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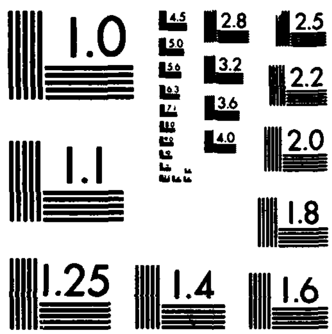
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AN ANALYSIS OF THE FEASIBILITY OF USING DESIGN STABILITY AS A DECISION PARAMETER FOR MAKING LOGISTICS SUPPORTABILITY DECISIONS

Debra E. Good, GS-12

LSSR 84-83

DEPARTMENT OF THE AIR FORCE
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This research investigated the criteria and analysis techniques which are currently being used in the Air Force to evaluate design stability as it relates to decisions concerning the establishment of an organic logistics support capability versus the use of ICS. The analysis was conducted in two parts: (1) a time series analysis of engineering change proposals (ECPs) which impacted logistics elements, and (2) a series of interviews designed to assess the adequacy of available techniques for determining the point at which design stability is achieved. Results of the ECP trend analysis indicate that while time series analysis can be used to define a model for a given set of historical data, the models for two very similar systems, the F-15 and F-16 fire control and flight control avionics, are entirely different. Thus, one cannot use a model developed with historical data from one program to predict the ECP trend for a new program. Results of the interviews indicate there is no consensus as to how to define design stability. Recommendations include: (1) another study be performed to replicate the results of this effort, and (2) revision of AFR 800-21 be considered to reflect these results.

LSSR 84-83

AN ANALYSIS OF THE FEASIBILITY OF USING DESIGN STABILITY AS A DECISION PARAMETER FOR MAKING LOGISTICS SUPPORTABILITY DECISIONS

A Thesis

Presented to the Faculty of the School of Systems and Logistics

of the Air Force Institute of Technology

Air University

In Partial Fulfillment of the Requirements for the

Degree of Master of Science in Logistics Management

By

Debra E. Good, BA
GS-12

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has been accepted by the undersigned on behalf of the faculty of the School of Systems and Logistics in partial fulfillment of the requirements for the degree of

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CHAPTER I

INTRODUCTION

Historically, Air Force policy has advocated the use of organic logistics support for weapon systems and equipment from the date of first article delivery to an operational unit. Planning for such a capability must begin in the early acquisition phases of a weapon system's life cycle, and requires early identification and acquisition of the necessary spares, support equipment, technical documentation, facilities, training equipment, and training. It also requires the establishment of base level on- and off-equipment maintenance facilities and depot level maintenance facilities. As the weapon system design changes and matures, all the logistics requirements are subject to change also. Premature acquisition of such logistics resources can thus lead to costly modifications and/or obsolescence of those resources. For this reason, the Air Force and the Department of Defense (DOD) began investigating possible alternatives to the use of organic logistics support at initial operational capability (IOC).

In October, 1971, former Deputy Secretary of Defense David Packard stated,

> We are making decisions to acquire an organic logistic support capability for major weapon systems far too early in the acquisition process. . . . These decisions reached before the design has stabilized results [sic] in compounding our costs for this support due to the necessity for accommodating the summation of the thousands of engineering changes that occur just prior to and subsequent to test programs . . . We must assure that such decisions are not made until we have reasonable assurance that the design has stabilized to a point where engineering changes will not be made that significantly impact on our decisions to acquire a full-fledged logistic support capability. I can see no reason why we can't rely on the contractor for such logistic support prior to design stabilization [15].

Air Force and Department of Defense (DOD) study groups formed in the early 1970s reconfirmed that

> Unrealistic initial operational capability schedules and the associated organic logistic support dates often resulted in costly decisions to prematurely acquire support equipment, spares, and technical data [9:76].

They emphasized that the achievement of an organic maintenance capability "must be determined primarily by the design stability of individual components and subsystems [9:76]" of prime mission equipment (PME).

A joint DOD-industry integrated logistic support advisory committee, formed in 1972, recommended that cost-effectiveness and design stability "be given as much emphasis as operational requirements [9:76]" when making decisions to use contractor initial support. DOD Directive 4140.40, "Basic Objectives and Policies on Provisioning of

End Items of Materiel," directs that "the integrated logistic support plan (ILSP) provide for the most cost-effective logistic support posture (24). It identifies items of low reliability, unstable design, high risk, and/or high unit cost as the most likely candidates for ICS. Such items can be identified through the logistics support analysis (LSA) process.

> LSA includes the determination and establishment of logistic support design constraints, consideration of those constraints in the design of the hardware portion of the system, and analysis of design to validate the logistic support feasibility of the design and to identify and document the logistic support resources which must be provided, as a part of the system/equipment, to the operating forces (AFR 800-7) [17:400].

Review of historical data from other, similar weapon system programs can aid this process by identifying those items which have been prone to design stability or resource availability problems (11:2-16).

These changes in Air Force philosophy regarding initial logistic support capability culminated in September, 1975 with the publication of Air Force Regulation (AFR) 800-21, "Interim Contractor Support for Systems and Equipment." AFR 800-21 defines interim contractor support (ICS) as

> a cost-effective logistics support alternative for a major system or high cost or risk Class V Modification. It allows the Air Force to defer investment in all or part of the support resources (such as spares, technical data, support equipment,

> and training equipment) and to use contractor support while the organic capability is being phased in [21:para 1.a].

According to AFR 800-21, ICS has a specific meaning and refers to the use of a contractor only in the two situations described below.

Situation 1. The items to be supported or items of support equipment have an unstable design; moreover, the projected cost of setting up an organic capability at the time operational support is first required is excessive, either because of uncertainties in the type and level of support required, or because of the risk that support resources will become obsolete if procured too early. For contractor support to be described as ICS in this situation, it must have been planned at least budget lead time away and have been subjected to rigorous cost and risk analyses.

Situation 2. All or part of the resources required to establish an organic capability will not be available until after operational support is first required. In this situation, the system development, production, and deployment phases do not allow enough time to develop the support resources before organic support is needed. (The most common example of this situation is the sequential phasing of automatic test equipment development, which generally lags development of the system it supports.) In

Situation 2, as in Situation 1, to qualify as ICS, early planning and analyses must occur (21:paras 1.a.1.a&b).

Support objectives identified in AFR 800-21 include 1) reducing the risk of incurring unnecessary costs by minimizing the initial investment in organic support resources when parts of the system being procured have items with unstable design characteristics; and 2) using ICS where economic and risk analysis studies of design and logistics support alternatives show that this approach is cost-effective, especially for those parts of the system that are complex, expensive, or unstable (21:paras 2.b&c).

> Under the ICS concept, the Air Force conducts risk analyses and other evaluations through the logistics support analysis (LSA) process, to identify potentially unstable design items and items having potentially high support costs. Through these analyses, it identifies those areas where it may be beneficial to use a contractor for logistics support during the early deployment phase [21:para 3.a].

Such risk analyses should be conducted during the demonstration and validation phases of a weapon system program and during full-scale engineering development as a part of LSA, refining the list of ICS candidate items as improved information is generated.

A risk analysis is defined in AFR 800-21 as

> an analysis that evaluates expected performance (cost, schedule, or technical) as compared with desired performance, with a view toward determining the probability that requirements will be met within available resources. This includes identifying the areas of uncertainty, assessing the

probabilities, analyzing to determine the driving or dominant parameters, evaluating funding alternatives, making tradeoff studies, and making decisions on course(s) of action [21:para 1.h].

An unstable design is defined in AFR 800-21 as

a design that has a high potential for change and may require more engineering in order to meet the design specification requirements for operational performance, producibility, maintainability, or reliability. Design stability considerations include determination or confirmation of the equipment failure mode and effects pattern under normal operating circumstances [19:para 1.k].

ICS Planning

A critical element in the definition of ICS is the requirement that it be planned for at least budget lead time away. The budget cycle takes a minimum of two years from the start of the planning phase to the beginning of the fiscal year, and budget cycles overlap for the various fiscal years. The Air Force portion of the DOD Five-Year Defense Program (FYDP), the Force and Financial Program, requires five-year cost projections be made at the beginning of the budget cycle for each fiscal year. AFLC is responsible for logistic support, and therefore is responsible for budgeting and funding for all ICS requirements. ICS is funded on a fiscal year basis, and requirements must be projected and justified for each fiscal year.

In order to ensure that ICS is properly implemented and that adequate funding will be available to support ICS requirements when needed, ICS planning must be fully integrated with the weapon system acquisition life cycle (see Figures 1.1 and 1.2).

Weapon System Acquisition Life Cycle

Each Air Force major command is responsible for a specific Defense Mission Area and must continuously analyze its mission capabilities with respect to the evolving threat, and identify operational needs. When such comprehensive mission analysis leads to the identification of an operational need which cannot be met within existing capabilities and may require new weapon system or equipment development, a Statement of Operational Need (SON) may be prepared. Prior to publishing a SON, the major command must review information on the technology base, integrated logistics support, life cycle cost, safety and training considerations provided by the originator. At this point, the evaluation of logistics support alternatives must be included to the extent that information is available. Planning for possible ICS should begin at this point, and remain a consideration throughout the remainder of the weapon system acquisition process.

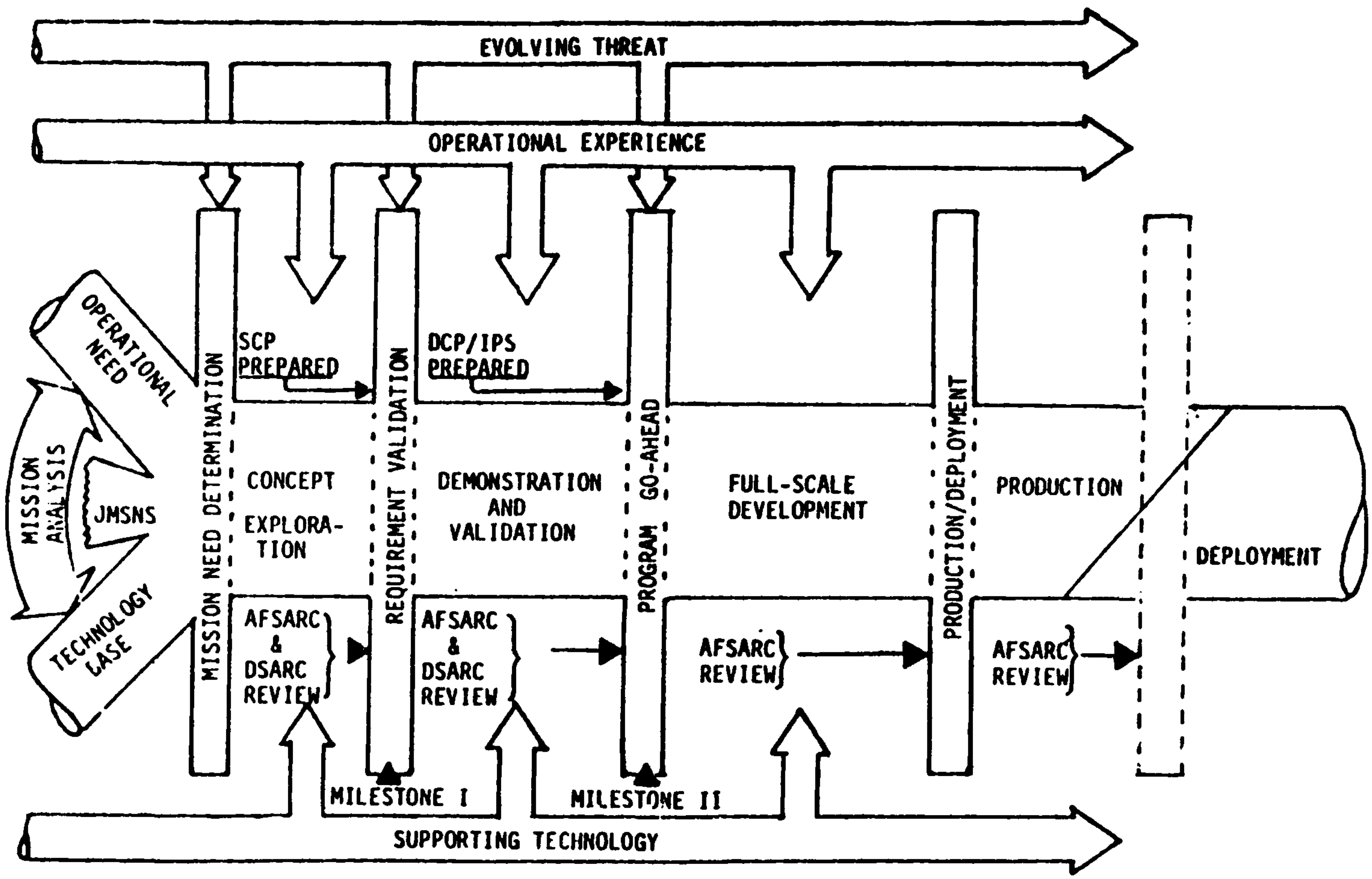

Figure 1.1. Major System Acquisition Life Cycle (12:7)

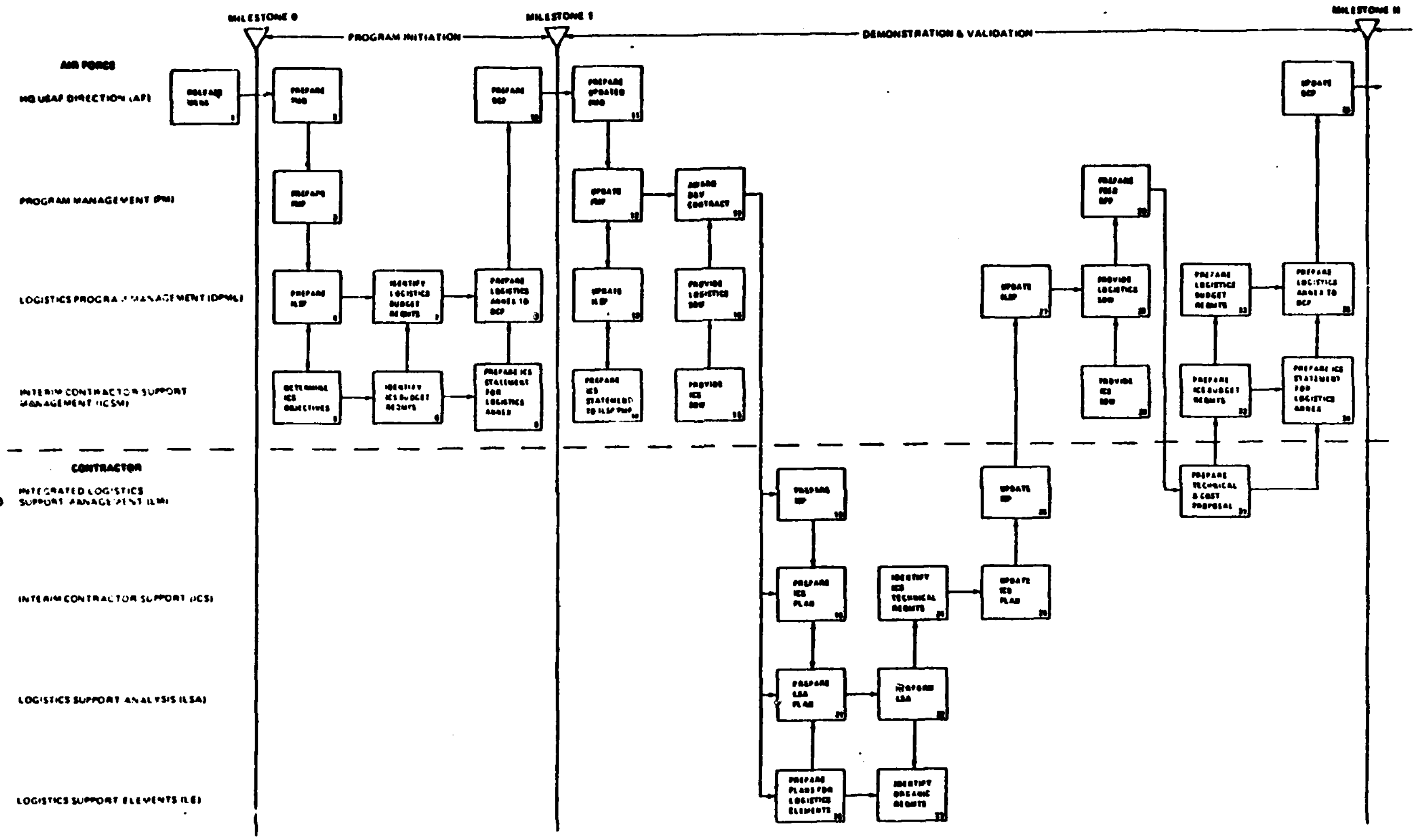

Figure 1.2. ICS Tasks Integrated with Major System Acquisition Life Cycle (11)

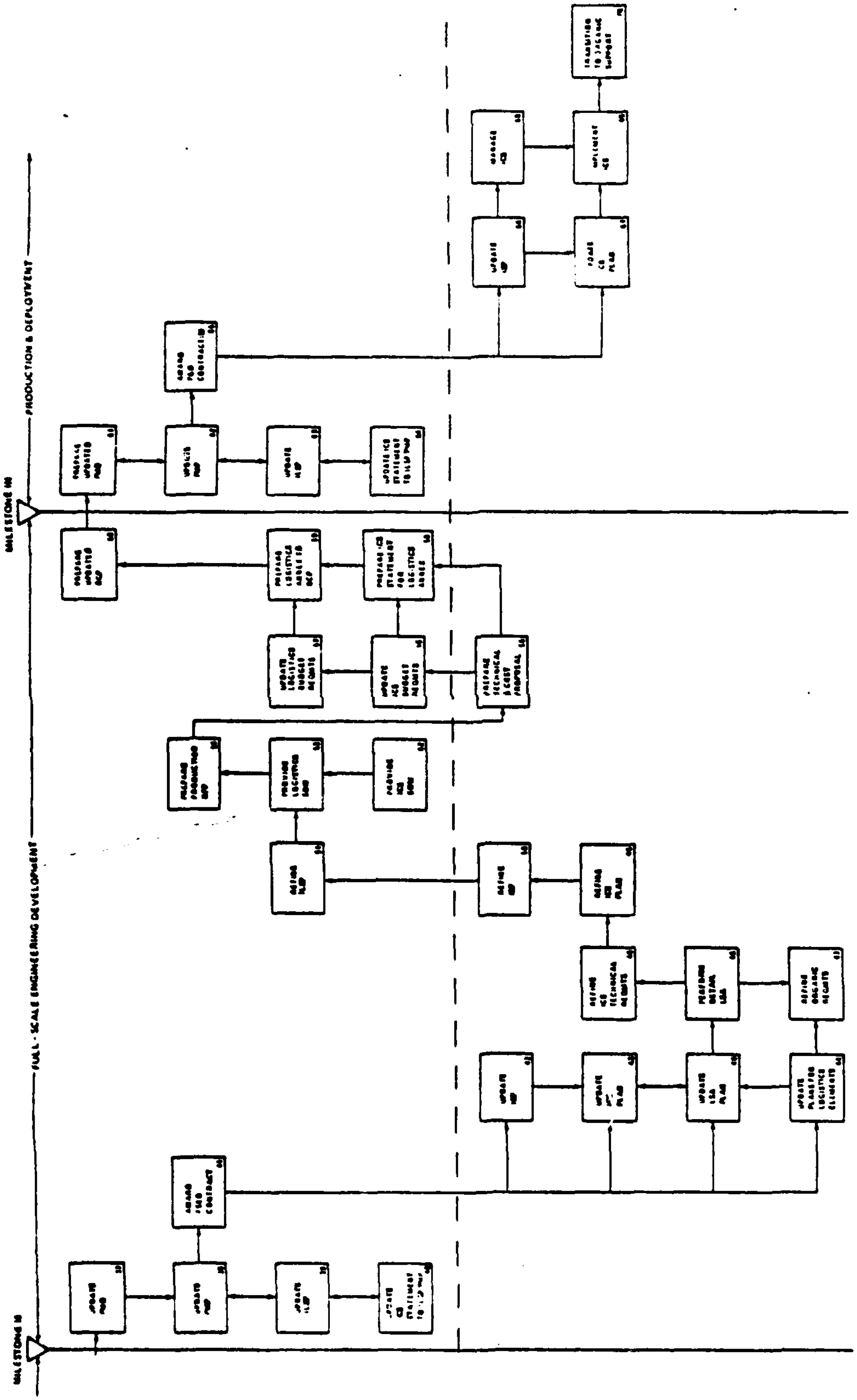

Figure 1.2 continued

The SON is submitted to Headquarters United States Air Force (HQ USAF) for review, along with a plan for the conceptual phase of the program. A justification of Major System New Start (JMSNS) is required for all acquisition programs for which the estimated costs exceed $200M ($FY80) for research, development, test and evaluation, and/or $1B ($FY80) for procurement. Such a program is designated a "major system acquisition program" and requires Secretary of Defense (SECDEF) approval.

The JMSNS is submitted in the Air Force Program Objective Memorandum (POM) (Air Force input to the congressional budget cycle). If it is included in the final DOD budget, the Air Force is authorized to begin concept exploration. (The Secretary of the Air Force may have discretionary funds available to start the concept phase prior to congressional approval.) If the program is approved, HQ USAF provides formal direction to the implementing and participating commands through the issuance of a Program Management Directive (PMD). The PMD provides the formal program direction throughout the acquisition process.

Conceptual Phase

Once the PMD is issued, the Conceptual Phase begins. During this phase, the Air Force identifies and explores alternative solutions to the requirements addressed in the

SON. A Request for Proposal (RFP) is issued, soliciting contractor solutions in the form of technical proposals. The RFP must address all known requirements, including logistics support requirements. The Deputy Program Manager for Logistics (DPML) must prepare the Section Nine Logistics portion of the Program Management Plan (PMP). This is the initial version of the Integrated Logistics Support Plan (ILSP) which will become a separate document in the Demonstration/Validation Phase. The PMP Section Nine/ILSP must include a statement of ICS objectives. During this phase, the DPML must also identify ICS budget requirements for later phases.

Selection of the alternative(s) for demonstration is documented in a System Concept Paper (SCP). The SCP must contain a logistics annex, which includes ICS requirements. The SCP is reviewed by the Air Force Systems Acquisition Review Council (AFSARC) and the Defense Systems Acquisition Review Council (DSARC). The Secretary of the Air Force requests SECDEF approval for Milestone I (Requirement Validation Decision) to enter into the Demonstration and Validation Phase.

The Milestone I decision is a SECDEF validation of the requirement for the major system. The AFSARC and DSARC are advisory bodies which provide information and recommendations to the Secretary of the Air Force and the SECDEF, respectively, in support of their decisions at

Milestones I, II, and III. The SECDEF prepares a Secretary of Defense Decision Memorandum (SDDM) which reaffirms the mission need and approves one or more selected alternatives for competitive demonstration and validation.

> The SDDM documents the SECDEF's milestone decision including approval of goals and thresholds for cost, schedule, performance, and supportability against which the program must be managed and will be evaluated [12:21].

Demonstration and Validation Phase

HQ USAF revises the PMD to provide direction to the implementing command (usually AFSC) and participating commands for the Demonstration and Validation (Demo/Val) Phase. The preferred approach to Demo/Val is to "select at least two contractors to build prototypes which are to be evaluated during the latter days of this phase [12:22]."

During the Demo/Val Phase, the DPML must prepare the initial ILSP, including ICS requirements, the logistics Statement of Work (SOW) including ICS requirements, and the logistics budget, including ICS requirements. The contractor(s) must prepare an initial Integrated Support Plan (ISP) including an ICS annex or ICS Plan (ICSP), perform an initial LSA to identify ICS candidate items and organic logistics support requirements, and submit a technical and cost proposal. It is essential that Air Force evaluation of such proposals be thorough during this phase, since competition will keep proposed costs low. This is the time to lock in the ICS requirements identification and planning effort. Supportability and cost-effectiveness must be given as much consideration as operational performance when evaluating proposals.

A Decision Coordinating Paper/Integrated Program Summary (DCP/IPS) is prepared, summarizing the Air Force acquisition plan for the system life cycle and providing a management overview. After an AFSARC/DSARC review, the SECDEF prepares a Secretary of Defense Decision Memorandum (SDDM). If the SECDEF approves the program, it enters Full Scale Development (FSD). This is the Milestone II, Program Go-Ahead Decision.

Full Scale Development Phase

During the FSD Phase, the system is "designed, developed, fabricated and tested [12:25]." Historically, support equipment, trainers, technical manuals, and other logistics resources have been developed in this phase, also. The frequent incidence of concurrent FSD and production programs in recent years has lead to supportability problems resulting in the use of ICS (often without adequate planning). During the FSD Phase, long-lead procurement of parts and materials for production is also authorized, as well as procurement of items necessary to support test programs.

During FSD, Developmental Test and Evaluation (DT&E) and Initial Operational Test and Evaluation (IOT&E) efforts, which may have begun in earlier phases, escalate, culminating in qualification tests at the Milestone III Decision timeframe (see Figure 1.3). "By the end of this phase detailed design specifications will be finalized and engineering drawings prepared which become the basis [12:25]" for the production configuration. The system design is stabilized at the Critical Design Review (CDR). In most system programs, design changes after CDR result in the generation of engineering change proposals (ECP) which bear a cost to the government for implementation. An ECP is "a formal proposal to alter the physical or functional characteristic of a system or item after the baseline configuration has been established [25:42]."

During the FSD Phase, the DPML must update the logistics and ICS budgets, the ICS SOW and the ICS annex to the ILSP. The contractor must update the ISP, ICSP, and LSA Plan (LSAP). He must perform a detail LSA, refining ICS and organic support requirements. After CDR for the PME, the support equipment designs can be stabilized, and also undergo a CDR. It is possible that a number of design changes or ECPs will be generated during CDR, and these changes may impact support equipment design and technical

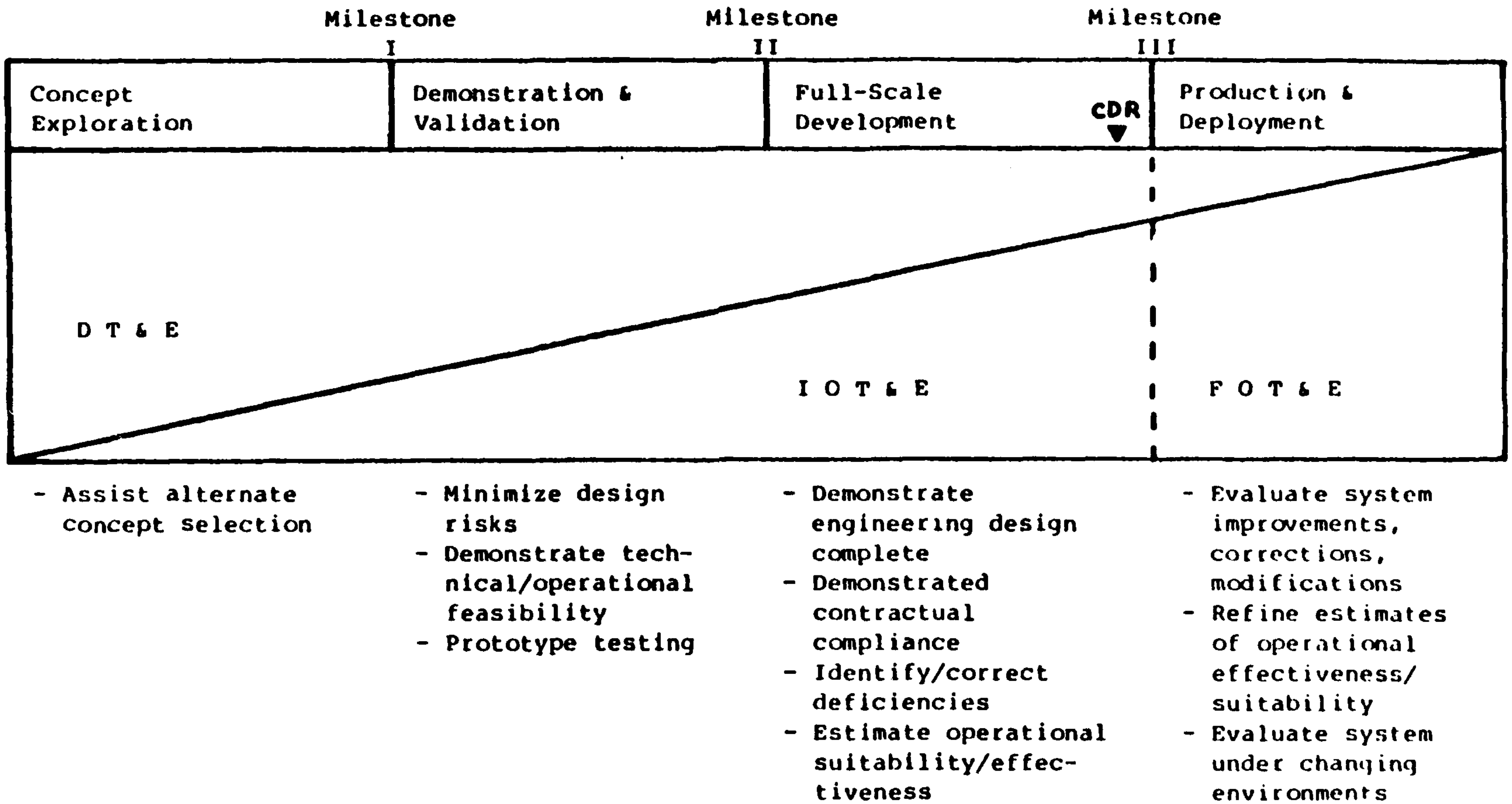

Figure 1.3 Test and Evaluation Cycle

manual content. The DPML must be certain to obtain detailed LSA updates and refine the ICS requirements before entering the production phase.

Production/Deployment Phase

"The Secretary of the Air Force has the authority to make the Production/Deployment (Milestone III) decision provided there is no major change to the program approved at Milestone II [12:28]." If approved, the decision is implemented by a revision of the PDM (12:28). During the Production Phase, the weapon system and all related logistics resources are produced for operational use. During this phase, any logistics decisions deferred from FSD must be finalized. The ILSP and ICS annex are updated one last time. With system deployment, ICS and organic support are implemented. During initial deployment, the DPML and contractor must work together to transition from ICS to organic support as planned in the PMD and ILSP. Frequently, development of an organic depot support capability lags behind PME development. Depot repair is at a much more detailed level, and development of depot support equipment must be deferred until PME is fully design stable. In some concurrent programs this may occur after the system is fielded. Depot ICS is usually the last portion of ICS to be transitioned to the Air Force. The actual length of an ICS program varies on a case-by-case basis and is determined by individual program requirements.

Logistic Support Analysis (LSA) Process

ICS requirements are derived primarily from LSA. The requirements are expressed as candidate items, required tasks, and time frames and schedules. The ICS plan and the LSA Plan address the relationship between the LSA and the ICS requirements determination process. A detailed description of the LSA process is outside the scope of this thesis and can be found in MIL-STD 1388, "Logistic Support Analysis, Data Element Definitions" (23). The LSA is an iterative process, repeated in increasing depth as the equipment design stabilizes over the acquisition life cycle. ICS requirements are developed primarily during the FSD Phase, but LSA results from other phases also impact ICS decisions [11:2-14]. The LSA is not used only to identify ICS requirements. It is used to identify a full range of maintenance and support tasks, resources (i.e., piece parts, tools and equipment) and schedules.

The LSA Record (LSAR) is the central repository of all data generated in the LSA process. It is the "single authoritative source of integrated technical data pertaining to operational logistics support [11:2-27]." ICS status reports are generated from the LSAR, in increasing detail as design data stabilizes. LSA data identifies the support resources required for ICS and organic logistic support, including support and test equipment, spares, repair parts, tools, and maintenance personnel skill levels. This information is generated as it becomes available, and lead times to procure the required resources become critical as the IOC date approaches. Thus, LSA must be included early in the weapon system acquisition life cycle, and updated frequently as the PME design stabilizes in order to ensure a full logistics support capability exists when the system is fielded at IOC.

Conclusion

Proper planning for ICS depends on full integration of that planning along with planning for the organic logistics support capability, into the weapon system acquisition life cycle. One program which is currently demonstrating how that integration is possible is the Air Force HH-60D Nighthawk Helicopter (7). Mr. C. Wayne Cerny of IBM Corporation and Mr. David Cuppett of the HH-60D DPML office, have co-authored a paper detailing their program's innovative approach to planning and managing for logistics supportability.

Cerny and Cuppett believe that, all too frequently, logistics managers "plunge headlong into the details of logistics documentation well before the engineering design (of the prime mission equipment [PME]) is mature [7:2]," resulting in what they call "throw-away" logistics, or "reams of data and early hardware procurements which, due to the normal evolutionary nature of system design, simply no longer reflected the latest configuration [7:3]." They believe that such "throw away" logistics result from improper use of LSA, and too early development of logistics support resources.

Key to their philosophy is the development of an integrated diagnostics capability, which will be reflected in the LSA data. Cerny and Cuppett also believe that timing of the LSAR is critical, so they planned the HH-60D LSAR to "complement the evolving design [7:6]." During FSD, only organizational support equipment (OSE) is being reviewed. The OSE will be developed by the contractor as a capability and demonstrated during IOT&E. Intermediate SE (ISE) design will take place during the first production lot buy. Depot SE (DSE) design is planned for the second production lot buy. Firm-priced options for ICS were obtained during the competitive source selection, and will be exercised as needed until organic logistics support capability exists. Development of other logistics support resources such as technical data, spares, training, and repair parts is also dependent on the LSAR.

To summarize their approach, Cerny and Cuppett state,

> Proper timing of the various support elements and the associated provisions for interim contractor support during the development of organic capability simply follows the logical progression as dictated by the evolving hardware maturity. If we can avoid the need to redo a significant portion of the supportability program, the actual support will be available when required at an overall lower cost. . . . To enhance the probability of achieving the supportability objective, we, as logistics professionals, must carefully avoid the pitfall of doing too much too early [7:8-9].

The complexity of modern weapon systems and the lead times required in the budget cycle and the acquisition process make early planning for ICS critical. The cost-effective development of logistics support resources appears to be very dependent on the prior achievement of PME design stability. Thus, design stability must be defined.

Problem Statement

Currently, there is no precise method for determining the status of equipment design stability as it is used in AFR 800-21 or for any other application to the development of an organic logistics support capability. Consequently, it is very difficult to comply with the requirement to conduct risk analyses and identify potentially design unstable components. To date, very little effort has been expended on the establishment of criteria or standards to be used as a baseline for the determination of weapon system and equipment design stability. The studies which have been conducted apply only to specific weapon systems and cannot be generalized to other systems or equipment. The most frequently used indicator of design stability is the rate of generation of engineering change proposals (ECPs).

> The point at which the rate of ECPs generated is reduced to near zero is generally assumed to coincide with the achievement of a stable design for purposes of developing logistics support resources [18].

There is a need for an analysis of the feasibility of using design stability as a decision parameter for making logistics supportability decisions.

Purpose of the Research

The purpose of this research was to investigate the criteria and analysis techniques which are currently being used to evaluate design stability as it relates to decisions concerning the establishment of an organic logistics support capability versus the use of ICS. Specifically, this research evaluated the use of the rate of generation of ECPs as an indicator of weapon system design stability for purposes of determining the feasibility of developing an organic logistics support capability versus the use of ICS.

Research Questions

1. Determine if there is a trend in the rate of generation of ECPs which can be measured over time and against program milestones, indicating when design stability has been achieved. (Trend as used here refers to dependencies in the data over time due to autocorrelations and periodicity.)

2. If there is a trend, investigate the application of the trend to all like systems as a predictor of the point at which design stability will be achieved.

3. If there is a trend, investigate its application to those ECPs which have a direct impact on logistics support resource development.

4. Investigate the adequacy of existing methods of determining whether or not a design is stable for purposes of developing organic logistics support capability.

Scope and Limitations

This research effort addresses only the F-16, F-15, and EF-111A aircraft. Only Class I ECPs were used in the ECP trend analysis, which was limited to the F-16 and F-15 fire control and flight control systems and the EF-111A avionics. Interviews were conducted to obtain current information on the subject of design stability from AFALD DPMLs involved in the acquisition of ICS and organic logistics support resources, and from aerospace industry personnel who provide such resources. As such, the responses are limited in scope to that population, and cannot be generalized to other situations or populations.

CHAPTER II

BACKGROUND AND LITERATURE REVIEW

Recent government and industry studies have determined that design stability from a logistics supportability standpoint is relatively undefined, and that cost and risk analyses as required by AFR 800-21 are not well-documented by program offices. The Air Force Audit Agency conducted a review of programs relying on ICS. The results of this review were published in a final report dated 3 September, 1982. The report cites a need for improved "documentation of planning and analysis supporting ICS decisions [20:i]," and states that,

> Acquisition program managers did not have documentation to adequately support ICS decisions for 9 of 14 programs reviewed. Consequently, management could not demonstrate that early planning or cost and risk analysis were accomplished for these programs which accounted for $151 million of projected ICS requirements for fiscal years 1982-1984 [20:8].

Since such analyses were not completed, logistics managers could not substantiate that ICS was the most cost effective logistics support alternative. The audit team believed the absence of specific directive guidance to be the cause of this lack of documentation.

Logistics managers agreed with this evaluation, but believed that the establishment of specific, minimum documentation requirements would also lead to the unintentional establishment of maximum requirements. The logistics managers maintained that "each program has unique considerations that must be analyzed on a case-by-case basis," and that "an open-ended requirement will result in more specific and better quantified studies [20:9-10]." The audit agency's final comment was that "analysis on a case-by-case basis will be effective if HQ AFSC establishes appropriate controls to ensure the analysis is documented [20:10]."

In order to perform the cost and risk analyses required by AFR 800-21, logistics managers must be able to identify certain parameters. They must know what the final prime mission equipment design will look like before they can begin to develop support equipment to test, maintain, and repair it. In his study of "Baseline Indicators of Production Readiness," (3), published in November 1980, Mr. John Bemis identified many hardware and software indicators of production readiness. One of those indicators is the rate of generation of ECPs. He states that, "Examination of the profiles of engineering change traffic can be revealing in terms of the design maturity of a system [3]." The curves depicting ECP rates plotted over time should follow a downward trend. "Sustained levels of high change rate indicate a risk to cost, schedule, and/or performance [3]." Since development of logistics elements follows development of prime mission equipment (PME), it is logical to assume that, while the PME is not design stable, there would be risk (both cost and schedule) associated with the development of logistics elements also. Bemis found that empirical data compiled during his study indicated that

> the shape of the engineering change traffic profile was of a similar shape for different kinds of systems including aircraft, electronic systems, tracked vehicles, and gun systems. The profile is sufficiently defined such that anomalies can be identified and investigated [3].

Thus, it would seem that this method could be used to determine design stability for a new system, by comparison to existing systems of a similar type.

The ARINC Research Corporation conducted a study of the impact of ECPs on logistics support for the Navy P-3 aircraft. Published in December 1972, the study assessed the impact of both avionics and airframe ECPs on spares support, publications, training, and/or ground support equipment. The following data was included in the study (2:3):

1. ECP number
2. Lockheed submission date (month, year)
3. Affected aircraft (P-3A/B/C)
4. Affected system description

5. Change control board number
6. Change control board date (month, year)
7. Change control board action (approved, disapproved)
8. Contract amendment date (month, year)
9. Type of engineering change (airframe, avionics, power plant, etc.)
10. Technical directive number
11. Technical directive date (month, year)
12. Incorporation status (forward fit only, or retrofit and forward fit)
13. Estimated cost
14. Description of ECP, including consideration of impact on a) spares; b) publications; c) training; and d) ground support equipment

Impact on spares support was further categorized as follows (2:4):

Minimum Impact. The ECP being reviewed results in no modification to existing sparing. It has no effect on the quantity of spares procured previously or on order.

Average Impact. The ECP being reviewed results in a minor modification to existing spares-procurement policy. It does not require scrapping any portions of existing inventory.

Maximum Impact. The ECP being reviewed results in a major modification to existing sparing policy. This modification can take one of the following forms:

1. Requirement to scrap portions of existing inventory
2. A change in spares procurement, necessitating additional spares purchases
3. A change in existing maintenance concept

Impact on training, publications, and ground support equipment: in these three areas, the prime consideration was an evaluation of whether the ECP did or did not have an impact on the specified area.

After a preliminary analysis of all available data, it was determined that the Lockheed submission date was the only date "with sufficient coverage available [2:5]." Therefore, that date was used as the common base date for all frequency analyses. The data analysis was then performed using all possible combinations of aircraft types, and the various types of ECPs (avionics, airframe, power plant, etc.).

The initial output was "a set of frequency distributions, one set per type of change," showing the following (2:6):

Cumulative number of relevant ECPs

Percentage of ECPs having maximum spares impact

Percentage of ECPs having average spares impact

Percentage of ECPs having minimum spares impact

Percentage of ECPs having publications impact

Percentage of ECPs having training impact

Percentage of ECPs having ground support equipment impact

Evaluation of the results led to the division of the data into two categories, P-3A/B and P-3C, since the P-3A and P-3B are very similar and very different from the P-3C. (The difference is primarily in the avionics suite.) The P-3A/B can be categorized as a mature system, and the P-3C cannot (2:6).

The data analysis showed that as the aircraft system matured, for both avionics and airframe ECPs,

> There was an increase in the relative number of ECPs having maximum impact on spares. . . . However, the absolute percentage having maximum impact never exceeded ten percent for the P-3A/B, and the remainder of the submitted airframe and avionics ECPs were evenly split between average and minimum impact [2:6].

The P-3C avionics ECPs "maximum impact reached twenty percent, possibly reflecting problems with the more advanced avionic subsystems [2:10]." These figures can be used to make estimates of impacts of future ECPs on logistics elements. They also demonstrate that "there is a definite leveling of ECP activity as the aircraft system matures [2:10]."

Conclusions of the ARINC study are as follows:

1. On the basis of the P-3A/B ECP data, it appears that the number of ECPs submitted by the prime contractor approaches zero as the end of production is reached.

2. The number of ECPs being submitted each year on the P-3C is still increasing, particularly for the avionic subsystems, possibly reflecting their complexity in comparison with the P-3A/B avionic subsystems.

3. There appears to be no central location where complete ECP data are available.

4. Only a small percentage (ten percent) of ECPs submitted had maximum impact on spares support.

5. A high percentage (ninety percent) of ECPs submitted affected publications [2:13].

Recommendations of the ARINC study are as follows:

1. A study similar to this one should be conducted on an aircraft that has recently completed the production phase of its life cycle. This additional study should be used to verify the results of the P-3 ECP Trend Analysis and to permit these results to be extended to other aircraft types.

2. A central repository of ECP data should be established and maintained within NAVAIR. As a minimum, this system should be established for the P-3C to continue the monitoring of ECPs initiated in this study [2:13].

Another study, conducted by the Aerospace Industries Association of America, Inc. (AIA), in October, 1979, revealed that while much effort has been expended on the topic of design stability from a logistics supportability standpoint, most of it focused on a specific weapon system or problem. The study consisted of two parts. A survey questionnaire was distributed to members of the AIA, and the results were analyzed for trends. Also, a quantitative analysis of design change activity as related to program milestones was performed on data from the Navy S-3A weapon systems program. This analysis was conducted to determine the optimum period to accomplish support responsibility transfer of new aircraft programs from the contractor to the Navy.

Results of the questionnaire indicated that many of the industries surveyed had conducted in-house studies to identify a method for assessing design stability. The indicator most often used by those industries to assess design stability from a logistics supportability standpoint is the point at which the number of ECPs has been reduced to near zero (18). The data suggests the number of ECPs generated per month builds to a peak during prototype development, with a smaller peak during prototype testing (18). This finding concurs with that of the Bemis study, which was noted earlier in this discussion (3). Another result of the AIA study is the consensus that delays in achieving design stability can have a significant impact on the development of logistics support elements, especially in the cost area (18).

The factors which were considered to have the most impact on a weapon system/equipment achieving logistics supportability as related to design stability are listed below, as prioritized by the survey respondents (1):

Number and duration of design change activity

Funding

Complexity of equipment

Support equipment development

Length of full-scale engineering development phase

Validation of logistics requirements

Parts replacement rates

Availability of resources

First article delivery requirements

Future technology vs. state of the art

IOC

Test history

Life cycle costs

Length of concept phase

Type of contract

> Four of the first five most significant factors relate directly to design stability which is identified as having the greatest impact on supportability during the critical introductory phase of a new weapon system [1].

Respondents cited many situations which forced the acceptance of an unstable design and resulted in the use of ICS, including the following: 1) urgent need by customer (forced production of an unstable design); 2) degree to which the state of the art is being pushed by the design; and 3) funds availability (18). These situations are not truly conditions which may be used to justify a requirement for ICS according to AFR 800-21. All of them appear to be situations which would warrant the type of cost and risk analyses required by AFR 800-21. They also appear to be situations which require individual (case-by-case) analyses and solutions.

The AIA survey did not result in the establishment of any criteria for the determination of design stability. It did identify an "increasing acceptance on the part of DOD acquisition agencies to contract for longer periods of ICS" which "allows for a significant increase in the quality and a decrease in the cost of the delivered logistics elements [18]." Finally,

> Effective planning and implementation of ICS is recommended as the best approach to provide logistics support services during periods of design instability and the time period needed to establish organic support capability [18].

> Transfer of support responsibilities from the contractor to the Navy depends upon two basic factors: (1) that point in time when the rate of engineering change approaches a steady rate and the design becomes stable, and (2) that point in time when the Navy has developed its resources (skills and facilities to support operational units). Attainment of these factors should coincide with a major milestone of the program identified as the Naval Support Date (NSD) [1].

The analysis of the data showed that "the greatest design change occurred . . . at the program NSD milestone [1]." The study panel concluded that "design stability of a new weapon system cannot occur until the rate of engineering change (with respect to time) drops sharply and approaches a steady state value [1]." They stated that the

> impact of design change activity upon systems/ equipment can be significant and affects logistics support resources such as maintenance plans, spares, technical manuals, ground support and test equipment, maintenance training and trainers, and facilities. This implies that the maturity of system design and logistics support must occur simultaneously [1].

They recommended realigning major program milestones to a more realistic time period and planning for a longer period of interim support (1).

In November, 1981, AFALD/XRG conducted a study of ICS wartime surge capabilities (16). The study included a survey of DPMLs in AFALD/SD and LW. Responses were received from forty of the seventy-four DPMLs. One question asked, "Why are you using ICS?" The following responses were received:

Design Instability	1
Concurrency	5
Logistics development delayed / funds cut, support equipment unavailable	9
Depot assignment delayed or not made	10
Option (use if needed)	6

Not needed	3
Requirements unknown at present	1
No response	5

These responses indicate that there is still a lot of ICS which results from improper or lack of planning. Design instability was cited only once as a reason for using ICS, and is the only reason given which is clearly defined as an acceptable reason in AFR 800-21. Support equipment unavailability and program concurrency could be categorized as Situation 2, where lead times for support resources are too long to achieve organic logistics support capability by IOC (21). The six respondents who stated that ICS is an option, available to be used if needed, have obviously planned for ICS.

Conclusion

The results of the studies discussed in this literature review are inconclusive at best. Results of both the ARINC (2) and the Bemis (3) studies appear to suggest that trend analysis of ECPs can be used to identify the point where design stability is achieved. The AIA study (1) supports this by identifying ECP trend analysis as the most frequently used indicator of design stability by industry. However, Air Force logistics managers do not appear to be using this technique in the ICS planning process for weapon system acquisitions.

CHAPTER III

RESEARCH METHODOLOGY

This research effort consisted of two parts. The first part was a trend analysis of ECPs and their impact on logistics support elements. The second part was a qualitative study of the adequacy of available alternative methods of determining the point at which design stability is achieved.

ECP Trend Analysis

The ECP trend analysis was conducted using data collected from the F-16, F-15, and EF-111A aircraft. The data collected included:

1. ECP number and title
2. ECP description of change
3. ECP impact on logistics elements
    a. spares
    b. support equipment
    c. publications
    d. training

Only Class I ECPs were considered in this thesis because of their possible impact on logistics elements.

ECPs are classified as Class I in MIL-STD-480 (25:2-3), when one or more of the following factors are affected:

1. Functional configuration identification
2. Product configuration identification
3. Technical requirements (i.e., maintainability, reliability, weight, performance, etc.) which are below product identification
4. Non-technical contractual provisions (i.e., cost, schedules, quantities, etc.)
5. Other factors such as safety, compatibility with test equipment, interchangeability, suitability, or replaceability.

Other classes of ECPs do not impact these factors, so they were not included. The fire control and flight control systems on the F-15 and F-16 were selected for analysis because they are very similar, and provide a basis for comparison. The EF-111A data were collected because, as a fighter aircraft avionics modification, compatibility was possible. Only those ECPs which directly impacted specific logistics elements were included in the data base. (The logistics elements included were: support equipment, spares, technical data, and training.) For the F-16 only those ECPs which impacted the United States models were included. All foreign modifications were excluded. Data sets for each aircraft type consisted of the quantity of ECPs approved per month, arranged in chronological order to facilitate identification of any time dependencies in the data.

Research Question Number One

Research question number one stated, "Determine if there is a trend in the rate of generation of ECPs which can be measured over time and against program milestones, indicating when design stability has been achieved." To answer this question the data were evaluated using the Statistical Package for the Social Sciences (SPSS) (10). The Box-Jenkins procedure was used to determine if the data are autocorrelated, i.e., if there is evidence of time dependencies. Time-series plots of the number of ECPs per month were generated for each aircraft type and are shown in Appendix D. With these plots and Box-Jenkins procedures, one can deduce any trends that may be embedded in the data. (Trends as used here refers to dependencies in the data over time due to simple auto-correlation and periodicity.) After analyzing the results of this step, the existence of simple autocorrelation and periodicity was confirmed. Thus, an observation at time t is not independent of observations prior to time t. This finding precludes the use of linear or multiple regression, since the residuals cannot be assumed to be independent. Thus, the data were evaluated using the TIMES time series analysis package (26). Based on analysis of the autocorrelation function (ACF) and partial autocorrelation function (PACF) of each time series, an Autoregressive Integrated Moving Average (ARIMA) model was proposed as a model of the time series for each weapon system. ARIMA models of order (p,d,q) were used, of the form:

$$(1 - \phi_1 B - \phi_2 B^2 - \ldots - \phi_p B^p)(1 - B)^d Z_t =$$
$$(1 - \theta_1 B - \theta_2 B^2 - \ldots - \theta_q B^q)\, e_t$$

Here, d denotes the degree of differencing necessary to convert a time series to a stationary process while the p and q are the order of the autoregressive and moving average components (13:205-206). The operator B is a backshift operator such that $B^n Z_t = Z_{t-n}$. The least-squares estimated values of the coefficients θ_j and ϕ_j were obtained using the TIMES computer code .

This analysis adhered to the principle of parsimony as espoused by Box and Jenkins. Models were selected which adequately described the time series, yet contained as few parameters as possible (13:192).

Once the ARIMA (p,d,q) model was tentatively identified, it was examined for adequacy, or goodness-of-fit. "If the fitted model is adequate, it should transform the observations to a white noise process [13:211]." This means that if the model is appropriate, the residual sample autocorrelation function "should not differ significantly from zero for all lags greater than or equal to one [13:211-212]." A "white noise process" refers to a distribution of error terms which has a mean of zero, constant variance, and no autocorrelation. A well-fitted ARIMA model reduces the error component to a white noise (4). A lag refers to the constant interval between the data points being plotted, i.e., the autocorrelation at lag one refers to the autocorrelation between observations one time interval apart. In order to test for white noise, the following diagnostics were performed.

Portmanteau Lack of Fit Test. The ARIMA (p,d,q) models were tested for adequacy using the Portmanteau lack of fit test. This test evaluates the smallness of an arbitrary K lags of a sample autocorrelation function (5). Specifically,

$$Q = n \sum_{j=1}^{K} r_j^2$$

is approximately distributed as $\chi^2_{(K-p-q)}$, where $n = N - d$ and r_j = autocorrelation at lag j. The observed value of Q was checked against the χ^2 value with the appropriate degrees of freedom at $\alpha = .05$. If Q is greater than $\chi^2_{(K-p-q)}$, then the ACF of the residuals is said not to be white noise (4:290-291).

Cumulative Periodogram Check. The periodogram is "specifically designed for the detection of periodic patterns in a background of white noise [4:294]." It was used to identify periodicities in the residuals not accounted for by the model. Periodograms were generated for each data set using the TIMES package.

Residuals Histogram. The residuals of each data set were plotted on a histogram to test for normality. Normally distributed residuals permit probability statements regarding the probability of falsely declaring a time series to be autocorrelated when in fact it is white noise.

Research Question Number Two

Research question number two stated: "If such a trend exists, demonstrate that this trend can be applied to all like systems, so that it can be used as a predictor of the point at which design stability will be achieved." To answer this question, the time series plots for all the aircraft data were evaluated to determine if any trends were similar. The ARIMA models developed for each type of aircraft were analyzed to determine if they could be used as predictors of ECP trends, and thus, predict achievement of design stability for new systems.

Research Question Number Three

Research question number three stated: "If there is a trend, demonstrate that it can be applied to those ECPs which have a direct impact on logistics support element development." To answer this question, ECPs for all aircraft were evaluated to determine if they impacted logistics support elements. Only those ECPs which did impact logistics support elements were included in the analysis.

Research Question Number Four

Research question number four stated: "Investigate the adequacy of existing methods of determining whether or not a design is stable for purposes of developing organic logistics support capability." To answer this question, results of the ECP trend analysis were evaluated to determine the adequacy of such an analysis for use as a measure of design stability for logistics supportability decisions.

Qualitative Analysis

The qualitative analysis was conducted using data collected from a series of interviews with logistics management personnel who have had varying amounts of experience managing ICS programs. The interview sample consisted of both military and civilian personnel from the Air Force Acquisition Logistics Division, Deputy for Aeronautical Programs (AFALD/SD), Wright-Patterson AFB OH, and civilian personnel from the aerospace industry. The interview sample size (eleven people) was not intended to be statistically significant, and the results of the interviews are useful only for discussion in this thesis and as a basis for further research. The sample size was deliberately limited because of time constraints. Therefore, the results "cannot be generalized to any population [19:81]" other than the sample population.

In order to facilitate the interview process, a package containing an interview guide and a worksheet (Appendix B) was mailed to the subjects in advance. Each subject was then contacted by telephone to arrange an interview, and requested to prepare the worksheet in advance. Questions on the worksheet are open-ended and subjective. The interviews followed the outline of the worksheet, but also included several demographic questions. The actual interviews followed a standard format and sequence (Appendix C), thereby assuring that each question was asked the same way in each interview. Questions built on previous responses, which added to the reliability of the interview technique (8:215). The interview guide was validated by a series of interviews designed to evaluate the respondent's understanding of the questions and their intent. The validation interviews were conducted using AFIT instructors as subjects.

The questions in the interview guide were designed to provide information which will aid in the evaluation of the research questions, within the expressed limitations and scope, and in the identification of areas requiring further research. The responses to the questions in the interview guide were especially pertinent to research question number four. Responses were compared and categorized, then conclusions were drawn based on the similarities and differences among them. Demographic data were used to ascertain any variance among responses from subjects which could be attributed to amount of experience in managing logistics support and/or ICS.

CHAPTER IV

ANALYSIS AND RESULTS

ECP Trend Analysis

After the data were collected for the F-15, F-16, and EF-111A aircraft, it became apparent that there were not sufficient quantities of EF-111A ECPs which had an impact on the logistics elements. The EF-111A data was therefore eliminated from this thesis effort. (Box-Jenkins time series analysis techniques require a minimum of fifty data points; there were only twenty-eight data points available for the EF-111A.) Thus, the analysis proceeded using only the F-15 and F-16 data.

All ECPs generated in each program were examined and included in the data base if they met the requirements stated in Chapter III, Research Methodology. The F-15 data set consisted of 113 ECPs and the F-16 data set consisted of 64 ECPs. The data sets consisted of the quantity of ECPs approved per month, arranged in chronological order so that autocorrelation could be identified. The research questions stated in Chapter III, Research Methodology, provided the framework for the analysis.

Research Question Number One

Research question number one stated "Determine if there is a trend in the rate of generation of ECPs which can be measured over time and against program milestones, indicating when design stability has been achieved." To answer this question, the data were evaluated using the SPSS Box-Jenkins procedure to determine the existence of autocorrelation in the data. Both data sets were found to contain autocorrelation. Next, both data sets were evaluated using the TIMES times series analysis package. By plotting the observed series deviation from the mean, both data sets were determined to be stationary, so no differencing was required and d = 0 for both data sets. The ACF and PACF plots were studied for patterns of autocorrelation. The two data sets exhibited different patterns, so individual models were developed for each aircraft. Results of the modeling process are given in Tables 4.1 and 4.2.

The F-15 data exhibited a pattern of significant autocorrelation at lags one, three, six and nine (see Appendix D). Four simple models were tested: AR(1), AR(2), MA(1), and MA(2). Of these simple models, the MA(1) model best fits the observed data. Using the Portmanteau lack of fit test, the MA(1) model reduced the Q statistic the most (see Table 4.1). However, the Q statistic value of

Table 4.1

F-15 ECP Trend Analysis Results

Model	Degrees of Freedom	Q Statistic	$\chi^2_{(K-p-q)}$, α = .05
Original Data	22	36.763	12.340
ARIMA (0,0,1)	20	31.624	10.850
ARIMA (1,0,0)	20	31.798	10.850
ARIMA (0,0,2)	18	30.983	9.390
ARIMA (2,0,0)	19	31.569	10.120
*ARIMA $(0,0,1)(0,0,3)_3$	17	10.310	8.672
ARIMA $(0,0,1)(3,0,0)_3$	17	12.055	8.672

* Final Model

Table 4.2

F-16 ECP Trend Analysis Results

Model	Degrees of Freedom	Q Statistic	$\chi^2_{(K-p-q)}$, α = .05
Original Data	12	55.2470	5.226
Original Data (zeros removed)	10	23.3480	3.940
ARIMA (2,0,0)	9	9.8117	3.325
ARIMA (0,0,3)	8	38.8640	2.733
ARIMA (3,0,0)	8	9.7892	2.733
ARIMA $(2,0,0)(1,0,0)_5$	8	7.1077	2.733
*ARIMA $(2,0,0)(1,0,0)_5(0,0,1)_6$	7	2.5391	2.167

* Final Model

31.624 was still much greater than $X^2_{20} = 10.85$. This model eliminated the autocorrelation at lag one, but did nothing about lags three, six and nine. Two new models were tested: ARIMA $(0,0,1)*(0,0,3)_3$, and ARIMA $(0,0,1)*(3,0,0)_3$. These two models both reduced Q, but the ARIMA $(0,0,1)*(0,0,3)_3$ model had the best results (see Table 4.1).

The final model for the F-15 data is an ARIMA $(0,0,1)*(0,0,3)_3$ model (4:305). The model equation (in Box-Jenkins backshift operator notation) is

$$\tilde{z}_t = (1 + .15593B)\,(1 + .18405B^3 + .036158B^6 + .33203B^9)\,e_t \qquad [4.1]$$

Multiplying out the right-hand side of equation [4.1] yields the equation:

$$\begin{aligned}\tilde{z}_t = 1 &+ .15593Be_t + .18405B^3e_t + .0294459B^4e_t \\ &+ .036158B^6e_t + .0056382B^7e_t + .33203B^9e_t \\ &+ .0517692B^{10}e_t\end{aligned} \qquad [4.2]$$

Equation [4.2] can be expressed in more conventional notation by removing the backshift operators to yield the final equation:

$$\tilde{z}_t = e_t + .15593e_{t-1} + .18405e_{t-3} + .0294459e_{t-4} + .036158e_{t-6} + .0056382e_{t-7} + .33203e_{t-9} + .0517692e_{t-10} \quad [4.3]$$

The F-16 data base contained a large number of data points early in the series which were equal to zero. To determine if this impacted the results, the TIMES package was used to produce original series, ACF and PACF plots for all sixty-four data points and for a fifty-one point data set which deleted the initial series of zeros. The resulting ACF and PACF plots indicated only a slight impact), so the sixty-four point data set was used for all further model testing.

Analysis of the ACF plot indicated an exponential decay pattern which would be indicative of an auto-regressive process (13:194) (see Appendix D). Models tested were: AR(2), AR(3), and MA(3). Of these simple models, the AR(2) model had the best fit. The Portmanteau lack of fit test Q statistic was 9.8117 with nine degrees of freedom. This was substantially lower than the original series Q value of 55.247 with twelve degrees of freedom (see Table 4.2), but was still greater than $\chi^2_9 = 3.325$. Both the periodogram and the autoregression function still indicated residual autocorrelation of periods five and six (see Appendix D). The next model tested was ARIMA

$(2,0,0)*(1,0,0)_5$ to eliminate the significant autocorrelations at lags five and ten. Results showed improvement. The Portmanteau lack of fit test Q statistic was 7.1077 with eight degrees of freedom. This was a substantial drop in Q for a loss of only one degree of freedom. However, the Q statistic 7.1077 was greater than $\chi^2_8 = 2.733$. The ACF and PACF plots still showed strong autocorrelation at lag six. To eliminate this autocorrelation, the model ARIMA $(2,0,0)*(1,0,0)_5*(0,0,1)_6$ was tested. Results were very good (see Table 4.2). The Q statistic was 2.5391 with seven degrees of freedom and $\chi^2_7 = 2.167$.

The final model for the F-16 data is an ARIMA $(2,0,0)*(1,0,0)_5*(0,0,1)_6$ model. The model equation (in Box-Jenkins backshift operator notation is

$$(1 - .37875B - .25808B^2)\ (1 - .23910B^5)\ \tilde{z}_t = (1 - .29997B^6)\ e_t \qquad [4.4]$$

Multiplying both sides of equation [4.4] yields the equation:

$$\tilde{z}_t = .37875B\tilde{z}_t + .25808B^2\tilde{z}_t + .23910B^5\tilde{z}_t - .0905591B^6\tilde{z}_t - .0617088B^7\tilde{z}_t + e_t - .29997B^7e_t \qquad [4.5]$$

Equation [4.5] can be expressed in more conventional notation by removing the backshift operators to yield the final equation:

$$\tilde{Z}_t = .37875\tilde{Z}_{t-1} + .25808\tilde{Z}_{t-2} + .23910\tilde{Z}_{t-5} - .0905591\tilde{Z}_{t-6} - .0617088\tilde{Z}_{t-7} + e_t - .29997e_{t-6} \quad [4.6]$$

Throughout the modeling process for both data sets, the periodograms and spectrograms were analyzed for improvements. The computer diagnostics for the initial run and final model for both data sets are included in Appendix D.

The first article delivery dates were November 1974 (month nine) for the F-15 and August 1978 (month twelve) for the F-16. These dates occurred long before the major portion of the ECPs impacting logistics were generated. Combined with the fact that each system has a different model, the first article delivery dates appear to have occurred too early to be useful in predicting design stability.

Research Question Number Two

Research question number two stated, "If such a trend exists, demonstrate that this trend can be applied to all like systems, so that it can be used as a predictor of the point at which design stability will be achieved." As stated in Chapter III, Research Methodology, the time series plots for the F-15 and F-16 data sets were analyzed for similarity. The models developed for the two data sets are very different (as evidenced by the different periodicities), and indicate that a trend for one system cannot be assumed to be similar to the trend for any other system. Thus, the models developed in this thesis ought not to be used as predictors of trends for any other like systems.

Research Question Number Three

Research question number three stated, "If there is a trend, demonstrate that it can be applied to those ECPs which have a direct impact on logistics support element development." As stated in Chapter III, Research Methodology, all ECPs used in this thesis effort did impact on logistics elements. This effort has identified the existence of a trend for those ECPs which impact on logistics elements. However, there was not sufficient time to evaluate total airframe ECPs and compare those trends and models to the trends and models developed here.

Qualitative Analysis

The question in the interview guide were designed to provide answers which would help to evaluate research question number four. It stated, "Investigate the adequacy of existing methods of determining whether or not a design is stable for purposes of developing organic logistics support capability." Responses to each interview question were categorized and tallied to identify similarities and differences among them. The demographic data were used to ascertain any variations among responses which could be attributed to amount of experience managing logistics support and/or ICS.

An analysis of the responses to each of the interview questions follows. Responses to the demographic questions and to interview questions one through nine are summarized in Appendix E. Responses to interview question ten are given in their entirety in this analysis discussion.

<u>Interview Question Number One</u>

Interview question number one asked, "Design instability is often cited as a reason for using interim contractor support (ICS). How would you define design stability vs. instability as it relates to such a decision, and to logistics supportability of a new/modified weapon system?" This question was designed to obtain an idea of what logistics managers look for in determining design stability, and when they think it has been achieved.

The most frequently given response was "Design stability has been achieved when system reliability or MTBF specifications have been achieved." Four people gave that response. Three people cited "advancement of the state of the art" as the biggest cause of design instability. Three people identified critical design review (CDR) as the point at which design stability is achieved, and another cited the reliability allocation, assessment, and analysis report (AAA Report) as an indicator. It is interesting to note that the person who cited the AAA Report also defined design stability in terms of achieved reliability specifications, but none of the other responses mentioned were from the same individuals. Three individuals stated that achievement of design stability could not be tied to any specific program milestone. When these answers were compared to the demographic data, no correlation was found between amount of management experience and any of the answers.

Interview Question Number Two

Interview question number two asked, "Do any of the following items have an effect on the date at which a weapon system achieves logistics supportability? If so, please indicate whether the effect is significant or minimal. Include any additional items that may affect logistics supportability under 'other'. Please rank according to impact (1 = most impact, etc.). Ties are allowed if necessary." The complete list of items considered is included in Appendix E.

Concurrency of FSD and production programs was ranked first in impact by six people and was rated as significant by eight. It was rated second in impact by only one person. Complexity of equipment was ranked first in impact by five people and was rated as significant by nine. It was ranked second in impact by three people. Three people added funding availability, ranking it first in impact. Number and timeframe of ECPs, IOC date, first article delivery date, and support equipment development were all ranked first by three people. Support equipment development was ranked second by three people also, and was rated significant by nine. IOC date was considered significant by eight people. Seven people considered number and timeframe of ECPs and length of FSD phase to be significant. Only one person considered concurrency of FSD and production programs to be of minimal impact, and two people rated complexity of equipment as minimal. Other responses were varied. There was no correlation between amount of experience and any of the responses to the question.

Interview Question Number Three

Interview question number three asked, "What is the effect on the following of a delay in reaching design stability? Indicate significant, minimal, or none." Responses were requested for delays of from one to three months and for delays of greater than three months. The complete list of elements considered is given in Appendix E.

Delays of from one to three months. Five people considered the effect on support equipment delivery, ICS, and organic capability date to be significant for delays of from one to three months. Four people considered the impact on LCC and spares provisioning to be significant. Most people considered delays of this length to have minimal effect on the elements listed. Very few believed there would be no impact at all.

Delays of greater than three months. A majority of people considered delays of this length to have a significant impact on all elements listed. All eleven people interviewed agreed that a delay of three months or more would significantly impact the organic capability date. Ten people believed the delay would significantly impact support equipment delivery and technical document preparation. Nine people felt the delay would be significant to support equipment development, spares provisioning computations and spares delivery dates. Eight people said that ICS and training equipment development would be impacted significantly. Seven people thought the delay would significantly impact support equipment requirement (SERD) development and LCC. Five people believed the impact on training development would be significant. Only three people felt that LSA would be significantly impacted, and four felt that the impact would be minimal. Two said there would not be any impact on LSA or SERDs. Two people believed the effects on LCC would be minimal. There was a consensus of opinion among the respondents that the greater the length of the delay, the greater the significance of the impact. Experience level was not correlated with the responses to this question.

Interview Question Number Four

Interview question number four stated, "One technique currently used to assess design stability is a trend analysis of engineering change proposals (ECPs). Please identify any other techniques which you have used (or are aware of) for assessing the design stability of a weapon system from a logistics supportability viewpoint."

Responses to this question were quite varied. The largest number of similar responses was three. Those three people cited the use of reliability analyses and the achievement of a mature MTBF (specification MTBF). In all, nineteen techniques were mentioned. One individual cited seven, and two people claimed not to be aware of any. There appear to be quite a lot of different techniques in use for assessing design stability. Once again, experience level did not have any obvious impact on the responses.

Interview Question Number Five

Interview question number five asked, "Prior to making a decision to use ICS, AFR 800-21 requires 'rigorous cost and risk analyses' to support such a decision. Can you comment on the adequacy of techniques available to perform such analyses?"

Five respondents stated that the available techniques were adequate. Four of the five had over fourteen years of logistics management experience. Two of them stated that techniques must be adequate since decisions to use ICS were seldom found to be incorrect after the fact. Four people stated they thought the techniques available were inadequate. All four had six or fewer years of logistics management experience. Perhaps experience influences the perceptions about the adequacy of the available techniques, or the ability to interpret their results. There was no consensus regarding adequacy of techniques available. In fact, people often gave opposite responses. For example, AFALD was credited with being of great assistance to one individual and also cited for giving inadequate and irrelevant guidance to another.

Interview Question Number Six

Interview question number six asked, "What techniques have you employed in the past to perform such analyses?"

Four people said they had used cost analyses, and three said they used pre-planning for ICS in lieu of such an analyses. One used both cost analyses and pre-planning for ICS. Two people gave four responses, one gave five, and one gave six. All others gave only one or two. Only a few individuals appeared to be attempting very many methods of performing such analyses. Three people had used trade studies of ICS vs. 100% NRTS. Experience level was not correlated with these responses.

Interview Question Number Seven

Interview question number seven stated, "Please list all such techniques with which you are familiar and rank them according to how effective you believe them to be."

Three people ranked ICS vs. 100% NRTS first. Two of the three had listed five and six techniques for question number six. The three people were also the only ones who had used that technique. LSA was ranked first by two people. No other methods received any consensus, and experience level of the respondents was not correlated with the rankings.

Interview Question Number Eight

Interview question number eight asked, "The previous seven questions have addressed the point of design stability vs. instability as it relates to decisions about the use of ICS. Would you care to comment on the feasibility of establishing such a point, and on its usefulness in making such decisions?"

Three people stated they felt design stability was over-stressed. One of these people had forty years of logistics management experience and had participated in the preparation of AFR 800-21. That individual commented that when the regulation was written, no one foresaw the effect that the inclusion of situation one would have, or the confusion it would create, and recommended its deletion from the regulation. Three different people stated that pre-planning for ICS was necessary and that such pre-planning precluded the necessity of identifying design stability. Two of those people, plus a third, stated that even when a point was determined, it was usually too late to allow for cost-effective ICS planning. Three different individuals stressed that lack of support resources was the real driver, but one of them felt that design instability drives the lack of support resources. Two individuals felt that a contractually defined design stability point could be useful in providing the contractor with incentives to achieve stability. Again, there did not appear to be any correlation between experience level and the responses to this question.

Interview Question Number Nine

Interview question number nine asked, "For programs with which you are familiar, which of the two situations described in AFR 800-21 resulted in a requirement for ICS?"

A large majority of justifications for the use of ICS resulted from only situation two. A few were driven by both situations. One individual stated that a certain program was "almost a one." None of the programs used only situation one as the justification for using ICS.

Interview Question Number Ten

Interview question number ten asked, "Do you have any additional comments on this subject?"

Responses to this question were so varied that no real consensus is evident. Many did not directly address the specific issue of design stability addressed in this thesis, but were related. All reflected the specific areas in which a particular respondent had experienced problems while planning for logistics support of a weapon system. The comments are included here to provide a basis for further discussion and recommendations.

-- Yes. As one of the original contributors to the development of the reg [sic], I think design stability as a requirement was overstated. The inevitable result of design instability is a deferred rescheduling of support resources, hence lack of support resources is the real driver and could be a sufficient reason. This was not foreseen at the time, but the evidence is now in. There is no mystery to the need for ICS--hence it should always be planned for!

-- Concurrency is the biggest challenge to logistics.

-- If concurrent, it is a calculated risk going ahead with the program if [the system] is not design stable. Design immaturity paralleling production leads to support resources not being available.

-- If FSD is compressed, that compresses the logistics support identification.

-- Even though the design is unstable, we can begin fundamental ILS planning (i.e., inputs/outputs to be measured).

-- Support equipment support is as complex as PME support.

-- After CDR, changes equal dollars.

-- You cannot look at ICS in isolation; you must view it within the whole acquisition program. The more ICS is planned for, the better is the management which is being used.

-- The emphasis should be on pre-planning. The prime objective is to field a supportable system. To the extent that you have to use ICS to do that, then that's what you'll have to do.

-- The smart manager plans for the "unks" [unknowns].

-- Key: Loggies [sic] have got to be there early in program planning. The key to LSA is early up-front plans and studies looked at to make meaningful decisions about long-range implications of logistics.

-- Proactive not reactive management.

-- Make logistics important in source selection.

-- Recognize [the need] early; include ICS as a contract option. [This] can negate the need for ICS or result in early transition.

-- Always include incentives to get out of ICS.

-- Motivate the contractor not to want to go into ICS, but have it as an option. Then it's covered if necessary.

-- We used to make decisions because funds were not available. Now we're saying even if funds are available, what's the better way of going? And that's a smarter management decision.

-- Define ICS as a capability.

-- Leadtime for spares deliveries and software programming are the biggest drivers for ICS. Technical data (i.e., depot level technical orders) is the next long lead item. Spares should not matter for ICS or organic but because they are required to accomplish software development, they become a driver. With a leadtime of thirty to thirty-six months for software development, that would require a finalized software program three years prior to delivery of the first aircraft. Our configuration is still changing 1½ [sic] years after delivery of the first aircraft. It is obvious we could not have ordered software 4½ [sic] years ago.

-- Lack of time to develop support resources is the main reason for using ICS, sometimes due to a late CDR date, but not necessarily a requirement. ICS should be seen as a viable, acceptable alternative for the Air Force in support planning, rather than a catch-up/band-aid admittance of failure, as it is currently perceived. Accelerated development/acquisition and restricted funding force a program into the ICS arena. However, since ICS is funded separately, through the AFLC chain, it is not always a fair tradeoff when considering budget cuts in programs. If the ICS costs were part of the overall program costs, and if the program manager had control of these and all support dollars (spares), a better cost analysis could be done.

-- A serious problem which is tied very closely to ICS is the provisioning area. Spares are computed for organic repair cycles only. These quantities are not sufficient for ICS repairs. Also, spare funding limitations and restrictions (design stability) are critical factors. In a concurrent program, the provisioning reg's [sic] should be altered to permit accelerated procurement, thus, reducing the cost of ICS--at the expense of the gov't [sic] assuming the risk of obsolete spares. These cost analyses are not being done currently.

-- ICS should be avoided whenever possible. My experience shows that it is much too expensive. Perhaps the Systems Command program managers should pay more attention to the "rigorous cost analyses." Also, in those instances where design instability is the justification, perhaps the system shouldn't be deployed.

-- FCA and PCA are not significant.

CHAPTER V

SUMMARY, RECOMMENDATIONS AND CONCLUSIONS

Summary

This thesis attempted to determine the feasibility of identifying a point in time at which a weapon system achieves design stability, and of using that point when making logistics supportability decisions. The analysis was conducted in two parts: 1) a quantitative trend analysis of ECPs, and 2) a qualitative interview series. Results of both analyses lead to the conclusion that identification of such a point may not be possible.

Results of the ECP trend analysis indicate that while time series analysis can be used to define a model for a given set of historical data, the models for two very similar systems, the F-15 and F-16 fire control and flight control systems, are entirely different. Thus, one cannot use a model developed on the basis of historical data from one program to predict the ECP trend for a new weapon system program. Since the models developed in this thesis were developed using only those ECPs which impacted logistics elements, it is apparent that the effect of ECPs on the development of a logistics support capability cannot be said to be the same for any two given weapon systems. The utility of such models to logistics managers is questionable.

Responses to the interview questions indicate that while some of the subjects believe that design stability can be measured, few agreed on how or on the definition of design stability itself. While most agreed that design stability can and does impact logistics support capability and interim contractor support, they felt that it occurs too late in a weapons system's life cycle to be a cost-effective decision parameter. They believed the real driver in the logistics decision-making process to be support resources availability and lead times. The most commonly cited factors impacting design stability included achieved MTBF, state of the art technology, and concurrency of FSD and production programs. Those factors differ for every program.

Although the interview sample population was not a statistically significant sample, the subjects were drawn from a population of people actively involved in making decisions about weapon system supportability. Their responses were based on their experience with the acquisition of logistics support resources and ICS, following the current DOD and Air Force regulations. Their responses indicate that they don't use design stability as a decision parameter when making logistics supportability decisions.

They rely on other means of determining their requirements. Responses to interview question nine indicate that Situation 1, design instability, was not used as a justification for ICS by any of the interview subjects on any of their programs. These findings are consistent with the AIA Study conclusion that, "The results of this questionnaire . . . did not surface any substantial new data that could be used to develop criteria for determining when a weapon system has achieved design stability," and "In view of the minimal results . . . further pursuit of this subject does not appear to be productive. [1]"

The results of the ECP trend analysis portion of this thesis support the conclusion of the ARINC study that "the number of ECPs submitted by the prime contractor approaches zero as the end of production is reached [2:13]." A second conclusion of that study, that "The number of ECPs being submitted each year on the P-3C is still increasing, particularly for the avionic subsystems, possibly reflecting their complexity [2:13]" is supported by the responses to the interview portion of this thesis. Many responses indicated continued ECP generation after first article delivery. The ARINC study recommended that a similar study be conducted to "verify the results of the P-3 ECP Trend Analysis and to permit these results to be extended to other aircraft types [2:13]." The Bemis study "indicated that the shape of the engineering change traffic profile was of a similar shape for different kinds of systems [3]." Bemis' finding was based on the use of regression analysis, and was not replicated by this thesis effort. This effort verified the existence of a trend in the rate of generation of ECPs for two similar fighter aircraft avionics systems (F-15 and F-16 fire control and flight control systems). However, each aircraft system exhibited its own distinct trend, and neither can be extended to other aircraft systems. This thesis used Box-Jenkins time series analysis, since the ECP data indicated the presence of autocorrelation. The use of multiple regression was therefore contraindicated. Any further efforts in this area should use Box-Jenkins time series analysis.

The qualitative portion of this thesis effort supported the results of the AIA Study. Responses to the AIA questionnaire indicated that "the impact of any delays in achieving design stability on the development of logistics elements is significant [1]." Responses to interview questions two and three lead to the same conclusion. The AIA Study recommended

> effective planning and implementation of Interim Contractor Support . . . as the best approach to provide logistics support services during periods of design instability and the time period needed to establish organic support capability [1].

Many of the responses to the thesis interview questions support the pre-planned use of ICS as a contract option to be exercised if needed. The Air Force Audit Agency Report stated that, "each program has unique considerations that must be analyzed on a case-by-case basis [20:9-10]." The interview responses indicate that many of the subjects believe that a pre-planned ICS option can be used in lieu of (or negates the need for) the "rigorous cost and risk analyses" required by AFR 800-21. The Audit Agency Report reiterates the requirement to perform such analyses, and cites the "absence of complete directive guidance [20:9]" as a factor contributing to such incomplete planning.

Responses to the interview questions indicate that many logistics managers believe that adequate techniques exist to perform such analyses. A few, however, felt that adequate guidance was lacking. The current tendency in acquisition toward concurrent development and production programs and the propensity to advance the state of the art were often cited as reasons why pre-planned ICS is a necessity. Such situations usually result in long lead times for support resource development. Former Deputy Secretary of Defense Frank C. Carlucci established thirty-two initiatives for streamlining the weapon system acquisition process. Recommendation 16 addresses "Contractor Incentives to Improve Reliability and Support" (6:18). Current regulations and guidance are not entirely consistent with this and many of his other recommendations, resulting in many problems in interpretation and implementation. The regulations and guidance should be revised to reflect current acquisition policies and practices, thereby enabling logistics managers to accomplish adequate planning.

Two specific areas of concern to many of the interview subjects are spares support and software support requirements planning. AFR 800-21 provides little guidance in these areas. Since ICS is a special type of support and differs from organic support in many ways, spares provisioning based on organic maintenance often is not adequate for ICS.

Recommendations

1. It is recommended that Situation 1, design instability, be considered for deletion from AFR 800-21 as a justification for the use of ICS. This recommendation is based on the results of the ECP trend analysis which demonstrates that a practical quantitative technique for forecasting design stability may not exist. This result is coupled with the lack of consensus among the interview subjects as to how to define design stability, when it occurs, and its usefulness as a decision parameter for logistics supportability decisions. The fact that none of

the interview subjects has ever used Situation 1 provides further support for this recommendation.

2. It is recommended that an attempt be made to replicate the results of this thesis using Box-Jenkins time series analysis on similar data. Since neither the Bemis study nor the ARINC study employed Box-Jenkins time series analysis, results are not strictly comparable. An additional study of this type is needed to confirm the results of this thesis.

3. It is recommended that further study be accomplished to determine adequacy of available analysis techniques for accomplishing the cost and risk analyses required by AFR 800-21, and that the regulation be revised to provide more explicit definition and explanation of such techniques. (Rigid requirements are not desirable, and are not recommended.)

4. It is recommended that further study be accomplished in the areas of spares support and software support requirements planning, as related to the use of ICS. Guidance in these areas is minimal, and needs to be revised and expanded. (Again, rigid requirements are not desirable, and are not recommended.)

Conclusions

This research effort has determined that design stability is not a very useful decision parameter for making logistics supportability decisions. Although it has an impact on all logistics elements, it cannot be adequately defined and is so program specific as to be virtually unpredictable. ECP trend analysis can be used on historical data to develop a model, but the model cannot be used to predict for a new system. Logistics managers currently involved in the acquisition of support resources for Air Force weapon systems are using other methods and parameters in their planning processes. Emphasis should be placed on the planning effort, and ICS should be used as an option when support resources are not available when required in the field.

APPENDIX A

TERMS AND ACRONYMS DEFINED

Class V Modification. Modification of a system or equipment that will provide: 1) a change in operational requirements or performance which provides an added capability not inherent in the baseline configuration; 2) the capability to accomplish an assigned mission that the basic system or equipment was not originally designed to accomplish; 3) a significant and measurable training or logistic improvement certified essential by the command or the agency primarily concerned; 4) a modification required to improve system operational capability (change in mission) [17:123].

Critical Design Review (CDR). A detailed design specification review conducted at the end of FSD prior to the production decision to verify the adequacy and producibility of the design. Design is frozen at CDR.

Deputy Program Manager for Logistics (DPML). An experienced logistician assigned by AFLC to a Program Office to serve as one of the deputies on the Program Manager's (PM) staff. Responsible for logistics support planning and acquisition during the weapon system acquisition process [17:218].

Development Test and Evaluation (DT&E). Test and evaluation conducted to demonstrate that engineering design and development are complete and that the system or equipment meets specifications. DT&E also verifies that proposed design changes do not degrade overall system performance. DT&E is conducted by the implementing command.

Follow-on Test and Evaluation (FOT&E). Test and evaluation which is conducted after IOT&E to continue and refine the estimates made during IOT&E, to evaluate changes, and to reevaluate the system to insure that it continues to meet operational needs and retain its effectiveness in a new environment or against a new threat.

Initial Operational Test and Evaluation (IOT&E). That portion of operational test and evaluation conducted prior to the first major production decision. The system is evaluated against operational criteria by personnel with the same skills and equipment which will be used in the operational environment.

Integrated Logistics Support Plan (ILSP). A document which provides a comprehensive and detailed plan for implementing the concepts, techniques, and policies necessary to achieve the integrated logistics support (ILS) objectives of assuring the effective economical support of a system or equipment for its life cycle (AFR 800-8) [17-356].

Justification of Major System New Start (JMSNS). Justifies the need for a major system new start to fill a mission requirement or meet a threat.

Life Cycle Cost (LCC). The total cost of an item or system over its full life. It includes the cost of development, production, ownership (operation, maintenance, support, etc.) and, where applicable, disposal [17:390].

Maintainability. A characteristic of design and installation expressed as the probability that an item will be restored to a specified condition within a given period of time when the maintenance is performed using prescribed procedures and resources. System maintainability may also be expressed in such terms as Mean-Time-to-Repair, Maintenance Manhours per Flying Hour, or Mean Down-Time (AFR 80-14) [17:406].

Maintenance Engineering Analysis (MEA). Similar to LSA; performs a design to cost, life cycle cost analysis. Superceded by LSA.

Maintenance Level Analysis (MLA). Analysis leading to decisions about the use of various maintenance concepts relative to reliability impacts, costs, and other tradeoffs.

Not Reparable This Station (NRTS). The percentage of failed items which must be sent to a central repair activity having greater repair capability, or not authorized for repair at that location [17:479].

Operational performance. Performance standards for operational use of a system, stated in measurable terms.

Preliminary Design Review (PDR). Equipment design review during the detail design development phase. Engineering models are tested for function, reliability, maintainability, etc., prior to finalizing the detail design.

Producibility. The composite of characteristics which, when applied to equipment design and production planning, leads to the most effective and economic means of fabrication, assembly, inspection, test, installation, checkout, and acceptance of systems and equipment (AFSCM 84-3) [17:547].

Production Reliability Qualification Test (PRQT). Tests conducted on the system or equipment prior to production go-ahead to evaluate the system development progress and to ensure that reliability specifications have been met. Also evaluates system supportability and compatibility between prime equipment and recommended test and support equipment.

Program Management Responsibility Transfer (PMRT). The transfer of program management responsibility for a system (by series) or equipment (by designation), from the implementing command to the supporting command. PMRT includes transfer of engineering responsibility [17:555].

Reliability. The probability that a system, subsystem, component, or part will perform a required function under specified conditions, without failure for a specified period of time (AFLCM 72-2) [17:576].

Reliability Allocation Assessment and Analysis Report (AAA Report). This report is used to 1) evaluate the contractor's estimate of reliability; 2) evaluate the potential reliability of the configuration item design; 3) provide information to assist in directing and planning for reliability and related program efforts; and 4) identify design features which are critical to reliability.

Repair Level Analysis (RLA). The basic decisions about: 1) Repair vs. throwaway; 2) the most desirable repair posture for reparable units to the lowest level between a single point depot repair capability and multiple base levels [17:580].

Rough Order of Magnitude (ROM). A contractor's rough estimate of cost for a given service or piece of equipment. Not a detailed cost breakdown, but a top-level cost only. Not contractually binding.

APPENDIX B

INTERVIEW PACKAGE

DEPARTMENT OF THE AIR FORCE
AIR FORCE INSTITUTE OF TECHNOLOGY (ATC)
WRIGHT-PATTERSON AIR FORCE BASE, OH 45433

13 JUN 1983

REPLY TO ATTN OF: LS

SUBJECT: Interim Contractor Support/Design Stability Study

TO: HQ AFALD/SDF SDB SDL SDS SDA SDR

1. AFR 800-21 (26 September 1978) defines interim contractor support (ICS) as "a cost-effective logistics support alternative" which "allows the Air Force to defer investment in all or part of the support resources . . . and to use contractor support while the organic capability is being phased in." ICS refers only to the use of a contractor in two situations: (a) The items to be supported or the items of support equipment have an unstable design; (b) All or part of the resources required to establish an organic capability will not be available until after operational support is first required. For contractor support to be described as ICS in either situation, it must have been subjected to rigorous cost and risk analyses.

2. Recent government and industry studies have determined that design stability from a logistics supportability standpoint is relatively undefined, and that cost and risk analyses as required by AFR 800-21 are not well documented by program offices. Ms. Debra Good, a graduate student in the School of Systems and Logistics, AFIT, is preparing a thesis on the topic of design stability as it relates to logistics supportability decisions. She will contact you within the next week to arrange an interview at your convenience. Your thoughtful advance preparation of the attached interview guide will facilitate the interview. Responses will be kept confidential, and names will not be used in data analyses or conclusions.

3. Prior to attending AFIT, Ms. Good managed ICS for the B-52 Offensive Avionics System. After completing the graduate program at AFIT, she will return to AFALD/SD, where she has been a logistics manager for five years. She has the full cooperation and support of AFALD/SD in her thesis effort. Your cooperation will be greatly appreciated by Ms. Good, AFIT, and AFALD/SD.

JEROME G. PEPPERS, JR.
Associate Dean
School of Systems and Logistics

1 Atch
Questionnaire

1st Ind, AFALD/SD 13 June 1983

I heartily endorse this thesis effort, and request your full cooperation and support.

ROBERT L. OWEN
Assistant Deputy for Aeronautical Programs
Air Force Acquisition Logistics Division

AIR FORCE—A GREAT WAY OF LIFE

INTERVIEW GUIDE FOR DESIGN STABILITY STUDY

According to AFR 800-21, ICS has a specific meaning and refers only to the use of a contractor in the two situations described below.

a. Situation 1. The items to be supported or items of support equipment have an unstable design; moreover, the projected cost of setting up an organic capability at the time operational support is first required is excessive, either because of uncertainties in the type and level of support required, or because of the risk that support resources will become obsolete if procured too early. For contractor support to be described as ICS in this situation, it must have been planned at least budget lead time away and have been subjected to rigorous cost and risk analyses.

b. Situation 2. All or part of the resources required to establish an organic capability will not be available until after operational support is first required. In this situation, the system development, production, and deployment phases do not allow enough time to develop the support resources before organic support is needed. (The most common example of this situation is the sequential phasing of automatic test equipment development, which generally lags development of the system it supports.) In Situation 2, as in Situation 1, to qualify as ICS, early planning and analyses must occur.

Under the ICS concept, the Air Force conducts risk analyses and other evaluations through the logistics support analysis (LSA) process, to identify potentially unstable design items and items having potentially high initial support costs. Through these analyses, it identifies those areas where it may be beneficial to use a contractor for logistics support during the early deployment phase. The Air Force then selects and plans the most feasible and practical alternative for providing responsive logistics support for the item when it is first introduced into the operational force.

Risk analysis is "an analysis that evaluates expected performance (cost, schedule, or technical) as compared with desired performance, with a view toward determining the probability that requirements will be met within available resources. This includes identifying the areas of uncertainty, assessing the probabilities, analyzing to determine the driving or dominant parameters, evaluating funding alternatives, making trade off studies, and making decisions on course(s) of action."

An unstable design is "a design that has a high potential for change and may require more engineering in order to meet the design specification requirements for operational performance, producibility, maintainability, or reliability. Design stability considerations include determination or confirmation of the equipment failure mode and effects pattern under normal operating circumstances."

INTERVIEW GUIDE FOR DESIGN STABILITY STUDY

1. Design instability is often cited as a reason for using interim contractor support (ICS). How would you define design stability vs. instability as it relates to such a decision, and to logistics supportability of a new/modified weapon system?

2. Do any of the following items have an effect on the date at which a weapon system achieves logistics supportability? If so, please indicate whether the effect is significant or minimal. Include any additional items that may affect logistics supportability under "other". Please rank according to impact (1 = most impact, etc.). Ties are allowed if necessary.

	Priority	Impact	
		Sig	Min
a. Number and timeframe of engineering change proposals (ECPs).	____	____	____
b. Validation of logistics support elements.	____	____	____
c. Length of conceptual phase.	____	____	____
d. Length of full scale development (FSD) phase.	____	____	____
e. Concurrency of FSD and production programs.	____	____	____
f. Complexity of equipment (i.e., leading edge of technology)	____	____	____
g. Initial operational capability (IOC) date.	____	____	____
h. First article delivery date.	____	____	____
i. Support equipment development.	____	____	____
j. Critical design review (CDR) date	____	____	____
k. Functional configuration audit (FCA) date.	____	____	____
l. Physical configuration audit (PCA) date.	____	____	____
m. Other (please specify) ______________________	____	____	____

3. What is the effect on the following of a delay in reaching design stability? Indicate significant, minimal, or none.

	1-3 month slide			3+ month slide		
	sig	min	none	sig	min	none
a. Support equipment requirement document (SERD) development	___	___	___	___	___	___
b. Support equipment development	___	___	___	___	___	___
c. Support equipment delivery	___	___	___	___	___	___
d. Technical document preparation	___	___	___	___	___	___
e. Interim contractor support (ICS)	___	___	___	___	___	___
f. Logistics support analysis (LSA)	___	___	___	___	___	___
g. Training equipment development	___	___	___	___	___	___
h. Training development	___	___	___	___	___	___
i. Spares computations (provisioning)	___	___	___	___	___	___
j. Spares delivery dates	___	___	___	___	___	___
k. Organic capability date	___	___	___	___	___	___
l. Life cycle costs (LCC)	___	___	___	___	___	___
m. Other (please specify) ______________________	___	___	___	___	___	___

4. One technique currently used to assess design stability is a trend analysis of engineering change proposals (ECPs). Please identify any other techniques which you have used (or are aware of) for assessing the design stability of a weapon system from a logistics supportability viewpoint.

5. Prior to making a decision to use ICS, AFR 800-21 requires "rigorous cost and risk analyses" to support such a decision. Can you comment on the adequacy of techniques available to perform such analyses?

6. What techniques have you employed in the past to perform such analyses?

7. Please list all such techniques with which you are familiar and rank them according to how effective you believe them to be. (1 = most effective, etc.)

8. The previous seven questions have addressed the point of design stability vs. instability as it relates to decisions about the use of ICS. Would you care to comment on the feasibility of establishing such a point, and on its usefulness in making such decisions?

9. For programs with which you are familiar, which of the two situations described in AFR 800-21 resulted in a requirement for ICS? (Please include all programs with which you are familiar.)

10. Do you have any additional comments on this subject?

APPENDIX C

INTERVIEW FORMAT

AD-A135 000 AN ANALYSIS OF THE FEASIBILITY OF USING DESIGN STABILITY AS A DECISION PA..(U) AIR FORCE INST OF TECH WRIGHT-PATTERSON AFB OH SCHOOL OF SYST.. D E GOOD 2/2

UNCLASSIFIED SEP 83 AFIT-LSSR-84-83 F/G 15/5 NL

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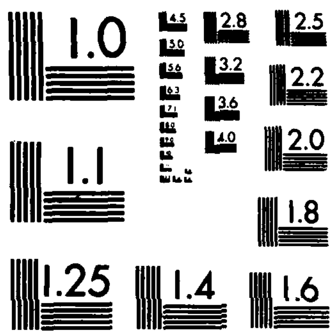


MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

1. How many years of logistics management experience do you have?

2. How many years of experience do you have involving the management of ICS?

3. How many ICS programs have you been involved with?

4. What types of weapon systems were they? (Please list all types.)

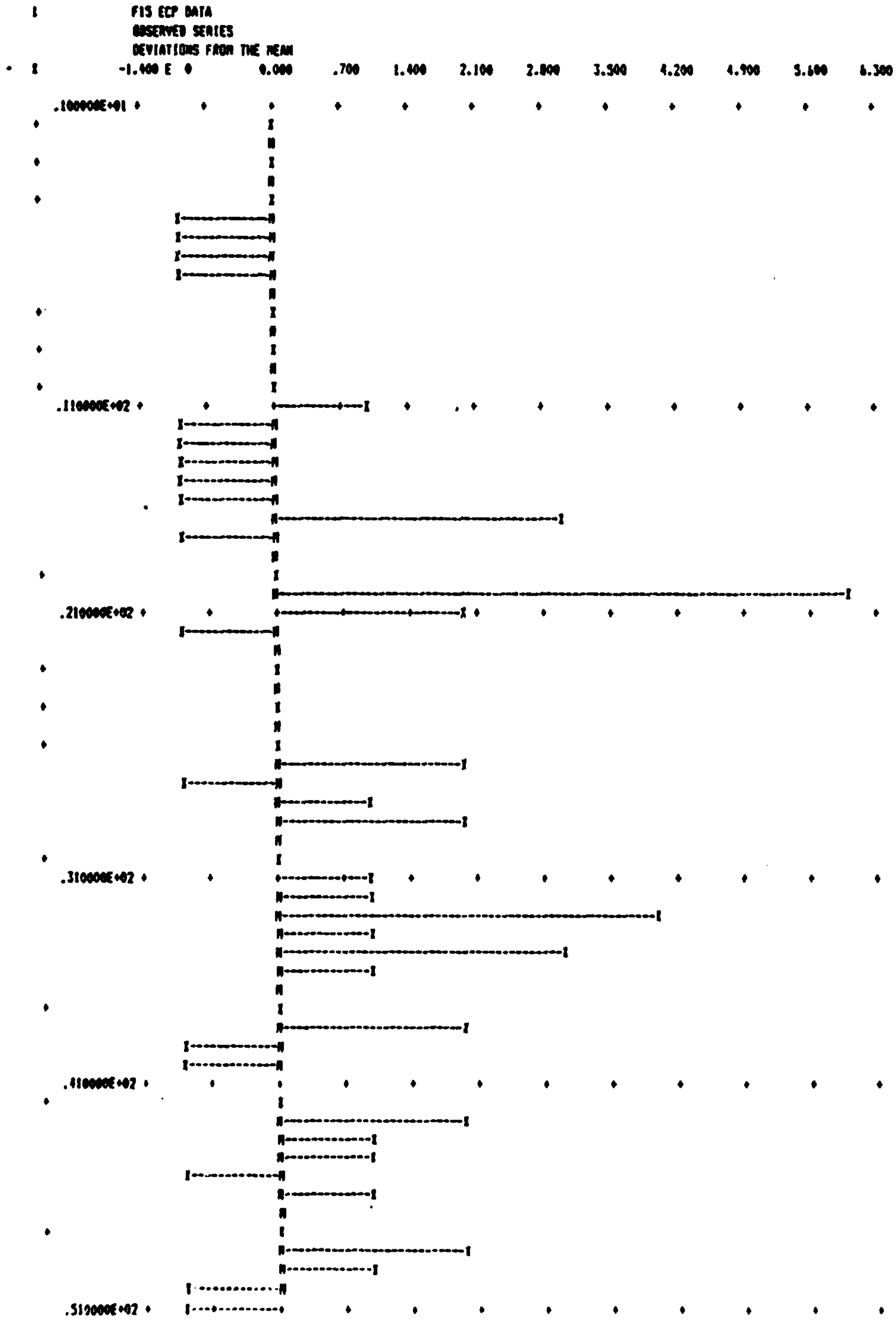
5. Now, I'd like to simply follow the interview guide worksheet and discuss your responses to those questions. I'd like to keep your completed worksheet when we are through. If you have any questions about the worksheet, please ask them as we get to the appropriate point.

(Begin worksheet questions)

6. What is your response to question number _____ on the worksheet?

APPENDIX D

ECP TREND ANALYSIS
COMPUTER DIAGNOSTICS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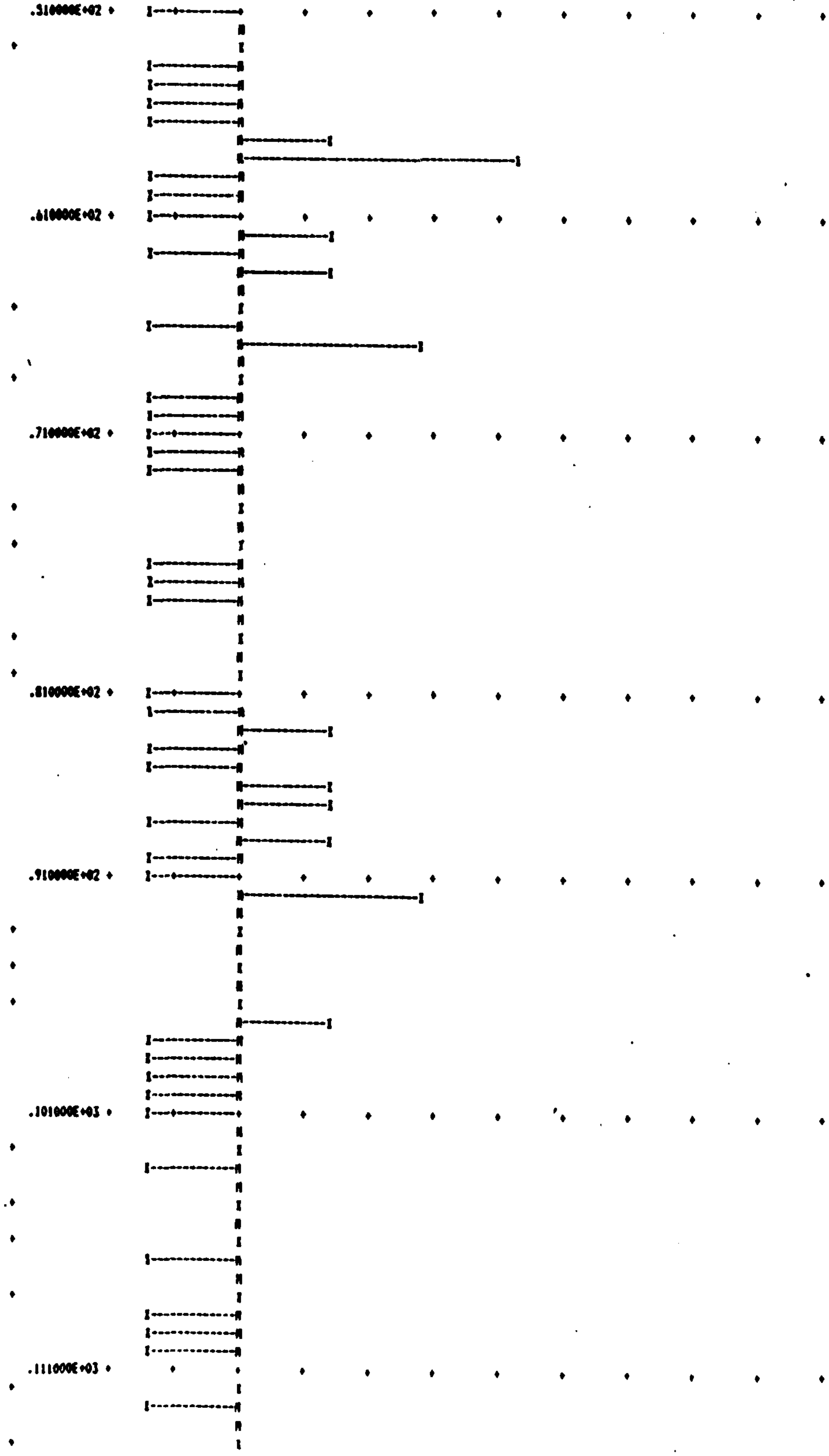
F-15 ECP DATA OBSERVED SERIES
DEVIATION FROM THE MEAN continued



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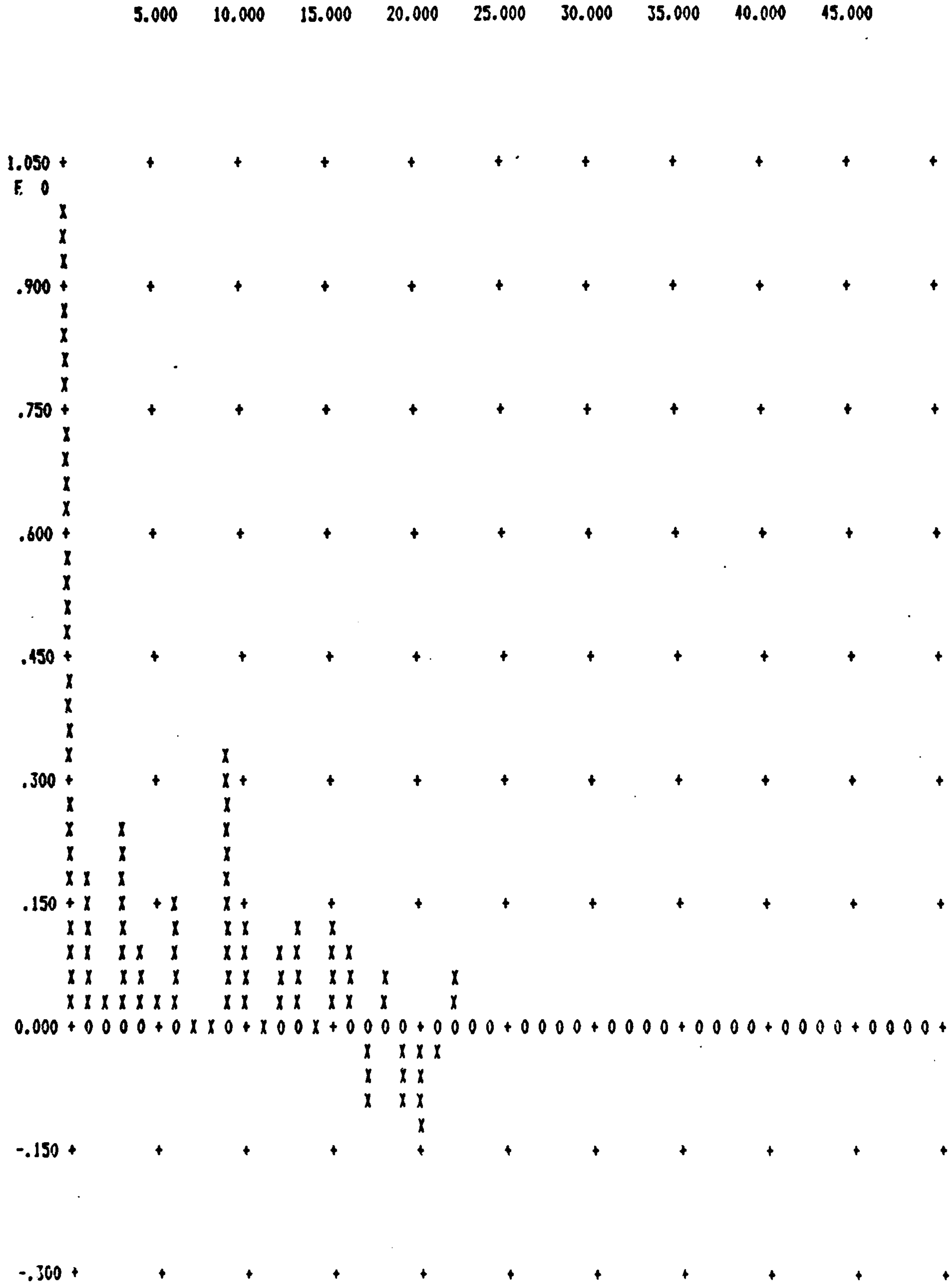

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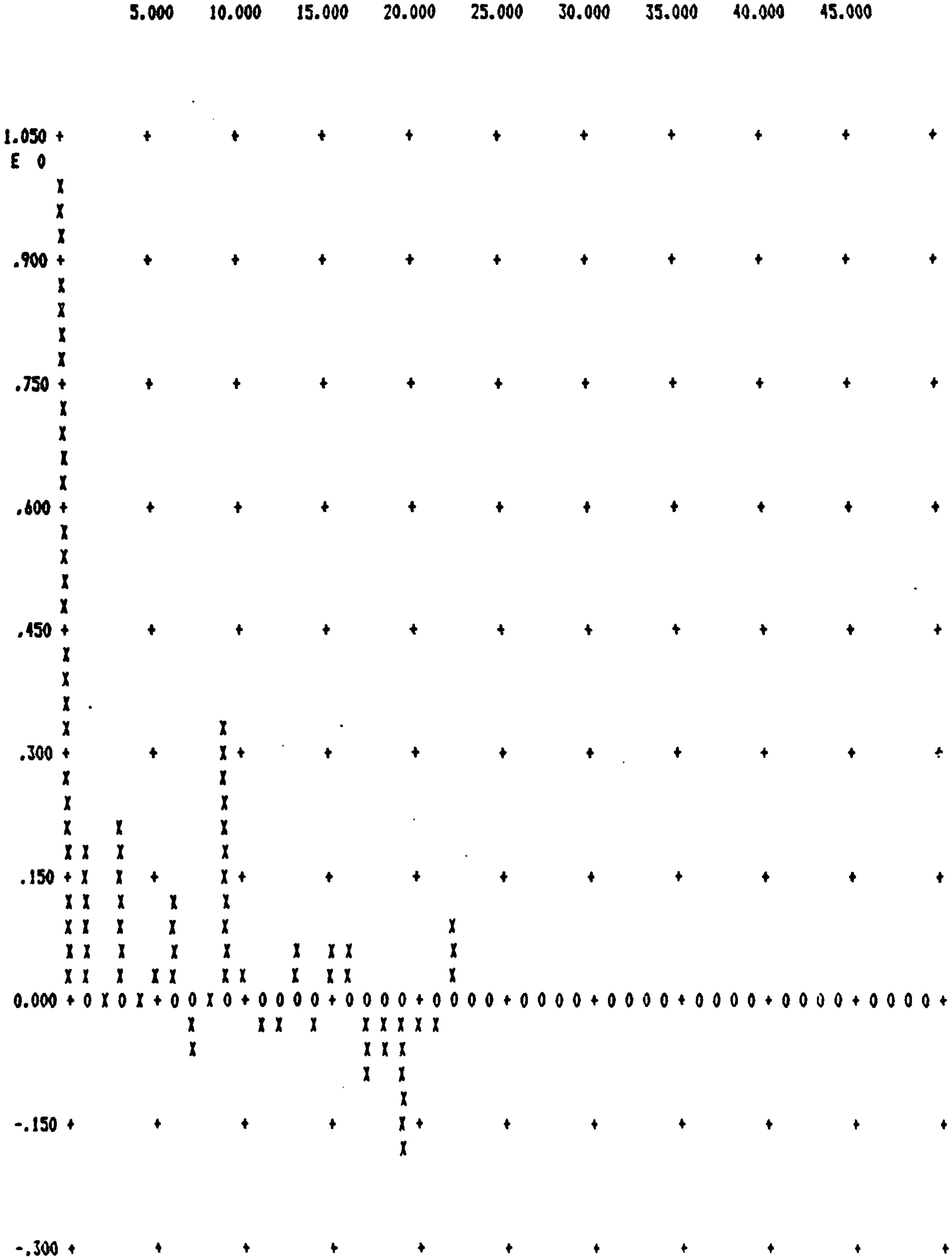

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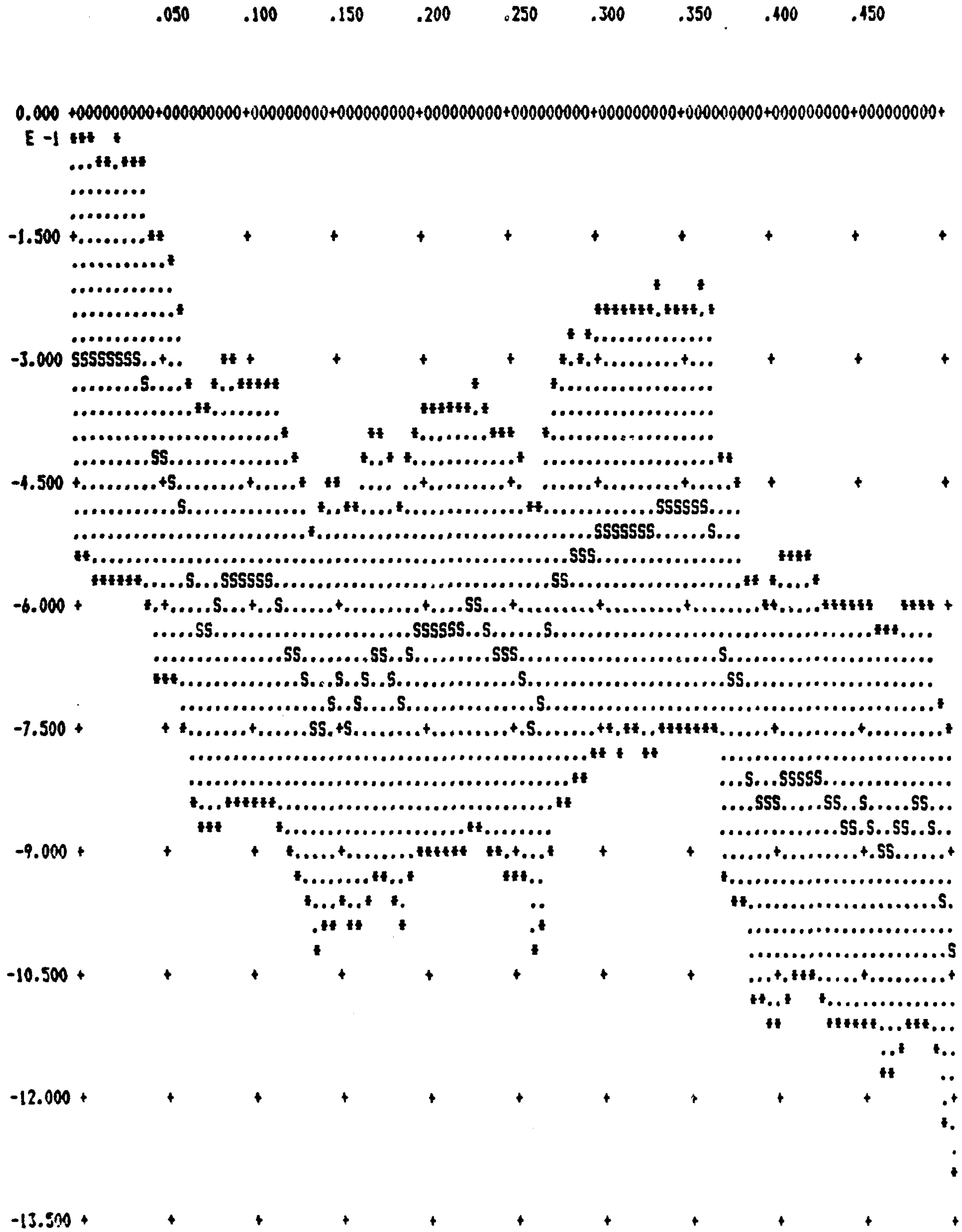

F-15 FINAL MODEL

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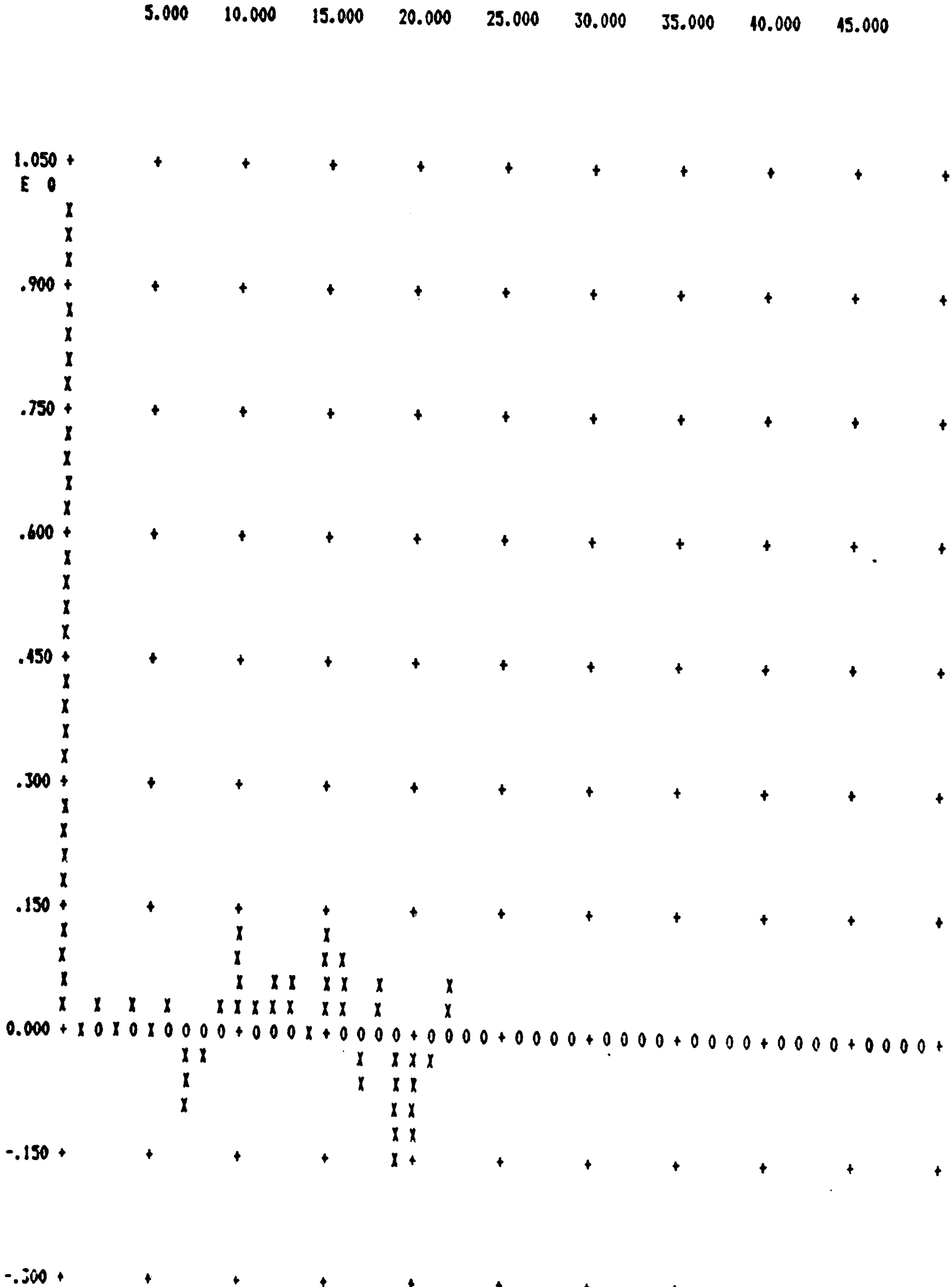

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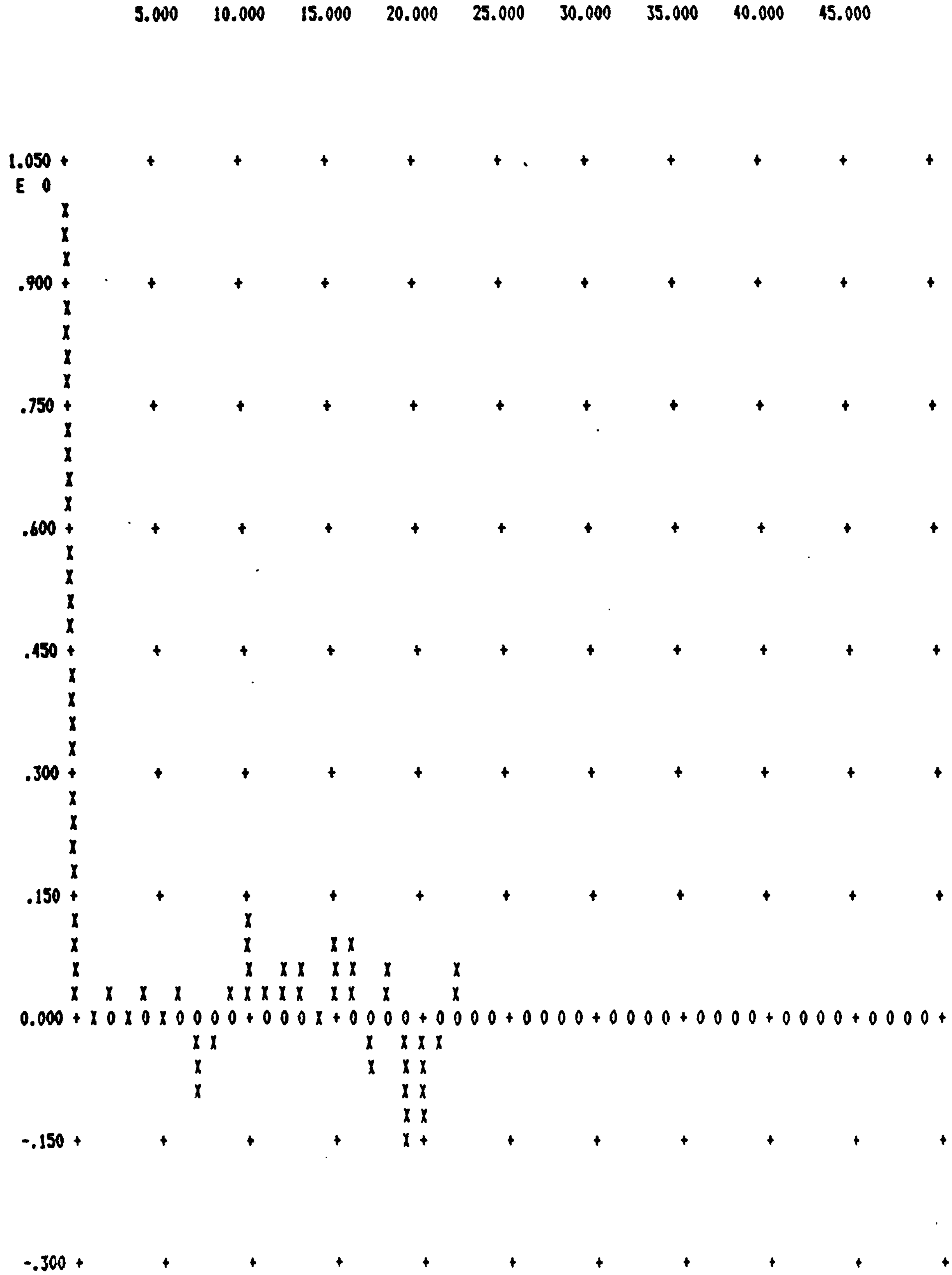

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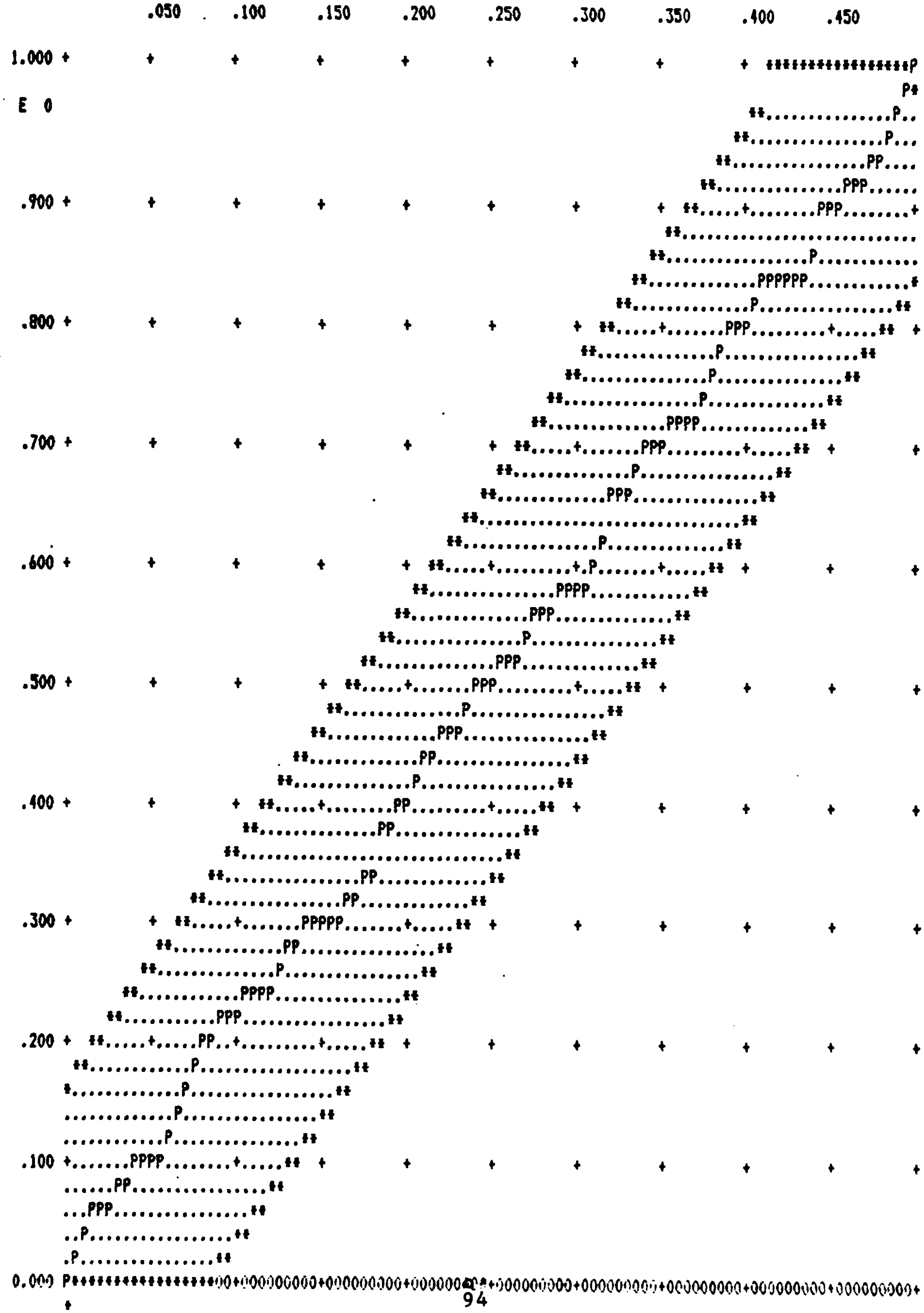
CUMULATIVE PERIODOGRAM .1 PROBABILITY LIMITS



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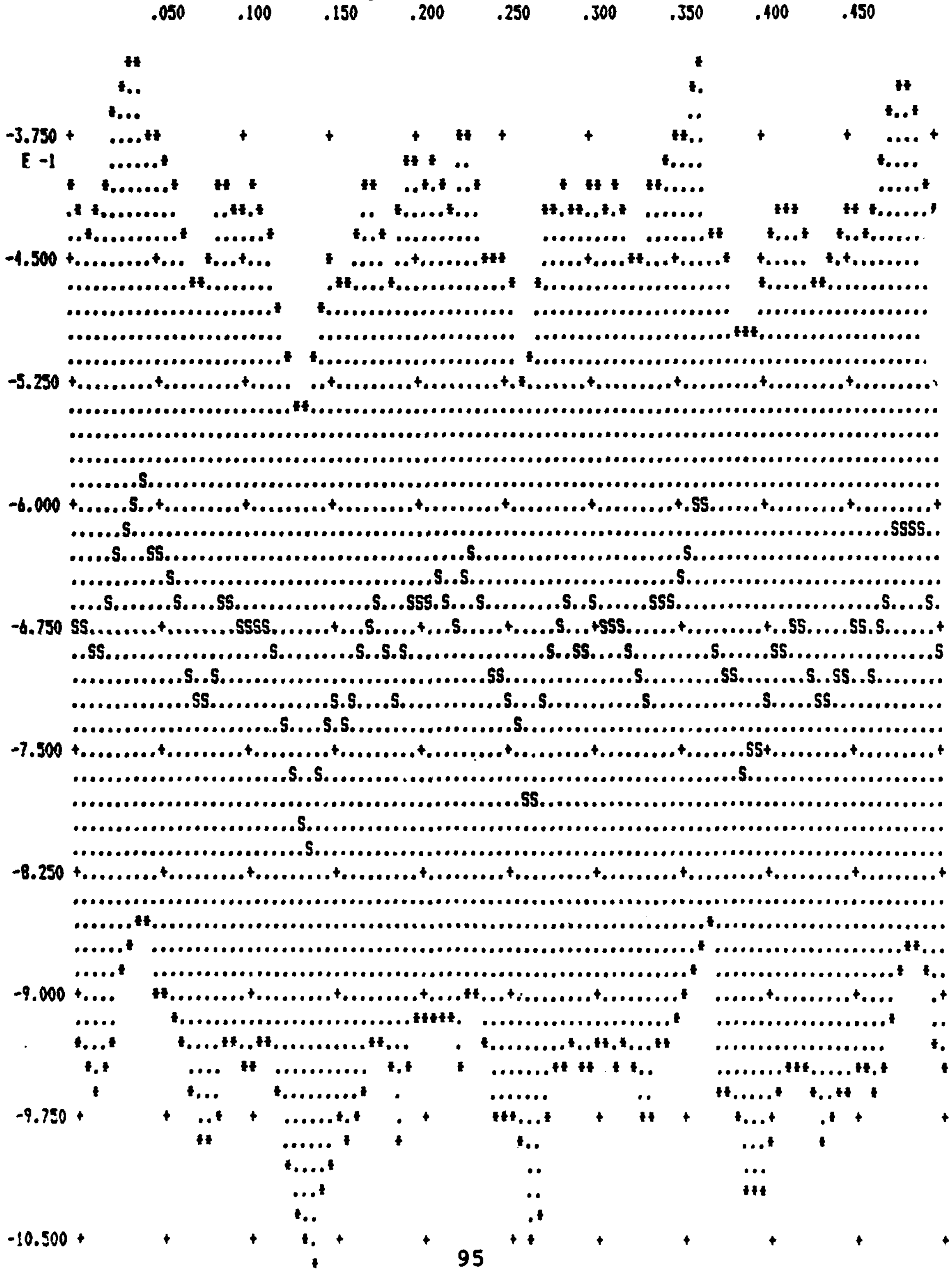

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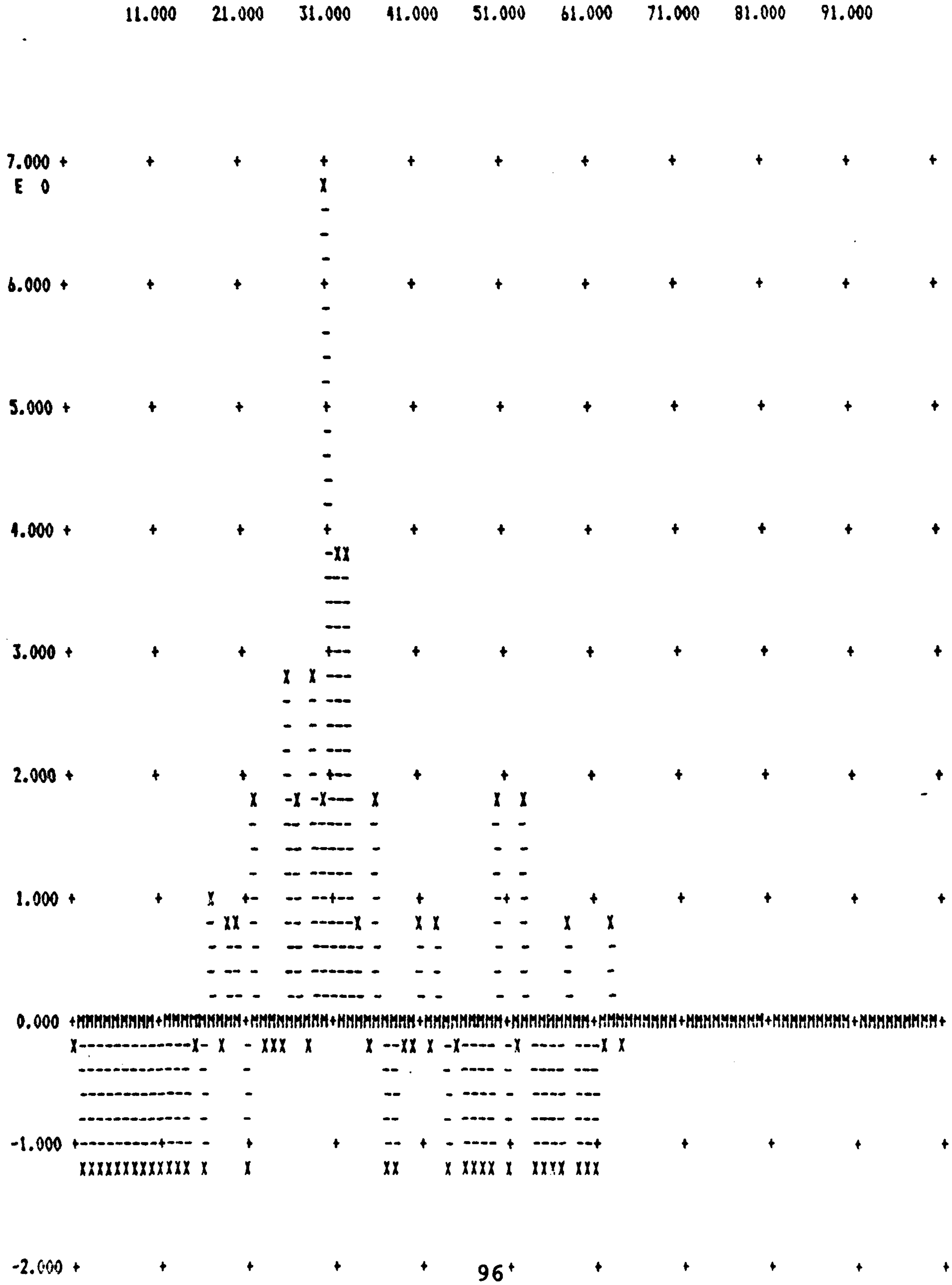

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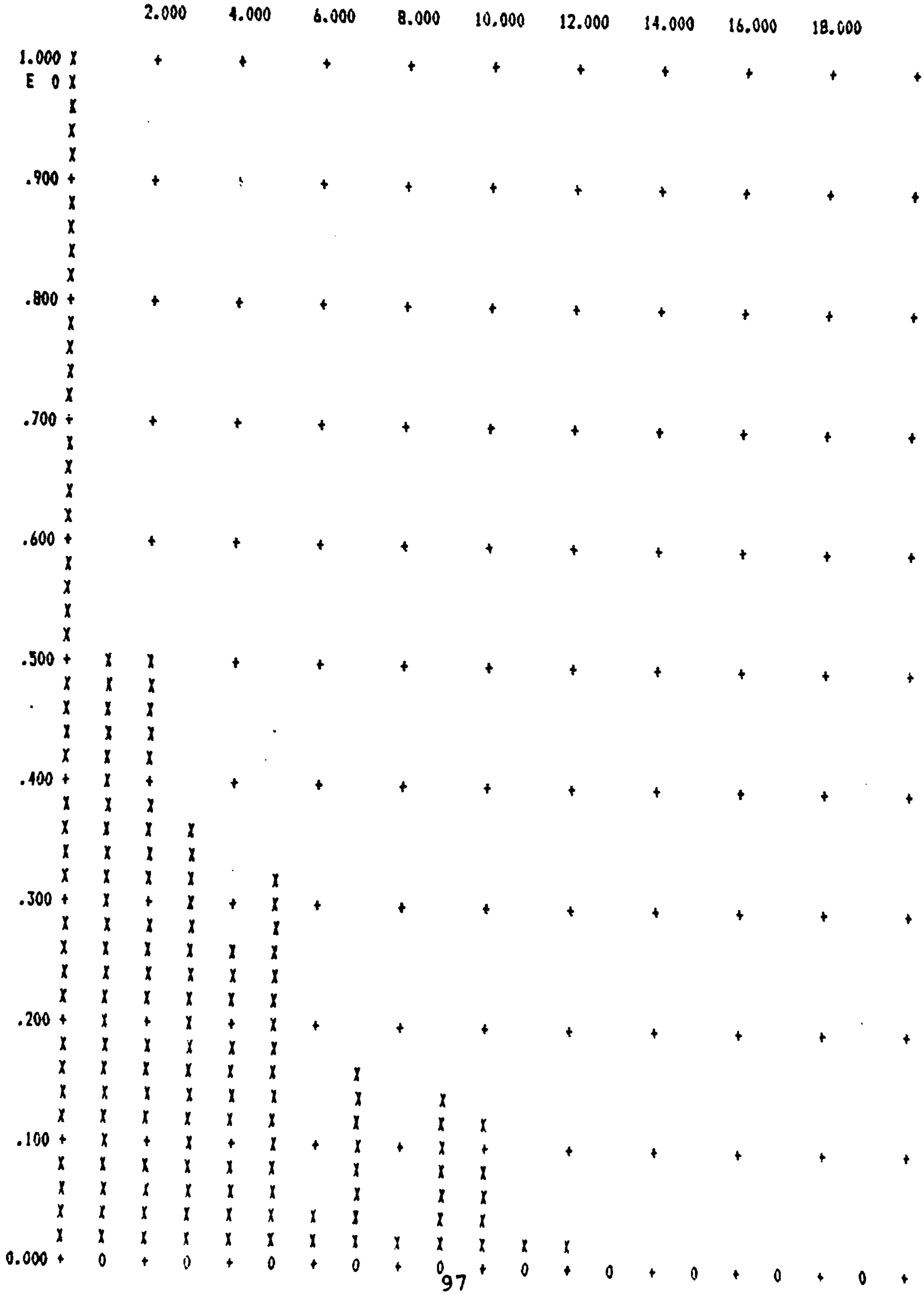

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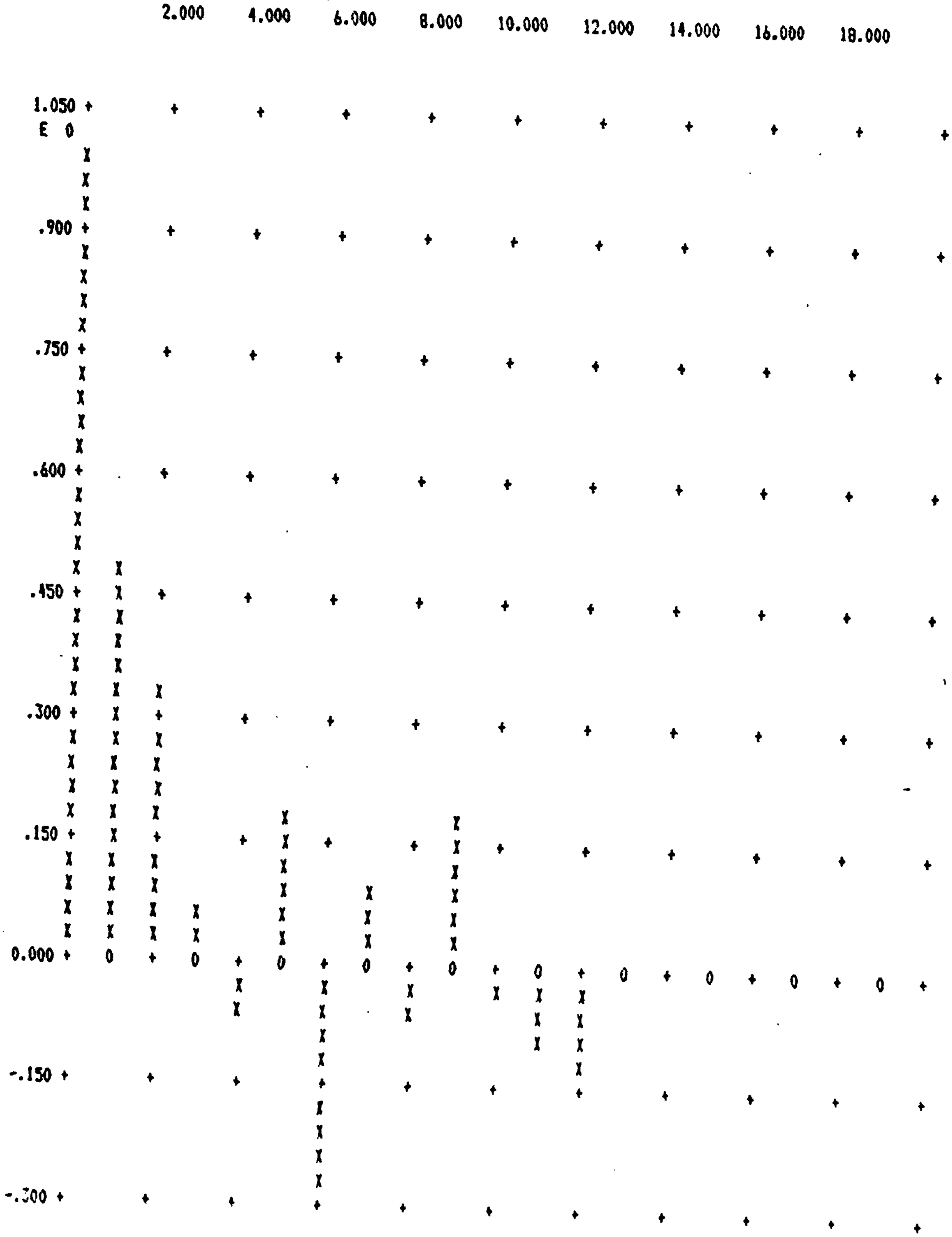

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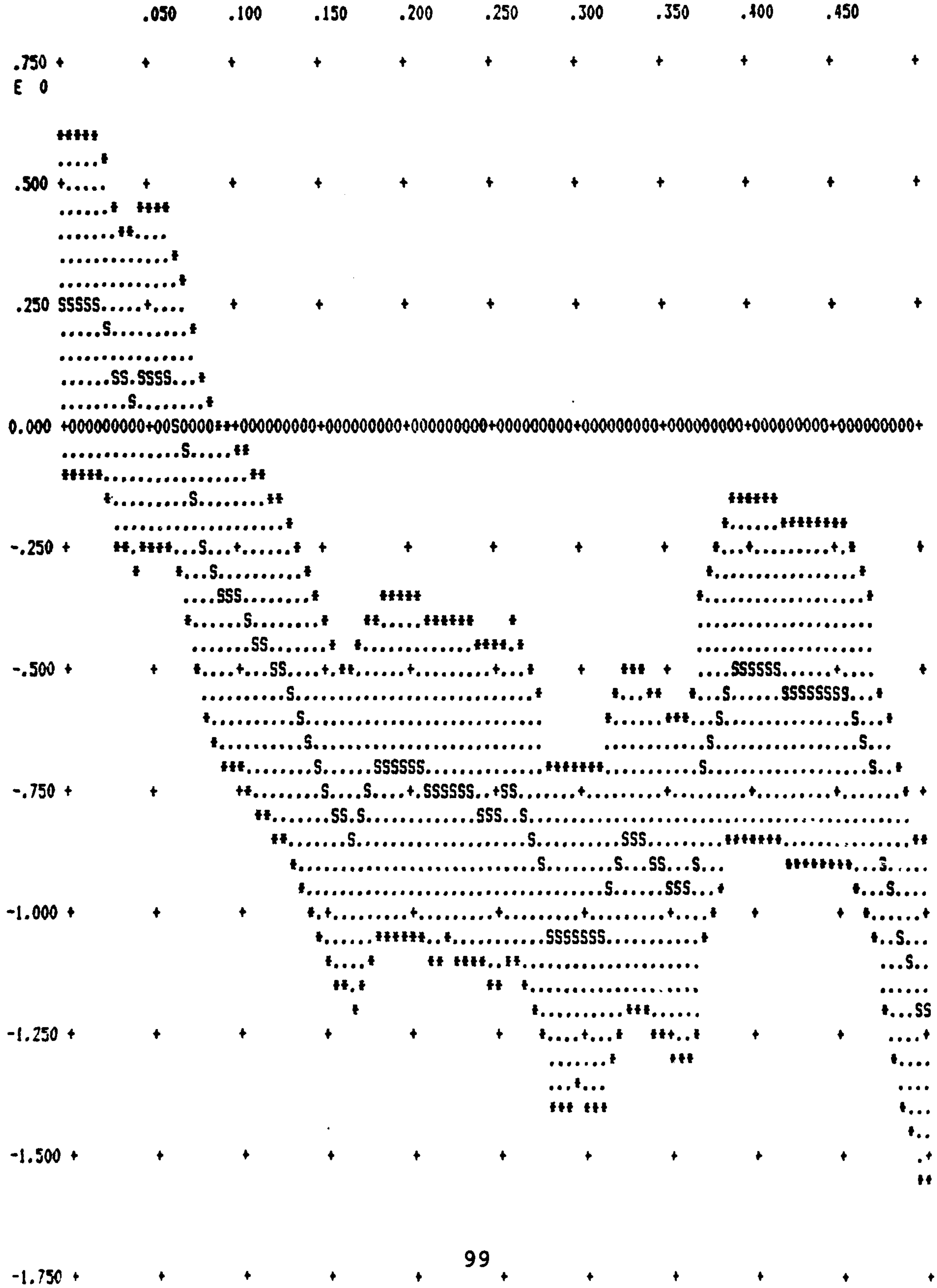

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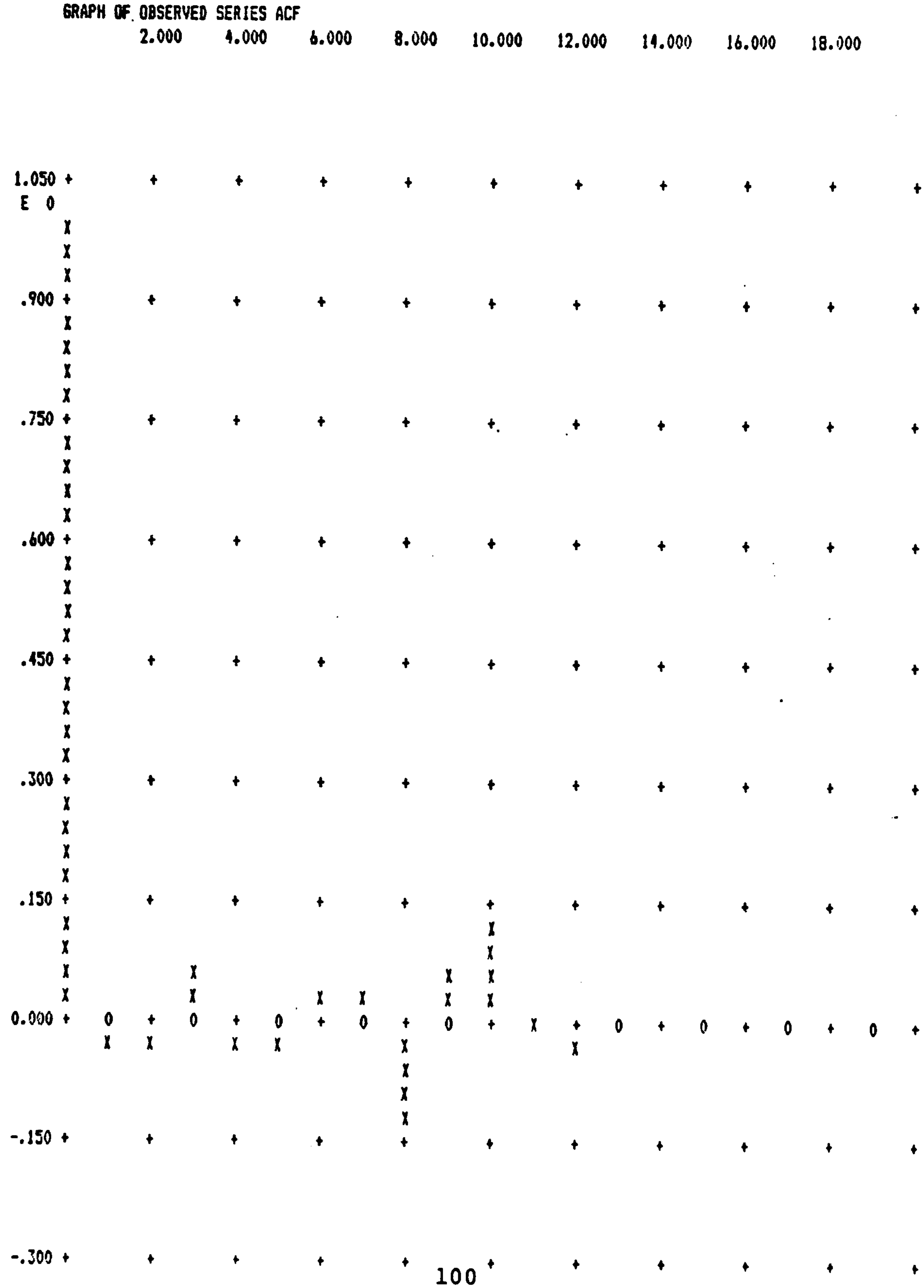

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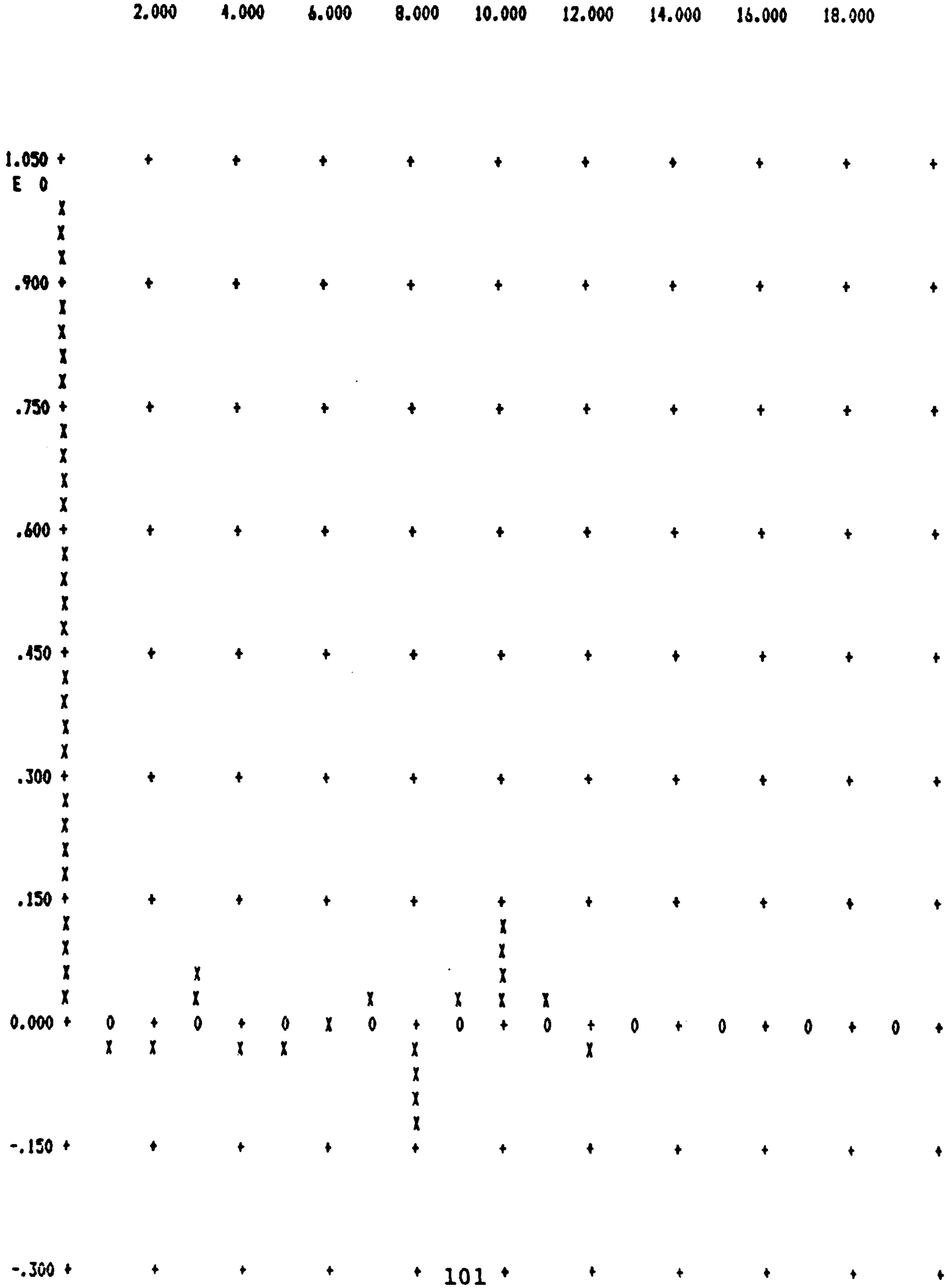
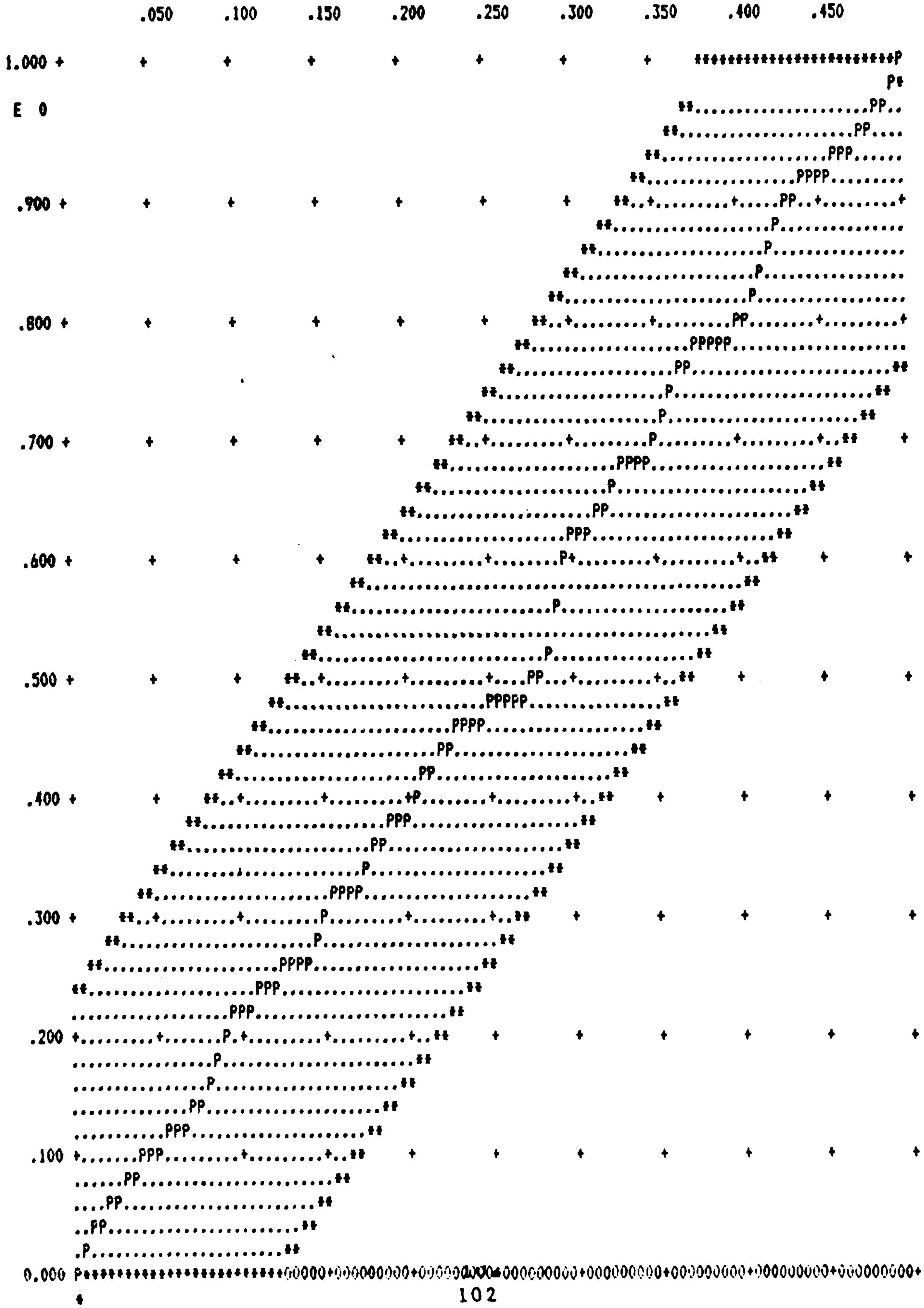
GRAPH OF OBSERVED SERIES PACF



F-16 FINAL MODEL
CUMULATIVE PERIODOGRAM .1 PROBABILITY LIMITS



F-16 FINAL MODEL

PREWHITENED F16 ECP DATA

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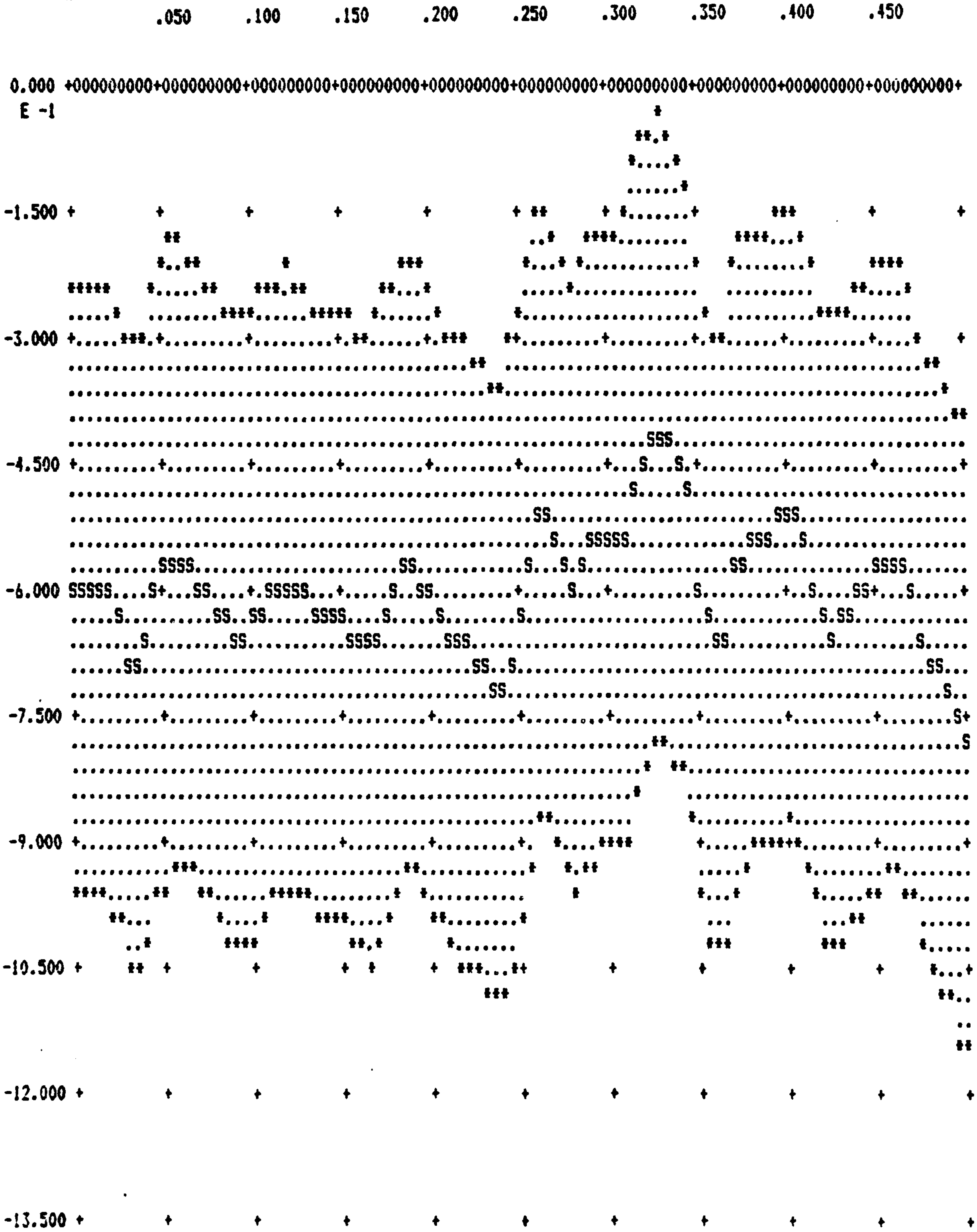

APPENDIX E

RESPONSES TO INTERVIEW QUESTIONS

Demographic Data

Question	Subject										
	A	B	C	D	E	F	G	H	I	J	K
1. How many years of logistics management experience do you have?	18	14	5	20	3	1	6	20	4	40	25
2. How many years of experience do you have involving the management of ICS?	3	6	1	3	3 mo.	2 mo.	1½	3	1	15	10
3. How many ICS Programs have you been involved with?	5	3	1	6	1	1	2	5	1	3	7
4. What types of weapon systems were they? Please list all types.											
Aircraft System Level	4	1	1	-	1	-	1	2	1	3	1
Major Subsystem Level (i.e., Avionics, etc.)	1	1	-	6	-	1	1	3	1	-	6
Support Equipment	-	1	1	-	-	-	-	5	1	3	6

Question 1

Design stability is often cited as a reason for using interim contractor support (ICS). How would you define design stability vs. instability as it relates to such a decision, and to logistics supportability of a new/modified weapon system?

Responses	Number
Design specifications met	4
Pass PRQT	1
AAA Report parts count	1
State of the art technology	3
CDR	3
PCA	2
PMRT	1
No specific milestone	3

Question 2

Do any of the following items have an effect on the date at which a weapon system achieves logistics supportability? If so, please indicate whether the effect is significant or minimal. Include any additional items that may effect logistics supportability under "other." Please rank according to impact (1 = most impact, etc.). Ties are allowed if necessary.

	Priority											Impact	
Question	1	2	3	4	5	6	7	8	9	10	11	Sig	Min
Number and timeframe of engineering change proposals (ECPs)	3	2	1	-	1	1	-	1	-	-	-	7	2
Validation of logistics support elements	2	-	-	2	3	1	-	-	-	-	-	6	2
Length of conceptual phase	-	-	-	-	2	2	1	-	1	-	-	1	6
Length of full scale development (FSD) phase	2	2	2	2	-	-	-	-	-	-	-	7	1
Concurrency of FSD and production programs	6	1	1	-	1	-	-	-	-	-	-	8	1
Complexity of equipment (i.e leading edge of technology)	5	3	-	1	-	1	1	-	-	-	-	9	2
Initial operational capability (IOC) date	3	2	-	3	2	-	-	-	-	-	-	8	3
First article delivery date	3	1	-	3	2	-	-	-	-	-	-	6	4

Question 2 continued

Question	Priority 1	2	3	4	5	6	7	8	9	10	11	Impact Sig	Min
Support equipment development	3	3	-	3	2	-	-	-	-	-	-	9	1
Critical design review (CDR) date	1	1	1	1	-	1	2	1	-	-	-	3	4
Functional configuration audit (FCA) date	-	-	4	-	-	1	1	-	1	1	-	3	4
Physical configuration audit (PCA) date	-	-	3	1	-	2	-	-	-	1	1	4	4
Other (please specify)													
Funding/Congressional action	3	-	-	-	-	-	-	-	-	-	-	3	-
Software support	-	1	-	-	-	-	-	-	-	-	-	1	-
Spares support	-	-	1	-	-	-	-	-	-	-	-	1	-
Technical data schedules	1	-	1	-	-	-	-	-	-	-	-	2	-
Training availability	1	-	1	-	-	-	-	-	-	-	-	2	-
Support equipment support	-	-	1	-	-	-	-	-	-	-	-	1	-
Reliability program	1	-	-	-	-	-	-	-	-	-	-	1	-
Facilities	1	-	-	-	-	-	-	-	-	-	-	1	-

Question 3

What is the effect on the following of a delay in reaching design stability? Indicate significant, minimal, or none.

Responses	1-3 Month Slide Sig	1-3 Month Slide Min	1-3 Month Slide None	3+ Month Slide Sig	3+ Month Slide Min	3+ Month Slide None
Support equipment requirement document (SERD) development	3	5	3	7	1	2
Support equipment development	4	6	1	9	1	1
Support equipment delivery	6	7	0	10	1	0
Technical document preparation	4	7	0	10	1	0
*Interim contractor support (ICS)	5	6	1	9	0	1
Logistics support analysis (LSA)	2	6	3	4	4	2
Training equipment development	2	8	1	8	2	1
Training development	0	8	3	6	4	2
Spares computations (provisioning)	5	5	1	9	2	0
Spares delivery dates	3	0	2	9	1	1
*Organic capability date	5	5	2	11	1	1
Life cycle costs (LCC)	4	6	1	7	2	1
Other (please specify)						
Software development	1	2	0	3	0	0
CS/PA	0	0	1	1	0	0
Support equipment support	1	0	0	1	0	0

* One subject gave separate responses for intermediate and depot level impacts.

Question 4

One technique currently used to assess design stability is a trend analysis of engineering change proposals (ECPs). Please identify any other techniques which you have used (or are aware of) for assessing the design stability of a weapon system from a logistics supportability viewpoint.

Responses	Number
Parts counts	2
Number of T.O. pages	1
SMR code changes	1
Reliability analysis/mature MTBF	3
CDR	2
AAA Report	1
National stock number changes	2
SRU/Circuit card changes	1
Contractor analysis	1
LSA	2
Life cycle cost analysis	1
Maintenance level analysis (MLA)	1
Dialogue with contractor	1
Software milestones met	2
Tracking recurring costs	2
Don't need analysis (pre-plan ICS option)	1
Not aware of any	2

Question 5

Prior to making a decision to use ICS, AFR 800-21 requires "rigorous cost and risk analyses" to support such a decision. Can you comment on the adequacy of techniques available to perform such analyses?

Responses	Number
Adequate techniques available	5
LSA adequate	2
LCC adequate	2
Cost analyses adequate	1
Contractor trade studies adequate	2
AFALD staff helpful	1
ALC analyses helpful	1
Lack of data/incomplete information, becomes a guess	1
Inadequate	4
Spares computations always too low	2
Unit cost/flying hours or weight inadequate, irrelevant	1
Not as good as good management techniques	1
Don't need if ICS a pre-planned option	2
AFR 800-21 provides inadequate guidance	2

Question 6

What techniques have you employed in the past to perform such analyses?

Responses	Number
Contractor trade studies (ICS vs. additional spares)	1
Unit cost/flying hours or weight	1
Contractor ROM ($ value of new equipment)	2
ICS vs. 100% NRTS	3
ALC reliability factors, repair cycle flow	2
Mature MTBF vs. AAA Report	1
Regression analysis of reliability growth	2
Duane-Codier growth curves	1
Cost analysis	5
AFALD staff support	1
Pre-plan ICS as option in lieu of analysis	4
LSA	1
LCC	1
RLA	1
MEA	1

Question 7

Please list all such techniques with which you are familiar and rank them according to how effective you believe them to be. (1 = most effective, etc.)

Responses	Rank 1	2	3	4
Contractor ROMS	1	-	1	-
Cost analyses	1	3	1	-
Schedule evaluation	-	1	-	-
ICS vs. 100% NRTS	3	-	-	-
ALC analyses	-	-	-	1
NSN assignments	1	-	-	-
Part number changes	-	1	-	-
LCC	1	-	-	-
RLA	-	2	-	-
Parametric costing	-	-	1	-
LSA	2	-	-	-
ICS a pre-planned option	1	-	-	-
*Don't believe in them	-	-	-	-

* No rank given

Question 8

The previous seven questions have addressed the point of design stability vs. instability as it relates to decisions about the use of ICS. Would you care to comment on the feasibility of establishing such a point, and on its usefulness in making such decisions?

Responses	Number
Selection of a point is arbitrary	1
Interdependencies too great	1
Meeting specification MTBF (useful contractual incentive)	2
Competition is key	1
Pre-planning for ICS is necessary	3
Lack of support resources is the real driver	3
Later into development that design stability occurs, greater the impact	1
Design stability is overstressed	3
Aid to assess likelihood of ICS need	1
Too late to be used to plan for ICS (Too late to be cost effective)	3
Design instability drives situation	2

Question 9

For programs with which you are familiar, which of the two situations described in AFR 800-21 resulted in a requirement for ICS? (Please include all programs with which you are familiar.)

Responses	Number
Situation 1	1
Situation 2	18
Both	6

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