is the lack of a total systems approach. This is particularly evident when comparing current CNAD and MAS activities with the system design model and system life cycle as shown in Figure 13. Figure 13 is a matrix illustrating how the system design model for decision-making applies at all phases of a system life cycle. The system life cycle is divided into three distinct periods. The planning period is primarily conducted by the users. Users are defined as the military and civilian officials and organizations responsible for establishing military requirements. The acquisition period is the responsibility of the producers. Producers are defined as the people and organizations (both government and private industry) who develop and produce systems to satisfy requirements. The use period represents the in-service life of a system. It has long been considered critical that the users and the producers maintain a close dialogue. The users tell the producers what is needed operationally. The producers tell the users what they can have system wise. The CNAD is attempting to establish the PAPS as a framework which will allow decision-making to occur throughout the system life cycle. However, the primary focus has been on developing operational requirements and establishing common needs. This is certainly a necessary step but reflects mainly the kinds of activities which occur during the conceptual formulation and system definition phases of the life cycle as shown in Figure 13. This involves the user side of NATO, both civilian officials of the CNAD and the NATO Military Authorities (NMA). The CNAD has not shown any indication of going further in the

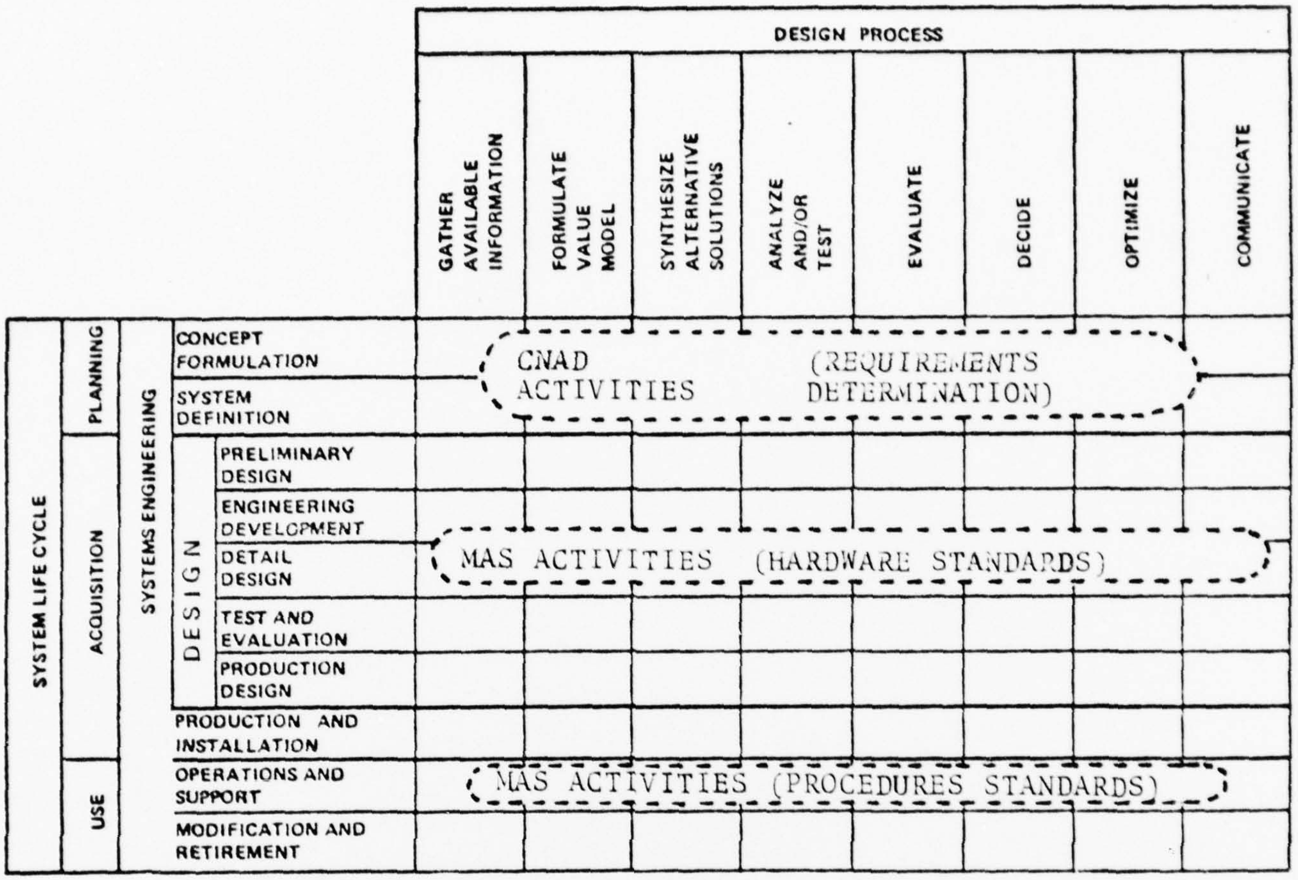


Figure 13
SYSTEM DESIGN MODEL APPLIED TO
THE SYSTEM LIFE CYCLE FOR CNAD
AND MAS ACTIVITIES

life cycle except as a monitor of individual and collaborative national efforts. In addition, the CNAD activities are not generally conducted in accordance with the system design model. The primary deficiency of the CNAD is in its lack of a total system approach for standardization decision-making at all life cycle phases.

The MAS, on the other hand, conducts its activities along entirely different lines. The hardware STANAGS, when fully ratified, are intended to support the detail design of systems which will be used in the NATO environment. In fact, no major system has ever been procured based on STANAGS [Ref. 3, p. 7]. The MAS also develops STANAGS related more closely to operational procedures and tactics. As with the CNAD, the MAS activities do not follow the systems design model in decision-making. With a few exceptions, the MAS conducts its activities at a low, detail level without considering the total system. Figure 13 shows how the hardware standards are intended to support detail design and the procedures standards support military operations.

The CNAD and the MAS need to recognize that making decisions and reaching agreements on standardization is a system problem. Solutions cannot be offered without consideration of their impact on all levels of a system and throughout the life cycle. Both organizations need to recognize that a hierarchy of standardization exists and has an impact on the decision-making process. The CNAD and the

MAS need to strengthen and formalize application of systems engineering to include total systems considerations. They need to be concerned with establishing agreements on interfaces between system elements at all levels. The STANAG process is well suited to this and only needs to be applied to systems from the top level downward rather than begin and stay at the lower levels.

The CNAD and the MAS perform complimentary functions and need to work more closely together in a true user-producer dialogue. By so doing, they can perform all of the functions of the system engineering methodology shown in Figure 13. Not only can they mutually assist each other during the early phases of planning and acquisition but through the rest of the system life cycle as well.

In summary, it is apparent from examining Figure 13 that there is no organization within NATO which is concerned with all phases and activities of the system life cycle. The CNAD concentrates its efforts during concept formulation and somewhat during system definition whereas the MAS is concerned about relatively low-level matters in support of detail design. NATO needs to restructure its efforts to accomplish standardization within a broad system engineering framework throughout the entire life cycle and to do so in the most cost-effective manner pos sible.

Although the thrust of this thesis is on standardization, there is a need to apply the same thinking to all other system related tasks in order to make tradeoffs among system design, reliability, maintainability, integrated logistics support, and cost.

V. SYNTHESIS, ANALYSIS AND EVALUATION OF ALTERNATIVES

A. INTRODUCTION

In chapter IV, the current activities of the NATO standardization organizations were analyzed and deficiencies were discussed. In particular, it was determined that neither the CNAD nor the MAS takes a total systems viewpoint regarding standardization decision-making over the entire system life cycle. In addition, there is a lack of user-producer communication between the CNAD, the MAS, and other NATO organizations. In this chapter, synthesis, analysis, and evaluation of alternative solutions to these deficiencies are presented. The system design model, the decision-making method described in chapter II, is used to arrive at a recommended solution. See Ref. 24, chapter 4, for a detailed discussion of the application of decision theory as applied to the systems design model.

B. SYSTEM DESIGN MODEL APPLIED TO CNAD AND MAS

1. Problem Formulation

Formulation of the problem consists of, first, redefining the deficiencies in terms of requirements and, second, establishing a list of criteria by which alternative solutions may be compared. Each of these is discussed in more detail.

a. Requirements

The purpose of requirements is to set up guidelines which can be used to develop alternative solutions to deficiencies. The requirement, in this case, is to restructure the NATO standardization efforts in such a way as to:

- .Establish a total systems engineering framework
- .Consider the impact of standardization over the entire system life cycle
- .Use the system design model as a tool for standardization decision-making
- .Establish an effective user-producer dialogue between the appropriate NATO organizations

b. Criteria

Criteria are the specific parameters which are relevant to the evaluation, comparison, and selection of one alternative over another. Three main criteria are of interest in this example. They are, in decreasing order of priority, effectiveness, communication, and resources. Effectiveness refers to the benefits of implementing the systems approach to standardization throughout the life cycle. Communication refers to the exchange of information on standardization requirements, capabilities and status between users and producers. In terms of priority, communication is nearly at an equal level with effectiveness. Resources is a measure of the cost and impact of implementing a particular alternative solution. Each criterion is assigned a weighting number according to its priority and value relative to the others on a 100% scale. Effectiveness is rated at .45 (45%), communication is rated .40 (40%), and resources is rated at .15 (15%). These weightings will be used in the evaluation of analysis results in section B.4 of this chapter.

Each of the three main criteria is further divided into more detailed supportive parameters. The complete list of criteria is shown below.

.Effectiveness

.External control - Ability to direct and enforce systems approach on standardization decision-making throughout the applicable NATO organization and over all system life cycle phases.

.Internal control - Ability to maintain control of resources needed to conduct systems engineering activities.

.Continuity - Degree of stability of personnel in remaining part of the systems engineering organization or process over a long period of time.

.Uniformity - Degree to which the systems approach is applied in the same way throughout the concerned NATO organizations.

.Span of control - Degree to which higher authority may have to expand span of control to watch over systems engineering activities.

.Communications

.User-producer dialogue - Ability to promote free exchange of information and viewpoints between users and producers throughout NATO.

.Subgrop dialogue - Ability to promote communication between and within CNAD subgroups.

.Working panel dialogue - Ability to promote communication between and within MAS working panels.

.Resources

.Cost - Incremental cost resulting from additional personnel and facilities required to support systems engineering activities.

.Reorganization - Degree to which NATO organizations need to be restructured to conduct systems engineering activities.

.Duplication of effort - Degree to which more than one organization is conducting systems engineering activities.

2. Synthesis of Alternative Solutions

There are a number of ways for introducing systems engineering into the CNAD and the MAS. Six of these are listed below and defined in the following paragraphs.

.Alternative 1 - No organizational change

.Alternative 2 - Systems engineering within functional organizations

.Alternative 3 - Dual matrix organization

.Alternative 4 - Single matrix organization assigned to CNAD

.Alternative 5 - Single matrix organization assigned to MAS

.Alternative 6 - Independent matrix organization

a. Alternative 1 - No Organizational Change

The first alternative is to leave both the CNAD and the MAS unchanged and simply introduce systems engineering as a new methodology. The tasks to accomplish systems engineering would be carried out using existing personnel and organizational structures.

b. Alternative 2 - Systems Engineering within Functional Organizations

The second alternative is illustrated in Figure 14. Each CNAD group and each MAS service board would establish a separate systems engineering subgroup or working panel. The members of each subgroup/working panel would consist of national delegates from each participating NATO nation. The delegates' activities would focus on standardization matters within the cognizance and interest of the particular group or service board. Coordination of these subgroups/working panels would be directed by the CNAD and MAS committees and their staffs. This is similar to a classical functional organization in that directors from the CNAD and MAS committees would be minimal with the subgroups/working panels cooperating to get the job done.

c. Alternative 3 - Dual Matrix Organization

Alternative 3 is a matrix organization with the systems engineering activities as the program managers and the subgroups/working panels as functional entities. The subgroups/working panels would carry out their activities under the direction of the systems engineering staff, which would, in turn, come under the scrutiny of the CNAD and MAS committees.

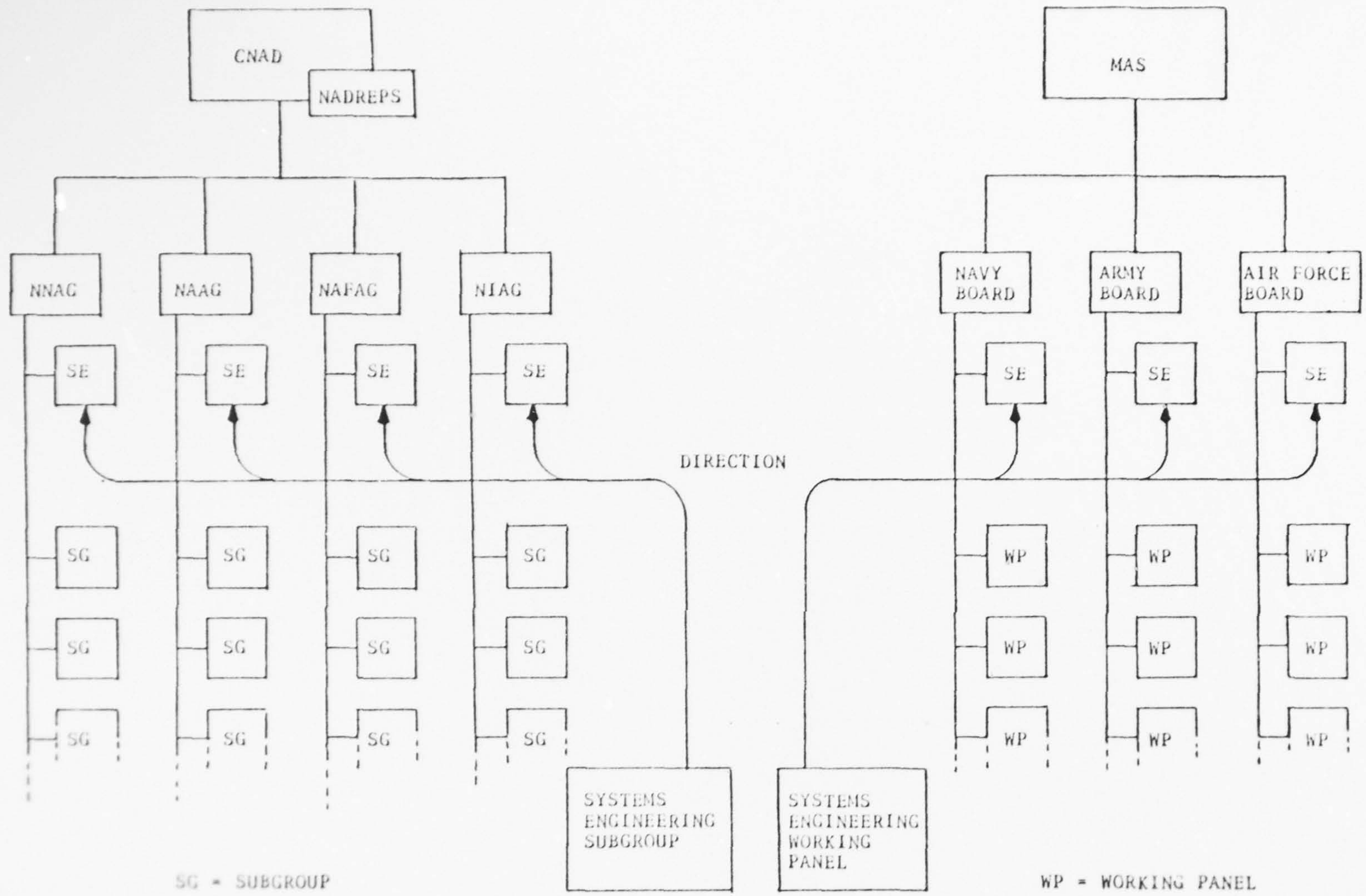


Figure 14
SYSTEMS ENGINEERING WITHIN
FUNCTIONAL ORGANIZATIONS

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A SYSTEMS ENGINEERING APPROACH TO NATO STANDARDIZATION. (U)

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Figure 15 depicts the third alternative. The systems engineering function has now been elevated to a higher position in the CNAD and the MAS. The organization would consist of permanent, duplicate staffs, each of which performs similar kinds of activities and tasks within its parent organization.

In this position each systems engineering activity would have responsibility for overall coordination of the groups and service boards, respectively. Along with this responsibility would be a greater degree of systems engineering authority over the functional groups and service boards. This is a result of the systems engineering activities close connection with the CNAD and MAS committees.

In order to maintain close working relationships, it would be necessary to assign one person as needed from the systems engineering activity to each CNAD group and MAS service board. This would help ensure full harmony and coordination of standardization activities among the various national representatives.

d. Alternative 4 - Single Matrix Organization Assigned to CNAD

The fourth alternative is simply a consolidation of the third alternative. As shown in Figure 16, this alternative eliminates the systems engineering activity from the MAS. All activities would be accomplished by a single systems engineering activity attached to the CNAD, thus eliminating

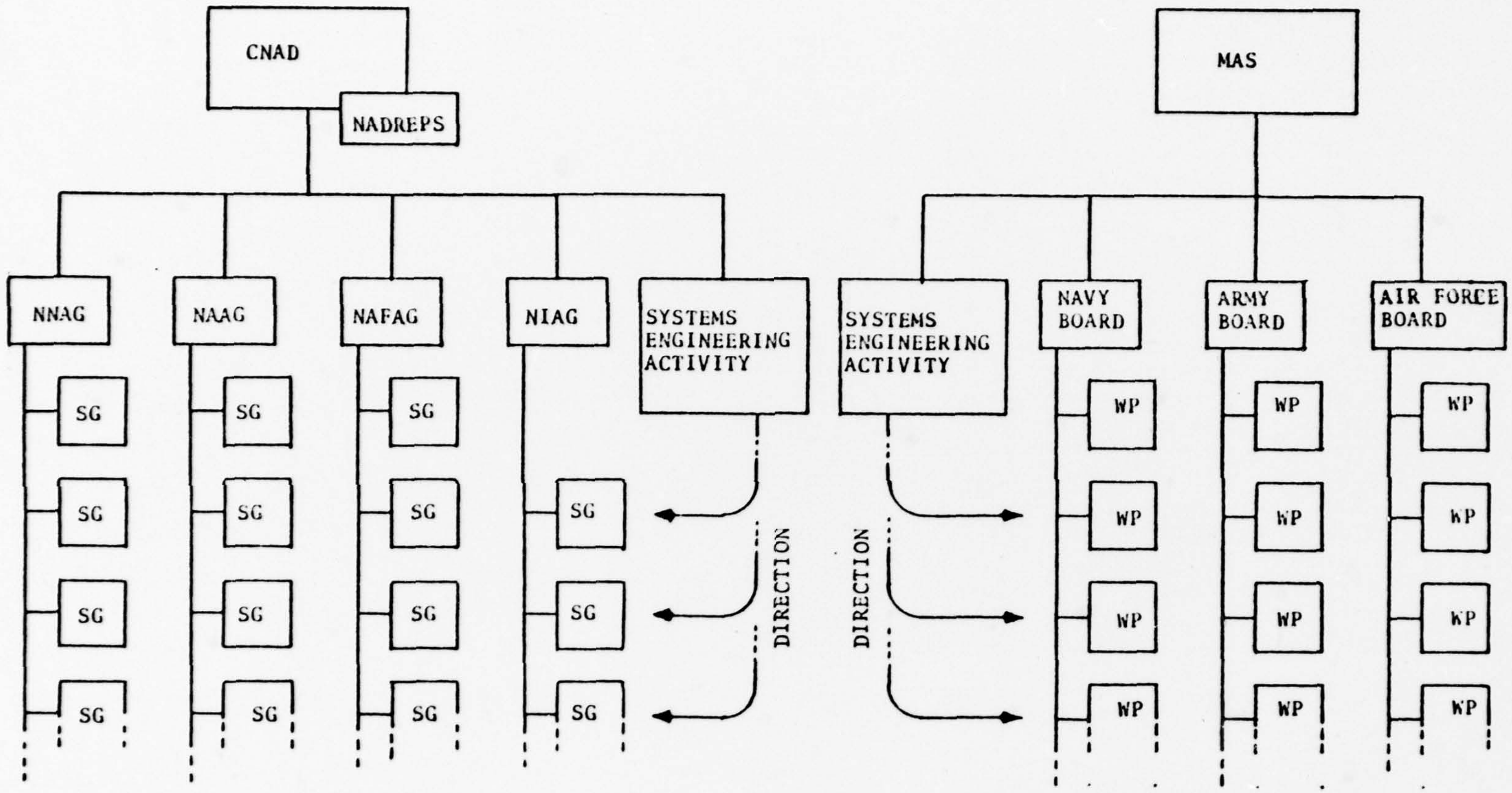

Figure 15
DUAL MATRIX ORGANIZATION

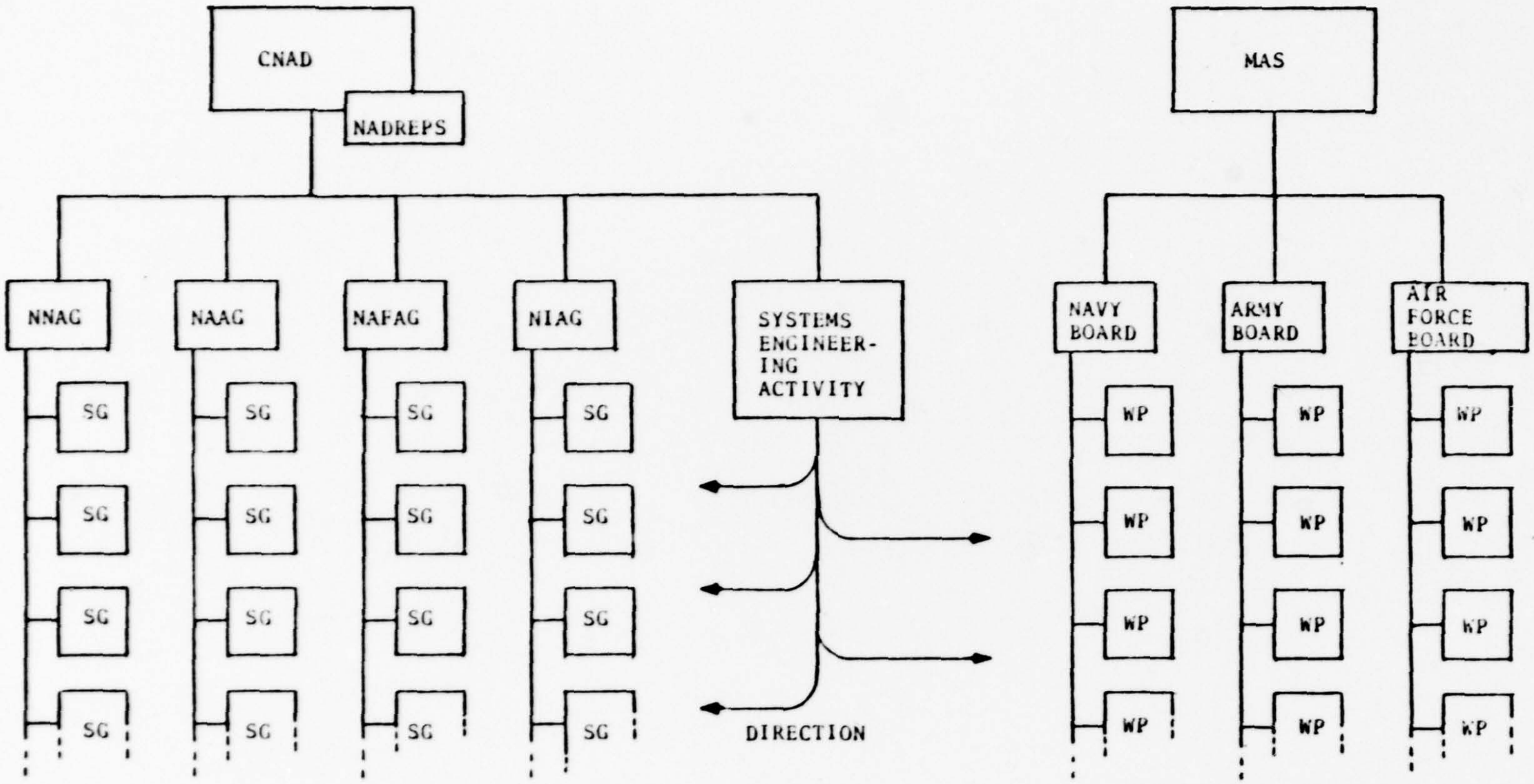

Figure 16
SINGLE MATRIX ORGANIZATION
ASSIGNED TO CNAD

the duplicative organizations in alternative 3. This one activity would coordinate and direct the standardization activities of both the CNAD and the MAS. In all other respects the responsibility and authority of the staff would be the same in alternative 3.

e. Alternative 5 - Single Matrix Organization Assigned to MAS

Alternative 5 is the same as alternative 4 except that the systems engineering activity would be located in the MAS rather than the CNAD. Activities would be similar to alternative 3 with the staff giving direction to both the CNAD subgroups and the MAS working panels.

f. Alternative 6 - Independent Matrix Organization

This alternative shown in Figure 17, separates the systems engineering activity from the direct authority of either the CNAD or the MAS. This independent matrix organization would conduct essentially the same activities as alternatives 3, 4, and 5 but with more direct decision authority and coordination. Several possibilities exist but the most likely is to place this activity under the Defense Support Division of the NATO International staff (see Figure 9). The Defense Support Division is a high-level, permanent international staff which concerns itself with policy level matters related to standardization of NATO systems.

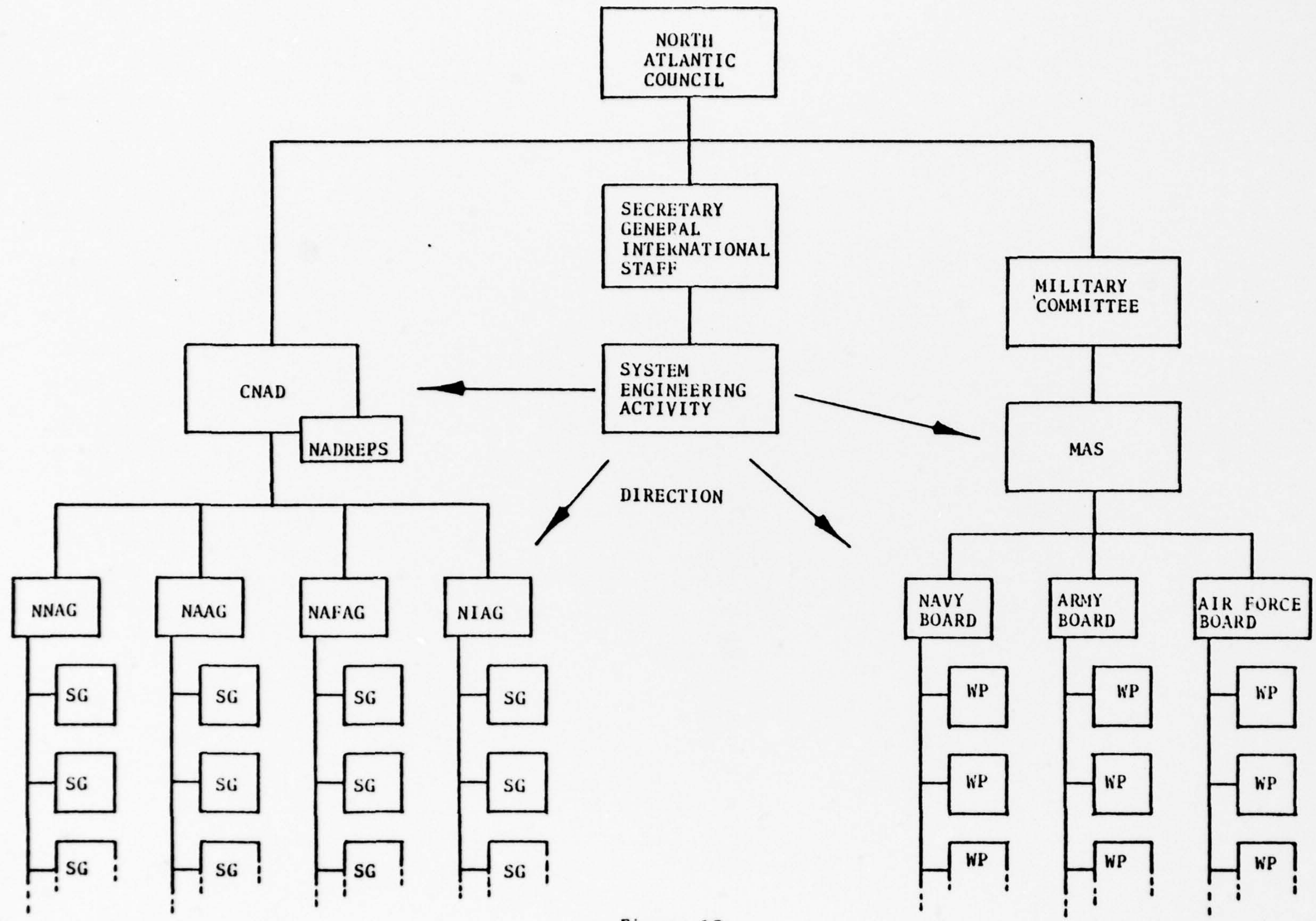

Figure 17
INDEPENDENT MATRIX ORGANIZATION

3. Analysis of Alternative Solutions

The analysis of the six alternative solutions will provide information on the advantages and disadvantages of each. The analysis will be based on the criteria and supportive parameters discussed in section B.1 of this chapter. Each alternative will be analyzed for advantages, disadvantages, and no effect relative to the current NATO approach for each supportive parameter.

a. Alternative 1

Advantages

.No reorganization is needed. A possible rewrite of charters and procedures may be required.

.Cost is low. There is a minimal investment of additional personnel and facilities.

No effect

.External control is no different since organizations are unchanged.

.Internal control of systems engineering activities is unchanged.

.Span of control is unchanged.

.User-producer dialogue remains difficult to accomplish but no worse than current approaches.

.Communications between CNAD subgroups and MAS working panels is insufficient for good coordination but no different from current approaches.

Disadvantages

.Constant change in composition of subgroups/ working panels and their personnel results in loss of continuity.

.Difficult for CNAD and MAS to maintain uniform systems engineering policies over entire system life cycle. This is due, primarily, to lack of full-time commitment.

.The CNAD and the MAS have duplicative functions and are therefore less efficient.

b. Alternative 2

Advantages

.No reorganization is required. System engineering subgroups and working panels are formed routinely.

.Group and subgroup dialogue is enhanced since the systems engineering subgroup is directly involved in activities.

.Service board and working panel dialogue is enhanced since systems engineering working panel is directly involved in activities.

.Cost is low. Subgroups and working panels are made up of national delegates and, thus, NATO personnel and facilities expenses are low.

No effect

.Span of control is unchanged for both the CNAD and the MAS committees.

Disadvantages

.No external control of other subgroups/working panels, except as the groups, service boards, and CNAD/MAS committees allow.

.National delegates are constantly changing. There is no internal control of the selection of qualified personnel assigned to the systems engineering subgroups and working panels. No adequate control of implementation of systems engineering methods.

.Continuity of activities suffers because of constant movement of personnel on the subgroups/working panels.

.Uniformity is hard to achieve because of the large number of organizations all attempting to accomplish the same thing but using different procedures. No central control.

.Systems engineering subgroups/working panels are at too low a level within NATO to effectively direct user-producer dialogue. Large number of additional subgroups/working panels may actually hinder coordination of user-producer dialogue.

.High degree of duplication of effort because of the large number of separate systems engineering subgroups/working panels.

c. Alternative 3

Advantages

.Adequate external control of standardization activities with authority to direct and enforce decisions.

.Permanent systems engineering activities allows internal control over selection of qualified personnel and adequate control of procedures for implementation of systems engineering methods.

.Permanent systems engineering activities allows continuity of tasks and procedures over entire life cycle.

.The user-producer dialogue is easier to achieve because relatively high-level activities are directing it.

.CNAD subgroups and MAS working panels are communicating better because the systems engineering activities are directing and coordinating them.

No effect

.Uniformity of procedures and methods is better than alternatives 1 and 2 but still split between CNAD and MAS systems engineering activities.

Disadvantages

.Reorganization of the CNAD and MAS will have to occur to accommodate the systems engineering activities.

.Cost is high because of need to support two full-time, permanent activities.

.Duplicate activities are less efficient.

.Span of control is a bit more of a problem for the CNAD and MAS committees.

d. Alternative 4

Advantages

.Adequate external control of standardization activities with authority to direct and enforce decisions. Full control exists over the CNAD subgroups with somewhat less control over the MAS working panels. However, the overall authority of the CNAD lends considerable weight to alternative 4.

.A permanent systems engineering activity allows internal control over selection of qualified personnel and adequate control of procedures for implementation of the systems engineering methods.

.A permanent systems engineering activity allows continuity of tasks and procedures over entire system life cycle.

.There is uniformity of procedures and methods because a single systems engineering activity is in control.

.The user-producer dialogue is easier to achieve because a single activity is coordinating communications.

.CNAD subgroups communicate under the direction of the systems engineering activity. MAS working panels also communicate but to a lesser extent.

.A single systems engineering activity is more efficient because of no duplication of effort.

No effect

.Span of control is slightly larger for the CNAD committee. No effect on the MAS committee.

Disadvantages

.Reorganization of the CNAD will have to occur to accommodate the systems engineering activity. The MAS will have to restructure procedures to allow direction by the activity.

.The cost is high because of the need to maintain a permanent, full-time staff. However, cost is lower than with the duplicate activity.

e. Alternative 5

Advantages

.Adequate external control of standardization activities. Somewhat less authority to direct and enforce decisions because of relatively low position of the MAS within the NATO organization, at least as compared with the CNAD.

.A permanent systems engineering activity allows internal control over selection of qualified personnel and adequate control of procedures for implementation of the systems engineering methods.

.A permanent systems engineering activity allows continuity of tasks and procedures over entire system life cycle.

.There is full uniformity of procedures and methods because a single systems engineering activity is in control.

.The user-producer dialogue is enhanced but still needs closer ties to the requirements determination process.

.MAS working panels communicate well under direction of the systems engineering activity. The CNAD subgroups also communicate but to a lesser extent.

.A single systems engineering activity is more efficient because of no duplication of effort.

<u>No effect</u>

.Span of control is slightly larger for the MAS committee. No effect on the CNAD committee.

<u>Disadvantages</u>

.Reorganization of the MAS will have to occur to accommodate the systems engineering activity. The CNAD will have to restructure procedures to allow direction by the activity.

.The cost is high because of the need to maintain a permanent, full-time staff. However, cost is lower than with the duplicative activity.

f. Alternative 6

Advantages

.Full external control of standardization activities with authority to direct and enforce decisions. Full control over CNAD subgroups and MAS working panels.

.A permanent systems engineering activity allows internal control over selection of qualified personnel and adequate control of procedures for implementation of the systems engineering methods.

.A permanent systems engineering activity allows continuity of tasks and procedures over entire system life cycle.

.There is full uniformity of procedures and methods because a single systems engineering activity is in control.

.The user-producer dialogue is easier to achieve because a single activity is coordinating communications.

.CNAD subgroups and MAS working panels are communicating under the direction and coordination of the systems engineering activity.

.A single systems engineering activity is more efficient because of no duplication of effort.

No effect

.Span of control has been removed from the CNAD and MAS committees but still exists at a higher level.

Disadvantages

.A relatively large reorganization will have to occur to accommodate the systems engineering activity. This will occur outside the confines of the CNAD and MAS.

.The cost of maintaining a relatively large systems engineering activity will be high.

4. Evaluation of Alternative Systems

a. Evaluation Method

Evaluation consists of listing the advantages and disadvantages of each alternative for each criterion parameter on a comparative basis. Table IV illustrates how this is done. Each criterion and supporting paramater is shown along with a weighting value as described in section B.1 of this chapter. The alternative solutions are arranged in columns 1 through 6. The advantages, no effect, and disadvantages described in subjective terms in the preceding section are quantified into numerical ratings with values ranging from one to five. The meaning of each rating is described below.

CRITERION PARAMETERS		ALTERNATIVE SOLUTIONS 1	2	3	4	5	6
EFFECTIVENESS 0.45	EXTERNAL CONTROL	3	2	4	5	4	5
	INTERNAL CONTROL	3	1	5	5	5	5
	CONTINUITY	1	1	5	5	5	5
	UNIFORMITY	2	1	3	5	5	5
	REORGANIZATION	5	4	2	2	2	1
	SPAN OF CONTROL	3	3	3	3	3	3
SUBSCORE = $.45 \times \frac{\Sigma \text{ PARAMETERS}}{6}$		1.275	.90	1.65	1.875	1.8	1.8
COMMUNICATION 0.40	USER-PRODUCER DIALOGUE	3	2	4	5	4	5
	SUBGROUP DIALOGUE	3	5	5	5	4	4
	WORKING PANEL DIALOGUE	3	5	5	4	5	4
SUBSCORE = $.40 \times \frac{\Sigma \text{ PARAMETERS}}{3}$		1.2	1.6	1.87	1.87	1.73	1.73
RESOURCES 0.15	COST	5	5	1	2	2	1
	DUPLICATION OF EFFORT	2	1	1	4	4	4
SUBSCORE = $.15 \times \frac{\Sigma \text{ PARAMETERS}}{2}$		.525	.45	.15	.45	.45	.38
TOTAL RATING (Σ SUBSCORES)		3.0	2.95	3.67	4.2	3.98	3.91

RATINGS

MOST ADVANTAGEOUS = 5
SOMEWHAT ADVANTAGEOUS = 4
NO EFFECT = 3
SOMEWHAT DISADVANTAGEOUS = 2
MOST DISADVANTAGEOUS = 1

TABLE IV

EVALUATION SCORING OF ALTERNATIVE SOLUTIONS

.Most advantageous - 5

.Somewhat advantageous - 4

.No effect or indifferent - 3

.Somewhat disadvantageous - 2

.Most disadvantageous - 1

Each parameter is assigned a rating for each of the alternatives. An average is taken of the parameters within each criterion. This average is then multiplied by the particular criterion weighting to obtain a criterion weighted average. The weighted averages (there are three for the three criteria) are summed up to obtain an overall rating for that particular alternative solution. The remaining alternatives are evaluated the same way. Reference 25 presents a detailed discussion of this method of evaluation.

The distribution of ratings, shown in Table IV, are the author's judgments. Other evaluators may assign different ratings and the result may be somewhat different. However, it is suggested that the end result will be essentially the same [Ref. 26].

b. Evaluation Results

Alternatives 1 and 2 do not offer any significant advantage over the current NATO approaches to standardization. Alternative 3 offers some increased effectiveness and communications but suffers from high cost and duplication of effort. Alternatives 4, 5, and 6 offer the highest degree of effectiveness and communications but require additional resources due to the need for a permanent systems engineering activity with accompanying personnel and facilities. Duplication of effort is eliminated.

Of the three acceptable alternatives, number 6 is lowest even though it exhibits a considerably higher degree of external control of systems engineering activities. The lower score is a result of the need for considerable reorganization at fairly high levels within NATO and the higher cost associated with a permanent activity.

Alternatives 4 and 5 exhibit the same trends in reorganization and cost as alternative 6 but to a lesser degree. Therefore, their scores are higher. The score for alternative 4, the systems engineering activity attached to the CNAD, is the higher of the two. This is a result of a more effective user-producer dialogue and a greater degree of external control of standardization activities. The CNAD has generally been more involved in establishing military needs and requirements and defining alternative systems to suit those needs through a user-producer dialogue. The CNAD seems to have a little more concern with the system life cycle, at least during the critical early phases. In addition, the CNAD has a more direct line of authority to the North Atlantic Council as well as ties to the various national defense ministries. The effect is to transfer some of the authority and influence of the CNAD to the systems engineering activity. This, in turn, affects the ability to control all the organizations involved in standardization decision-making.

C. DECISION

If NATO is willing to undergo a relatively major reorganization and is able to bear the cost of a large systems engineering activity, then alternative 6 is recommended as most effective. If alternative 6 is not feasible, then alternative 4 is recommended as the best compromise between effectiveness and usage of resources. The CNAD has all the necessary basic attributes for making decisions on standardization of NATO systems. The addition of a system engineering activity, as recommended in alternative 4, will strengthen the technical basis on which decisions are made and result in more emphasis on the viewpoint of the producers.

VII. SUMMARY AND RECOMMENDATIONS

A. SUMMARY

The increased threat from strengthened Warsaw Pact forces combined with recognition of the inability of NATO forces to cooperate fully in combat has caused much emphasis to be placed on the need for standardization of equipment, procedures, tactics, and doctrine. The result of this has been interest in the development of new procedures, such as PAPS, by which the NATO nations may decide which systems need to be standardized. These procedures are a considerable improvement over past methods.

Further improvements, however, can be made. NATO needs to recognize that a hierarchy of standardization exists and that it can be combined with systems engineering methods. The end result will be a more rational, coordinated approach to standardization decision-making. NATO also needs to be prepared to reorganize, not only to aid in making standardization decisions, but to manage and support the development, production, and operational use of systems over their entire life cycle.

Following is a summary list of the main conclusions in this thesis:

.A hierarchy of standardization has been developed and can be used to help make standardization decisions.

.The systems approach offers a rational means for decision-making whereby all relevant information is considered and weighed.

.The system design model is a generally applicable tool by which the systems approach may be implemented.

.It is most important to consider the impact of standardization during the planning phases of the system life cycle. This should be used as a guide to standardization efforts in all other phases.

.Interfaces between system elements are critical. If these are not well understood then the higher degrees of standardization will be difficult to achieve.

.Neither the CNAD nor the MAS use a systems approach in standardization decision-making.

.The CNAD and the MAS perform complementary functions but do not communicate well.

.The MAS is a good organization for establishing interface standardization but currently is active only at lower system levels.

.The CNAD has the necessary atrributes to be an effective systems engineering organization. It only needs to consolidate its efforts on a more formal basis.

B. RECOMMENDATIONS

The following recommendations are made:

.Introduce a systems engineering framework as a way of making decisions on standardization issues. Broaden the systems perspective of all the CNAD subgroups and MAS working panels so they can see the impact of their efforts on other systems and system elements.

.Establish a permanent systems engineering activity with a charter to implement the systems approach throughout the CNAD and the MAS. Give the staff enough authority to direct and coordinate all of the standardization activities within these organizations.

APPENDIX A

GLOSSARY OF TERMS

Concept Formulation - This is the initial phase of the system life cycle in which efforts are directed toward identifying and evaluating the feasibility of operational requirements.

Form. Fit. Function. - Terms used to describe the three primary attributes of a system. Form describes the shape of a system, equipment, or component. Fit describes how well it interfaces with other systems, equipment, or components. Function describes the operation and performance of the system, equipment, or component.

FRG - Federal Republic of Germany, also known, informally, as West Germany.

IFF - Identification Friend or Foe. Equipment installed in all combat aircraft which, when interrogated by another aircraft, identifies itself as friendly. No reply or an improperly coded reply would warn the other aircraft of possible enemy intrusion.

Laser Seeker - One form of PGM component wherein a target is illuminated by a laser (ground or airborne) and a seeker, mounted on the weapon, detects and homes on reflected laser energy from the target.

NATO Nations - All the member nations of the NATO alliance. This includes Belgium, Canada, Denmark, France, Greece, West Germany (FRG), Iceland, Italy, Luxemborg, The Netherlands, Norway, Portugal, Turkey, United Kingdom, and United States. Of these fifteen, France and Greece have withdrawn from the military alliance but remain active in all other NATO affairs. Iceland has no military force. This leaves twelve nations in an armed alliance as of spring 1979.

NMA - NATO Military Authorities. These are the top military positions of the operating forces and are represented by four NATO commands along with their staffs. These commands come under the Military Committee and consist of the Supreme Allied Commander, Europe, the Supreme Allied Commander, Atlantic, the Canada-U.S. Regional Planning Group, and the Allied Commander in Chief, Channel.

PGM - Precision Guided Munitions. This term represents a generic class of aircraft-delivered weapons which have been developed during the last decade. They are characterized by sophisticated internal mechanisms, complex interfaces with aircraft systems, and exceptional performance (range, accuracy, velocity, etc.).

Planning Period - The period of a system life cycle during which concept formulation and system definition take place.

Rearm - The act of replacing an aircraft's weapons.

Refuel - The act of replenishing an aircraft with fuel and other consumable supplies.

SACEUR - Supreme Allied Commander, Europe. The top command of all NATO forces in Europe.

System Definition - This is the second phase of the system life cycle. Technical plans and operational requirements are further refined in light of more detailed information regarding technical, economic, and financial feasibility.

System Life Cycle - The entire period of time during which a system is in existence. Extends from military requirements determination through concept formulation, definition, development, production, usage, and phase-out.

TACAIR - Tactical Air. All components of the air forces used to support local or regional military operations. TACAIR is typically used to provide air superiority, close support of ground troops, interdiction and deep strike at supply depots, transportation lines, etc.

Weapons/stores - Any item which is attached to an aircraft which is not part of the aircraft fixed configuration. A weapon or other store may or may not be ejected or launched during a routine mission; however, it may always be easily attached or removed on the ground and usually is. This definition includes bombs, external fuel tanks, guided weapons, electronic warfare pods, and so on.

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