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PROGRAM MANAGEMENT COURSE

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DEVELOPMENT PROTOTYPING/ INTEGRATED LOGISTICS SUPPORT STUDY REPORT 73-1

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DEFENSE SYSTEMS MANAGEMENT SCHOOL

STUDY TITLE: DEVELOPMENT PROTOTYPING/ILS
(COMPLIMENTARY CONCEPTS OR A DICHOTOMY?)

STUDY PROBLEM/QUESTION: To evaluate the objectives and guidance regarding prototyping and integrated logistics support and to determine if they are complimentary or contradictory.

STUDY REPORT ABSTRACT:

The 1970's has seen the renaissance of prototyping and with it came many questions regarding its implementation. The role of integrated logistics support as it relates to prototyping is one of these pressing questions. This report is an evaluation of the objectives, policies, and other influencing factors regarding the role of ILS in the prototyping process. The study identified a need for a working terminology and a more definitive definition of prototyping objectives. It concluded that development prototyping as distinguished from experimental prototyping and integrated logistic support are basically complimentary concepts. However, because of misunderstanding and lack of direction, the two concepts are considered incompatible by numerous industry and government program managers. The proper role of ILS during development prototyping is one of participation in design, operating, and maintenance trade-offs.

KEY WORDS: MATERIEL DESIGN AND DEVELOPMENT PROTOTYPES INTEGRATED LOGISTICS SUPPORT PROGRAM MANAGEMENT

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Study Report
by

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May 1973

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Prototyping, the art of developing the first of a kind, is as old as history. However, the 1970's has seen the renaissance of prototyping and with it came many questions regarding its implementation. The role of Integrated Logistics Support as it relates to Prototyping is one of these pressing questions. This study deals specifically with ILS as it relates to development prototyping, e.g., prototypes designed during the conceptual/validation phases with the intent to continue development and eventual incorporation into the operational inventory.

The lack of directives governing prototyping and the relatively slow implementation of Integrated Logistics Support concepts have resulted in misunderstandings and inconsistencies in the application of ILS on prototype programs. Prototyping as it is being implemented stresses "hands-off" management to create an environment which encourages innovation and emphasizes performance.

The prototyping policy and guidance which has been put forth has been very broad and general and has failed to adequately define the objectives of prototyping. The guidance essentially recognizes only the prototypes at the extremes of the spectrum, e.g., preproduction/production and experimental prototyping. Development prototyping has essentially been ignored. Under Secretary Packard's policies,

development prototypes replace the paper studies of the validation phase. However, the prototype is more final and deterministic than the studies they replaced and have, in fact, moved some of the finality of full-scale development effort into the validation phase.

However, for many reasons, the development prototype concept has been used more in the context of experimental prototyping than development prototyping. They have in many cases emphasized performance to the exclusion of support considerations. There are several influencing factors which have contributed to this situation: 1. There has been a void in guidance regarding development prototyping. The guidance that has been issued has been very general and failed to distinguish it from experimental prototyping. 2. ILS has received a lot of attention and discussion; however, the implementation has been slow and to a large extent has not progressed past the discussion stage. 3. The program manager's incentives are not compatible with Integrated Logistics Support concepts. The program manager continues to be motivated to hold down acquisition costs, meet schedules and meet performance parameters, sometimes at the expense of support considerations. 4. The incremental nature of funding policies has also been a detriment to providing adequate support considerations. The funding frequently fluctuates drastically from year to year and is

frequently cut from the current year with promises for appropriate adjustments in the out years, thus resulting in moving the support considerations to the out years along with the money while design of performance characteristics continues. 5. The turnover of personnel at all levels of government has also reduced the efficiencies of program management and contributes to the laxity regarding support requirements. The frequent turnover of policymakers at all levels of government and DOD results in such frequent changes of policy that they cannot be fully implemented before the next change occurs.

The study identified a need for a prototyping directive which provides working terminology so that a common understanding can be achieved at all levels on what is meant by the various types of prototyping. In conjunction with this, it is also necessary for the development agency to determine the objectives of the specific prototype programs prior to embarking on the efforts. The specified objectives will then make the role of the "ilities" more apparent.

In conclusion, the development prototyping and Integrated Logistic Support are basically complimentary concepts. However, because of misunderstanding and lack of direction, the two concepts are considered incompatible by numerous industry and government program managers and policy makers. Consequently, they have attempted to serialize the design

effort by first designing the performance characteristics (through development prototyping) and subsequently considering support requirements during full-scale development. The proper role of ILS during the development protoype effort is one of participation in design, operating, and maintenance trade-offs. However, the detail to which support considerations are included in development prototyping should be limited to the elements of a requirements nature and should not be concerned with the "how" of requirements implementation.

Once a system or equipment has transistioned from the exploratory stage to development effort, the maintenance concept and other support considerations must influence the early design effort (including development prototyping). Design analysis and trade-offs must include support considerations to have meaning in an operational context.

DEVELOPMENT PROTOTYPING/INTEGRATED LOGISTICS SUPPORT (COMPLIMENTARY CONCEPTS OR A DICHOTOMY?)

The General Problem

Prototyping, the art of developing the first of a kind, is as old as history. However, the 1970's has seen the renaissance of prototyping and with it came many questions regarding its implementation. The role of integrated logistics support is one of these pressing questions. The recent redefinition (DOD Directive 4100,35, dated 1968) and slow implementation by the services of the Integrated Logistics Support Concept has contributed to the uncertainty of this relationship.

In the early 1970's former Deputy Secretary of Defense Packard issued broad policy guidance which was the mandate for reorientation of weapon systems acquisition philosophy. The guidance emphasized minimizing technical risk by taking deliberate measures, such as extensive prototyping during the concept and development phases.

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*ABSTAINER

This study represents the views, conclusions, and recommendations of the author and does not necessarily reflect the official opinion of the Defense Systems Management School nor the Department of Defense.

"We want to evaluate both the feasibility and utility of a new weapon to the extent possible with hardware demonstrations in advance of production." [1]

This policy of trading risk and cost for time is consistent with current national attitude.

The implementation of the prototyping policies has emphasized a hands-off management with greatly reduced requests for proposals, few design constraining standards with major emphasis on performance and low acquisition costs, the theory being that the prototype should be developed in an environment which encourages innovations and requires minimum resources. Should a workable design concept evolve from the prototype, then the "ilities" can be designed in during full-scale development.

In this environment questions arise, such as, is it practical to constrain the design of a protype with consideration of maintainability, reliability, human factors,etc., or is it more reasonable to expend funds for these and other "ilities" on two competing designs, when one is going to be scrapped after the selection process?

The policy makers at all levels of DOD have wrestled with these descriptions. Mr. Laird, Secretary of Defense, stated:

"If these prototype programs are to be efficient, they must be managed with the minimum of constraints.

[1] David Packard, "Statement before the Senate Armed Services Committee", 9 Sept 71, p.2

> They should be designed to meet to meet performance goals not detailed specifications. They should not require detailed confirmation of requirements nor careful consideration of all alternatives in advance because the very purpose of building prototypes is to use operational testing of hardware to confirm requirements and evaluate alternatives.... It is my clear intention that the management of prototype programs be as simple and streamlined as possible." [2]

Mr. Packard, Deputy Secretary of Defense, said in this regard:

> "Generally speaking, the advanced development prototype will not be a production prototype. Additional engineering development and testing is necessary to take the advanced development prototype stage where it can be the basis for a production program." [3]

General Chapman, DCS Development Plans AFSC, expressed his policy in this regard as follows:

> "In other words, we see a rather uninhibited and hopefully unencumbered opportunity for system demonstrations involving new high risk technology, without being bound to detailed force structure considerations, or to the formalities of programs where eventual procurement is initially intended." [4]

Assuming that it is not considered practical to constrain the design by the "ilities" and expend funds for their incorporation into the design during prototyping, one might ask if it is reasonable to expect that they will be

[2] David Packard, "Statement before the Senate Armed Services Committee, 9 Sept 71, p.3
[3] Ibid, p. 4
[4] Kenneth r. Chapman, Brigadier General, USAF. "Statement for the Senate Appropriations Sub-Committee on Defense, Sept 71,p.17

incorporated later should the product prove to work well, performance wise, during the competitive fly-off; Or since it worked well, maybe it should be produced as is, or conversely, if the contractors in the heat of competition, possibly even at their own expense, develop a unit of highly capable equipment, does it make any sense to redesign it?

This emphasis on competition was stressed by Mr. Packard:

> "The prototype program will provide for competition in real performance and actual hardware and it will require the competing teams to demonstrate the superiority of their salesmanship." [5]

These are some of the tough and agonizing questions which have accompanied the revitalization of the prototype concept. In examining these questions, I will focus on the specific questions of Integrated Logistics Support as it relates to development prototypes, designed during the conceptual/validation, production and ultimately incorporation into the operational inventory.

5 David Packard,"Statement before the Senate Armed Services Committee," 9 Sept 71, p. 5

FOCUSING ON THE PROBLEM

Prototyping--Definition

Much of the floundering, misunderstanding, and inconsistencies regarding prototyping stems from the lack of direction and guidance on prototyping. There is not a common understanding between DOD components or within a single service as to what prototyping is and what the objectives of prototyping should be. Indicative of this situation is a statement by Vice Admiral Ralph Weymouth in an article published by the Defense Management Journal:

> "To achieve a completely successful and highly efficient set of prototype terminology is one of the most important goals which the Navy feels must be achieved, if we are to be successful in implementing the new acquisition policies contained in DOD Directive 5000.1."

He goes on to state that he considers there are three categories of prototypes: 1. experimental prototypes (brassboard), 2. development prototype (advance development models), 3. productions prototypes (pilot productions and engineering development models, fly-before-buy) [6]

Consequently, it is necessary for purposes of discussion and understanding to define prototyping. In actuality, there are several distinct types of prototyping, each with different and distinguishing objectives.

[6] Ralph Weymouth, Vice Admiral, "Prototyping for Navy Must Contibute to Reliable and Effective Systems," Defense Management Journal, July 72, p. 12

However, people at all levels of the DOD hierarchy use the term without distinguishing between the types. Hence the confusion with regard to implementing prototypes is understandable. Mr. Packard, Deputy Secretary of Defense, in an article published in the Defense Management Journal in July 1972 stated.

> "It will be helpful to consider the prototype approach in two separate phases, each of which can serve to correct some of the serious failings we have had in this business. The advanced prototype is one kind of a prototype program. The production prototype is another kind of a prototype program. Each has its place. Each can contribute to a better job in the future." [7]

These two broad general categories are not sufficiently definitive to permit understanding of what the scope or objective of the prototype program is. To help bridge this gap in understanding, DOR&E has a directive in draft which defines the various types of prototypes. The directive cites two broad categories of prototypes: 1. Exploring Development Prototypes: those whose objectives are purely exploratory in nature and are not intended to fulfill immediate operational requirements and 2. Force Structure Systems Prototypes: those that are intended to meet valid operational requirements and for inclusion in the force structure.

The exploratory development prototype is an experimental model whose purpose is to prove or disprove theoretical concepts (technological operational cost).

[7] David Packard, "Improving R&D Management Through Prototyping," Defense Management Journal, July 1972, p. 5

It may be funded with exploratory (6.2) or advanced (6.3) development money as appropriate to the nature of the work. This category of prototype is then divided into the following types of prototypes:

1. Technology prototypes should be used to demonstrate the engineering feasibility and practicality of new technological discoveries. These will apply potentially new capabilities for which no formally documented military requirement or specific system solution exists. It is characterized by relatively low cost projects with technological risk and potentially high, long-range payoffs.

2. Operational practicality prototypes are low-risk test articles fabricated in operationally realistic configurations as potential solutions to known military needs. The origin of the Air Force Gunship program was a good example of this type (even though it preceded this definition). This kind of prototyping can provide an early assessment of the operational utility of alternative approaches and are characterized by a relatively small number of projects requiring substantial investment.

3. Low Cost/Price limited prototypes are armed at exploring the development, manufacturing operations or logistics support concepts which offer opportunities for substantial cost savings. The objective of this prototype is to significantly reduce the cost of system acquisition,

support or operations through reduced dollar outlay for equipment, facilities, services, or manpower.

The force Structure Systems category of prototypes are used to support the full-scale development of systems intended for force structure and includes the following types:

1. Development prototype effort precedes and supports the decision to enter full-scale development. Development prototypes differ from technology and operational practicality prototypes in that military requirements are known to exist; applicable technology also exists. These prototypes enable us to continue to choose the best combinations of technology and the best overall solution in response to the generally defined system requirement.

2. Preproduction prototypes precede and support the production decision. The objectives of preproduction prototyping are to ensure that engineering is complete and the system is ready for production and to ensure that production methods, toolings, and procedures are in hand and ready to produce the system.

3. Production prototypes provide the fly-before-buy experience to verify the engineering and production and demonstates that the system meets the necessary performance levels. [8]

8 "Exploratory Development Prototypes," Department of Defense Instruction (Draft), Feb 1973, p. 1-6

Having defined the various categories and types of prototypes, I will limit my discussion to the Force Structure Systems Prototypes and specifically to the development prototypes.

Prototyping Policy and Guidance

The policy governing development prototyping has been almost non-existent. The policy which does exist was presented in speeches and articles published in various trade journals. Neither DOD nor the Air Force has published policy on implementing directions. Even the draft directive on prototyping cited above deals with only the Exploratory Development category of prototypes. However, it does direct some light onto the Development Prototypes through the process of differentiating between the categories. The draft directive states that Force Structure Systems Prototypes used to support the full-scale development of systems intended for inclusion in the force structure are excluded from the provisions of the instruction since "they are managed in accordance with the policy of DODD 5000.1" However, DODD 5000.1 makes no specific mention of prototypes efforts and consequently does not differentiate development prototyping policy from full-scale development policy. In Feb 1972, after his departure from DOD, Mr. Packard gave a speech at a seminar on prototyping conducted by the National Security Industrial Association which shed some

light on his rationale in reemphasizing the prototyping concept.

> "The advanced prototype can serve to verify and reduce the technology of hardware. It can also serve to evaluate the operational concept of the new weapon. Let me emphasize that the advanced prototype should not be tied to a completely firm program. The advanced prototype program should be administered whenever possible to provide alternate choices for the force requirement.... I am sure we will have better decisions on the question of what weapons to develop for our future forces. Once an advanced prototype has been selected as the basis for a major program, there will be much yet to be done in engineering before a commitment to production is made. The third serious problem that troubles all of our recent weapon programs is reliability. ...there is only one road to reliability. Build it, test it, and fix the things that went wrong. Repeat the process until the desired reliability is achieved. It is a feedback process and there is no other way. Prototypes are an important key to this procedure.... If reliability is a design objective of both advanced and production prototypes, and if the testing of both included testing for reliability, real progress will be made." [9]

With regard to prototyping, AFSCP 800-3, "A Guide for Program Management," states,

> "A more suitable approach to system acquisition includes increased use of prototype or models suitable for evaluation of design, performance, and production potential. Prototypes may be categorized by the objective for their use, such as, 1. to determine the feasibility of new concepts or techniques, 2. to provide engineering data to verify design or to test critical interfaces, 3. to approve production techniques." [10]

It appears that what's new about prototyping is the application of the prototyping principle in the validation

[9] "Seminar on Prototyping," National Security Industrial Association, Feb 1972, p 139

[10] "A Guide for Program Management," May 1971, p. 3-7, Air Force Systems Command Pamphlet 800-3.

phase of the program. It is this type of prototype, e.g. development prototyping, that is least understood. Statements made by people at policy making levels at OSD and the Air Staff generally ignor the development prototype and are centered around either the preproduction/production or experimental prototypes. Consequently, there is a void of directives and guidance regarding development prototyping.

Integrated Logistic Support---Definition

Integrated Logistics Support (ILS) is a concept of designing for support instead of supporting the design. The concept was re-emphasized and formulated by DODD 4100.35, dated 1 Oct 70, which defines ILS as follows:

> "Integrated logistics support is a composite of all the support consideration necessary to assure the effective and economical support of a system for its life cycle. It is an integral part of all other aspects of system acquisition and operation. Integrated logistics support is characterized by harmony and coherence among all the logistic elements. The principal elements of integrated logistic support...
>
> 1. The maintenance plan
> 2. Support test equipment
> 3. Supply support
> 4. Transportation and handling
> 5. Technical data
> 6. Facilities
> 7. Personnel & training
> 8. Logistic support resource funds
> 9. Logistic support management [11]

ILS Policy and Guidance

The concepts and objectives of ILS as stated in

[11] "Integrated Logistics Support Implementation Guide for Systems and Equipments," Department of Defense Guide, Mar72

DODD 4100.35 are as follows:

A. Operational capability and availability and availability of systems require adequate and timely logistic support planning for the acquisition of support resources for all systems.

B. The primary objective of the Directive is to assure the achievement of such capability and availability by requiring the development of an effective and efficient logistic support program with emphasis and priorities that are consistent with major objectives and in phase with major program accomplishments.

1. Planning logistic support requirments shall begin at the conceptual stage and any special problems should be identified early in the program.

2. The logistic support program must be formalized by the Project Manager at the beginning of full scale development with appropriate performance milestones throughout development, production, and deployment.

It shall be the responsibility of the Integrated Logistic Support function to provide recommended support parameters for the above elements. Such parameters shall be provided as qualitative and quantitative maintainability and reliability inputs to the design process for use in design trade-offs, risk analysis and development of logistic support capability responsive to the operational requirements of the weapon systems.

Requests for Proposal for Conceptual Phase and Validation Phase effort shall outline essential quantitative and qualitative integrated logistic support requirements. Maintenance engineering analysis paper documentation submitted to DOD components shall be delayed until the release of design drawings for Full-Scale Development.

To achieve capability and availability on a cost effectiveness basis during the life of a system, logistic support considerations must have a meaningful relationship to design, development, test, evaluation, production, and operation at all stages beginning with early conceptual studies.

Trade-offs appropriate to the stage of development shall be made that will maximize the effectiveness and efficiency of the support system to a degree which is in consonance with the overall system operational requirement.

The planning, management and design of integrated logistic support shall proceed with continuity through the life cycle of a program and shall be kept in place with development of the program. The level of detail in support planning, analysis and design shall be consistent with the stage of development of the program and shall include only that which is necessary and useable at that stage or required for transition to the next stage.

The directive goes on to state that only a broad general plan for ILS is needed during the conceptual phase and that only special problems of logistics need be addressed during

the validation phase. It also states that,,

> "The DCP shall specify that the Project Manager shall develop an appropriate Integrated Logistic Support Plan with milestones at the beginning of the Full-Scale Development." [12]

Other guidance documents in support of DODD 4100.35 include:

1. "Integrated Logistics Support Planning Guide of DOD Systems and Equipment," dated Oct 68. (this guide presents a systematic management approach to the early integration of support criteria into design activities).
2. "Standard Integrated Support Management System," dated Mar 69. (this manual implements a standard system for integrated support management for use on multiservice aeronautical systems.)
3. "Integrated Logistics Support Implementation Guide for DOD Systems and Equipment," dated Mar 72. (designed to assist program managers in government and industry in the implementation of the policy contained in DODD 4100.35)

The implementation guide states:

> "Program managers must keep the operational mission clearly in view during the early stages, and they should recycle and refine their planning to determine what is the minimum which must be accomplished prior to full-scale development. Once the basis logistics system characteristics are formulated, they must be stated to the design engineers in a design--in a design constraint fashion. When requirements are stated in this format, they may be used in analytical and trade-off studies. In the development of the logistic support concepts and the early planning for support, program managers must assure that logistic and design personnel work together in an atmosphere of maximum cooperation and communication. Thus the ILS function must be closely identified as an integral part of the total system engineering process.
>
> "The logistics effort in the early stages must be confined to development and formulation of inclusive but broad logistic plans and support characteristics. The result should be a road map of what specific steps will be taken, at what time, and in what detail as the developement progresses and the design matures. The detailed planning and preparation of detailed data packages must be deferred until the configuration of the hardware

has been reasonably stabilized. Detailed support planning which is accomplished prior to establishment of the basic configuration and dependent on that configuration is almost certain to require extensive rework to become valid and useable.

"Although the application of ILS must be given managerial and technical attention beginning with conceptual studies, the program manager must be judicious as to the degree of application as a function of the specific acquisition process. The phases may vary with each acquisition and the depth of application must be tailored to the specific programs." [13]

A military standard for Logistic Support Analysis has been proposed and is presently in draft form (MIL-STS-1388). The proposed standard establishes requirements for conducting Logistic Support Analysis integral to the system Engineering process in a four-step approach:

1. "Initially, the logistic support analysis will develop, pursuant to guidance from the procuring activity, quantitative and qualitative logistic support objectives."
2. "As design progresses, these logistics objectives shall be defined into design parameters for use in design/cost/operational capability trade-offs, risk analysis and development of logistic support capabilities. The initial effort also evaluates the alternative hardware design effect on life cycle cost and operational readiness. Known scarcities, constraints or logistic risks will be identified, and methods for overcoming and minimizing problems will be established."
3. "Next, during design, the analysis is oriented toward monitoring and assisting the designer in incorporating logistics requirements into the hardware design. The goal is to create an optimum system/equipment that meets the complete specification and is most cost-effective over its planned life cycle. Logistic deficienceis continue to be identified as the design evolves and are provided to designers for purposes of making trade-off studies."
4. "Finally, the Logistic Support Analysis subjects the designand hardware to a formal appraisal to identify

[13] "Integrated Logistic Support Implementation Guide for DOD Systems and Equipments," Department of Defense Guide, Mar72, Chapter 3.

the firm logistic support requirements. The final statement of logistic support analysis will also consider producibility changes and any other hardware modifications. [14]

The proposed MIL-SID also states a design review shall be performed at major milestones within the acquisition phases. As a minimum, logistic design appraisals shall be conducted upon completion of conceptual design, prior to release of design drawings for full-scale development.

Also, OSD has a draft directive entitled "Criteria for Logistic Support Plan Summary DSARC Milestone 3," which impacts on the subject of ILS. The draft directive states in part the following:

> "Summarize the extent to which logistic support requirements were demonstrated during the development phase....summarize significant features/tradeoffs effected to minimize logistic support requirements over the life cycle of the programmed system." [14]

DODD 5000.1 states that

> "Logistic support shall also be considered as a principal design parameter with the magnitude, scope and level of this effort in keeping with the program phase. Early development effort will consider only those parameters that are truely necessary to basic defense system design, e.g., those logistic problems that have significant impact on system readiness, capability or cost. Premature introduction of detailed operational support considerations is to be avoided." [16]

[14] "Military Standard-Logistic Support Analysis, MIL-STD-1388" (proposed) Aug 72, p. 23

[15] Barry J. Shillito, "Criteria for Logistic Support Plan Summary-DSARC Milestone III," Memorandum for Assistant Secretaries of the Military Services, July 72

[16] "Defense Procurement-Directive 5000.1," Government Executive, Apr 72, p. 58-60

It is interesting to note that the word prototyping is virtually never used in any of the ILS directives or implementing documents. In those few instances where the term is used there is no distinguishing differentiation as to the type of prototyping. The ILS directives are in keeping with the flexibility intended in DODD 5000.1 and thereby places the responsibility for determining the extent of ILS application during the development prototype phase at the discretion of the individual program manager.

AMore Concise Statement of Problem

The development prototype concept as it is being implemented on such systems as the AWACS radar, F-15 radar and the B-IECM subsystem has specifically held all "ilities" including ILS virtually to a non-existant level. The ILS directive states that

> "Maintenance engineering analysis paper documentation submittal to DOD components shall be delayed until the release of design drawings for full-scale development." [17] (This statement has been construed to mean that ILS should not be applied to development prototyppes because they occur in the validation phase.)

However, the development prototype in effect has moved full-scale development efforts forward in the program to the validation phase. It is during the development

[17] Robert Perry, "A Prototype Strategy for Aircraft Development," Rand Study RM-5597-1-PR, July 1972

prototype effort that

> "...logistic problems can be identified which will have significant impact of system readiness, capability or cost."

However, DODD 5000.1 also states

> "Premature introduction of detailed operational support considerations is to be avoided."

Historically this has meant prior to full-scale development. But effort equivalent to what was formerly known as full-scale development is now being conducted during the validation phase. Because of the nature of prototyping (building of hardware), it is in fact more final and deterministic than the paper studies which it replaced. The question then becomes, to what extent should the "Ilities" be applied to this very early hardware effort. Based on existing directives, a case can be made to support either implementing the "ilities" or withholding their application during development prototyping. In most cases it is not being implemented.

It is interesting that ILS people speak of ILS as <u>influencing</u> the design while design people speak of ILS as <u>constraining</u> the design.

INFLUENCING FACTORS

OBJECTIVES OF DEVELOPMENT PROTOTYPING?

There is a general lack of consensus concerning the objectives of development prototyping. This has resulted because of several factors, such as no directives, the use of the word prototype as a generic term (at all levels of the DOD hierarchy) without distinguishing between experimental and developmental prototyping. Development prototyping by definition recognizes that the objectives have changed from exploration of knowledge to the development of discrete systems. The development prototypes address 1. the technological options to a specific system environment, 2. the potential trade-offs and, 3. the financial and schedule uncertainties. In a study prepared by the Air Force by Rand Corp., Mr. Robert Perry stated:

> "The function of a prototype is to permit the early identification of previously unrecognized problems and the resolution of recognized uncertainties that might, if they went undetected, precipitate major changes in the performance, cost, or availability of specific weapon systems."[18]

However, the impulse of many industry and military managers is to emphasize the performance parameter and provide little or no support consideration influence on the prototype effort. In testimony to the Senate Armed Services Committee Mr. Packard stated:that prototype programs would be managed "with minimum of constraints"

18 Robert Perry, "A Prototype Strategy for Aircraft Development." Rand Study RM-5597-1-PR, July 1972, p. 9

and would have "performance goals, not detailed specifications" as their objective.

The development prototype programs conducted by the Air Force in recent years have in the most part more closely resembled experimental programs than development programs. The design efforts have been almost exclusively performance oriented. The contracts have contained very few or no support consideration requirements. The feasibility trade-offs, in most cases, did not include support feasibility. There becomes a question as to the validity of such trade-offs which have not included fairly rigorous support parameters. As pointed out by Mr. Kendall Perkins, Corporate Vice President, Engineering and Research of McDonnell Douglas Corp. at the NSIA seminar on prototyping,

> "Let me hasten to add, however, that simply building prototypes won"t of itself insure good results. There will still be need for lots of careful thinking about what they should be for and how they should be done."[19]

Mr. Clarence "Kelly" L. Johnson, Senior Vice President of Lockheed Aircraft Corp. and of "Skunk Works" fame, expressed similar concerns at the same conference.

> "Now I disagree with some of the things being discussed in the present prototype planning. I think that we should prototype things we expect to produce. Otherwise, it's just fun for the engineers and heartache for the taxpayer. I am not for going through

19 "Seminar on Prototyping," National Security Industrial Association, Feb 1972, p. 16

three prototypes before you get to production. You don't have to. We're better than that.

"I don't think we should have one just to fly an empty airplane around with no gun and no avionics... being done on a certain program. Because you find out as you go to put that two-ton gun in and then the airplane gets four feet longer, and it doesn't have any resemblance to the first airplane at all.

"Every line we draw, and every report we write, we write it with the idea being that we're making something useful, and we intend to produce it. That doesn't mean that the government is guaranteeing production in any sense. But I think we'd be stupid not to take this view, because generally if you design it with consideration for production, the experimental machine will do better."[20]

It is only reasonable to conclude that the eventual system is going to be substantially the same as the successful development prototype. Mr. David S. Lewis, Chairman of the Board, General Dynamics Corporation, supported this view in his speech at the NSIA prototyping seminar.

"I think it is almost sure that as long as these programs anticipate a military requirement, the two winning companies will consider themselves in a head-to-head competition. They will spend their own money to add capability--extra--performance--more versatility. They will have a great incentive to be number one."[21]

It is frequently argued that designers "worth their salt" include support consideration in the design process automatically. However, we have many systems in the field today that serve as evidence of inadequate consideration

20 "Military Standard-Logistic Support Analysis," MIL-STD-1388 (proposed), Aug 1972, p. 44

21 "Seminar on Prototyping," National Security Industrial Association, Feb 1972, p. 16

of support during design. It is also argued that support demonstrations during the prototype fly-off will provide adequate incentive and control for support influence of the design and that the test results provide an adequate baseline for full-scale development. However, the testing is performance oriented and is not sufficient to prove ILS impacts. Mr. John H. Richardson, Senior Vice President of Hughes Aircraft Company stated at the NSIA conference,

> "Producibilfty or traceability is a very important factor too, and again it's subjective. One of the questions this morning bore on this. The business of maintainability and how do you judge this when you look at the competitive hardware. But it is a very important judgemental factor. It may look awfully good for the two months that it was flying, but as Dr. Puckett used to explain when he was asked why all those space components are plated gold: 'It's cheaper than solid.'" 22

With the experimental prototype approach it is generally agreed that government management controls and "ility" constraints will be minimal. The contractor will be given largely a free hand to provide an atmosphere conducive to innovativeness and creativeness. Col. L.W. Cameron, USAF, Director Prototype Program Office, Aeronautical Systems Division, AFSC, states,

> "Typical proposal data requirements will consist of the engineering/technical approach, the test/evaluation plan, the management plan, GFE requirements, and the cost proposal. There will be no requirements for the numerous "ility" plans and other information which relate to full engineering development, and

22 "Seminar on Prototyping," p. 115

which have no direct or significant relation to the advanced prototype procurement." [23]

Accordingly, the Air Force experimental prototypes which are not initially considered for future operational employment have waived many of the DOD, Hqtrs. USAF and Air Force Systems Command regulatory documents, such as production plan, ILS plan, AGE and training plan, military specification drawings, technical orders, value engineering and CSCSC. Other requirements, such as reliability, maintainability, survivability/vulnerability, configuration management and aircraft structural integrity program are applied during the prototype effort only to the extent determined essential or desirable by the contractor. Formal reports are not required; However, the Air Force will monitor the contractor's approach. Contractors should be encouraged to be attentive to design considerations of reliability, structural integrity, etc., to the extent that he normally follows as good design or fabrication practice. It is intended to eliminate formal configuration reviews, control over contractor preliminary testing, simplify program status reporting to higher authority, and substitute personal observation for formal reports. [24]

Some elements of industry and government have carried this experimental prototype thinking forward into the development prototype efforts. For instance , Mr. Edward L. Ball, Ass't. Director, Research and Engineering Plans and Policy OSD stated at the NSIA prototyping seminar,

[23] "USAF Prototype Study," Finnl Report, Sept 1971, p.68

"Although development prototyping is a part of the system development process, we feel that many of the characteristics of an experimental effort should still prevail...that the effort be free from the constraints of formal management requirements... that the effort be driven by the issues that must be faced at the full-scale development decision."[24]

A study by Rand Corporation prepared for the Senate Armed Services Committee states:

"An alternative acquisition strategy, appropriate to present knowledge, and weapons requirements, could be characterized in these terms: 1. Incremental acquisition, based on a sequence of decision points and a succession of development and production phases, and 2. Pronounced austerity in the early phase of development. These are not new principles, and they actually are being applied in some current DOD programs." [25]

The philosophy of unrestrained design effort during development is actually less applicable with the advent of experimental phase that performance should be maximized. Whereas, during development, the system should be designed to specified requirements. If the requirements cannot be adequately specified, the system should not be in development.

[24] "Seminar on Prototyping," National Security Industrial Association, Feb 1972, p. 23

[25] Robert Perry, "European and U.S. Aircraft Development Strategies," Rand Study, p. 4748, Dec 1971, p. 14

ILS--Lip Service

The Integrated Logistic Support concept has received a lot of attention and has been the subject of much discussion at all levels of the DOD hierarchy. However, the implementation has been slow and in many respects has never progressed beyond the discussion stage.

Many managers in both industry and DOD look to the prototype concept as a way to circumvent the constraining nature of the "ilities" and support considerations. In a report dated Dec 71, prepared by Rand for the Armed Services Committee, Mr. R. Perry stated that an alternative acquisition strategy, appropriate to present budgetary constraints, levels of technical knowledge, and weapons requirements would be an incremental acquisition approach.

> "Incremental acquisition would require separating the development of systems from their subsequent production. Further it would depend on completing those aspects of system development required to demonstrate the performance potential of a system before addressing such issues as are involved in verifying the reliability and maintainability of the system. Thus, the initial design and development phase should not include elaborate efforts to resolve maintainability, reliability, and similar issues unless there is a reasonable assurance that the system, as conceived, has an achievable performance that is relevant to current and anticipated needs." [26]

Following this concept the F-15 program conducted a development prototype of the radar subsystem which will use a phased logistics support concept (contractor support

[26] Robert Perry, "European and U.S. Aircraft Development Strategies," Rand Study, P-4748, Dec 1971, p. 14

until 1977) because of an unstable design. A similar development prototype program is being conducted on B-1 ECM equipment in which no "ility" or support considerations were included in the contract. The AWACS radar was also conducted under these conditions.

Dr. R.J. Massey, President of Project Management Services states:

> "Reliability and life-cycle costs receive some attention (and much lip-service) but absolute performance, such as top-speed, range, firepower, etc., are the primary objectives which shape RDT & E effort in the early stages of defense system development." [27]

The A-X development prototype program placed considerable emphasis on life cycle costs. Also, a maintainability demonstration was conducted for two weeks under staged conditions as a final part of the competition. However, the fly-off demonstrations were primarily performance oriented. The ground rules stated that the contractors could make modifications or repairs to their prototypes only if safety was involved.

Support considerations, such as reliability, maintainability, and life cycle costs can be most efficiently and effectively considered concurrently as the design progresses, beginning with the early trade-offs. If the constraints are not considered during the early development phase, we will in fact end up supporting the design as

[27] Dr. Robert J. Massey, "A Proposal: Improving Operational Systems by Experimental Prototyping," Defense Management Journal, Jan 1973, p. 40

we have historically done or if the design is found to be unsupportable, we will continue R&D through the operational phase as we have also historically done.

Program Manager Incentives

The program manager's incentives are not consistent with the Integrated Logistic Support concept. The program manager has historically been evaluated on his ability to hold down acquisition costs, meet schedules and in meeting performance requirements. The program manager does not normally have to use or support the system which he develops. Consequently, when the dollar crunch forces a reduction of effort, the first things reduced from the contract are the "ilities." The only incentive working on the program manager to hold down life cycle costs through a rigorous application of support consideration is one of moral respnsibility. When it comes to a choice between career advancement and moral responsibility, I'm afraid moral respnsibility frequently comes in a poor second with most of us. Even the current "buzz word" concept of "design to costs" which falls within the realm of the program manager's incentives is bases on unit production cost and not life cycle costs. In fact, the design-to-cost concept may conceivably be in conflict with life cycle cost considerations. It may well come to a trade-off where a desirable maintenance feature could increase (and probably will in many instances) production and design costs.

The Congress and the public pay much attention to development and unit production costs, but there is never

any criticism directed to high support costs.

Mr. Shillito, ASD for Installation and Logistics stated:

> "DOD anxiety for new systems and early deployment; contractor anxiety to get through R&D to volume production; desire of each department or command to maintain or improve its relative position; industry reliance on government help in the event of serious trouble; DOD self-delusion about reliability of its plans and estimates; unrealistic objectives regarding transfer of risk from the buyer; the small number and large size of programs, and the corresponding impact on a company of failure to obtain a desired contract; inflation; scarcity of R&D funds and the associated limitations on R&D effort; funding uncertainties; drive to incorporate latest technological advancements; industrial gamesmanship.
>
> "These pressures have beaten down the better parts of previous attempts at improvement. They can spell success or failure in the announced management approach of the 70's." [27]

Hence, until we find a means of appropriately motivating government and industry program managers to seek operational support efficiency we can expect to continue to see primary emphasis on acquisition costs, schedules and performance characteristics with secondary interest on operational support characteristics.

Funding Policies

The incremental nature of funding policies has also been a detriment to providing adequate incorporation of support considerations. The funding frequently fluctuates drastically from year to year. Funds are frequently cut from the current year with promises of appropriate adjustments in the out years. So to continue with the

[27] "Prototyping-Aircraft Progress Report," Government Executive, Mar 1973, p. 60

program, it becomes necessary to concentrate the available resources on the performance characteristics of the design. Full funding of programs at the start, or at least funding in accordance with the programmed effort, would greatly increase the efficiency of the acquisition effort.

Changing the "Watch"

The turnover of personnel at all levels of government has also reduced the efficiency of program management and contributes to the laxity regarding support requirements. The changes of administration at the Presidential level every four years, Senate every six years, the House every two years, consequential changes of OSD personnel, and rotation of military personnel at policy levels, as well as at the program manager level, results in such frequent changes of policy that they cannot be fully implemented before the next change occurs. Policies of the 60's, such as concurrency and total package procurement are taboo in the 70's. Many of the policies of the 70's, without a doubt, will be taboo in the 80's.

In this regard, Mr. Shillito stated in an interview by Government Executive magazine:

> "To oversimplify the whole situation, I feel very strongly that we have pulled together the right policies. I also feel very strongly that historically policies have not been all pulled together. There was an engineering policy; there was a manpower policy-and rarely did they come together.

> "This is the way frequently in any large organization; an uncoordinated tendency to go with the new name of the game. When contracting had to be incentivized, everything tended to move in that direction. When it was total package procurement, everything moved that way. And in either case, contractors were willing to commit several times their net worth to going after the programs."

Theoretically, 5000.1 pulls it all together, but theoretically that has been done before too.

> "It is going to be a long time, as much as six or seven years, before the impact of these policies will be felt." [28]

A large part of the problem is simply getting large numbers of people in a complex organization to change established habits and routines. Now, even prior to getting all the implementing directives written for 5000.1, the whole top echelon of OSD has turned over. In addition, program managers seldom see a program through to fruition.

28 "Prototyping-Aircraft Progress Report," Government Executive, Mar 1973, p. 58

RECOMMENDATIONS

REQUIREMENT FOR WORKING TERMINOLOGY

It is imperative that a directive for prototyping be published which provides a working terminology so that a common understanding can be achieved at all levels on what is meant by the various types of prototyping. Presently it is impossible to hold intelligent communications regarding prototyping without first defining the subject because of the lack of agreed to language. Brigadier General Kenneth R. Chapman, USAF, Deputy Chief of Staff for Development Plans, AFSC, stated at the NSIA prototyping seminar:

> "Much of the problem emanates from semantic difficulties in discussing what a prototype really is, and this has been troublesome on occasion. 'Prototype' means many different things to different people, but the important thing is that the intent of the developer must be an integral part of the definition in any given context."

The lack of a common baseline with regard to the meaning of prototype was very apparent in the interviews, articles and speeches reviewed for this study. A good working terminology common to all levels of DOD is urgently needed.

Definition of Objectives

Another major concern identified by this research is the imperativeness that the development agency determine

the objectives of the specific prototype program prior to embarking on the effort. The specified objectives will then make the role of the "ilities" more apparent. The proposed directive for exploratory prototyping requires that a Project Memorandum be prepared for prototype programs, which provides:

1. a statement of the problem and primary purpose of the proposed project.
2. a description of the effort, objectives and significant issues.[29]

Although the proposed directive is for only exploratory prototype efforts, a similar definition of objectives is also necessary for development prototyping.

When establishing a development prototype program, it should not be expected to resolve experimental issues. Mr. Shillito in his interview by Government Executive magazine stated:

> "We really haven't done yet the job we're going to have to do, the component job, the kinds of things going into a system. Just three or four components are usually the guts of a weapon system. Some people continue to think we must move ahead with a total system when in fact the avionics or the engine will involve more time than all the rest of the system together. These subsystem component problems need to be resolved in a continuing experimental prototyping program,"

Another factor which must be considered is that if a prototype is built, it must include vital subsystems which, if changed later in the program, will substantially alter the performance of the total system.

The essential point here is that if a system or component has been designated for a development prototype effort, the objectives must be well defined and in consonance with the fact that the ultimate objective is to develop a system for inclusion in the force structure.

CONCLUSION

Development prototyping and Integrated Logistics Support are basically complimentary concepts. However, because of misunderstanding and lack of direction, the two concepts are considered incompatible by numerous industry and government program managers and policy makers. Consequently, they have attempted to serialize the design effort by first designing the performance characteristics (through development protoyping) and subsequently considering support requirements during full-scale development. In fact, it would appear the development prototype concept has been used to circumvent the consideration of ILS requirements during the early design phases on some programs.

The proper role of ILS during the development prototype effort is one of participation in design, operating and maintenance trade-offs. ILS must be considered before the design becomes locked in through substantial sunk costs or through performance results that bespeak the final product. The development prototype need not necessarily have the maintainability features incorporated in the handcrafted model. However, the maintainability factors must have been considered, understood, and provisions made for them in the design documentation. Thus the support considerations can constrain the full-scale development design without unduly

inhibiting the prototype model.

The program manager must strive for a reasonable balance between the design phase and the support considerations. The ILS efforts should not be of a detailed nature with regard to such things as spares provisioning, technical orders, training and support equipment design. To do detailed level analysis in these areas during this early phase would in effect be an estimate based on an estimate (the design) and would be undoubtedly costly.

In conclusion, 1. the development prototype objective must be well defined, 2. the design analysis and the trade-offs must include support considerations, 3. the detail to which support considerations are included in development prototyping should be limited to the elements of a requirements nature and should not be concerned with the details of how the requirements will be implemented.

Once a system or component has transitioned from the exploratory stage to development effort, the maintenance concept and other support consideration must influence the early design effort (including development prototyping). Design analysis and trade-offs must include support considerations to have meaning in an operational context.

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