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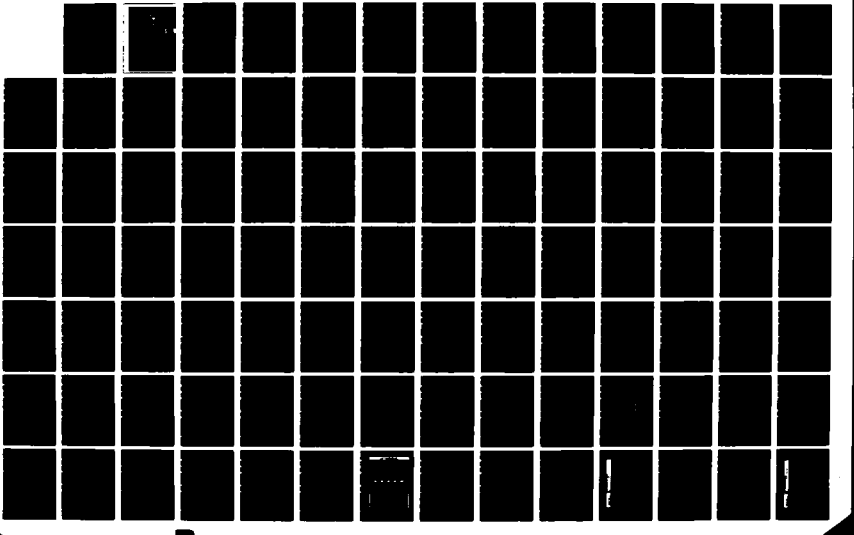

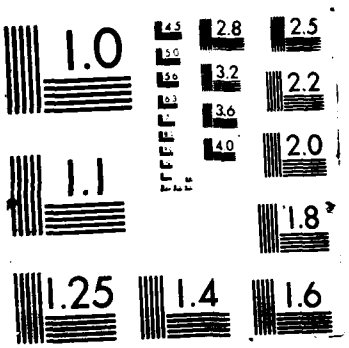
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USING THE LOGISTICS ASSESSMENT METHODOLOGY PROGRAM FOR SUPPORTABILITY ANALYSIS DURING ACQUISITION: A CASE STUDY OF THE F-15E AN/ALQ-135 SELF-PROTECTION JAMMER

THESIS

Gaylen L. Tovrea
Captain, USAF

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DEPARTMENT OF THE AIR FORCE
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USING THE LOGISTICS ASSESSMENT METHODOLOGY PROGRAM FOR SUPPORTABILITY ANALYSIS DURING ACQUISITION: A CASE STUDY OF THE F-15E AN/ALQ-135 SELF-PROTECTION JAMMER

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

Gaylen L. Tovrea, B.S.

Captain, USAF

September 1987

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Preface

The overall motivation for this study was the well-documented problem of assuring successful weapon system lifecycle supportability through acquisition-phase action. This thesis is more of a demonstration of one approach to this problem than it is a 'watertight' assessment of the aircraft subsystem chosen for analysis.

This research was far from a one-man endeavor. I would like to recognize my advisor, Lieutenant Colonel Robert D. Materna, who originally suggested a topic area which has proven to be both educational and challenging. I appreciate the patience of those who provided elements of primary data, as they were kind enough to interpret more than a few disoriented inquiries on my part. Sincere thanks are definitely in order to Dynamics Research Corporation engineers Kevin Deal and Eric Davis, without whose personal attention and assistance this effort would have unceremoniously ended some months ago. Finally, I wish to express my gratitude to my wife, Jeanie, who supported this undertaking and who provided encouragement daily by asking, 'Is it done yet?'

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List of Acronyms

AFALC:	US Air Force Acquisition Logistics Center of AFLC
AFLC:	US Air Force Logistics Command
AFR:	Air Force Regulation
AFSC:	US Air Force Systems Command
AFSC:	Air Force Specialty Code
AFWAL:	US Air Force Wright Aeronautical Laboratories
AIS:	Avionics Intermediate Station
ALPS:	Automated Logistics Provisioning System
AO:	Action Officer
ASD:	Aeronautical Systems Division of AFSC
ATE:	Automated Test Equipment
ATF:	Advanced Tactical Fighter
AUF:	Airborne Uninhabited Fighter
BCS:	Bench Check Serviceable
BIT:	Built-in-Test
CAD:	Computer Aided Design
CAL:	Computer Aided Logistics
CAM:	Computer Aided Manufacturing
CCA:	Circuit Card Assembly)
CDR:	Critical Design Review
CDS:	F-16 Central Data System
CERT:	Combined Environmental Reliability Test
CFD:	Contractor-Furnished Data
CMD:	Countermeasures Dispenser
CND:	Can Not Duplicate
CO:	Control Oscillator
CPFF:	Cost Plus Fixed Fee
CSIAC:	Combat Support Information and Analysis Center
CSNAS:	Computer Supported Network Analysis System
D-level:	Depot-level Maintenance
DCG:	Data Collection Guide (for LAMP/LAWS)
DFT:	Design For Testability

DOD:	Department of Defense
DODD:	Department of Defense Directive
DPML:	Deputy Program Manager for Logistics
DRC:	Dynamics Research Corporation
DRF:	Dual Role Fighter
DSARC:	Defense Systems Acquisition Review Council
DSS:	Decision Support System
DT&E:	Developmental Test & Evaluation
ECA:	Electronic Component Assembly
ESA:	Electronically Scanned Antenna
EW:	Electronic Warfare
EWWS:	Electronic Warfare Warning System
FFP:	Firm, Fixed Price
FIT:	Fault Isolate and Test
FMC:	Fully Mission-Capable
FPIF:	Fixed Price, Incentive Fee
FSD:	Full-Scale Development
GFD:	Government-Furnished Data
I-level:	Intermediate-level Maintenance
ICS:	Internal Countermeasures System
ILS:	Integrated Logistics Support
ILSP:	Integrated Logistics Support Plan
IOC:	Initial Operational Capability
JMSNS:	Justification for Major System New Start
LAMP:	Logistics Assessment Methods Program
LAWS:	Logistics Assessment Work Station
LCC:	Lifecycle Cost(s)
L&MM:	Logistics and Materiel Management
LRU:	Line-Replaceable Unit
LSA:	Logistics Support Analysis
METS:	Mobile Electronic Test Set
MLV:	Memory Loader/Verifier
MMH:	Maintenance Manhours
MSIP:	Multi-Stage Improvement Plan
MTBF:	Mean Time Between Failures

MTBM:	Mean Time Between Maintenance
NATO:	North Atlantic Treaty Organization
NCO:	Non-Commissioned Officers
NDSD:	Northrop Defense Systems Division
NRTS:	Not Repairable This Station
O-level:	Organizational Level Maintenance
O&S:	Operations and Support
OT&E:	Operational Test & Evaluation
PACAF:	Pacific Air Forces
PM:	Program Manager
PMD:	Program Management Directive
PMP:	Program Management Plan
POS:	Peacetime Operating Stock
P^3I:	Pre-Planned Product Improvement
QRC:	Quick Reaction Capability
R&D:	Research and Development
R&M:	Reliability & Maintainability
R&R:	Remove & Replace
RIP:	Repair-in-Place
RFA:	Radio Frequency Amplifier
RLG:	Ring Laser Gyroscope
RTOK:	Re-Test OK
RWR:	Radar Warning Receiver
SE:	Support Equipment
SOW:	Statement of Work
SPF:	Super Plastically-Formed
SPJ:	Self-Protection Jammer
SPO:	System Program Office
SRAM:	Short Range Attack Missile
SRU:	Shop-Replaceable Unit
TAC:	USAF Tactical Air Command
TCTO:	Time Compliance Technical Order
TEWS:	Tactical Electronic Warfare System
TISS:	TEWS Intermediate Support Set
TITE:	TEWS Intermediate Test Equipment

TWT:	Travelling Wave Tube
USAF:	United States Air Force
USAFE:	United States Air Forces, Europe
VHSIC:	Very High Speed Integrated Circuits
WR-ALC:	Warner Robins Air Logistics Center
WRSK:	War Readiness Spares Kit
WSR:	Weapon System Reliability

Abstract

The purpose of this research was to demonstrate how weapon system supportability can be assessed through the use of the Logistics Assessment Methodology Program (LAMP) during acquisition and modification. The F-15E's AN/ALQ-135 self-protection jammer was used as the subject aircraft subsystem in this qualitative and quantitative analysis.

Reliability and Maintainability (the main factors in system supportability), general F-15 program logistics objectives, and specific AN/ALQ-135 acquisition program projections are discussed as background information. LAMP is presented as a potentially helpful decision-making aid to be used in the pursuit of AN/ALQ-135 supportability goals. The LAMP framework is particularly appropriate for analysis, as it considers the five operational goals of the U.S. Air Force's 'R&M 2000 Action Plan' as performance criteria against which AFR 800-8's ten elements of Integrated Logistics Support are measured.

In this study, an existing standard LAMP research approach was 'tailored' to to the AN/ALQ-135 scenario. The two main thrusts of this adapted methodology are an investigation of the sensitivity of supportability goals with respect to design characteristic uncertainties and a determination of supportability goal impacts due to potential changes in operational and support environments.

Overall, the findings of this research indicate that the P^3I design offers significant supportability improvements over its predecessor, the Band 1/2 self-protection jammer. In particular, benefits in Survivability, Mobility, and Manpower accompany the new configuration. The P^3I design was found to be reasonably tolerant to posited deterioration in relevant logistics support elements. The most crucial variable was a measure of maintainability, base repair cycle time, which had major impacts on the R&M 2000 goals of Combat Capability and Survivability. With respect to operational and support environments, the availability of the P^3I ALQ-135 was nearly insensitive to reductions in spares levels. The cumulative effects of battle attrition reduced the importance of most supportability elements, and system capabilities remained high even in the advent of increased sortie demands.

LAMP was seen as a promising tool for supportability assessment. Several suggestions for improvements and extension of the program are listed. The thesis closes with three recommendations: further development of the LAMP concept, an objective comparison of LAMP relative to similar methodologies, and expansion of the idea of using LAMP as an educational aid.

USING THE LOGISTICS ASSESSMENT METHODOLOGY PROGRAM FOR SUPPORTABILITY ANALYSIS DURING ACQUISITION: A CASE STUDY OF THE F-15E AN/ALQ-135 SELF-PROTECTION JAMMER

I. Introduction

General Issue

Supportability is a weapon system characteristic which determines, to a large extent, the ability to meet mission requirements at low cost. Supportability depends heavily on reliability and maintainability, so much so that the term 'R&M' has become synonymous with supportability. In fact, Department of Defense (DOD) and US Air Force (USAF) R&M awareness has recently become so acute that in September 1984 and February 1985, Secretary of the Air Force Verne Orr and U.S. Air Force Chief of Staff Gen. Charles A. Gabriel issued to the major commands two joint memoranda concerning R&M. The September 1984 memorandum established the Air Force position on R&M:

> Everyone must insure reliability and maintainability requirements are met through every step of the [acquisition] process. Reliability and maintainability must be coequal with cost, schedule, and performance as we bring a system into the Air Force inventory (34:11).

The subsequent February 1985 memorandum was part of a follow-on initiative which became known as the Air Force's 'R&M 2000 Action Plan.'

Air Force Wright Aeronautical Laboratories (AFWAL) and Dynamics Research Corporation have developed a quantitative, computerized decision support system which is intended to assist in the integration of the Action Plan's supportability goals during system acquisition. This computer program, known as the Logistics Assessment Methodology Program (LAMP), analyzes weapon subsystem supportability cost/benefit issues. LAMP uses a matrix which treats five specific goals enumerated within the 'R&M 2000 Action Plan' as performance criteria against which the ten elements of Integrated Logistics Support from Air Force Regulation 800-8 are measured (26:Sec 2,5).

One subsystem which is typical of those which can be analyzed by LAMP is the AN/ALQ-135, the self-protection jammer component of the F-15's Tactical Electronic Warfare System (TEWS). The latest version of the AN/ALQ-135 is now under full-scale development for retrofit into the single-seat F-15C and for installation into the two-seat F-15E also under development. USAF Aeronautical Systems Division (ASD) manages the procurement of the new AN/ALQ-135.

Research Purpose

The purpose of this research is to demonstrate how weapon system supportability can be assessed through the

use of LAMP during acquisition and modification. The AN/ALQ-135 is used as the subject system for qualitative and quantitative analysis. In this manner, both an examination of AN/ALQ-135 supportability characteristics and an evaluation of LAMP utility is accomplished.

Investigative Steps

The following steps were undertaken in the course of this research effort:

1. Background events associated with this research (DOD and USAF R&M policies; supportability issues within the F-15 acquisition program; key aspects of the AN/ALQ-135 acquisition program; and the development, main features, and application of LAMP) were investigated.

2. The LAMP methodology was applied to the AN/ALQ-135 scenario, and representative AN/ALQ-135 data was developed.

3. LAMP outputs were produced, summarized, and interpreted in order to assess the supportability characteristics of the new AN/ALQ-135.

4. Positive and negative aspects of using LAMP as a decision support tool for supportability assessment were considered.

Chapter II is concerned with step 1. Step 2 is dealt with in Chapter III. Chapter IV covers steps 3 and 4.

Terminology

There are several terms in this thesis which are used with rather specific intended meanings. It is important at this point to clarify their context:

> Mission requirements: the wartime features of readiness, capability, and sustainability which make a system a credible deterrent and, if necessary, a valuable asset during conflict. (Mission requirements

may also be expressed as combat or operational effectiveness.) Mission requirements tend to be qualitative, but logistically they can be quantified in terms of number of requested sorties and so forth.

Performance requirements: those mission requirements which define a fully operational system's functionality. Desirable performance characteristics for an aircraft may include high maximum speed, short landing roll, and precision payload delivery. For an Electronic Warfare (EW) subsystem, high jamming power, versatile threat coverage, and low overall weight might be important. Traditionally, performance characteristics have been the driving considerations in weapon system acquisition.

Ownership costs: all total weapon lifecycle costs except acquisition (including research and development) and disposal costs. Ownership costs primarily consist of operations costs and support costs.

Operations costs: the portion of ownership costs which result from the rate of use of an asset (operations). One such cost is aircraft fuel costs, which are mostly factor-based, that is: Fuel cost = (Number of Flying Hours) multiplied by (Fuel cost per Flying Hour). For the most part, operations costs are indirectly determined by various acquisition-stage performance demands.

Support costs: the portion of ownership costs incurred by maintaining mission requirements. Supportability (maintenance and support) is influenced mainly by reliability and maintainability (23:Sec 2,42). While support cost is normally thought of in terms of dollars, the lack of support carries with it a qualitative cost in terms of inability to achieve mission requirements. Support costs are determined largely by supportability (R&M) decisions during the acquisition phase.

Reliability: "the probability that an item will perform its intended function for a specified interval under stated conditions" (17:1).

Maintainability: "the ability of an item to be retained in or restored to specified condition when maintenance is performed by personnel having specified skill levels, using prescribed procedures and resources" (14:Encl 1).

Scope and Limitations

The assessment of the AN/ALQ-135 will be restricted by any inherent LAMP limitations, by the completeness and

accuracy of only unclassified primary data and by the need to keep the findings at the unclassified level. This thesis is written from the perspective of an outsider 'looking in' on a System Program Office without the advantages of access to real-time data which could alter certain conclusions. This application of LAMP is a step beyond previous LAMP case studies in that it is (1) employed outside the F-16 community and (2) is applied to a program under full-scale development, with an awarded contract. Most AN/ALQ-135 characteristics are already fixed, even if not yet 'known.' As the data is drawn from a single subsystem, it would be unwise to project specific outcomes onto other programs, although general lessons learned may be applicable to similar projects.

The AN/ALQ-135 is a representative subsystem, one of many subsystems on many aircraft which could have been chosen as subject equipment for this study. This self-protection jammer was selected solely based on the author's interest in the F-15E and due to his familiarity with the general nature of Electronic Warfare technology.

II. Background Information

This chapter is intended to familiarize the reader with the background for this research by:

1. Developing the concept of R&M: its significance, evolution, and important documents and policy governing its present-day application in the DOD and USAF.

2. Examining the role of R&M priorities within the F-15 acquisition program.

3. Focusing on the AN/ALQ-135: the new version compared to the existing system, its acquisition program, its operations and maintenance concepts, the role of R&M and Integrated Logistics Support, and future updates.

4. Providing an overview of LAMP and an example of its previous application in an acquisition environment.

Reliability and Maintainability

Significance. Reliability and maintainability, in the broadest sense, are two of many characteristics which describe the quality of a weapon system. An executive from one of the DOD's major defense contractors defines quality as 'conformance to requirements' (44:14). For the military, those requirements are some combination of cost-effectiveness and mission requirements which, in many ways, act as constraints on one another.

Cost-effectiveness. Cost-effectiveness has two dimensions. The first dimension is the highly visible initial acquisition cost, the 'up-front' expenditure often

debated by Congress and the using services. In the second dimension, however, the bigger issue of lifecycle cost-effectiveness should be taken into consideration. Lifecycle cost (LCC), according to to Air Force Regulation (AFR) 800-8, is "the total cost of an item or system over its full life. It includes the cost of acquisition, ownership (operation, maintenance, support, etc.), and disposal" (15:8). Low LCC contributes to cost-effectiveness.

Over the past 25 years, LCC has become a prominent DOD concern during the procurement of its major weapon systems (51:5). As the complexity and service life of these systems have increased, the proportion of LCC attributable to ownership (operations costs and support costs) has increased dramatically. Cumulative operations and support costs now far exceed the more visible cost of actual acquisition (51: 5-6). One source estimates that operations and support costs over the life of a defense system are six times the engineering cost and two times the manufacturing cost (40:4-5). As previously mentioned, operations costs are largely a function of performance demands and sortie rates (the sheer amount of flying accomplished). As such, they may be uncontrollable during the design/acquisition phase. Support costs, however, are severely influenced by supportability decisions during the acquisition process; these costs warrant close attention during the earliest phases of a weapon system's life.

Mission Requirements. By measuring system quality in terms of mission requirements, R&M again emerges as a

major contributing factor. A reliable system is dependable in combat; a maintainable system is ready for combat. R&M is a force multiplier which contributes to fully mission-capable (FMC) rates (37:1). For example, a 1% increase in the FMC rate for a fleet of 700 F-15s is effectively an increase of seven more F-15s to the inventory (46:122-123). In addition to capability, readiness and sustainability are two other primary objectives which contribute to 'operational effectiveness' (mission requirements) (12:2). Figure 1 shows the relationship of R&M to cost-effectiveness, mission requirements, and system quality.

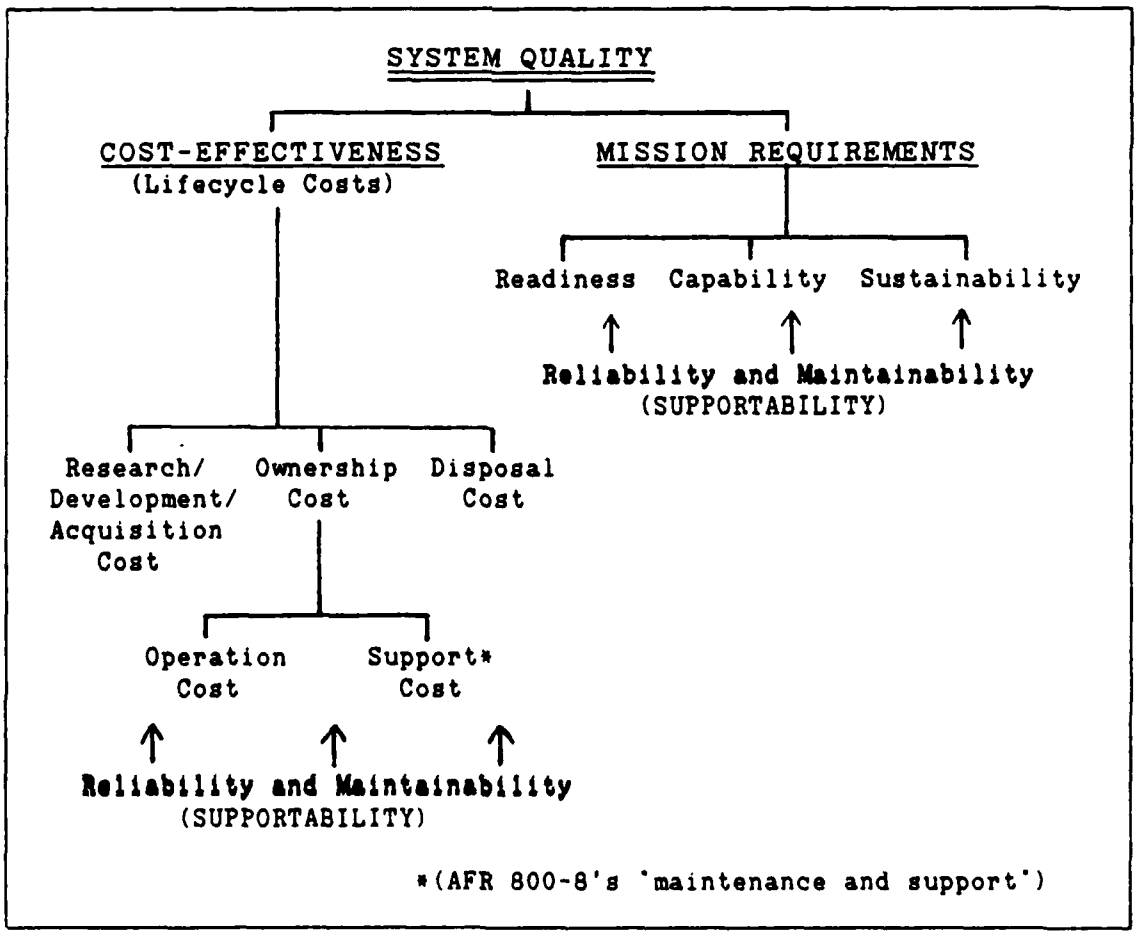

Fig. 1: R&M and System Quality

The Evolution of R&M Awareness. R&M has been approached differently and with various emphases in the past 40 years. Thomas A. Musson focuses on reliability issues in a 1983 article written for Logistics Spectrum. Musson considers reliability as a means rather than an end in itself. One problem affecting the emphasis (or lack of emphasis) on reliability over the years is that the end toward which reliability has been directed has changed continuously, due to either environmental changes or to the satisfaction of the previous end (41:14). Musson summarizes these changing goals as follows:

1950s: More operational time (less downtime).

1960s: Greater mission performance.

1970s: Lower costs (and a resulting peacetime perspective).

1970s-80s: Increased readiness (initiation and completion of the mission).

1980s and the future: More efficient use of manpower and skill levels (41: 14).

The DOD and separate services have conducted many reviews in attempts to achieve these shifting goals. Musson identifies two recent events (in addition to four significant historical movements) which are representative of the search for reliability: the July 1980 DOD Directive on Reliability and Maintainability (DODD 5000.40) and the 1981 Defense Acquisition Improvement Program. These potentially significant influences will have to be time-tested before their impact can be fully measured (41:16).

In a further chronological vein, Musson outlines several methodologies the defense establishment has used to improve reliability:

1950s: Statistics and mathematical solutions.

1960s: Emphasis on piece parts (better components lead to reliable parent systems).

late 1960s: Mandatory contractor demonstration.

1970s: Focus on piece parts again (due to the many new emerging electronic technologies).

1970s: Combined Environmental Reliability Test, or CERT (field environment simulation).

1970s: Reliability Improvement Warranty.

1970s: Reliability by Design.

1980s: Piece parts <u>again</u> (due to new Very High Speed Integrated Circuits, or VHSIC) (41:16-17).

Musson sees these 'panaceas' as the most honest of various attempts by the DOD to cure its reliability ills. He notes, though, the danger of considering such efforts 'simple solutions to complex problems' (41:17).

<u>Current DOD R&M Policies</u>. The DOD has acted to improve R&M since the appearance of Musson's article. Dr. Richard D. Webster, a former Deputy Assistant Secretary of Defense for Logistics and Material Management, sought increased attention to and funding for DOD logistics programs. He and Dr. Lawrence J. Korb (Assistant Secretary of Defense for Manpower, Reserve Affairs, and Logistics) reorganized the DOD's Logistics and Material Management (L&MM) structure in 1981. They added directorates of

Weapon Support and of Logistics Requirements and Analysis. They also moved an existing Energy Policy directorate to the L&MM organization. As a result of these actions, Dr. Webster envisioned a synergistic environment for improvements in the field of support logistics (51:3-4). In general, he prioritized long-term solutions over short-term problems. Dr. Webster's concerns were primarily for long-term mobilization and surge requirements (i.e., mission requirements), balanced by the short-term issue of peacetime cost-effectiveness (51:5).

Lifecycle management was one of Dr. Webster's main objectives. As outlined in a 1982 Defense Management Journal article, his efforts were concentrated into four general areas. First, he pointed out the inadequacy of our current planning horizon for major weapon systems which, if extended to more realistic lengths, would make the importance of front-loaded logistics planning obvious. Second, he insisted on early involvement of logisticians in the planning process, a goal which was supported by the creation of a new position on the Defense System Acquisition Review Council (DSARC). Third, Dr. Webster emphasized the logistician's place in the modification process, just as in the original system acquisition. Fourth, he added his opinion to those of others who note that cumulative operation and support costs for weapon systems exceed development and production costs (51:5-6).

USAF Gen. Robert D. Russ, Commander of Tactical Air Command (TAC), and former Deputy Chief of Staff for Research, Development, and Acquisition, contends that R&M has traditionally received less emphasis in the acquisition process than the more visible criteria of cost, schedule, and performance. In 1985, Gen. Russ wrote that the pursuit of R&M has been 'erratic' and that 'Lifecycle costs, which are strongly driven by R&M, have often assumed a secondary role in the effort to produce system performance within budgeted front-end [acquisition] costs' (46:122).

In the view of HQ USAF Logistics Plans and Programs analyst Maj. Gordon M. Hodgson, the Air Force has had 'difficulty in programming and budgeting for the support of its weapon systems' (36:10). Between 1976 and 1982, there was a growing shortfall between Air Force Logistics Command (AFLC) spares requirements and the available funding for those spares (36:10-11). Fewer spares led to more manpower and support equipment (SE), and a greater reliance on intermediate level maintenance in general. A Rand study found a possible solution in one case: a four-fold reliability improvement in just 11 of approximately 110 Line Replaceable Units carried by the F-15 could allow the elimination of the intermediate (test) station for squadron deployments. The resulting mobility payoff would include deletion of a requirement for some 22 pallets of cargo (spares and test equipment) and 40-50 maintenance personnel per squadron (36:11).

In addition to R&M's historical 'back seat' priority compared to performance, cost, and schedule concerns, Paul J. McIlvaine, Director of the Technical Management Department at Defense Systems College, points out a growing modern impediment to Integrated Logistics Support (ILS). Improvements in Computer Aided Design (CAD) and Computer Aided Manufacturing (CAM) have shortened design and manufacture times for new systems. Recent success in integration between CAD and CAM will further reduce that time (40). Traditionally, designers' problems in just making their design work overrode many interests of logisticians. With the emergence of CAD/CAM, engineers will have even less inclination to wait for logisticians to 'catch up' in order to influence fast-paced design programs. To continue to be effective, logistics planning must become Computer Aided Logistics (CAL), which must in turn be integrated into design and manufacture processes (40:3-4).

Col. Thomas C. Hruskocy, a member of the Air Force's new 'R&M Office' (HQ USAF/LE-RD), writes that the Air Force takes for granted many of its R&M problems, which is a virtual acceptance of the status quo. U.S. industry could deliver 'top-notch' R&M if the Air Force demands it and supports the effort with commitment and resources (37:6). At the time of this writing, the commitment is clear, and the resources are apparently being made available.

According to Gen. Russ, there are three reasons for the Air Force's current emphasis on R&M. First, manpower is becoming a critical resource, in terms of both raw numbers and increased competition from within and outside of the DOD for specialized skill levels. Second, improved R&M will reduce the high cost of spares inventory. Third, and most importantly, R&M is a means of achieving the need for more combat effectiveness. In Gen. Russ' view, the joint policy memoranda from the Secretary of the Air Force and Chief of Staff of the Air Force directly related R&M to these needs of lower manpower requirements, lower lifecycle costs, and greater operational effectiveness (46:125).

The USAF Chief of Staff, Gen. Larry D. Welch, identifies exploitation of new technologies as an important precept. These remarks are taken from his July 1986 memorandum to all USAF Major Commands:

> New technologies allow quantum increases in system reliability while reducing our dependence on vulnerable support structures [thus providing] added flexibility, which equates to combat capability (52).

Gen. Welch has communicated his feelings to industry leaders. For example, his July 1986 letter to Mr. Sanford N. McDonnell of McDonnell Douglas Corporation both praises recent aerospace industry R&M achievements and appeals for R&M as 'a fundamental part of [McDonnell Douglas] research, design, and manufacturing efforts' (53). Gen. Welch promises that forthcoming R&M-based decisions concerning

the Advanced Tactical Fighter (ATF) and the Short Range Attack Missile (SRAM) will be demonstrative of USAF R&M resolve (53).

There is additional evidence of R&M emphasis within the DOD. Greater involvement of maintenance officers and Non-Commissioned Officers (NCOs) (including a series of maintainability workshops) is part of a commitment to help the design community get as firm a grip on maintainability problems as it is beginning to get on reliability (37: 6-7). A recent $250 million radar warning receiver procurement was terminated because the proposed unit did not promise significant R&M improvements over its predecessor (17:4). Even more recently, a policy letter from USAF Vice Chief of Staff Gen. Monroe W. Hatch reveals that effective nearly immediately, senior civilian employees involved with R&M issues will be formally evaluated in R&M performance. Within one year, all appropriate civilian personnel are to be so evaluated (20).

Department of Defense Directive (DODD) 5000.1, Major System Acquisition, dated March 12, 1986*, is the document which updates the DOD statement of acquisition policy. Of the seven 'Acquisition Management Principles and Objectives' enumerated within the directive's opening

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* Expected changes to DODD 5000.1 and DODD 5000.2 were not approved at the time of this writing. Even in consideration of projected changes in the arrangement of Milestones, DSARCs, etc., the concepts presented in this discussion remain valid.

pages, one in particular is especially pertinent to this discussion of R&M:

> Improved readiness and sustainability are primary objectives of the acquisition process. Resources to achieve readiness will receive the same emphasis as those required to achieve schedule or performance objectives (12:2).

The directive goes on to outline responsibilities from the Deputy Secretary of Defense down to the Program Manager (PM), who is the person "responsible for acquiring and fielding . . .a system that meets the approved mission need and achieves the established cost, schedule, and affordability objectives" (12:13).

The implementing document accompanying DODD 5000.1 is DODD 5000.2, Major System Acquisition Procedures. This directive contains nothing especially new concerning the importance of R&M in the acquisition process. It does, however, emphasize early consideration of R&M during the acquisition cycle. According to DODD 5000.2, such concepts as "lifecycle costs" and "logistics and manpower constraints" are important enough to be driving issues as early in the acquisition cycle as the Justification for Major System New Start (JMSNS)(13). Figure 2 illustrates how approximately 70% of LCC is committed by DSARC I and that approximately 85% is committed by DSARC II (36:11). (DSARC I and II are acquisition review events conducted by the Defense Systems Acquisition Review Council.) Notice that the actual spending of funds for those costs occurs downstream, in a sort of "fly now, pay later" scheme.

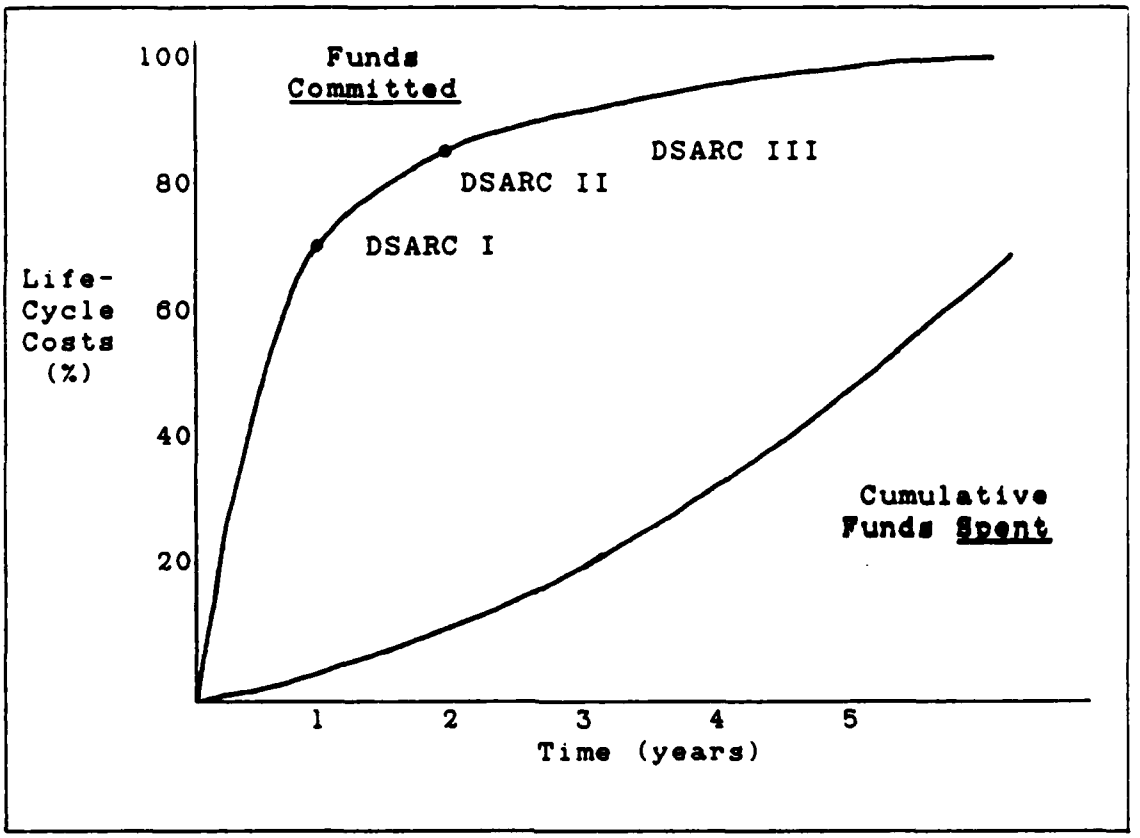


Fig. 2: Early Determination of Lifecycle Cost (36:11)

The Orr/Gabriel memorandum of September 1984 was part of a sweeping move to address these various R&M issues. The two authors explain their thoughts on R&M by writing:

> Reliable weapon systems reduce lifecycle costs, require fewer spares and less manpower, and result in higher sortie rates. Similarly, maintainable weapons require fewer people and lower skill levels, and reduce maintenance times. Equally important, good reliability and maintainability improve the mobility of our forces - fewer people and less support equipment to deploy. They reduce dependence on airlift and prepositioning, while increasing our ability to generate sorties (34:11).

The follow-on February memorandum included the newly created USAF Reliability and Maintainability Action Plan, R&M 2000, with its list of six major objectives:

1. Establish clear direction for R&M improvement.

2. Establish an organizational infrastructure to implement the new R&M program.

3. Establish an R&M planning system.

4. Establish a system to ensure accountability, review, and feedback.

5. Establish a communication and motivation program.

6. Establish industry commitment to R&M (19:i).

The last page of the plan is a schedule containing some 37 actions to have been accomplished by September 1986 in order to implement the plan (19:13).

The R&M 2000 Action Plan. The five operational support goals established by the R&M 2000 Action Plan are aimed at achieving the plan's major objectives by:

1. improving readiness by increasing availability,

2. increasing dependability by improving mission completion success,

3. lowering manpower requirements by decreasing total maintenance manpower,

4. decreasing costs,

5. and improving mobility (19:1).

Consistent with Musson's historical view, R&M is considered a means; in this case the end is combat capability (17:4).

In October of 1986, the Action Plan was formalized by a new regulation AFR 800-18, Air Force Reliability and Maintainability Policy, which mandates that:

> All research and development for R&M improvement; all system developments; and all product support and improvement efforts will be structured to demonstrate the linkage and contribution to the five Air Force operational goals (16:Atch 1).

The emphasis on combat capability is evident in the following prioritized list of the five goals:

1. Increase combat capability.
2. Increase survivability of the combat support structure.
3. Decrease mobility requirements per unit.
4. Decrease manpower requirements per unit of output.
5. Decrease costs (16:1).

TAC, in response to the Air Force's Action Plan and AFR 800-18, produced its own Action Officers Guide for R&M. The Action Officers (AO) Guide states that, as a 'benchmark,' Air Force policy directs R&M levels which double system-level reliability and halve system-level measure(s) of maintainability compared to a 'like system' (25:11). Along with several pages of precise mathematical definitions for R&M measurement (25:14-17), TAC's AO Guide provides a graphic portrayal of how incremental improvements in Weapon System Reliability (WSR) impact combat capability. For instance, with an 80% WSR, one can expect 4.48 sorties per aircraft without major maintenance. An improvement in WSR to 90% yields 9.5 sorties per jet between major maintenance actions, a doubling of the sortie generation rate for a 10% increase in WSR (25:4-5).

Integrated Logistics Support (ILS). According to Benjamin S. Blanchard of Virginia Polytechnic Institute and State University:

> ILS is basically a management function that provides the initial planning, funding, and controls which help to assure that the ultimate

> consumer (or user) will receive a system that will not only meet performance requirements, but one that can be expeditiously and economically supported throughout its programmed life cycle (3:13).

The concept of Integrated Logistics Support is closely related to the Air Force's R&M 2000 goals. The objective of a DOD ILS program is "to field weapon systems and equipment that achieve the required readiness and sustainability posture at an affordable lifecycle cost" (15:1). DODD 5000.39, Acquisition and Management of Integrated Logistics Support for Systems and Equipment, contains Program Manager responsibilities in the areas of R&M and support objectives (11:4). According to the directive, early ILS planning is to be based on:

1. system operational and maintenance concepts,
2. alternative options and strategies,
3. realistic estimates of R&M characteristics,
4. and documented Logistics Support Analysis (11:3-4).

AFR 800-8, Acquisition Management: ILS Program, is the regulation which implements DODD 5000.39 in the Air Force. This document emphasizes early and continuous application of ILS throughout a system's lifecycle as a means of ensuring R&M (15:1). The regulation lists ten ILS elements, "the basic components of a weapon system's total support capability" (15:11):

1. Maintenance Planning
2. Manpower and Personnel
3. Supply Support

4. Support Equipment

5. Technical Data

6. Training and Training Support

7. Computer Resources Support

8. Facilities

9. Packaging, Handling, Storage, and Transportation

10. Design Interface (15:11-13)

By specifying ILS activities to be accomplished during each milestone and phase of the acquisition cycle, AFR 800-8 directs the pursuit of ILS as an integral consideration during acquisition (15:14-18).

The basic management tools for the implementation of ILS within USAF are the Integrated Logistics Support Plan (ILSP) and Logistics Support Analysis (LSA). An ILSP is the government's approach to achieving each ILS objective throughout a particular acquisition or modification program (23:2). LSA is a process whose intended result is integration of the 10 ILS elements (15:11). DOD guidelines for LSA are provided in MIL-STD-1388-1A, Logistics Support Analysis; and in MIL-STD-1388-2A, DOD Management for a Logistics Analysis Record.

According to Blanchard, "LSA is an iterative analytical process by which the logistic support necessary for a new system is identified" (3:14). In LSA, quantitative methods are employed to determine initial logistics criteria, evaluate design alternatives, identify provisioning requirements, and assess system support

capability. The end result of LSA is identification of a 'preferred system' and of a support configuration in terms of the best mix of logistics resources (3:143). Blanchard lists these typical applications for LSA:

1. evaluation of a system's operational requirements,
2. evaluation of alternative repair policies,
3. evaluation of specific characteristics (e.g., R&M features),
4. evaluation of two or more comparable components,
5. evaluation of resource requirements for a fixed or assumed design configuration,
6. and measurement of overall system effectiveness (3:139-140).

All six of these 'typical' LSA applications will be evident in subsequent chapters of this thesis.

R&M in the F-15 Program

The literature is full of examples of advances in R&M within the F-15 program. According to Col. Frederic L. Abrams, a former F-15 Deputy Program Manager for Logistics (DPML), the majority of modifications made to the F-15 during the past 12 years have been driven by the need for R&M improvements. Because the F-15 as a whole now goes longer between corrective maintenance actions, and because of reductions in repair times, its FMC rate has doubled in a decade (1:253).

Figures provided by Gen. Russ indicate that the F-15 requires one-third fewer maintenance man-hours per flying hour than the F-4. The general also observes that the F-15

now has greater radar and EW performance, greater range, 2.5 times longer intervals between corrective maintenance actions, and a 50% higher sortie rate than in 1975 (46:122). In short, 'Today's F-15 is quite a different aircraft from the F-15 delivered ten years ago' (46:123).

In June 1985, the first F-15s incorporating Multi-Stage Improvement Plan (MSIP) changes were delivered. The special significance of these changes is that they will allow more efficient future capability enhancement through 'new capabilities or changes to computer technologies' (1:253).

The F-15E Dual Role Fighter (DRF) was authorized on 27 February 1984 as the newest F-15 version. The Deputy Secretary of Defense's Program Management Directive (PMD) PE 27130F, F-15 Squadrons, governs modification of the existing F-15 design to include systems necessary to perform large payload strike missions against second-echelon targets at night, under the weather, while maintaining current air superiority capabilities (18:6-7). The Fiscal Year 1987 budget allocates funds for 392 F-15Es to be added to the F-15 force which will eventually comprise some seven F-15 Tactical Fighter Wings, seven independent Tactical Fighter Squadrons, and four independent Fighter Interceptor Squadrons (18:7).

At the time of this authorization, a budget cap restricted the funds available for R&M (1:253). Support-ability features were going to have to be integral to the

design process. Designers and logisticians embarked on a four-part gameplan which was built around the understanding that field reliability is more important than mere Mean Time Between Failure (MTBF) criteria. As a result of efforts in this area, a Critical Design Review (CDR) projected that field reliability of the F-15E will be 20% better than in the F-15C (1:253-254). According to Col. Abrams, maintainability has a faster payoff than reliability. He highlights the integration of pylons and conformal fuel tanks and the role of Built-in-Test (BIT) and Design for Testability (DFT) as good examples of F-15E maintainability design (1:254-255).

By all indications, the new F-15E will continue on the same enhanced R&M path as the single-seat F-15C. (For the purposes of this research, the term F-15C will represent the F-15A, B, C, and D.) Two significant ongoing reliability improvements are a Ring Laser Gyro (RLG) navigation system with 10 times the reliability of the present system, and a consolidated engine monitor display with a projected MTBF of over 1000 hours versus the current unit's 80 hours (46:123-124). Col. Abrams provides the following list of other priority F-15E subsystem projects:

1. An Electronically Scanned Antenna (ESA) with greater R&M, less support equipment, and fewer mobility spares.

2. Replacement of the Inertial Navigation System's 10 Line-Replaceable Units (LRUs) with the RLG, which has greater R&M, fewer mobility constraints, and greater capability.

3. Replacement of troublesome honeycomb structures within many airframe parts with Super Plastically Formed (SPF) materials.

4. Greater use of a Mobile Electronic Test Set (METS) for additional mobility benefits.

5. More accurate onboard fault data capture, which is useful in aircrew/maintenance debrief (1:256-257).

To summarize the role of R&M in the F-15E's design, Col. Abrams runs an 'R&M 2000 scorecard' on the aircraft. In terms of R&M goal number 1, warfighting capability, Abrams sees greater R&M, and hence more (warfighting) sorties. For goal number 2, survivability, he points out better counter-threat systems and less reliance on support facilities due to METS. Goal number 3, mobility, is supported through greater aircraft range, less required tanker support, and fewer mobility support requirements. Decreased manpower is goal number 4, but until METS reduces intermediate avionics maintenance, there will be little change in maintenance personnel levels from those of the F-15C. Finally, lower LCC and built-in incentives for further R&M improvements mean that goal number 5, reduced cost, is being achieved (1:257).

The TEWS and AN/ALQ-135 Internal Countermeasures Set

The Tactical Electronic Warfare System (TEWS) is an internal EW 'suite' which serves as the major F-15 airborne defensive system (23:13). The four separate components forming this integrated package are:

1. the AN/ALR-56 Radar Warning Receiver (RWR),
2. the AN/ALQ-128 Electronic Warfare Warning Set (EWWS),
3. the AN/ALQ-135 Internal Countermeasures Set (ICS),
4. and the AN/ALE-45 Countermeasures Dispenser (CMD) (24:1).

The AN/ALQ-135 (or simply 'ALQ-135') is a self-protection jammer (SPJ) which is the component of particular interest for this study. Because of the concept of integration (24:10; 9:6; 23:2,16), the ALQ-135 shares many characteristics with its counterpart systems within the TEWS. For example, in the F-15E the ALQ-135 depends partly on signal inputs from LRU-6 of the ALR-56C RWR. Close integration is necessary to prevent ALQ-135 transmissions from jamming that same RWR (23:Pt II,Sec 2,5). The literature addresses many logistics goals which apply to the ALQ-135 and TEWS almost interchangeably. Accordingly, these two entities will be discussed together in much of this chapter. Figure 3 illustrates TEWS integration within the F-15C and F-15E.

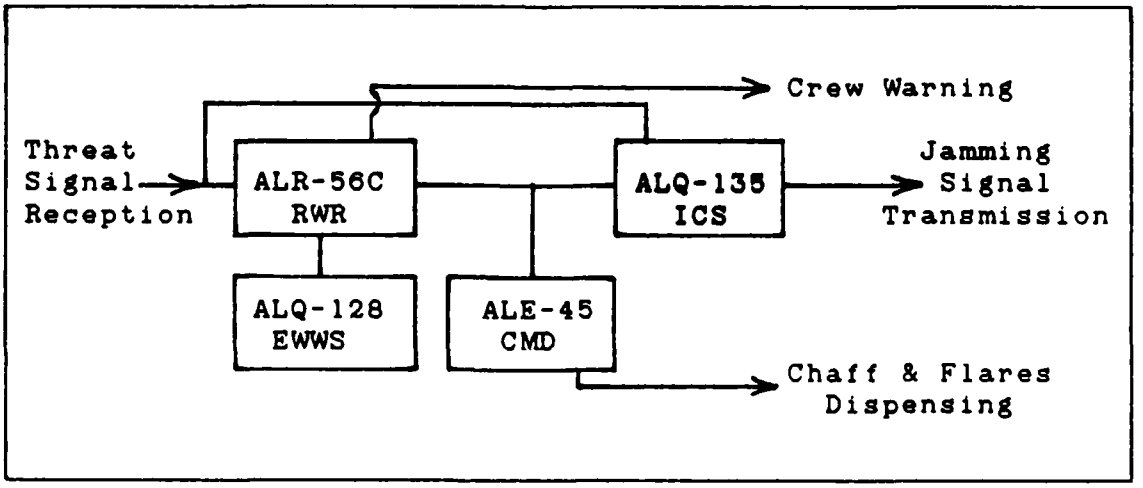


Fig. 3: TEWS Integration (23:3)

As there are some differences in the configuration of the ALQ-135 between the F-15C and F-15E, it is important to point out that this research will focus on an examination of the ALQ-135 in its configuration for the F-15E.

The 'original equipment' ALQ-135 used in F-15A and C models was developed in the early 1970s and first delivered in February 1977. It contained capability over the portion of the electromagnetic spectrum known as Bands 1 and 2. The first investigation of enhancement in order to counter an evolving threat was conducted in 1981. A January 1983 PMD directed an additional Band 3 capability in the form of 65 Quick Reaction Capability (QRC) units for some F-15C aircraft. The same PMD (# 3028(1)QRC81-C4) directed a Pre-Planned Product Improvement (P^3I, read 'P-cubed-I') program to add a potential Band 3 capability for all F-15 versions (24:10). These improvements to the ALQ-135 system are driven primarily by operational performance requirements necessary to counter an evolving electro-magnetic threat. R&M enhancements are also a design objective, but it is crucial to understand that the P^3I program is built on basically the same-generation technology as the original system. As such, the new system may be logistically more similar to the predecessor configuration than different.

TEWS and P^3I ALQ-135 improvements are part of the larger MSIP which is an effort to improve capabilities of the entire F-15 fleet (24:2). TEWS components are in various stages of the modification process. The ALQ-128

EWWS is now under the jurisdiction of AFLC and the using commands, with no further improvements planned. The latest version of the ALR-56C RWR is in full-scale development (FSD). The ALE-45 CMD is in production with an accelerated retrofit program underway. Part of the ALQ-135 (Band 3) is in the QRC development phase, and part (the F-15E Band 1.5) is in preproduction (24:2-5). Four major contractors are producing portions of TEWS equipment, and McDonnell Douglas is responsible for overall system integration (23:16).

Due to space limitations in the F-15E, Band 1 and 2 coverage will be handled by a consolidated "Band 1.5" group (7:51; 23:Pt II,Sec 2,2; 38). This Band 1.5 group is capable of the same frequency coverage as the original Band 1 and 2 but is a more reliable package "which uses [newer] common Band 3 technology and shares some Band 3 SRUs [Shop-Replaceable Units]" (24:2). The Line Replaceable Units which make up the ALQ-135 for the F-15E are:

1. one Control Oscillator (CO) LRU and two Radio Frequency Amplifier (RFA) LRUs which form the Band 1.5 Transmitter Group,
2. one CO LRU and two RFA LRUs which form the Band 3 Transmitter Group,
3. and one LRU-14 preamplifier serving the entire system (24:10).

According to Northrop's Reliability Predictions Report:

> These seven LRUs are made up of various Circuit Card Assemblies (CCAs), Electronic Component Assemblies (ECAs), and modules which have been packaged as SRUs. All SRUs are type-for-type interchangeable within the P^3I system. With the exception of the Traveling Wave Tubes (TWTs), all SRUs are solid-state (10:2).

The seven LRUs and associated antennas are located at various positions around the airframe (Figure 4). The COs and two of the four RFAs are positioned in a reduced-capacity ammunition bay. The remaining two RFAs and the preamplifier are located in the aft fuselage. The ALQ-135 environment is classified as Airborne Uninhabited Fighter (AUF) which includes equipment bays where temperature cycling may be aggravated by contamination due to engine oil, hydraulic fluid, and engine exhaust (10:5).

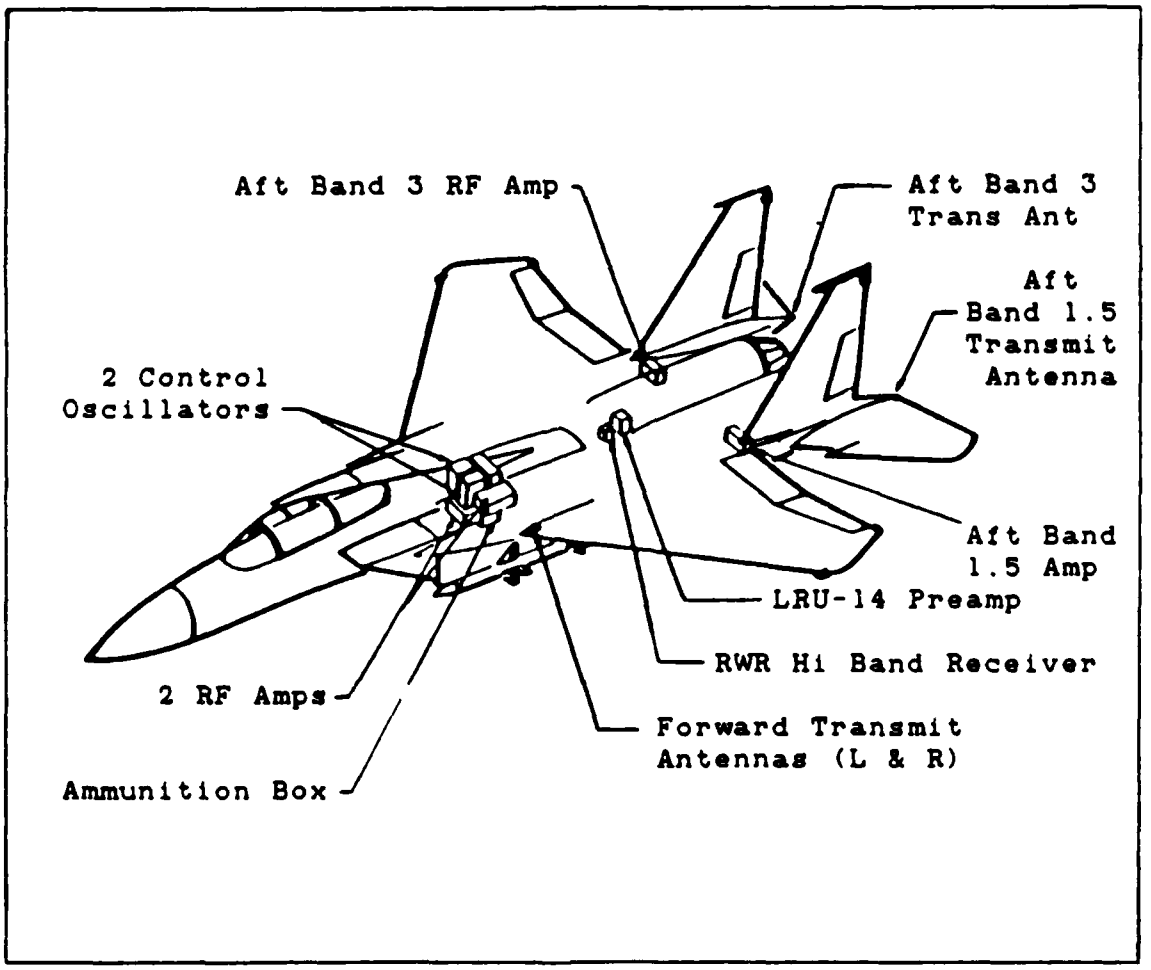


Fig. 4: F-15E AN/ALQ-135 Configuration and Locations (24:10A)

The function of the Control Oscillators is to receive, analyze, and prioritize incoming threat signals and to select appropriate jamming techniques. Radio Frequency Amplifiers magnify outgoing jamming signals. In the P^3I version, a Preamplifier, or Preamp, functions to amplify incoming threat signals prior to Control Oscillator processing (54).

In the original configuration (hereafter referred to also as the 'Band 1/2' version), one CO and one RFA function together to form a 'set' for either Band 1 or Band 2 coverage. Normally, one Band 1 set and two Band 2 sets (six LRUs total) form a Band 1/2 system (47). In the P^3I configuration, one CO and two RFAs function together as a 'transmitter group' for either Band 1.5 or Band 3. A Band 1.5 transmitter group and a Band 3 transmitter group, along with one Preamp, (seven LRUs total) form the P^3I version of the ALQ-135 (38) as illustrated in Figure 5.

An assumed basic serial reliability function is based on the following reasoning: According to Jim Shelby, Northrop Defense Systems Division (NDSD) ALQ-135 Program Manager, a failure of any LRU in a Band 1.5 or 3 transmitter group means the loss of jamming coverage in that band (48). The aircraft may then be vulnerable to thr ats from a significant portion of the electromagnetic spectrum, so in effect, the entire ALQ-135 can be considered 'inoperative.' For reliability calculation purposes, the component LRUs may be considered logically

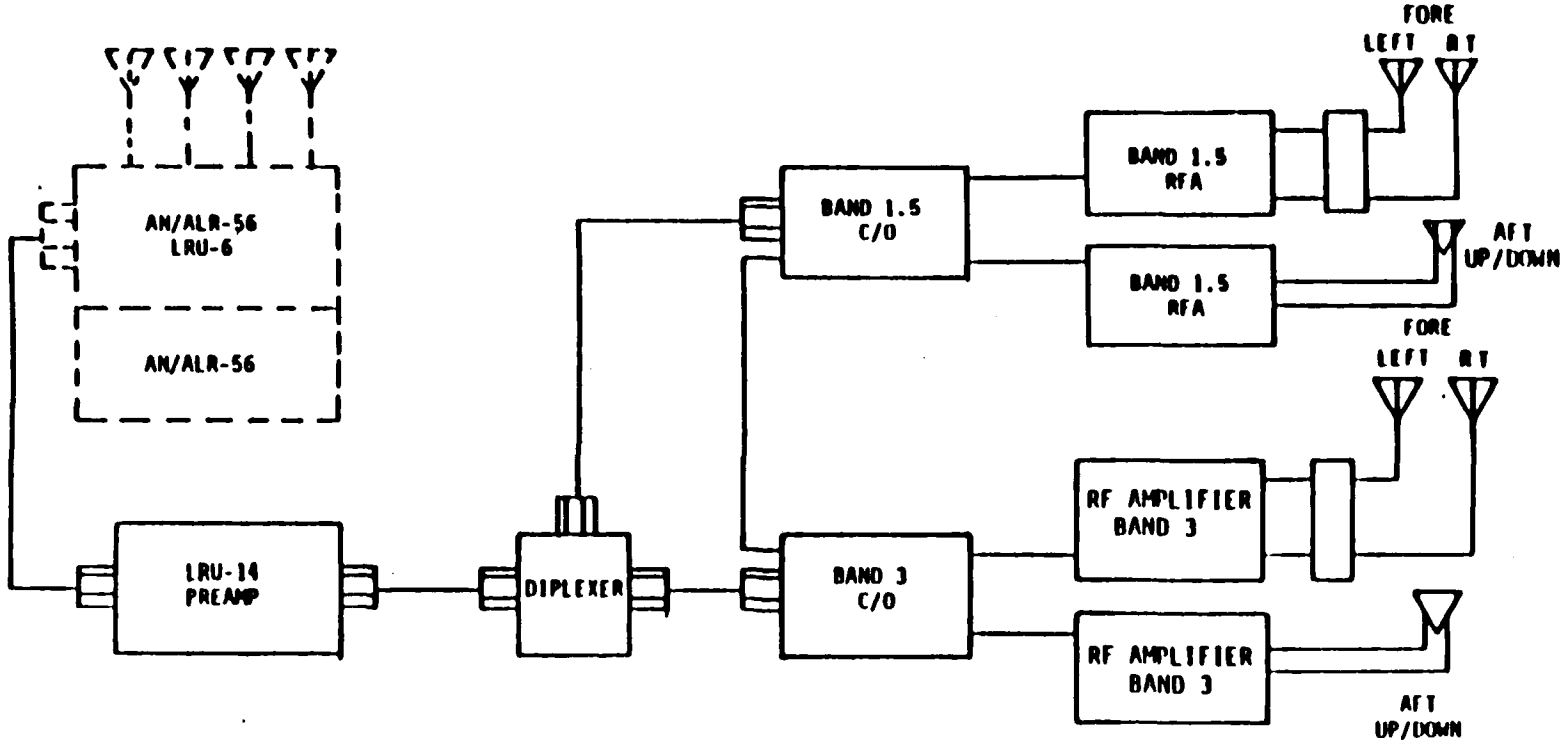


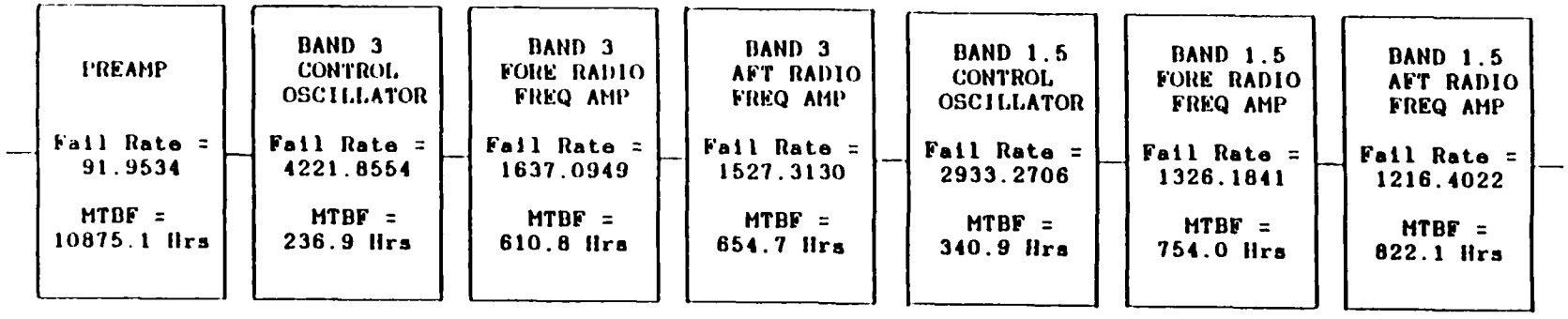
Fig. 5: AN/ALQ-135 LRU Integration (F-15E) (24:10C)

as shown in the reliability block diagram seen in Figure 6. Miscellaneous components such as chassis, cables, fixed microwave elements, etc. are considered to have negligible failure rates (10:19).

An inoperative ALQ-135 is unlikely to be a mission 'no go' item. Due to the importance of threat protection, however, and the ALQ-135's function as an integral part of the TEWS, in such an event its contribution to the overall aircraft's combat capability would in effect be negative.

Acquisition Program. The acquisition strategy for the TEWS in general is 'based on fulfilling a tactical operational need in a minimum amount of time, by modifying existing systems' (23:16). Single source contracting has been chosen as the *only* practical contracting method for the ALQ-135, since only one year and 66 units would remain by the time a second source could be developed. Single-sourcing also reduced the risk of the update due to 60% commonality between Bands 1.5 and 3 at the SRU level (24:11). The acquisition strategy is based on modification and update of the present system along with required changes to the ALR-56C RWR where required for integration purposes (23:Pt II,Sec 2,47).

Due to the concurrency of the QRC and P^3I initiatives, the ALQ-135 was originally accepted as a high risk program in terms of both cost and schedule. A Fixed Price, Incentive Fee (FPIF) production contract has since reduced the cost risk to 'medium,' but the schedule risk remains



(Failure Rates are in Failures per Million Hours)

OVERALL MTBF (Serial Reliability): 77.2 Hours

Fig. 6: AN/ALQ-135 Reliability Block Diagram (10:3-4,23)

high due to the nature of high-technology components and evolving software (24:30-31). In fact, the TEWS program in general is behind schedule, a condition which can be attributed to delays caused by concurrency of the QRC and P^3I programs, major changes to contracting requirements, and contractor development problems (24:2).

The contract between the Air Force and Northrop for ALQ-135 P^3I consolidation amounts to approximately $136.7 million. Although the contract overall is an FPIF arrangement, $3.6 million of the total figure is in the form of Cost Plus Fixed Fee (CPFF) and Firm Fixed Price (FFP) agreements(22:2). The Statement of Work (SOW) encompasses

> work to be performed. . .to develop an AN/ALQ-135 Band 1.5 and integrate it with the P^3I Band 3 [including tasks from] a study phase through flight testing and a limited portion of the non-recurring tasks associated with. . .production (22:5).

The SOW goes on for some 32 total pages to detail responsibilities for many of the concepts and tasks mentioned elsewhere in this literature review (22).

According to AN/ALQ-135 Program Manager Maj. Ted Kissel, deliveries of Band 1.5 and 3 hardware are scheduled to coincide with deliveries of the F-15E main airframes in Calendar Years 1986 through 1991. Maj. Kissel also projects that the P^3I version of the ALQ-135 will undergo Developmental Test and Evaluation (DT&E) in early 1988 with Operational Test and Evaluation (OT&E) to follow in late 1988 through 1989 (38). Critical milestones noted for the ALQ-135 are P^3I installation by June 1988 (ILSP:23), F-15E

Band 3 testing by December 1987, P^3I initial operational capability (IOC) by July 1988, Band 1.5 FSD completion by March 1989, and F-15E Band 1.5 testing by July 1989 (23:Pt II,Sec 2,69). These milestones were derived from the Computer Supported Network Analysis System (CSNAS) (23:1).

Operations and Maintenance Concepts. The TEWS Integrated Logistics Support Plan outlines the operations concept for the ALQ-135. In general, the TEWS is designed to complement Air-to-Air, Air-to-Ground, and jamming flight profiles, although specific mission profiles are classified. TEWS equipment is to be in 'off,' 'standby,' and 'on' (manual and semi-automatic) modes during various mission phases (23:14). Autonomous or integrated operation of the TEWS components is possible (23:2).

As outlined in the Program Management Plan (PMP) and ILSP, the TEWS is to be maintained under the traditional three-level maintenance concept. Organizational (O) level Maintenance will perform fault analysis through the SRU level as well as standard Remove and Replace (R&R) tasks. Intermediate (I) level Maintenance will perform calibration, Time Compliance Technical Order (TCTO) modification, and more detailed fault analysis using BIT functions and Automated Test Equipment (ATE). Depot (D) level Maintenance at Warner Robins Air Logistics Center (WR-ALC) is required for repair of LRUs, SRUs, and sub-SRU components beyond I-level maintenance capability ('Not Repairable This Station,' or NRTS) (24:12; 23:14 & Pt II,Sec 2,7).

Facilities impact should be minimal, consisting primarily of expansion of existing structures to accommodate the Avionics Intermediate Set (AIS) (23:14-15).

Several items of support equipment (SE) will sustain the maintenance concept. The Memory Loader/Verifier (MLV) enables BIT, fault isolation, and software change functions at the O-level (23:12). As part of the P^3I update a TEWS Intermediate Support Set (TISS) is replacing TEWS Intermediate Test Equipment (TITE) for support at I-level (39), with units to be allocated as follows:

1. one TISS per 48 aircraft,
2. one additional TISS per combat-coded independent squadron,
3. and one additional TISS per USAFE/PACAF combat-coded squadron (18:7).

The ALQ-135 is a sophisticated, computer-intensive piece of equipment. The P^3I version is expected to account for 63% of the total I-level TEWS maintenance workload (24:13). Depot maintenance actions will be supported by the AN/ALM-205 for analog components and by the AN/ALM-206 for digital components, as is now the case for existing ALQ-135 systems (39,24:12). For the purposes of this research, these two units will be considered collectively as 'ALM-205' SE.

R&M and ILS. 'The ALQ-135 reliability program is based on a specified MTBF of 54 hours, for the Band 1.5/3 system' (24:12). Specified MTBF for the Band 3 Transmitter Group is 120 hours (23:Pt II,Sec 2,42). Northrop projects ALQ-135 system-level reliability at 77.2 hours MTBF which

is 143% of the specified design requirement and 95% of the initial reliability design goal of 81.0 hours. The 77.2 hour MTBF prediction is based on a 'worst case' serial model, which assumes a 100% duty cycle for components (10:22). Reliability growth and reliability qualification tests are to be performed on Band 3 and Band 1.5, respectively. Appropriate maintainability design criteria, analysis, parameter prediction, and testability initiatives are part of an established program for maintainability (24:12).

Aeronautical Systems Division is requiring Northrop to conduct LSA only for the ALQ-135 portion of the improved TEWS. ASD is to provide data (such as utilization rates, annual operating requirements, average mission duration, etc.) for the contractor's use in its LSA effort (23:16). LSA will address the 10 elements of ILS using Northrop's own methodology known as the Automated Logistics Provisioning System (ALPS) (23:Pt II,Sec 2,9-10). The prominence of R&M issues within the LSA process is evident in the following excerpt from the ALQ-135 ILSP:

> ...selection of design alternatives are optimized by analyzing/simulating the effects of each option on support costs and operational readiness. . . Only the R&M status are discussed [in the ILSP] since they are the only parameters having the greatest design impact [sic] (23:Pt II,Sec 2,42).

Future Improvements. The TEWS will continue to be updated under various program elements. These updates will require corresponding updates of the TITE/TISS in order to

ensure AIS growth along with improvements to the TEWS. The F-15 System Program Office (SPO) is responsible for these updates (18:13,14). Although there are no specific objectives for further supportability improvements to the ALQ-135 (38), general goals implied by the Air Force's ten elements of ILS and mandated by the R&M 2000 Action Plan surely apply.

Logistics Assessment Methodology Program

Several methodologies are available to the planner in pursuit of the kinds of desirable weapon system characteristics which have been discussed so far. Most recent methods for working support issues have been primarily qualitative. They have been applied during pre-source selection, source selection, and post-source selection phases of acquisition (26:Pt II,Sec 2,12). One deficiency of such qualitative approaches is a lack of structure in their approaches. This shortcoming causes configuration-specific methodologies which result in late identification of problem areas (26:Sec 2,13). The Logistics Assessment Methodology Program, LAMP, represents an attempt to overcome this problem.

The LAMP Environment. Dynamics Research Corporation (DRC) referenced various applicable regulations, military specifications, the R&M 2000 Action Plan, existing models, and similar sources in its effort to develop LAMP (26:Sec 1,2-4). LAMP is a decision support system (DSS) in that it is a user-friendly computerized (interactive) tool which

is to be used at the decision-maker level to solve unstructured problems (50:4). The goal of LAMP "is to address supportability in the laboratory" (28:2). This objective is in line with Hodgson's expectation that:

> early developmental work of advanced subsystems could provide a set of proven, reliable building blocks for future development and selective retrofit. A methodology to select the optimal mix of R&M modifications ... will help determine the best way to apply these improvements (36:13).

LAMP uses just such a building block approach to assess supportability. Within LAMP, the five "R&M 2000 Action Plan" points are used to categorize operational goals, and the USAF's 10 ILS elements function to delineate supportability characteristics (26:Sec 2,5). When represented as horizontal and vertical dimensions of a matrix in the LAMP framework, R&M goals and ILS elements interact as tradeoffs as shown in Figure 7. LAMP is a methodology which is intended for eventual use by the Program Manager, DPML, and contractor, with the assistance of a Combat Support Information and Analysis Center (CSIAC) (26:Sec 2,6-8;6;29:12-13).

A typical DSS is composed of three major subsystems: a data subsystem, a models subsystem, and a dialog subsystem (50:28-33). In LAMP the data and models subsystem functions are performed by software. (The models are internal to LAMP; the data base is a manual input by the operator/decision-maker.) The third major subsystem, dialog, is hardware and software in the form of a Logistics Assessment Work Station (LAWS). LAWS is a microcomputer

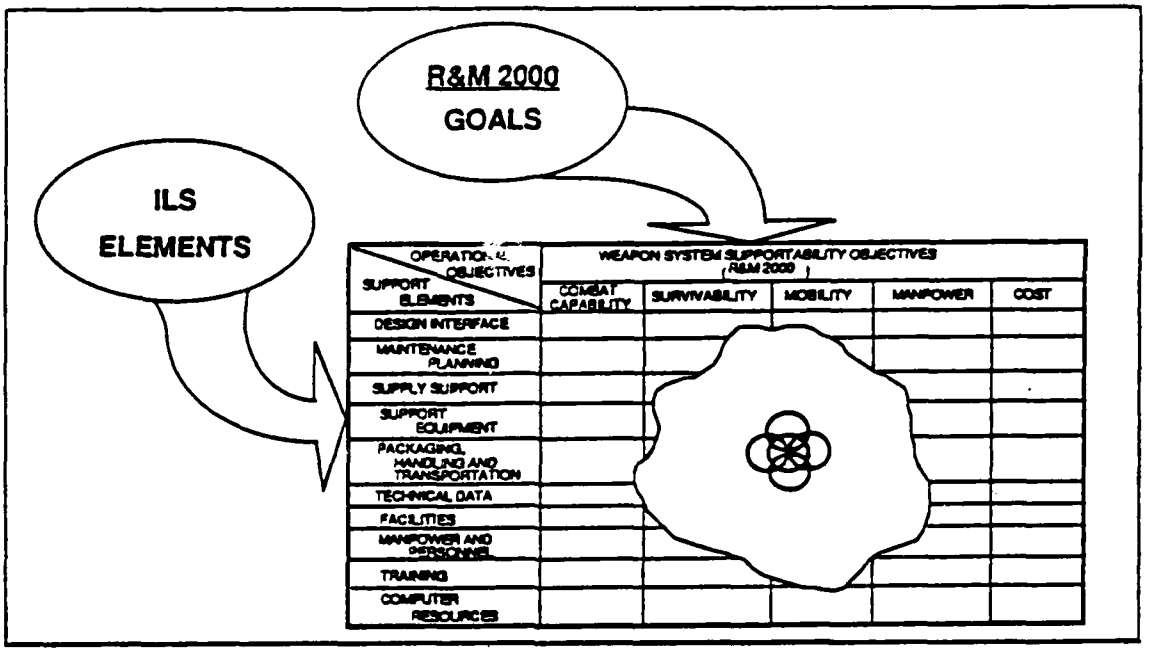


Fig. 7: LAMP Assessment Framework (29:17)

terminal which allows the necessary interface between man and methodology. These three subsystems allow accomplishment of LAWS' objectives which are to:

1. be a tool to facilitate LAMP,
2. be user friendly and interactive,
3. be a first-order, analytic tool for 'what if' investigative analysis,
4. enhance communications and interactions among individuals in the acquisition community,
5. utilize an integrated data base and modeling environment,
6. derive its own models from other working models,
7. and enable LSA investment in areas with the greatest potential payoff (26:Sec 2:10-11).

In most contexts, the terms 'LAMP' and 'LAWS' can be used interchangeably.

LAMP is expected to refine interactions between acquisition offices through quantifiable feedback and control (26:Sec 2,10). The environment described in DRC's LAMP Functional Description is one where the contractor, the DPML, and PM agree on baseline data which represents one or more design/support/operational combinations. Logistics analysts then gather data on a proposed alternative from the contractor. This data, when input according to a standard LAWS format, represents design and/or logistic characteristics of the system under analysis. LAMP translates these support characteristics into their effect on mission requirements and cost-effectiveness criteria such as number of sorties, mobility and manpower requirements, and lifecycle cost. In this way LAMP will enable the PM and DPML to evaluate mission and cost impacts of potential supportability tradeoffs and to influence system design accordingly (26:Sec 2,15).

Operationally, LAMP makes use of available standard Air Force Zenith Z-248 'PC' computer resources and requires minimum formal training, but no additional SPO personnel (28:27; 26:Sec 4,1; 26:Sec 5,2). The actual assimilation of LAMP into the SPO environment is beyond the scope of this research, but user-oriented 'lessons learned' are presented in Chapter IV as part of an evaluation of LAMP.

Data. LAMP inputs represent characteristics of three categories of comparative systems: Predecessor (previous), Baseline (existing), and Alternative (contractor-proposed)

designs. Inputs describing each of the systems under analysis are entered interactively into LAWS, and become data elements in three types of data set collections: Operational, Support, and Design. When three of these data set collections are designated (one of each type), they become an assessment file, or Workfile, which defines a particular scenario for comparative analysis. One or two of the Workfile's data set collections may be held constant and the other(s) altered to determine impacts of changes in operational, support, and/or design conditions (26:Sec 4,3-8).

Data for each category is derived from government and/or contractor sources (30:Sec 1,1-2). Coordinated data is a critical prerequisite to valid LAMP analysis. The acquisition of coordinated data represented the major portion of the costs involved in DRC's initial case studies (26:Sec 6,1). More specific discussion of how LAMP develops these input variables and relationships for analysis is contained in Chapter III and in the appendices.

Models. The LAMP models base is an integrated collection of specific models, each of which is a factor in measurement of one or more of the R&M 2000 goals. These models come into play automatically (that is, internal to LAWS) as required for the data provided and for the specific analysis underway.

Output. Output from LAWS models may be viewed from five perspectives, Views A through E (26:Sec 3,9-14).

View A is the most basic output in that it displays overall Workfile assessment with respect to the five R&M 2000 goals. It is a 'macroscopic' overview which is useful for initial comparison of the Workfiles under consideration (26:Sec 3,9). Table and bar chart formats are available.

View B allows the user to view individual variable relationships and their impact on the five R&M 2000 goals. The role(s) of all input and calculated variables may be seen in at least one of the R&M 2000 hierarchy 'paths.' For example, all variables and relationships which influence the goal 'Survivability' may be determined. View C is analogous to View B, but the variables are categorized by ILS element. For example, all variables and relationships which impact the ILS element 'Supply Support' are displayed (26:Sec 3,9-10). Hierarchy display options include overall analysis, or specific day(s), and/or LRU(s) of interest in bar chart, line graph, and/or tabular format.

View D is an alphabetical (by variable description and by abbreviated variable identifier) listing of all primary and calculated variables. By designating a variable of interest, the LAWS user can obtain the variable's definition as well as its primary relationship with other variables (26:Sec 3,13).

View E allows the user to 'pair' any two variables to determine isolated sensitivity relationships (26:Sec 3,13). This view can be considered a more specific

depiction of relationships considered in Views A-D. Sensitivity curve and tabular formats are available.

All outputs are designed to be 'stand alone' in that each contains these self-explanatory features:

1. A legend stating that it is a LAWS output.
2. Identification of all variable names.
3. Dimensions and axis labels.
4. Units of measurement.
5. Description of analysis type, if any (26:Sec 3,13).

A pictorial summary of the five views available is provided in Figure 8. Examples of output views A, B, C, and E will be seen in Chapter IV.

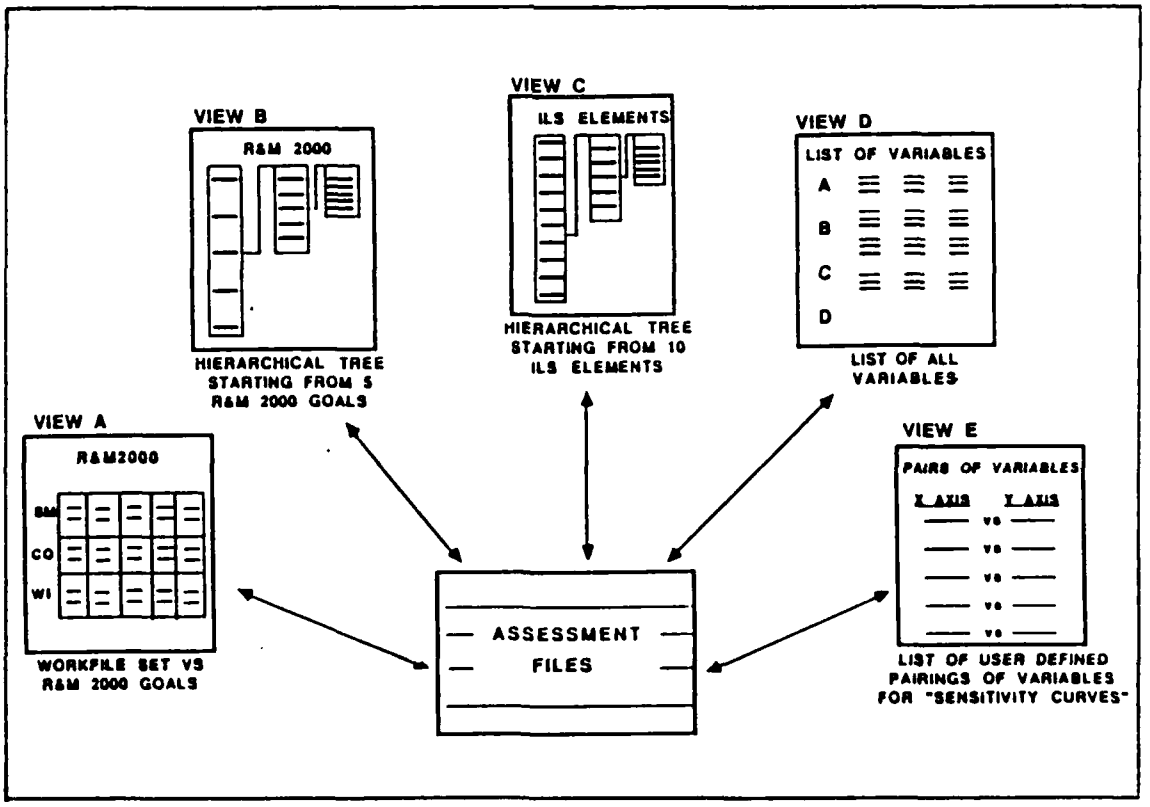


Fig. 8: LAMP Output Formats: the Five Views (26:Sec 2,22)

It has been stated that LAMP's strength is in its being a quantitative tool. DRC has selected these measures of merit to quantify the R&M 2000 goals:

Combat Capability: the ratio of possible (subsystem FMC) sorties to requested sorties.

Survivability: the ratio of possible (subsystem FMC) sorties to requested sorties, under the conditions of no I-level maintenance (a measure of infrastructure survivability).

Mobility: the number of C-141B cargo aircraft required to transport SE, manpower, and facilities necessary to support the subsystem.

Manpower: the number of maintenance personnel per fighter required to support the subsystem.

Cost: projected total lifecycle cost (26:Sec 3,10).

For assessment of lower-level goals and criteria, LAWS allows options among familiar logistics measures such as number of backorders, number of fully mission-capable aircraft, etc. Outputs are presented on a per-squadron basis, so inputs must be converted to per-squadron quantities and allocations to insure meaningful results.

A Previous LAMP Application. DRC and AFWAL have conducted a previous case study involving LAMP analysis of the V1750A computer, a proposed F-16 radar component with new-technology Very High Speed Integrated Circuitry (VHSIC). This particular analysis focused on issues of reliability, cost drivers, and the feasibility of a two-level maintenance concept. Supportability assessment was based on a comparison of the proposed high-reliability

V1750A Fire Control Computer design with the existing component as well as a predecessor component (31:Sec 1,11-16). The analysis plan followed an eleven-step process. The first four steps were qualitative, and the last seven were quantitative (31:4-9). The close of the qualitative phase was marked by the identification of four areas worthy of further investigation:

1. the effect of reliability on the R&M 2000 goals,
2. the impact of system complexity on maintenance and support requirements,
3. the evaluation of LCC high drivers,
4. and the impact of a two-level maintenance concept (31:Sec 1,4).

Quantitative analysis of these four issues led to the following summary remarks:

1. The proposed and predicted reliability is well within the limits to be supported by two-level maintenance.
2. Many potential R&M 2000 drivers were insensitive to measures of performance and supportability once these drivers were quantified (31:Sec 1,9-10).

Based on the results of both phases (qualitative and quantitative), the analysts were able to conclude comprehensively that:

1. The V1750A proposed design has high reliability.
2. LCC of the proposed V1750A would be lower than for the Predecessor and Baseline designs due to both high reliability and the benefits of two-level maintenance.
3. A two-level maintenance environment is suitable for support of a wing equipped with the V1750A, with no significant impact on R&M 2000 goals (31:Sec 4,1).

Predicted reliability of the V1750A computer was estimated at 886 flying hours (MTBF), a level which is 10 times greater than that necessary to achieve 100% Combat Capability (as measured by LAMP). The study enabled the analysts to project that it would be possible to 'maintain fewer spares on hand at the flightline, eliminate the shop level, and minimize the contribution from the depot' (31:Sec 4,2). Such predictions are typical of the manner in which supportability issues can be resolved by the use of LAMP as a Decision Support System.

Summary

This background discussion has centered around the issue of supportability as a critical weapon system feature. The evidence indicates that the Department of Defense is giving increasing consideration to R&M as it becomes clearer that acquisition-phase emphasis on performance, cost, and schedule alone is insufficient to optimize the cost-effectiveness/mission requirements balance. 'R&M 2000,' a useful policy which supports the DOD's ten elements of integrated logistics support, has recently added momentum to the pursuit of R&M objectives.

Supportability has been a prominent factor in improvements to the F-15 over its 13-year operational life. The AN/ALQ-135 is one F-15 subsystem which, when updated with R&M objectives in mind, can contribute substantially to further increases in the overall

aircraft's ability to meet mission requirements cost-effectively.

AFWAL and DRC have high hopes for their jointly-developed Logistics Assessment Methods Program. The laboratory intends for this quantitative methodology to be a tool available to acquisition decision-makers for their analysis of supportability tradeoffs.

III. Methodology

Chapter II provided the necessary background information for an AN/ALQ-135 supportability assessment. This chapter begins with a discussion which differentiates the cases of the V1750A and the ALQ-135. Then, by using those differences as a point of departure, the chapter continues with a description of a three-stage adaptation of the standard DRC methodology. Support Issues Identification is stage one. Stage two is concerned with an extensive Data Development procedure. The third and final stage is the actual LAMP AN/ALQ-135 Analysis which is conducted on the basis of stage one and stage two results. Figure 9 serves as an outline of the chapter and as an illustration of the DRC methodology as modified for application to the ALQ-135 situation.

The V1750A and the AN/ALQ-135: Two Different Cases

As explained in DRC's V1750A Supportability Analysis Final Report, the assessment of the V1750A radar computer was a 'standardized' eleven-step qualitative and quantitative LAMP implementation (31:Sec 1,5-10). Some of the key features of the V1750A case were:

1. LAMP evaluation was of a contractor proposal, not of a system already contracted for.
2. The driving motivation behind the proposed design was improved R&M, not particularly enhanced performance capability.

CASE EXAMINATION: V1750A vs. AN/ALQ-135

Adaptation of DRC Methodology

SUPPORTABILITY ISSUES STAGE:

Overall: system context

Specific subsystem:
ILS issues and R&M 2000 impacts

DATA DEVELOPMENT STAGE:

Data Gathering

Data Base Evaluation:

Step 1. Input data, form Workfiles

Step 2. Trace R&M 2000 Hierarchy, refer to Contrib. Matrix

Step 3. 'Raw' sensitization

Step 4. Classify variables as Fixed/Modifiable/Irrelevant

LAMP ANALYSIS STAGE:

Sensitivity Analysis Phase	Direct comparison of Alternative and Predecessor designs
	Alteration of Design variables
Environmental Analysis Phase	Alteration of Support and Operational variables

Fig. 9: Adapted Methodology

3. The Alternative (proposed) design was of radically improved technology.

4. In addition to the V1750A Alternative (proposed) design, Predecessor and Baseline designs were identified.

5. The Predecessor and Baseline designs are F-16 subsystems for which historical data was available from the F-16 Central Data System (CDS).

Several specific conditions within the ALQ-135 acquisition program, however, make its scenario distinctly different from that of the V1750A system:

1. The P^3I version of the ALQ-135, now under full-scale development, is beyond the stage of a mere contractor proposal.

2. The ALQ-135 is an F-15 subsystem, so historical data is not available through the F-16 CDS.

3. Since the analysis is centered on a system already purchased, data on only two comparative designs, (the Band 1/2 and P^3I configurations) is sufficient. The Band 1/2 version serves, in effect, as Baseline and Predecessor in one. It is mainly considered for reference and used to derive P^3I data, instead of as a 'competing' design.

4. The P^3I ALQ-135 is intended to be primarily a performance capability improvement over its predecessor. R&M improvements are desirable, but they are not the driving issue. Lifecycle costs will be difficult to compare because of the quantum jump in performance capability.

DRC's standard implementation is appropriate for most LAMP analyses, but the above basic differences between the V1750A and ALQ-135 cases were the reason for the three-stage 'modified' methodology outlined in Figure 9. Instead of phases differentiated as simply 'qualitative' and 'quantitative,' an adapted process in three stages, each

identified by content (Supportability Issues, Data Development, and LAMP Analysis), is more appropriate for the ALQ-135 case.

Supportability Issues Stage

The context of overall F-15E supportability objectives and specific ALQ-135 ILS issues provided an appropriate backdrop for LAMP analysis. Recalling Col. Abrams' contention that an early 1970s budget cap forced the F-15 into a three-level maintenance concept, unit mobility was subsequently limited due to the resulting demand for SE and manpower as an alternative to expensive spares (1:255). Therefore, investigation of opportunities to move the F-15 toward a two-level (Organizational and Depot only) maintenance concept and away from the mobility and high manpower burdens associated with I-level is welcome. In Col. Abrams' opinion, maintainability improvements provide faster payback than do reliability improvements. (Reductions in false alarms through improved BIT and reduced 'Can Not Duplicate' (CND), 'Bench Check Serviceable' (BCS), and 'Re-Test OK' (RTOK) rates are especially important.) Since EW equipment operating time is, on the average, much less than average sortie duration, the 'gap' between ALQ-135 MTBF and MTBMA which the colonel mentioned is, if anything, negative. Within this context, LAMP supports the F-15E supportability 'gameplan' of:

1. understanding existing and potential R&M drivers on the aircraft,

2. influencing new and modified equipment with priority to those high drivers,

3. scaling down and enhancing the R&M of SE,

4. and establishing field R&M product performance agreements (1:235).

ILS characteristics and predicted R&M 2000 goal impacts for the ALQ-135 in particular further served to direct the LAMP analysis into appropriate avenues. Familiarity with the P^3I ALQ-135 program, gained from personal interviews and program documents, enabled consolidation of the following notable supportability predictions. They are listed according to ILS element.

'Maintenance Planning' is the first ILS element listed in AFR 800-8 (15). *There is no scheduled maintenance for* either the Band 1/2 or P^3I versions of the ALQ-135, nor is there any proposed change to the three-level maintenance plan. Little or no change is expected for Repair-in-Place (RIP) and condemnation rates. Improvements in base/depot repair cycle times are mainly a function of the support environment. Improved O-level CND and I/D-level RTOK rates (due to BIT and Design for Testability (DFT) improvements), however, should have a positive impact on all five R&M 2000 goals.

'Manpower & Personnel' is ILS element two, and 'Training' is ILS element six as presented by AFR 800-8. P^3I O-level maintenance tasks, as projected, are comparable to those of Band 1/2, but R&R times may be longer due to

more inaccessible equipment locations. I- and D-level maintenance tasks should take much less time. Training impacts should be minimal, since existing 326XX (O-/I-level) and civilian technicians (D-level) will transition gradually to the P^3I system. The effect of probable reduced manpower requirements implies a positive impact on the R&M 2000 goals.

'Supply Support' is ILS element number three. The only real change predicted between the two ALQ-135 versions is unit cost of LRUs, since P^3I LRUs are, on the average, 10-15 times as expensive as Band 1/2 parts. The increase in performance in return for that expense is difficult to quantify, but logistically the impact on the R&M goal 'reduced Lifecycle Costs' is likely to be negative, due to the P^3I design's relatively small increase in MTBF.

In terms of the fourth ILS element, 'Support Equipment,' performance of ALQ-135 P^3I Depot-level SE (ALM-205) should be about the same as for the Band 1/2 version. I-level SE (TISS) should represent capability and availability improvements over TITE. Accordingly, the overall impact of P^3I SE, compared to earlier SE, should mean improvements in Combat Capability. Effects on other R&M goals (attributable to SE) are difficult to predict.

Requirements for 'Technical Data' (ILS element five) should increase slightly with the increased P^3I complexity and the addition of a fifth LRU to the ALQ-135 design. The R&M 2000 impact will be at least a slight increase in LCC.

'Computer Resources' is the seventh ILS element. The P^3I incorporates higher-technology software, and more of it than in the Band 1/2 version. The additional software enables greater performance, but logistically the impact on the R&M goal 'reduced Lifecycle Cost' will be adverse.

'Facilities,' the eighth ILS element listed in AFR 800-8, are not applicable to this ALQ-135 analysis. No mobile shelters are associated with the support equipment, and TITE, TISS, and ALM-205 units share floor space in a common-use Avionics Intermediate Shop. Consequently, there will be no measurable R&M 2000 impact when using the methodology selected for this study.

'Packaging, Handling, and Transportation' is the ninth ILS element. These characteristics are considered constant across both versions of the ALQ-135, but LRU transportation times could limit achievement of Combat Capability and Survivability goals if LRU MTBF is low.

The tenth and final ILS element listed in AFR 800-8 is 'Design Interface,' which in many respects is the most crucial of the elements. LRU R&D cost and weight are slightly higher, which could weigh against LCC and Mobility goals, but improved MTBF should cause an overall positive effect on R&M 2000 goals in terms of design interface.

To summarize the impact of supportability characteristics, the P^3I version of the ALQ-135 should represent some logistics improvements over the Band 1/2 version. It should be kept continually in mind, however, that the most

visible difference in these two subsystems is in their operational performance. By looking at supportability issues alongside R&M 2000 impacts, the following issues appeared appropriate for design characteristics sensitivity analysis:

1. Are Northrop's projected maintenance characteristics (primarily Maintenance Manhours and NRTS) crucial to the maximization of R&M 2000 goals? What effect would some Repair-in-Place capability have?

2. How critical are projections about TISS and ALQ-135 BIT performance?

3. Are repair cycle times (base and depot) limiting factors in supportability of the ALQ-135?

4. What if LRU MTBFs are less than predicted? How do changes in part utilization per sortie (MTBF vs MTBMA) affect supportability?

5. How would changes to LRU weight, size, and unit cost affect the R&M 2000 goals?

Data Development Stage

LAMP requires specific, quantified data in order to address the five supportability issues identified in Stage one. Toward that end Stage two, the next procedure in the investigation, entailed extensive data development. According to the 'adapted' methodology sequence, this Data Development stage consists of two tasks: Data Gathering and Data Base Evaluation.

Data Gathering. Locating, utilizing, and interpreting the information provided by data sources is at the heart of data gathering. For a subsystem under full-scale development, the rather strict distinction

between Government-Furnished Data (GFD) and Contractor-Furnished Data (CFD) implied by DRC (30:Sec 1:1-2) is not critical. Data elements for all input categories can be found nearly interchangeably from government and/or contractor sources. Among the data gathering techniques used in order to satisfy LAMP input requirements were derivation, projection, estimation, extrapolation, and compromise between best-available sources. Without the luxury of the F-16 CDS, the ALQ-135 data gathering process was manual and piecemeal. Therefore, a great deal of effort and and ingenuity was required to collect what it can only be hoped is uncorrupted data. One positive aspect of this approach, however, is the more thorough understanding gained of just what assumptions and real-world factors underly the data instead of 'blind' extraction of information from an all-purpose database. Some data on the P^3I design was derived from Band 1/2 historical experience, and some Band 1/2 data was projected 'backwards' from characteristics known about the P^3I program.

DRC's LAMP Data Collection Guide (DCG) is of some aid in that it provided definitions as well as allowable minimum and maximum values for input variables. In some cases, LAMP default values were relied upon. The sources for these defaults and for all variable definitions are listed within the software and in the DCG (30). Conversion factors necessary to compare dissimilar-year dollar

amounts are extracted from AFR 173-13 and listed in Appendix A. Appendix B is a list of input variables for the Band 1/2 and P^3I versions. Appendix C contains line-by-line background information on the ALQ-135 input data, including calculations, sources, assumptions, etc.

It is appropriate at this point to explain the structure of the LAMP database, a manual input and update system, into which the ALQ-135 data was loaded. Once primary data was gathered, it was organized according to reference, parts, and data set collection files. Reference files describe pertinent characteristics of support equipment, manpower, and facilities associated with a given design. Parts files contain information concerning supportability characteristics of a design, categorized by the ten ILS elements. Data set collections are normally the last input files accessed. They consist of Support and Design data sets (which assign quantities to parts, spares, SE, manpower, and facilities already described within parts and reference files) and Operational data sets (which define conditions such as sortie and attrition rates) (26:Sec 3,3-5). LAMP also uses eighteen adjustable scalar 'constants' which reflect global values such as the average weight of a man, the capacity of a C-141B transport aircraft, etc. (30:Sec 2, 93-103). Figure 10 illustrates the relationship between reference, parts, data set collection, and scalar files.

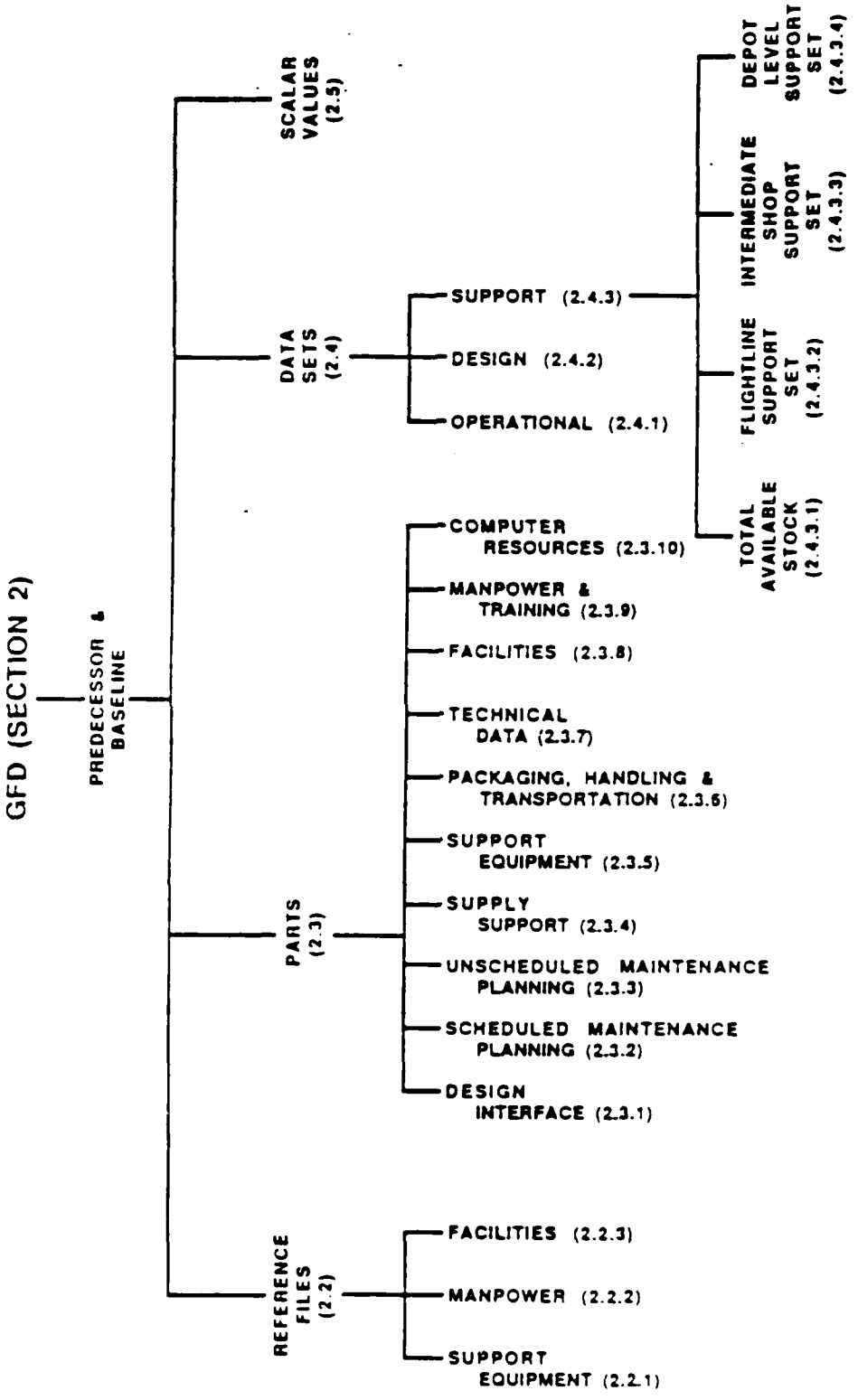


Fig. 10: LAMP/LAWS Database Overview (20:Sec 2,2)

From stored multiple data set collections, one of each type can be mixed together to compile a Workfile. A Workfile is incomplete until it is run through LAMP's integrated model base (a process which requires less than ten seconds), at which time it becomes a 'complete' Workfile. An incomplete Workfile contains only direct input data; a complete Workfile contains input and calculated (output) variables, which are produced by the models. Multiple completed Workfiles may be stored and analyzed simultaneously, which expedites comparative processes (26:Sec 3,5-7). A summary of LAWS' database structure and relationships is provided on the next page in Figure 11.

The proper relationships between input and calculated variables are accounted for by LAWS' set of integrated models. Figure 12 (on the second page following) illustrates the applicability each LAMP 'submodel' to the R&M 2000 goals.

Database Evaluation. Once representative data was in hand for ALQ-135 versions Band 1/2 and P^3I, an evaluation of the data base could be conducted. The first step in this evaluation (and the first applications of LAWS software) required the formation and completion of Band 1/2 and P^3I Workfiles in the manner described above, using the same Operational data set for each.

Step two in data base evaluation involved accessing LAMP 'View B,' the R&M 2000 Goals Hierarchy, for any of

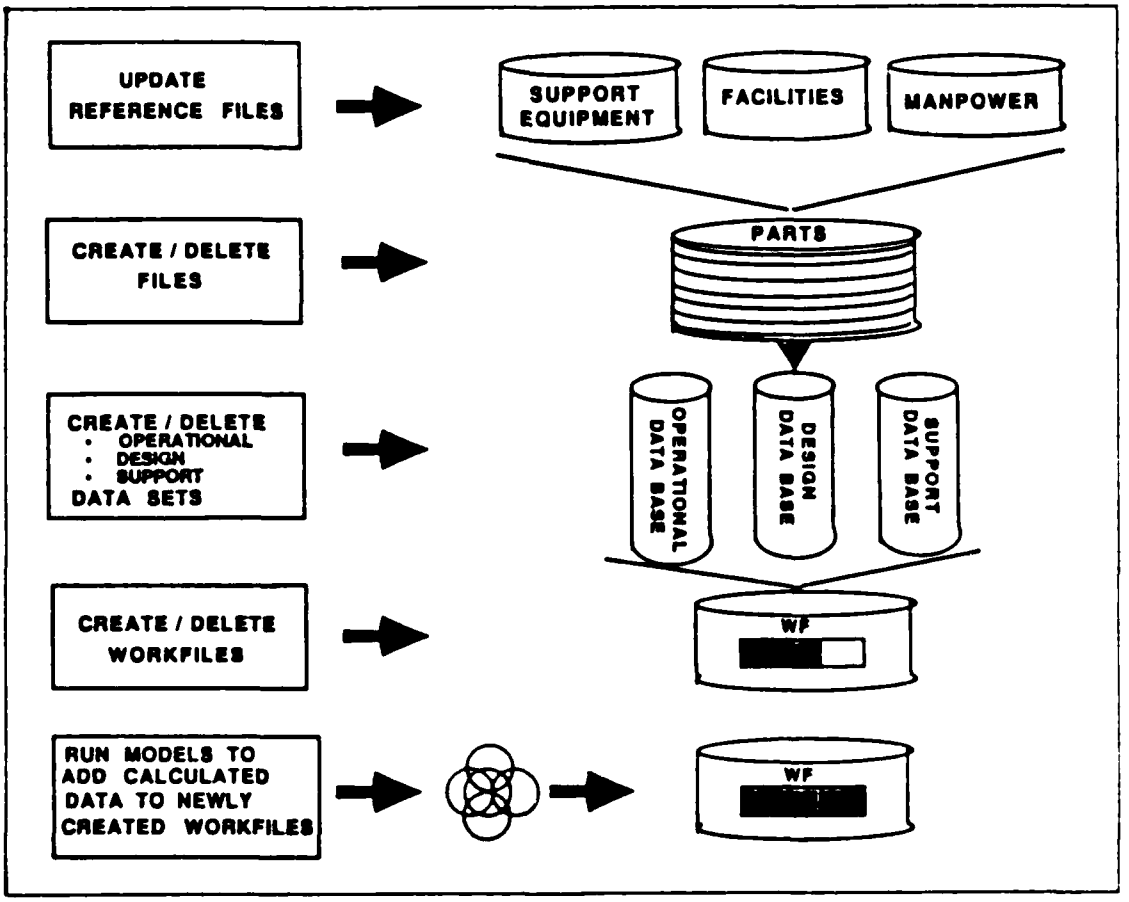


Fig. 11: LAMP/LAWS Database Structure (27:82)

the stored Workfiles. By tracing paths leading from each of the five R&M 2000 goals, relationships between the goals and input and calculated variables were determined. Appendix D is a representative R&M 2000 Hierarchy diagram for the goal 'Combat Capability.' Input variables are shown positioned at the right-most end of each hierarchy 'branch.' One or more LAMP models determines the value of each 'calculated' (intermediate) variable (annotated with '+') as a function of any variable(s) to the right of its position in the hierarchy.

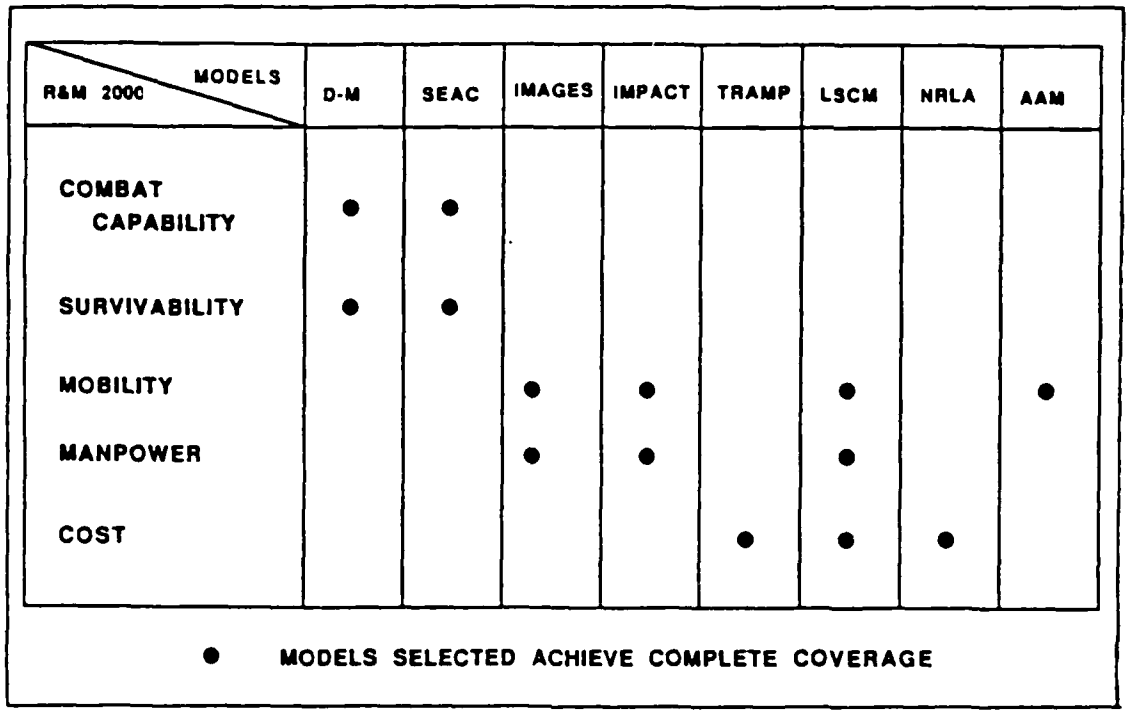


Fig. 12: LAMP/LAWS Models and the R&M 2000 Goals (27:60)

Appendix E is an Input Variable/R&M 2000 Goal contribution matrix which was derived from the R&M 2000 Hierarchy for all five goals. This matrix allows isolation of exactly which variables potentially influence each goal. The hierarchy relationships apply to any Workfile; therefore the Variable/Goal matrix will serve as a valid reference for future LAMP analyses.

In the third step, most input variables were sensitized by commanding positive and negative changes in their values within the ALQ-135 P^3I Workfile. Typically, two increments of 10 or 20% of base value are representative of a reasonable range of uncertainty. Thus, 'raw' sensitivity was determined by assessing the impact of each

change on any of the R&M 2000 goals as displayed in LAMP 'View A.' Particularly sensitive input variables were researched, adjusted, and/or confirmed in order to increase overall confidence in the data base. This sensitization served a secondary purpose by allowing a 'preview' of likely effects during later analysis. Some variables did not need to be sensitized due to non-applicability. As a rule, scalar values also need not be sensitized, since they are based on regulations, technical data, or are commonly agreed upon. The results of this raw sensitization process for ALQ-135 P^3I variables can be found in Appendix F.

Step four of Data Base Evaluation (and the final task of the overall Data Development stage) was a quantitative determination of candidate variables for treatment during the subsequent LAMP Analysis stage. For a study concerned with supportability impacts on all five R&M 2000 goals, each input variable is (technically) relevant to the analysis. As discussed earlier under 'Supportability Issues,' however, it is unlikely that <u>every</u> variable will have a significant impact on the goals. Therefore, in combined consideration of raw sensitization and the Input Variables/R&M 2000 Goal Contribution Matrix, each input variable was initially classified as fixed, modifiable, or insensitive. Fixed variables include many cost figures, for example, or values which are realistically beyond the influence of the contractor and/or SPO. Modifiable

variables are the ones identified by raw sensitization as sensitive, provided that they are subject to some degree of change or uncertainty. Examples are sortie rates, MTBF, and spares quantities. Insensitive variables may be fixed or modifiable, but compared to other drivers, their quantified impact is simply insignificant. (Variables which are not applicable to the ALQ-135 case were listed as insensitive.) In an ideal case, the list of 'modifiable' variables would closely parallel the summarized supportability issues listed during the first stage of the methodology. Appendix G lists all input variables for the P^3I design, initially categorized as either fixed, modifiable, or insensitive.

The Data Development stage functions as a 'bridge' which links the Supportability Issues stage with the two-phase LAMP Analysis stage to follow. Fixed and insensitive variables were not forgotten, but it is the 'modifiable' variables which formed the basis for the LAMP Analysis Stage, the final portion of the methodology.

LAMP Analysis Stage

As previously shown in Figure 9 (page 50), the LAMP Analysis Stage occurs in two phases:

> Phase one (Sensitivity Analysis)$_3$ is to determine the sensitivity of an accepted P^3I design's projected ILS characteristics with respect to 'given' (assumed) operational and support plans.
>
> Phase two (Environmental Analysis) is to evaluate the effects of changes in operational and support plans, assuming 'given' design characteristics.

'Design characteristics' refers to the actual ALQ-135 equipment itself. Operational plans involve mainly sortie rates, sortie durations, and aircraft attrition rates. Support plans encompass such details as spares, support equipment, maintenance facilities, and manpower levels.

It is important to realize that LAMP is a subsystem-level decision support tool. In this application, analysis will only be down to the next-lowest, or LRU, level. Occasionally, the term 'part' is used in accordance with LAMP terminology. In these cases, 'part' represents an LRU. Manpower is treated as a single skill-level for the two types of Air Force Specialty Codes (AFSCs) considered, namely 326XX and a representative depot technician position termed 'Civ Tech.' Dollar amounts are expressed as constant 1987-year values.

Phase One: Sensitivity Analysis. Phase one is intended to determine the sensitivity of characteristics addressed during the Supportability Issues stage. To establish an initial reference, the P^3I ALQ-135 was compared 'head-to-head' against the Band 1/2 version. LAMP 'View A,' the most basic output format, displays logistics parameters translated into R&M 2000 impacts. View A serves as a starting point for this comparison and for all other analyses in this study. For this basic comparison, the F-15C's B1/2 ALQ-135 was lined up against the F-15E's P^3I ALQ-135 with an average sortie duration

held at 1.32 hours and against the same P^3I design flown at an expected F-15E average sortie duration of 2.00 hours.

During subsequent design variable sensitivity analysis, P^3I configuration characteristics were examined assuming the projected F-15E average sortie duration of 2.00 hours (8:299). The wartime attrition rate was set at .001 aircraft losses per sortie, which provided the best indication of 'inherent' system-level attrition. Specific variables investigated during Phase one (determined from the results of the Supportability Issues and Data Development stages) are identified in Chapter IV.

Phase one decreases the uncertainty surrounding the P^3I version's logistics attributes. As with any system not yet fielded, reliability statistics such as MTBF figures can only be projected. In addition, many maintainability requirements associated with this design are unclear. For example, spares quantities are yet to be determined (23:18), TISS support equipment performance will not be evaluated until 1989 (24:30) and manpower/support equipment quantities are only now being figured (23:Pt II,Sec 2,8). Such equipment, manpower, SE, and spares unknowns mean that repairability predictions easily can be unreliable.

Phase two: Environmental Analysis. The second portion of the analysis is structured to to account for changing environmental conditions in which the P^3I version of the ALQ-135 could operate. Candidate Design data set

variables were held constant, and significant Operational and Support variables were altered in order to further determine P^3I flexibility and limitations. These variables (to be identified specifically in Chapter IV) were varied in isolation and in combination to determine their influence on ALQ-135 supportability.

Phase two considers the possibilities of various operational and support plans. The value of Environmental Analysis is in its potential to exploit opportunities presented by a new system. In a more pessimistic sense, determining the impact of more demanding operational and support scenarios could reveal critical limitations of the P^3I ALQ-135. Clearly, phases one and two are related procedures. Their combined results support the research purpose.

Summary

This chapter has investigated more closely the logistical characteristics of the AN/ALQ-135 subsystem. A three-stage methodology has been presented which entails supportability issues identification, data development, and LAMP analysis.

The first two stages are prerequisite to the actual analysis to be conducted in Stage three. In this chapter, the ALQ-135 scenario was considered in the context of these first two stages, and intermediate observations were listed.

A two-phase Stage three procedure was briefly described, again with respect to ALQ-135-specific conditions. At the completion of Stage three, LAMP Analysis, the R&M 2000 impact of logistics characteristics initially identified during the Supportability Issues stage will have been assessed. Chapter IV contains the findings of that LAMP Analysis Stage.

IV. Analysis and Findings

The content of this chapter is divided into two parts. The first contains the findings of the LAMP Analysis Stage (Stage three) of the methodology which entails presentation, interpretation, and summarization of LAMP outputs. This process provides a supportability assessment of the AN/ALQ-135 P^3I design. The second part reviews positive and negative points regarding the use of LAMP as a support-ability assessment tool. The outcome of the chapter ultimately leads to conclusions (in Chapter V) which satisfy the two-fold research purpose.

LAMP Analysis Stage

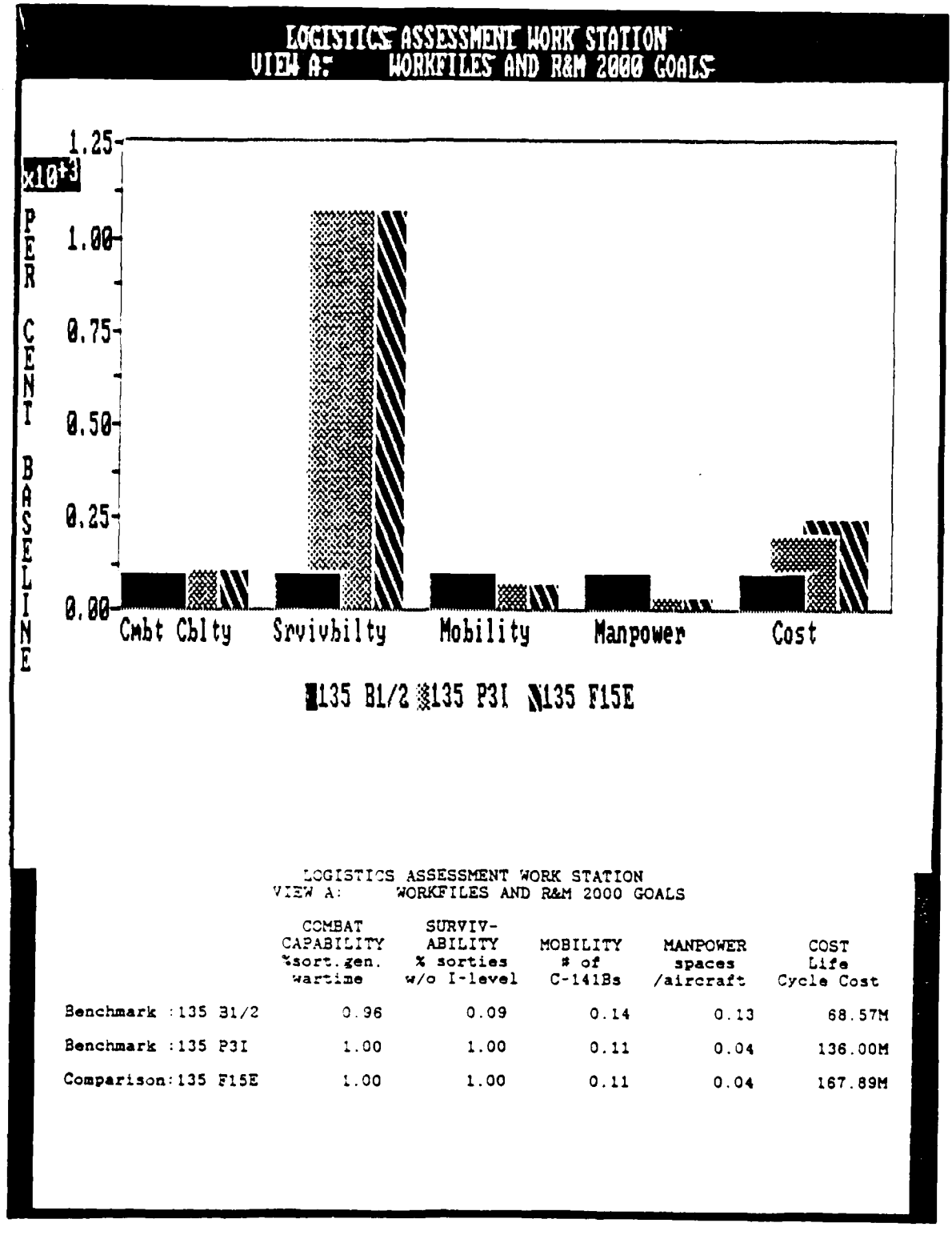
As outlined in the previous chapter, LAMP Analysis was conducted within to a two-phase framework. Phase one, Sensitivity Analysis, was a direct comparison of the P^3I and Band 1/2 designs, followed by iterative alteration of the P^3I design variables. In Phase two, Environmental Analysis, the P^3I design is considered a 'given,' and its performance is measured with respect to restrictive conditions associated with hypothetically more demanding operational and support environments.

Sensitivity Analysis Findings. The P^3I design was defined in two forms for purposes of direct comparison with

the benchmark Band 1/2 (predecessor) configuration. In the first Workfile, the average sortie duration (LAMP variable 'TFH,' for Total Flying Hours) was held constant at that of the Band 1/2 design, 1.32 hours per sortie. In the second Workfile, TFH was considered to be 2.00 hours which is the expected sortie duration for F-15E mission profiles (8:299). For each of the three designs, the 'inherent,' (non-battle damage) F-15 attrition rate was estimated at .0001 per sortie (peacetime) and .001 per sortie (wartime). For the Design Variable Sensitivity portion of Phase one, the 2.00 hour F-15E average sortie duration was assumed. Assumed spares, SE, manpower quantities, and sortie rates (all held constant for this phase) are explained in Appendix C.

LAMP makes two assumptions to increase the probability of achieving the requested sortie rates defined within the associated Operational data set. First, LAMP models recognize the ability of FMC aircraft to fly 'extra' sorties over their requested share (not to exceed a user-defined maximum) to compensate for sorties 'lost' by jets down for ALQ-135 repair. Second, LAMP allows for 'cannibalization' of aircraft which may be awaiting or undergoing repair, but which may have parts available if needed for other fighters to continue to generate sorties.

Direct Comparison. Figure 13 is LAMP View A which presents a comparison of the three Workfiles of interest.



LOGISTICS ASSESSMENT WORK STATION
VIEW A: WORKFILES AND R&M 2000 GOALS

	COMBAT CAPABILITY %sort.gen. wartime	SURVIV-ABILITY % sorties w/o I-level	MOBILITY # of C-141Bs	MANPOWER spaces /aircraft	COST Life Cycle Cost
Benchmark :135 B1/2	0.96	0.09	0.14	0.13	68.57M
Benchmark :135 P3I	1.00	1.00	0.11	0.04	136.00M
Comparison:135 F15E	1.00	1.00	0.11	0.04	167.89M

Fig. 13: Direct Comparison of Band 1/2, 135 P^3I, and 135 F-15E Workfiles (View A)

In the graphical portion of this figure, the solid bar, '135 B1/2' represents the existing ALQ-135 design. '135 P3I' is the shaded bar which represents the P^3I configuration flown at an average sortie duration of 1.32 hours. '135 F15E' (the diagonal stripe bar) is that same P^3I configuration flown at an average sortie duration of 2.00 hours. Brief definitions of the five R&M 2000 goal measures of merit are shown on the view itself, and complete details are available 'on-line' through several LAMP definitions features. (Refer to page 45 of this thesis to review the quantified measures of these R&M 2000 goals.) The graphical portion of Figure 13 displays goal achievement relative to a Band 1/2 Baseline which is normalized at 100%. In this format, the user can more directly discern relative differences between the three Workfiles under consideration.

LAMP assessed the Band 1/2 design as capable of supporting 96% of requested wartime sorties over a 30-day conflict. The low Survivability figure indicates a heavy reliance on Intermediate-level maintenance in order to sustain the requested sortie rate. (Without I-level maintenance, the design would be sufficiently operational only to meet 9% of the rather high Combat Capability otherwise possible.) The design requires 14% of a single C-141B's payload to deploy the necessary I-level support (SE, spares, and manpower) to meet sortie rate requirements. Manpower (maintenance) requirements are .13

personnel per F-15, or roughly three individuals per 24-aircraft squadron allocated to the ALQ-135 alone. Finally, Lifecycle Cost (LCC) of the Band 1/2 design is calculated as $68.57M (constant 1987 dollars) per squadron, assuming a 20-year service life.

The P^3I design fares much better at both low and high average sortie durations. Again referring to Figure 13, Combat Capability would be adequate to generate 100% of requested sorties. Survivability is projected to be vastly better than for the Band 1/2 version; the 100% figure shown implies no wartime dependency on I-level maintenance. Mobility requirements should be slightly lower than for the Band 1/2 design, and maintenance Manpower requirements are projected to be about one-third of those of the predecessor. LCC can be expected to be significantly higher, but the underlying increase in ALQ-135 performance must be considered when making such cost comparisons. The additional $31.89M in LCC for '135 F-15E' (over '135 P3I') is attributable to its longer sortie duration.

In general, these quantified values should not be considered as points on a zero scale. It is not so critical, for instance, to predict precisely three maintenance personnel per squadron as it is to note the relative difference between Workfiles. This an especially important concept in light of how LAMP models call on resources to generate sorties. In Figure 13, only the support resources necessary to meet requested sortie rates were considered in

the Mobility and Manpower goals. For example, only one maintenance technician per squadron (.04 per F-15) was counted in the Manpower column despite the fact that four O-level and two I-level individuals were designated in (made available through) the Support data set. Likewise, LCC values shown are based on manpower, SE, facilities, and spare parts requirements (not actual levels). This modeling assumption may be overridden, but as a rule, it allows the most straightforward interpretation of LAMP outputs.

Additional LAMP views were used to 'dig deeper' into the logistics characteristics of the designs. It is important to understand that, beginning with the overview provided by View A, the analysis is interactive rather than pre-planned. That is, the LAMP user is expected to investigate conditions presented by the analysis itself as the methodology unfolds.

The following series of figures (Figures 14-16) are the result of tracing the R&M 2000 Hierarchy (LAMP View B). Combat Capability, Survivability, Mobility, and Cost measures were investigated. Figure 14, from the Combat Capability hierarchy, shows the expected number of generated sorties by day over the course of a 30-day war. The Band 1/2 configuration is unable to support any sorties whatsoever until day two of the war. This condition indicates some form of initial backorder problem with spare LRUs. On the second page following, Figure 15 lists those expected back-orders by LRU for peacetime and by day of the war (for the

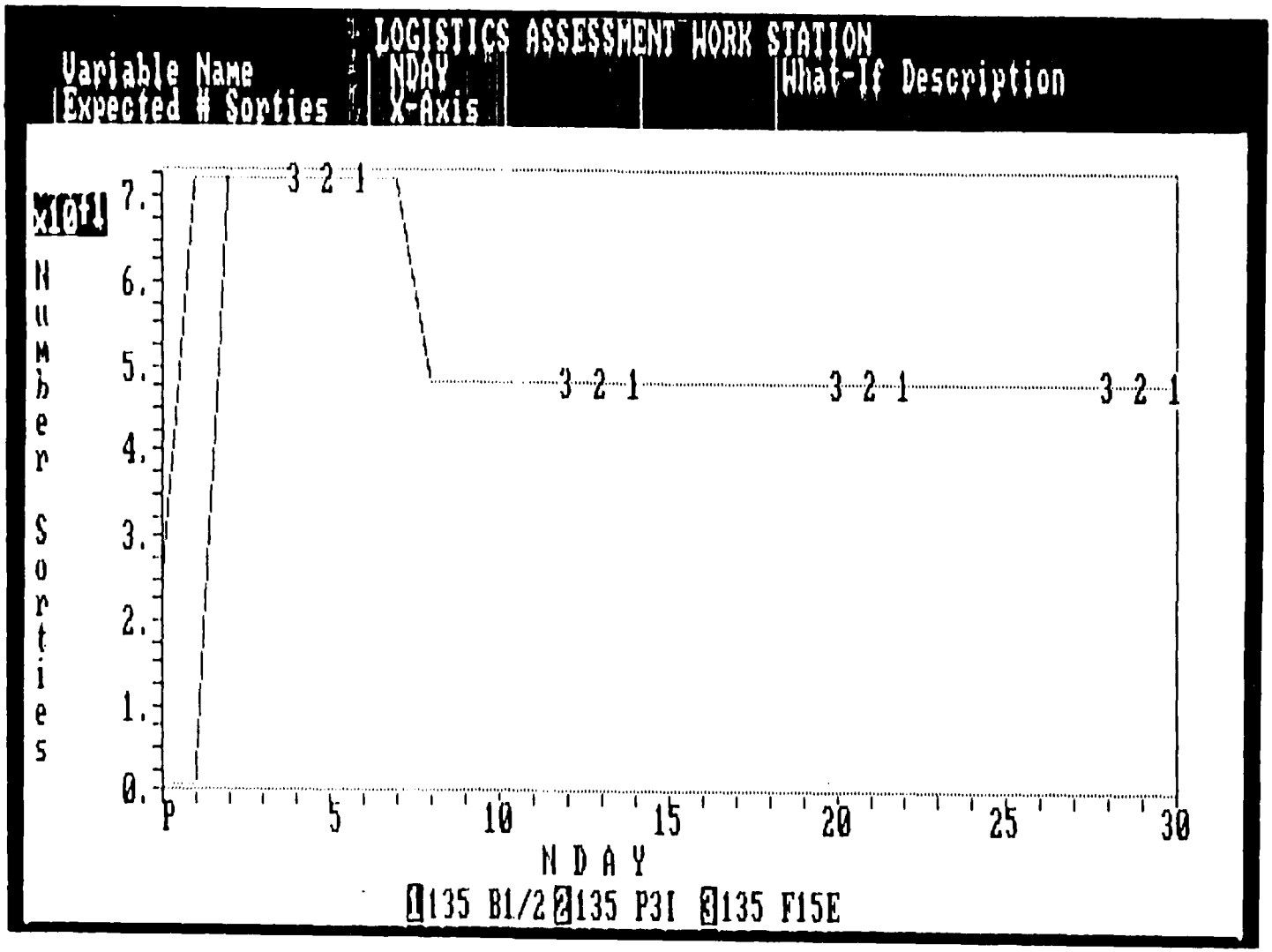


Fig. 14: Band 1/2, 135 P^3I, and 135 F-15E Versions: Expected Backorders by Day (View B)

LOGISTICS ASSESSMENT WORK STATION

Variable Name 3 NLRU 3 NDAY 3 3What-If Description
Expected Back-Order 3 X-Axis 3 Shades 3 3

# of Back-Orders

NLRU	P	1	2	3	4	5	6	7
CO B2	41.53	16.86	2.56	0.05	0.00	-0.00	-0.00	-0.00
RFA B2	2.37	0.00	0.00	-0.00	-0.00	-0.00	-0.00	-0.00
CO B1	0.38	-0.00	-0.00	0.00	0.00	0.00	0.00	0.00
RFA B1	0.93	0.00	-0.00	-0.00	0.00	0.00	0.00	-0.00

LOGISTICS ASSESSMENT WORK STATION

Variable Name 3 NLRU 3 NDAY 3 3What-If Description
Expected Back-Order 3 X-Axis 3 Shades 3 3

# of Back-Orders

NLRU	P	1	2	3	4	5	6	7
PREAMP	0.015	0.000	0.000	0.001	0.001	0.001	0.001	0.001
HI CTL O	0.929	0.000	0.000	0.000	0.000	0.000	0.000	0.000
HI RFA	0.698	0.000	0.000	0.000	0.000	0.000	0.000	0.000
LO CTL O	0.565	0.000	0.000	0.000	0.000	0.000	0.000	0.000
LO RFA	0.554	0.000	0.000	0.000	0.000	0.000	0.000	0.000

LOGISTICS ASSESSMENT WORK STATION

Variable Name 3 NLRU 3 NDAY 3 3What-If Description
Expected Back-Order 3 X-Axis 3 Shades 3 3

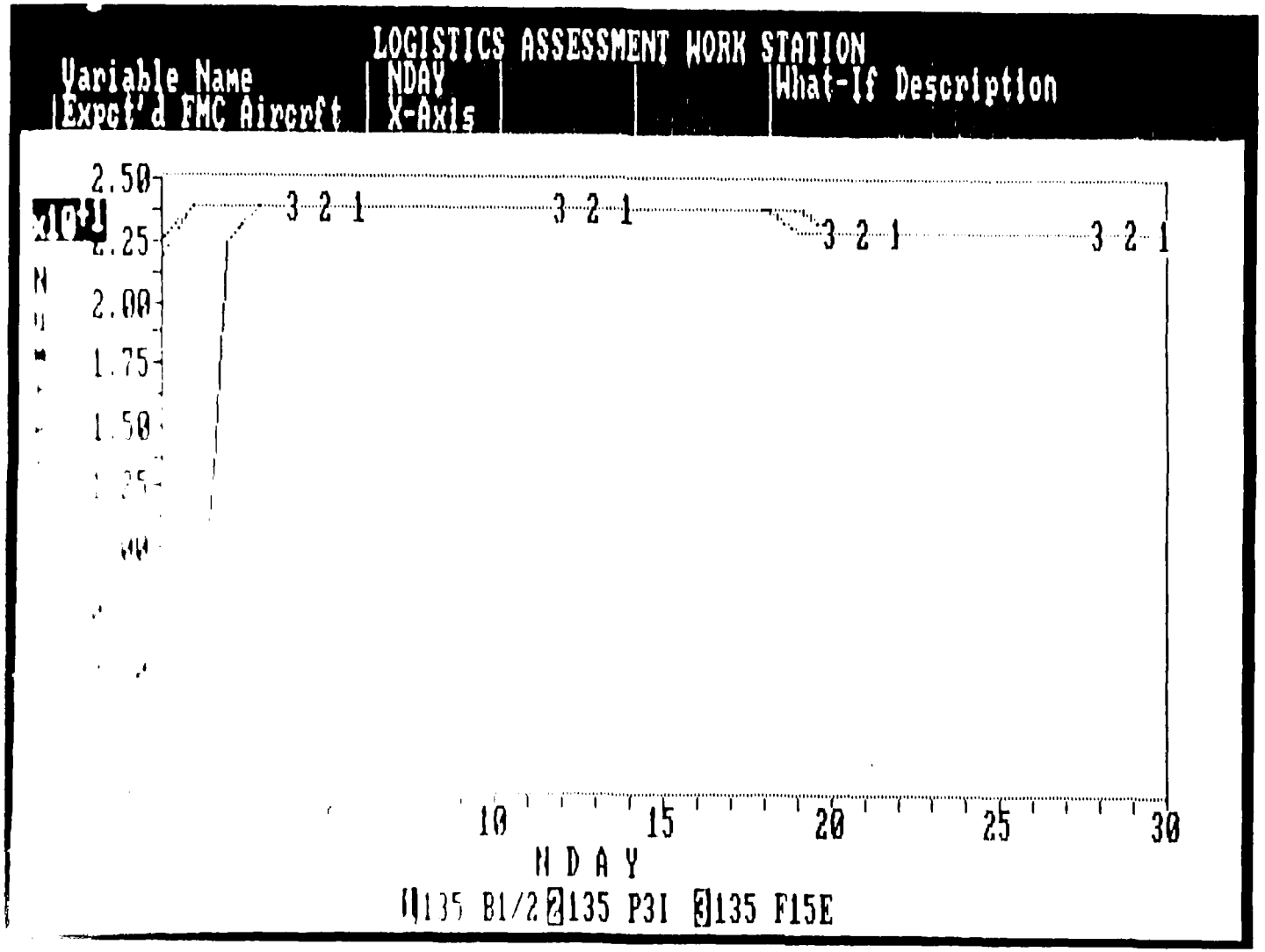
# of Back-Orders

NLRU	P	1	2	3	4	5	6	7
PREAMP	0.022	0.000	0.001	0.001	0.002	0.002	0.002	0.002
HI CTL O	1.820	0.000	0.000	0.000	0.000	0.000	0.000	0.000
HI RFA	1.191	0.001	0.001	0.002	0.002	0.003	0.003	0.004
LO CTL O	0.980	0.000	0.000	0.001	0.001	0.001	0.001	0.001
LO RFA	0.904	0.000	0.000	0.000	0.001	0.001	0.001	0.001

Fig 15: Band 1/2, 135 P^3I, and 135 F-15E Versions: Expected Backorders by Day (View B)

first seven days) for each of the three ALQ-135 Workfiles. The Band 2 Control Oscillator (CO B2) LRU is by far the main contributor to the backorder problem within the Band 1/2 design. Until the War Readiness Spares Kit (WRSK) is available at the outbreak of war, no ALQ-135-capable sorties are possible due to this low MTBF part which is used two per aircraft. The same data, expressed in Figure 16 in terms of expected FMC aircraft, confirms these early limitations on ALQ-135 capability).

LAMP shows how critical the assumption of 100% ALQ-135 utilization per sortie (LAMP variable 'UF,' #15) is for the Band 1/2 design. Figure 17 is LAMP View A for the Band 1/2 design in isolation. The solid bar now represents the basic design, and other bars stand for 'What-if' changes applied to each LRU. In this case, each 'What-if' shown represents a 5% reduction in part utilization time. By only the third 5% increment, Combat Capability and Survivability increased to 100%, and there was an apparent #2M savings in terms of LCC. Figure 18 displays improvements over the basic design in the number of FMC aircraft early in the 30-day war for each of the three 5% 'steps' down in UF. Similar information is presented in Figure 19, but in terms of expected peacetime backorders (preceding day 1 of the war). Note the decrease in quantities of LRU 'CO B2' backorders. For the measures 'Expected FMC Aircraft' and 'Expected Backorders,' the third 5% increment eliminated ALQ-135 utilization per sortie as a constraining factor. In the



135 P^3I, and 135 F-15E Versions:
FMC Aircraft by Day (View B)

AD-A186 474 USING THE LOGISTICS ASSESSMENT METHODOLOGY PROGRAM FOR 2/3
SUPPORTABILITY ANA (U) AIR FORCE INST OF TECH
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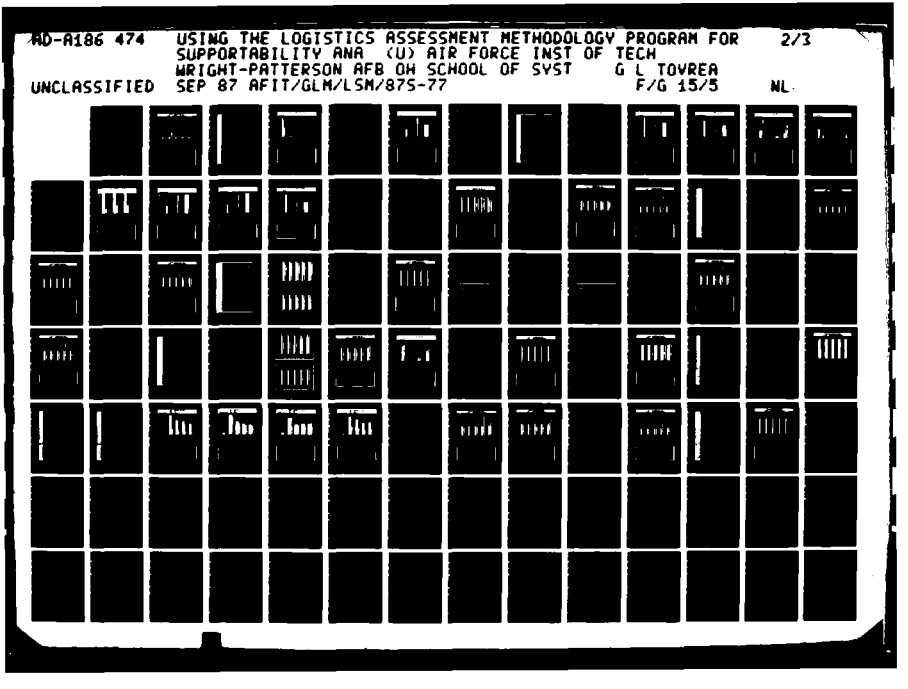
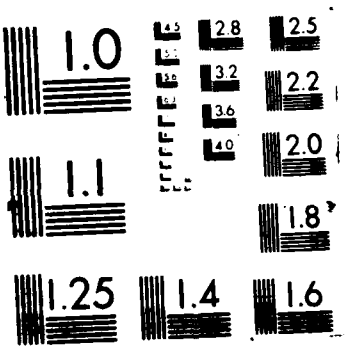
UNCLASSIFIED SEP 87 AFIT/GLM/LSM/87S-77 F/G 15/5 NL




1.0
1.1
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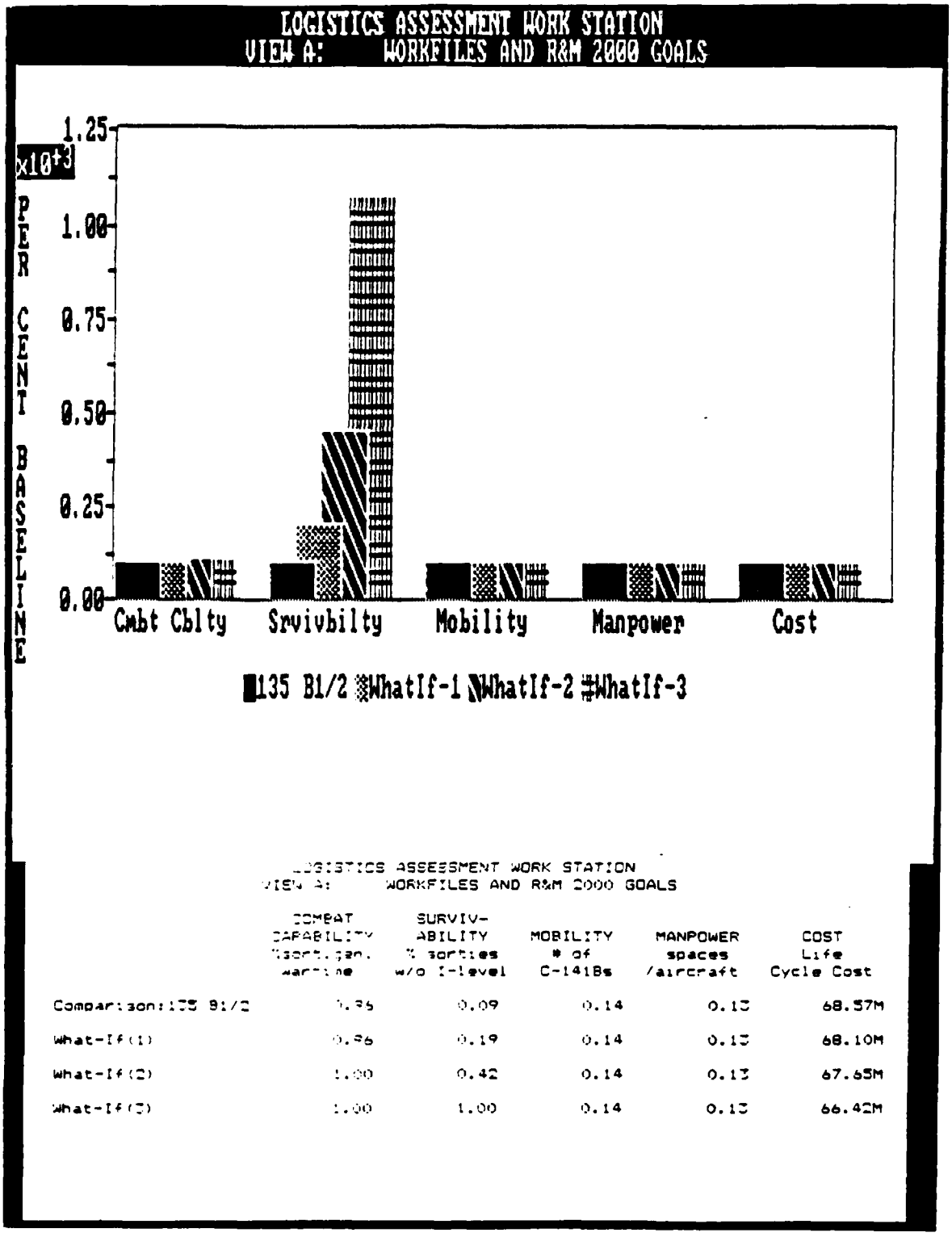
2.2
2.5
2.8
3.2
3.6
4.0



LOGISTICS ASSESSMENT WORK STATION
VIEW A: WORKFILES AND R&M 2000 GOALS

	COMBAT CAPABILITY %sorts.gen. wartime	SURVIV-ABILITY % sorties w/o I-level	MOBILITY # of C-141Bs	MANPOWER spaces /aircraft	COST Life Cycle Cost
Comparison:135 B1/2	0.96	0.09	0.14	0.13	68.57M
What-If(1)	0.96	0.19	0.14	0.13	68.10M
What-If(2)	1.00	0.42	0.14	0.13	67.65M
What-If(3)	1.00	1.00	0.14	0.13	66.42M

Fig. 17: ALQ-135 Band 1/2 Version: 5% Reductions in ALQ-135 Utilization per Sortie (View A)

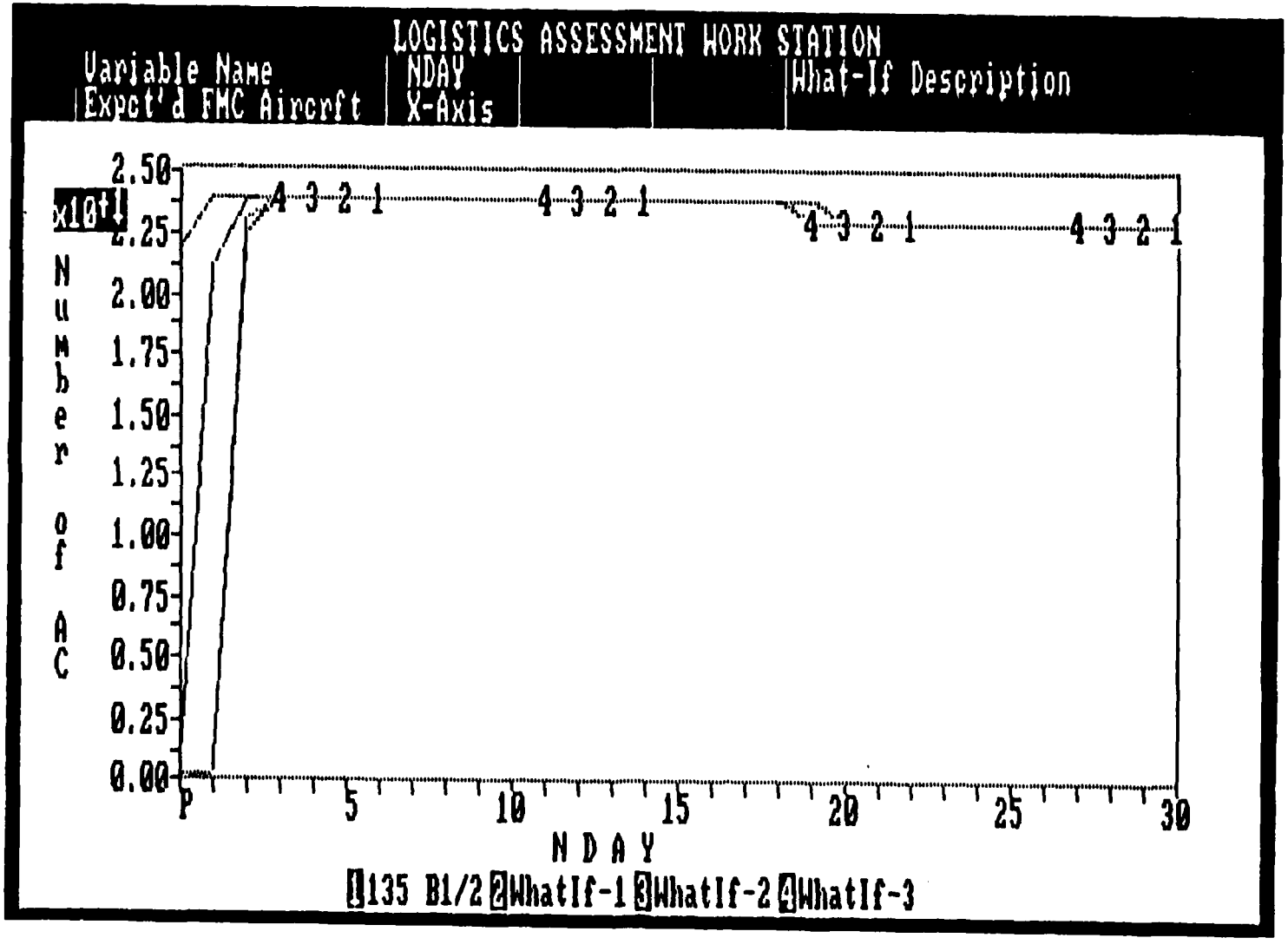
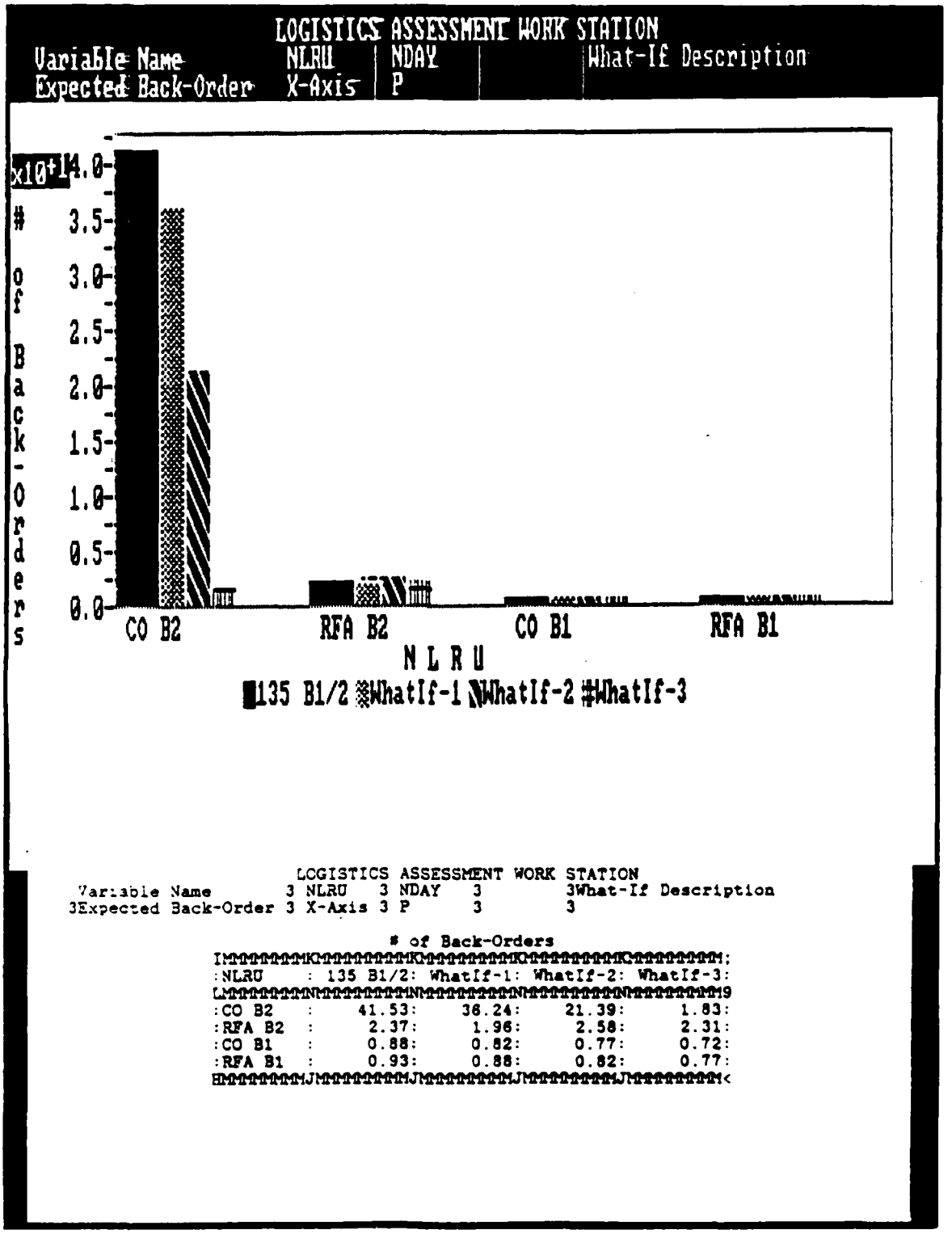


Fig. 18: ALQ-135 Band 1/2 Version: Expected FMC Aircraft with 5% Reductions in ALQ-135 Utilization per Sortie (View B)



LOGISTICS ASSESSMENT WORK STATION

Variable Name	3 NLRU	3 NDAY	3	3What-If Description
3Expected Back-Order	3 X-Axis	3 P	3	3

# of Back-Orders

:NLRU	: 135 B1/2:	WhatIf-1:	WhatIf-2:	WhatIf-3:
:CO B2	: 41.53:	36.24:	21.39:	1.83:
:RFA B2	: 2.37:	1.96:	2.58:	2.31:
:CO B1	: 0.88:	0.82:	0.77:	0.72:
:RFA B1	: 0.93:	0.88:	0.82:	0.77:

Fig. 19: ALQ-135 Band 1/2 Version: Expected Backorders by LRU (Peacetime) with 5% Reductions in ALQ-135 Utilization per Sortie (View B)

absence of any other corrective action, decreasing part utilization time by perhaps turning the ALQ-135 to 'off' or 'standby' for a minimum of 15% of each mission could improve Combat Capability and restore Survivability.

The analysis then returned to the direct comparison for Figures 20 through 27. In terms of number of sorties without maintenance (Figure 20), the Band 1/2 system should fly just over 22 sorties between maintenance actions. At 1.32 hours per sortie, the P^3I design would average nearly 54 sorties between maintenance, and at a 2.00 average duration, an F-15E can be expected to fly over 35 sorties between ALQ-135 repairs. LAMP expresses a squadron demand rate as expected failures per day (by LRU) as shown in Figure 21 for peacetime and the first seven days of the war. Again, the Band 1/2 LRUs (especially CO B2) have the worst 'track record,' the P^3I at 1.32 hours per sortie is best, and the P^3I at 2.00 hours per sortie is somewhere in between.

Figure 22 was extracted from LAMP's Survivability hierarchy. It shows the number of generated sorties by day over the course of a 30-day war, assuming no I-level maintenance. The total number of sorties generated is consistent with View A's figure of 9% for the Band 1/2 design and 100% for both ALQ-135 scenarios.*

---

*The 'spike' shown on day 27 which suddenly restores the sortie rate to the requested level is only a LAMP representation of what actually occurs. In reality, the 9% of requested sorties generated occur in a 'trickle' over the course of the 30-day battle (5).

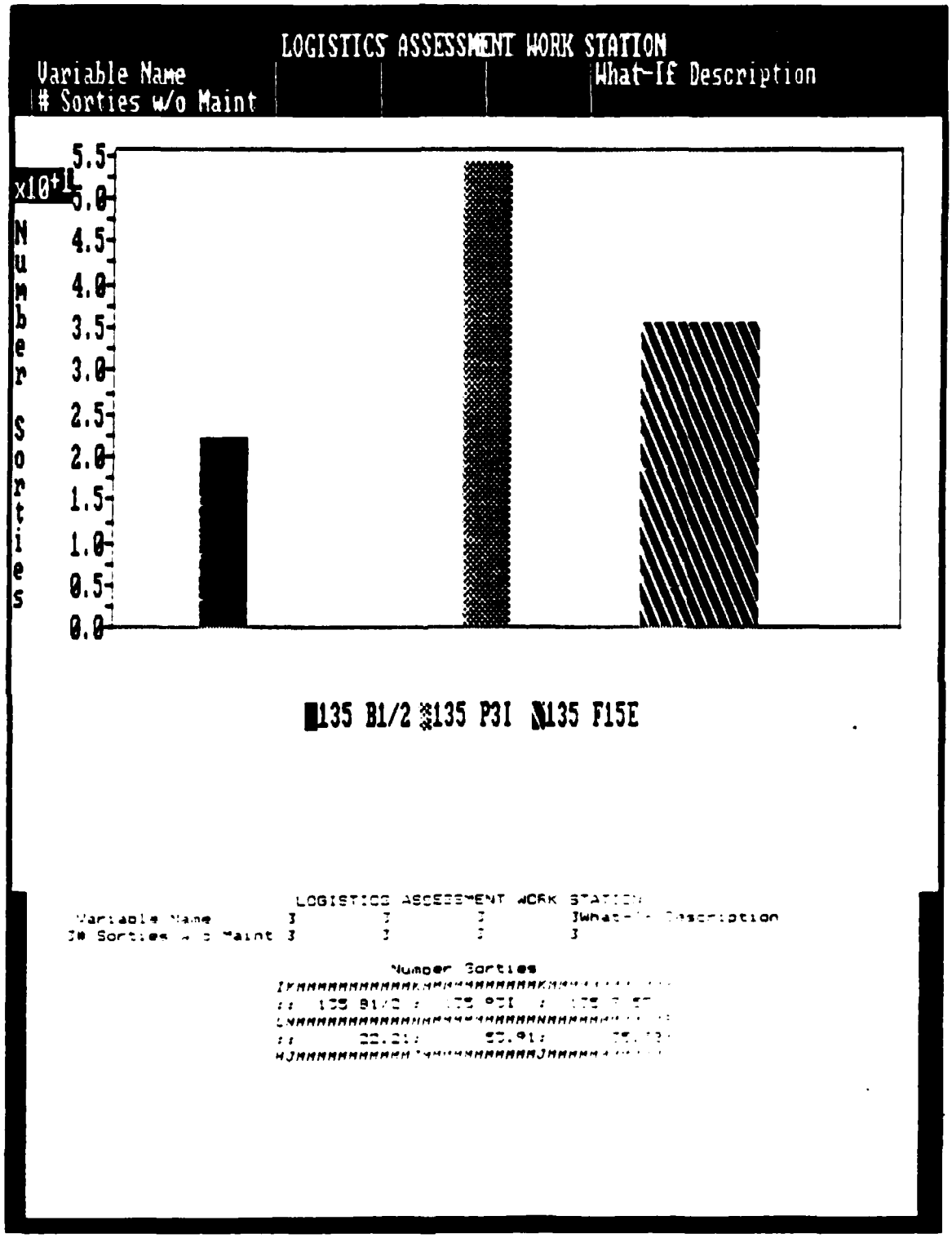


Figure 20: Band 1/2, 135 P^3I, and 135 F-15E Versions: Number of Sorties without Maintenance (View B)

LOGISTICS ASSESSMENT WORK STATION

Variable Name ∃ NLRU ∃ NDAY ∃ ∃What-If Description
Demand Rate/Fleet ∃ X-Axis ∃ Shades ∃ ∃

Exp Failures/Day

NLRU	P	1	2	3	4	5	6	7
CO B2	0.470	1.410	1.410	1.410	1.410	1.410	1.410	1.410
RFA B2	0.310	0.930	0.930	0.930	0.930	0.930	0.930	0.930
CO B1	0.150	0.460	0.460	0.460	0.460	0.460	0.460	0.460
RFA B1	0.140	0.430	0.430	0.430	0.430	0.430	0.430	0.430

LOGISTICS ASSESSMENT WORK STATION

Variable Name ∃ NLRU ∃ NDAY ∃ ∃What-If Description
Demand Rate/Fleet ∃ X-Axis ∃ Shades ∃ ∃

Exp Failures/Day

NLRU	P	1	2	3	4	5	6	7
PREAMP	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
HI CTL O	0.140	0.430	0.430	0.430	0.430	0.430	0.430	0.430
HI RFA	0.100	0.320	0.320	0.320	0.320	0.320	0.320	0.320
LO CTL O	0.100	0.300	0.300	0.300	0.300	0.300	0.300	0.300
LO RFA	0.080	0.250	0.250	0.250	0.250	0.250	0.250	0.250

LOGISTICS ASSESSMENT WORK STATION

Variable Name ∃ NLRU ∃ NDAY ∃ ∃What-If Description
Demand Rate/Fleet ∃ X-Axis ∃ Shades ∃ ∃

Exp Failures/Day

NLRU	P	1	2	3	4	5	6	7
PREAMP	0.000	0.010	0.010	0.010	0.010	0.010	0.010	0.010
HI CTL O	0.210	0.650	0.650	0.650	0.650	0.650	0.650	0.650
HI RFA	0.150	0.490	0.490	0.490	0.490	0.490	0.490	0.490
LO CTL O	0.150	0.450	0.450	0.450	0.450	0.450	0.450	0.450
LO RFA	0.130	0.390	0.390	0.390	0.390	0.390	0.390	0.390

Fig. 21: Band 1/2, 135 P^3I, and 135 F-15E Versions: LRU Fleet Demand Rates by Day (View B)

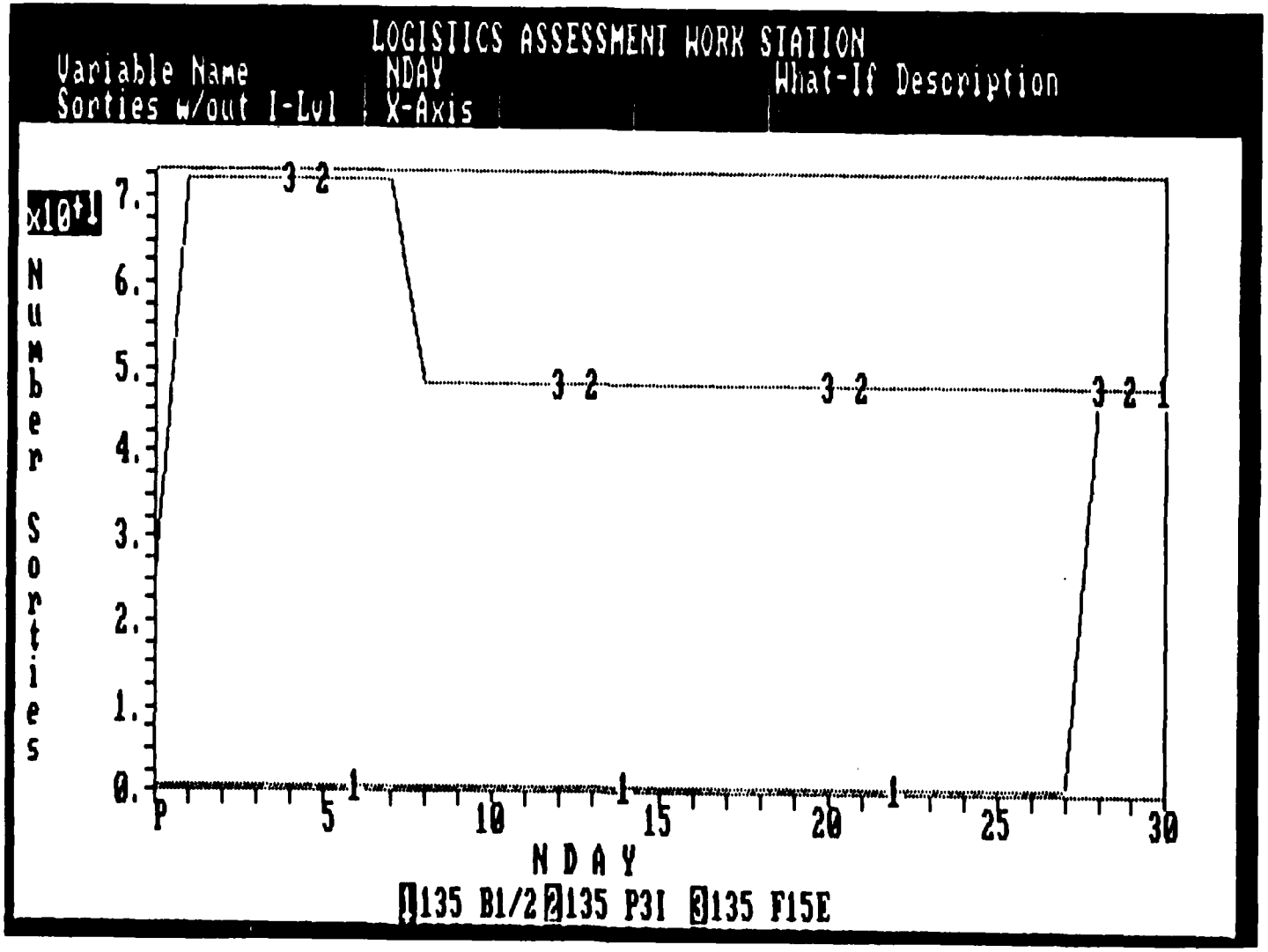


Fig. 22: Band 1/2, 135 P^3I, and 135 F-15E Versions: Sorties without I-level Maintenance by Day (View B)

Figures 23 and 24 are from part of the Mobility hierarchy. They display the cubic volume and weight, respectively, of a deploying squadron's support resources. The P^3I design can be expected to provide an approximate 20% reduction in mobility (SE, spares, and manpower) requirements.

As previously mentioned, the LCC values shown in Figure 13 are based on the cost of resources required to meet requested sortie goals. The View B hierarchy for LCC can break down that LCC total into R&D (TRDCST), acquisition (ACQCST), and 20-year operations and support (TOSCST) costs as shown in Figure 25. The LAMP models calculate the operations and support (O&S) costs to be over two-thirds of total design LCC for each of the three Workfiles. SE (TSECST), spares (ASCOST), and technical data (AQMTD) costs represent the bulk of acquisition costs for the ALQ-135 as shown in Figure 26. (The high cost of parts for the P^3I configuration makes spares costs a proportionately higher share of the acquisition bill for that system.) Finally, O&S costs for the P^3I design would be double those of the Band 1/2 system if flown at the same rate of 1.32 hours per sortie. If flown at 2.00 hours per sortie, P^3I O&S costs would be nearly triple those of the Band 1/2 version. Figure 27 illustrates these O&S costs for a twenty year total (TOSCST) and for a single year (OSCOST).

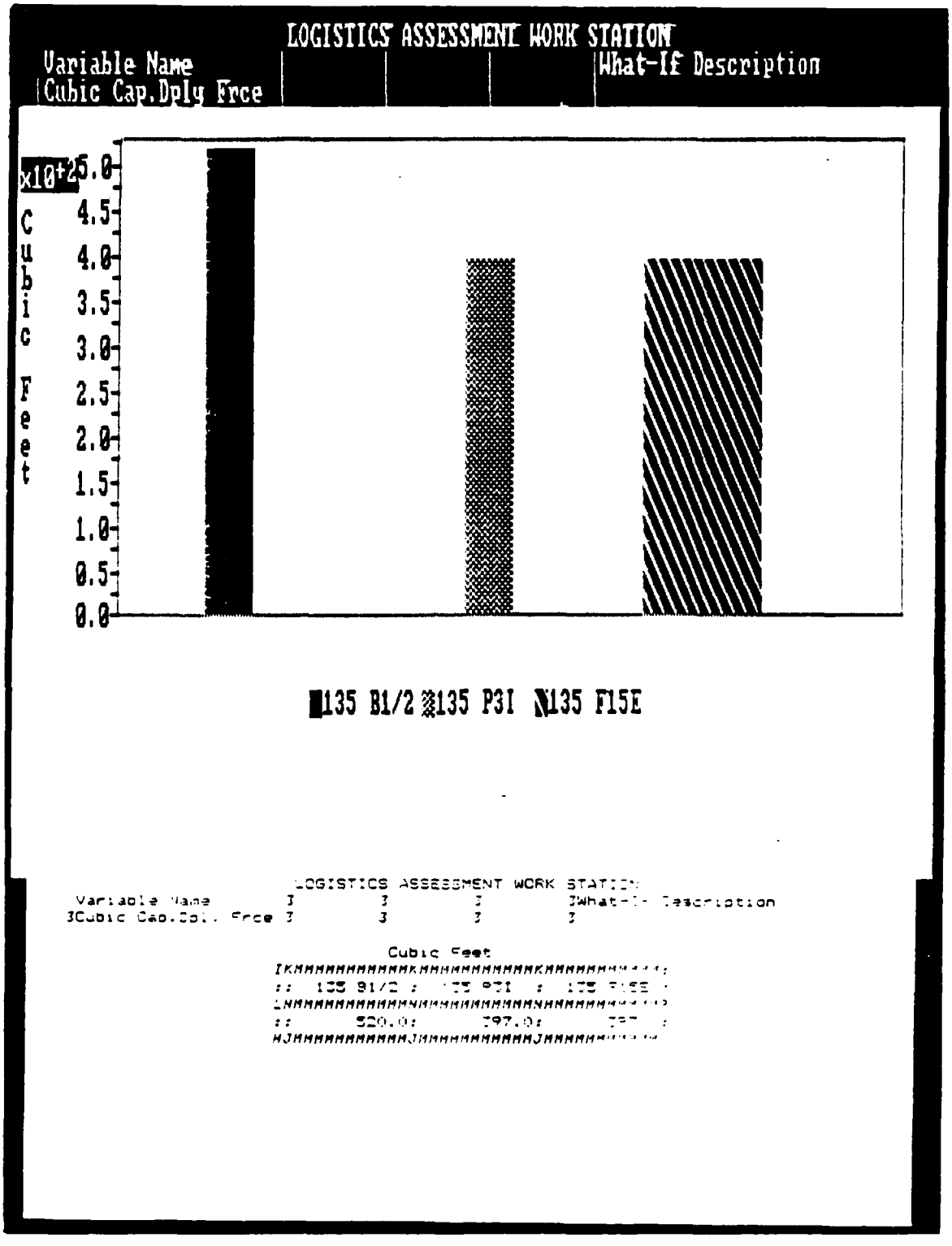


Fig. 23: Band 1/2, 135 P^3I, and 135 F-15E Versions: Cubic Capacity of Deploying Forces (View B)

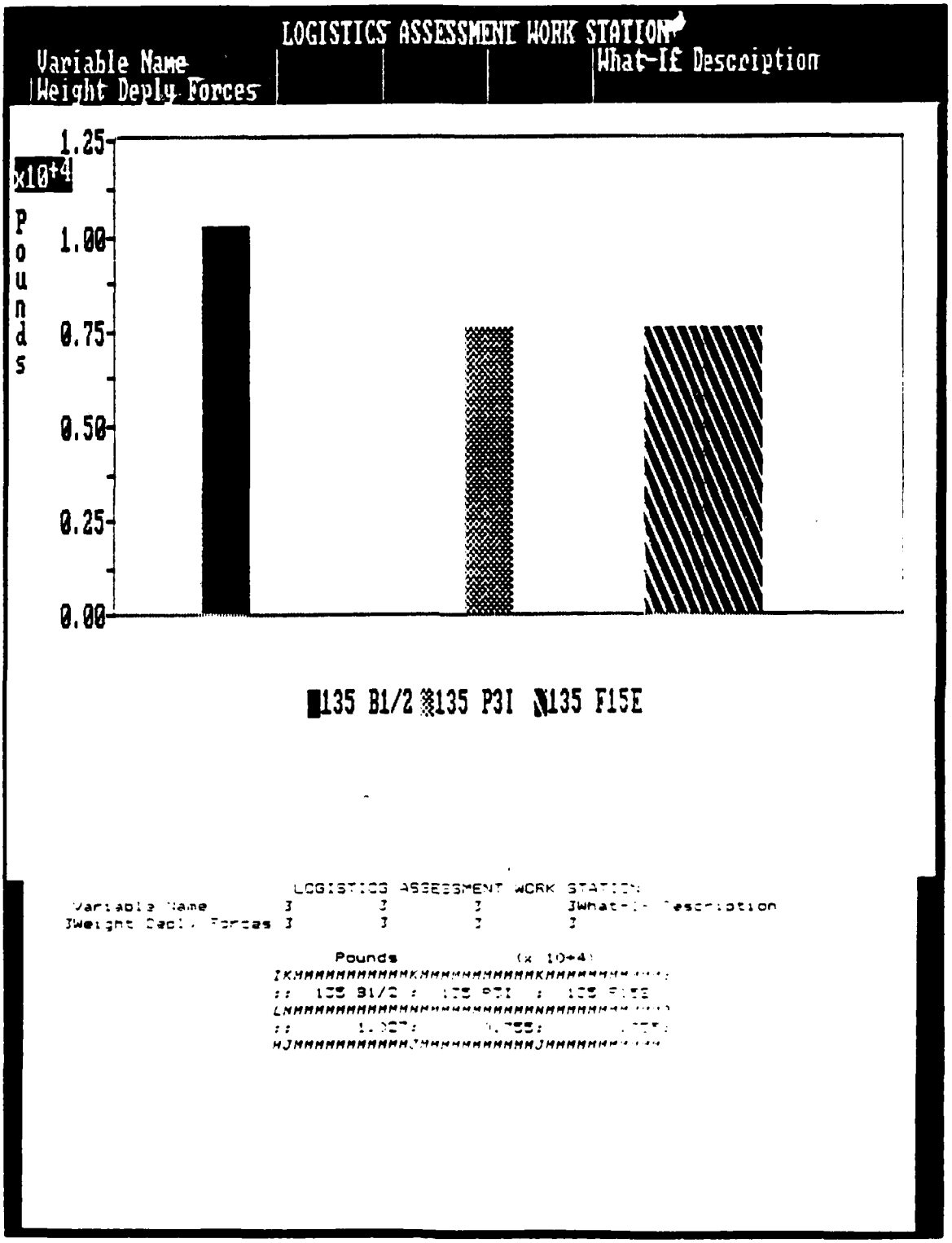
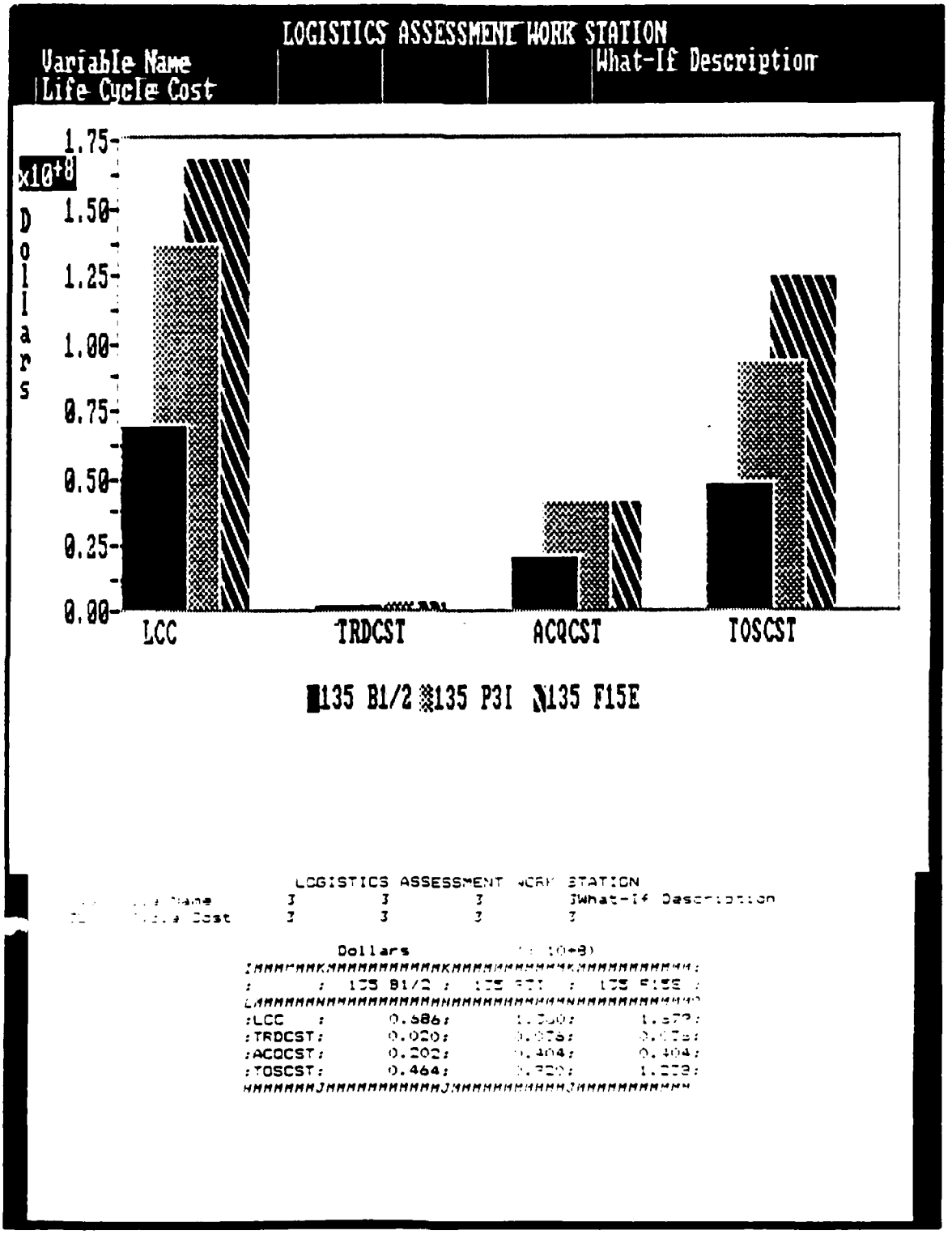


Fig. 24: Band 1/2, 135 P^3I, and 135 F-15E Versions: Weight of Deploying Forces (View B)



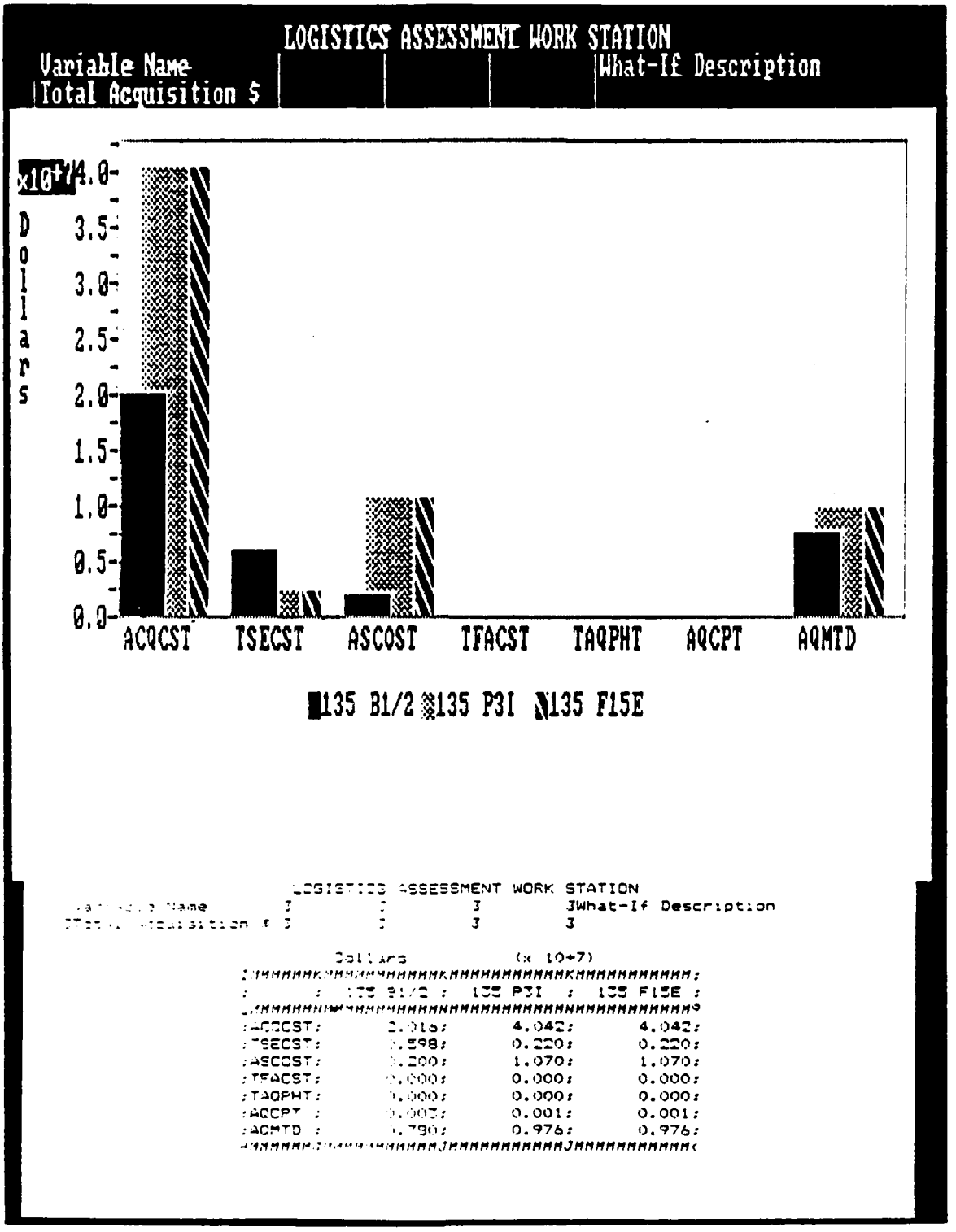
LOGISTICS ASSESSMENT WORK STATION

Variable Name				What-If Description
Life Cycle Cost				

Dollars (x 10+8)

	135 B1/2	135 P3I	135 F15E
LCC	0.686	1.350	1.379
TRDCST	0.020	0.036	0.036
ACQCST	0.202	0.404	0.404
TOSCST	0.464	0.920	1.039

Fig. 25: Band 1/2, 135 P^3I, and 135 F-15E Versions: LCC Breakout (View B)



LOGISTICS ASSESSMENT WORK STATION

Variable Name | What-If Description

Total Acquisition $

Dollars (x 10+7)

	135 B1/2	135 P3I	135 F15E
ACQCST	2.016	4.042	4.042
TSECST	0.598	0.220	0.220
ASCOST	0.200	1.070	1.070
TFACST	0.000	0.000	0.000
TAQPHT	0.000	0.000	0.000
AQCPT	0.000	0.001	0.001
AQMTD	0.790	0.976	0.976

Fig. 26: Band 1/2, 135 P^3I, and 135 F-15E Versions: Acquisition Cost Breakout (View B)

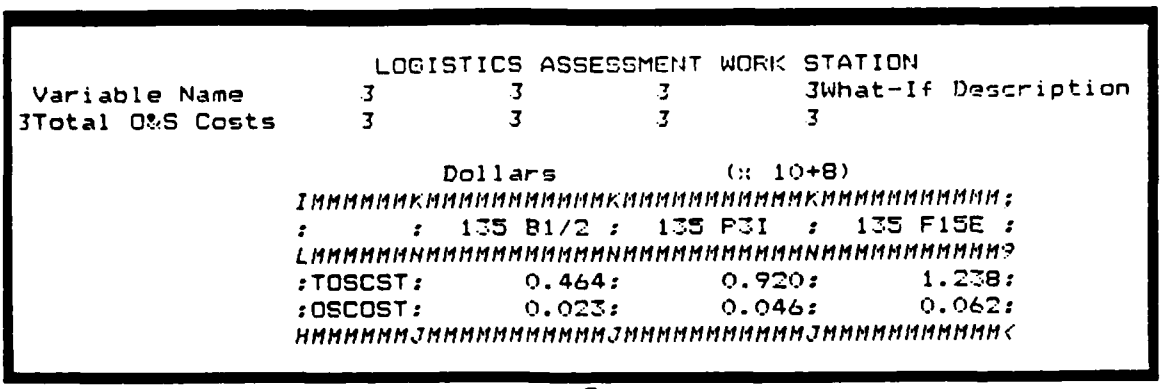
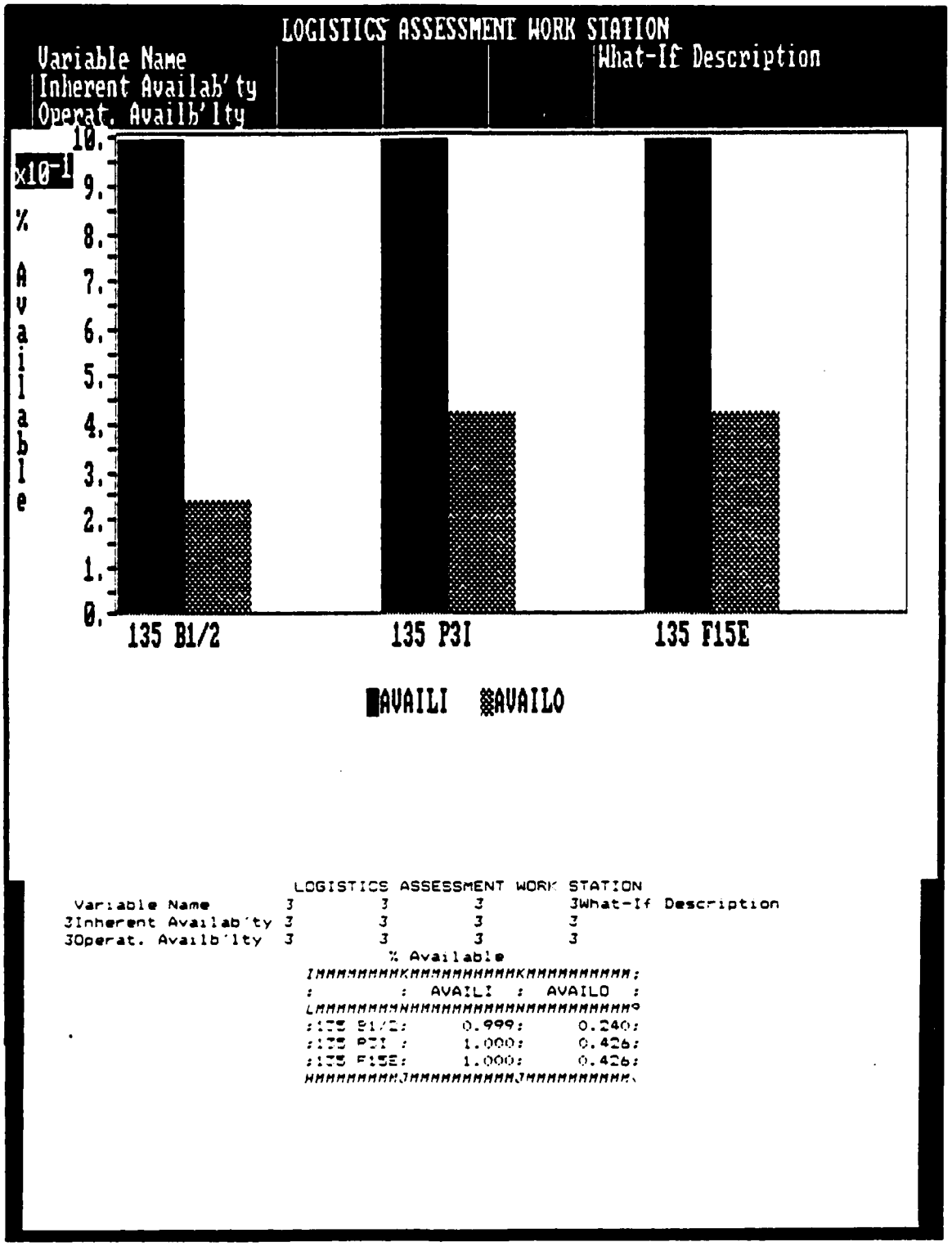


Fig. 27: Band 1/2, 135 P^3I, and 135 F-15E Versions: Operations and Support Costs (View B)

The next series (Figures 28-31) is from View C, the ILS Elements Hierarchy. Figure 28 compares ALQ-135 inherent and operational availability. Each design has high inherent availability, but in terms of operational availability (the probability of satisfactory function in an operational environment), the P^3I design is nearly twice as reliable as the Band 1/2 system. Figure 29 presents reliability in terms of mean time (as opposed to sorties shown earlier) between maintenance actions, or MTBMA. The P^3I system has roughly two and one-half times the (sub)system-level MTBMA of the Band 1/2 design. (Sub)system-level MTBF is shown in Figure 30. MTBF figures are the result of a basic serial reliability model, and 77.2 hours for P^3I (identical to Northrop predictions (10:4,21)), is over twice that of the Band 1/2 predecessor. The P^3I ALQ-135 also features significant improvements in Maintenance Manhours (MMH) per Flying Hour. Figure 31 illustrates that the P^3I version of the ALQ-135 should offer approximately a 40% reduction in MMH per Flying Hour as compared to the Band 1/2 version.



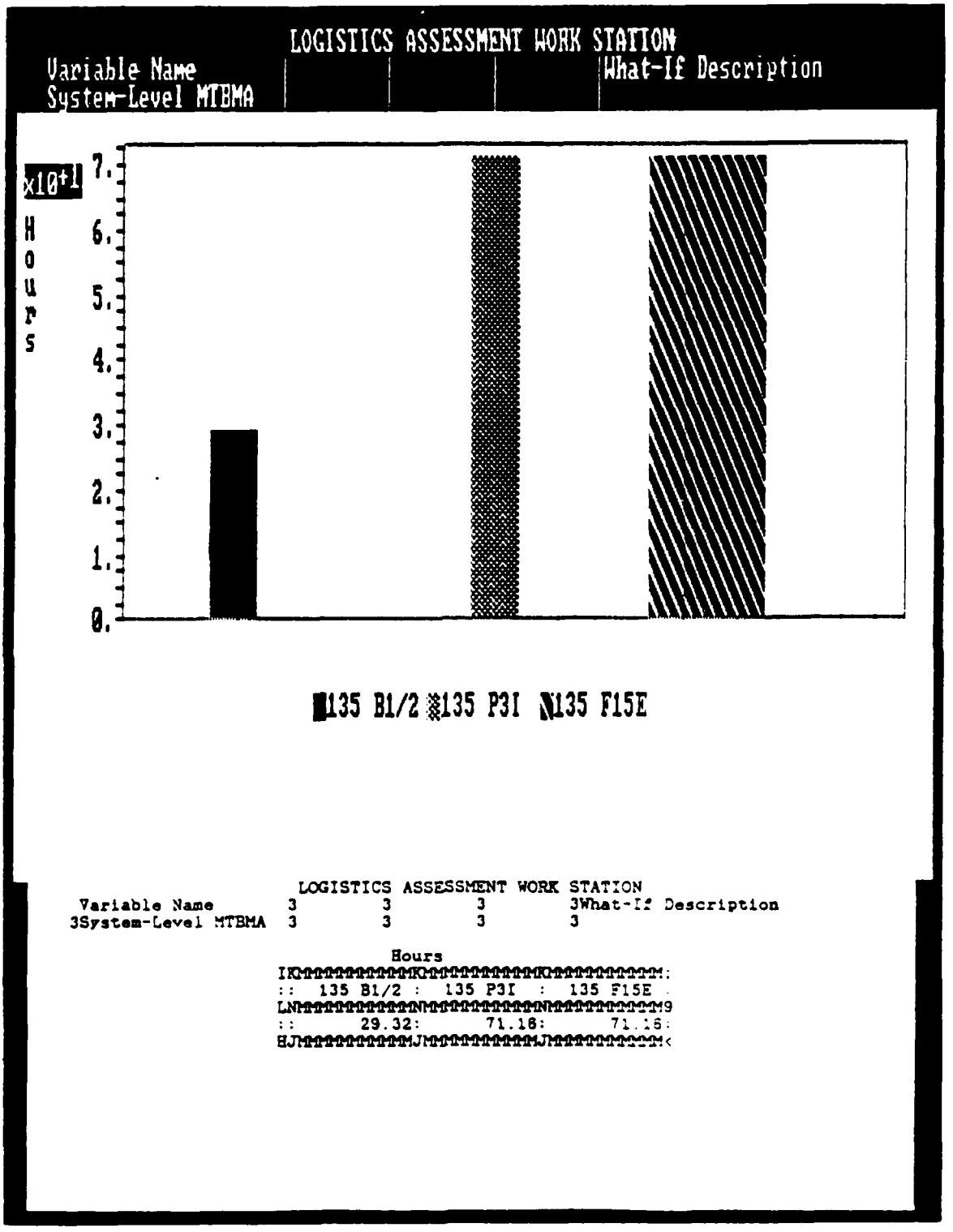
LOGISTICS ASSESSMENT WORK STATION

Variable Name				What-If Description
Inherent Availab'ty				
Operat. Availb'ty				

% Available

	AVAILI	AVAILO
135 B1/2	0.999	0.240
135 P3I	1.000	0.426
135 F15E	1.000	0.426

Fig. 28: Band 1/2, 135 P^3I, and 135 F-15E Versions: Comparison of Inherent and Operational Availability (View C)



LOGISTICS ASSESSMENT WORK STATION

Variable Name	3	3	3	3What-If Description
3System-Level MTBMA	3	3	3	3

Hours

135 B1/2	135 P3I	135 F15E
29.32	71.16	71.16

Fig. 29: Band 1/2, 135 P^3I, and 135 F-15E Versions: System-level MTBMA (View C)

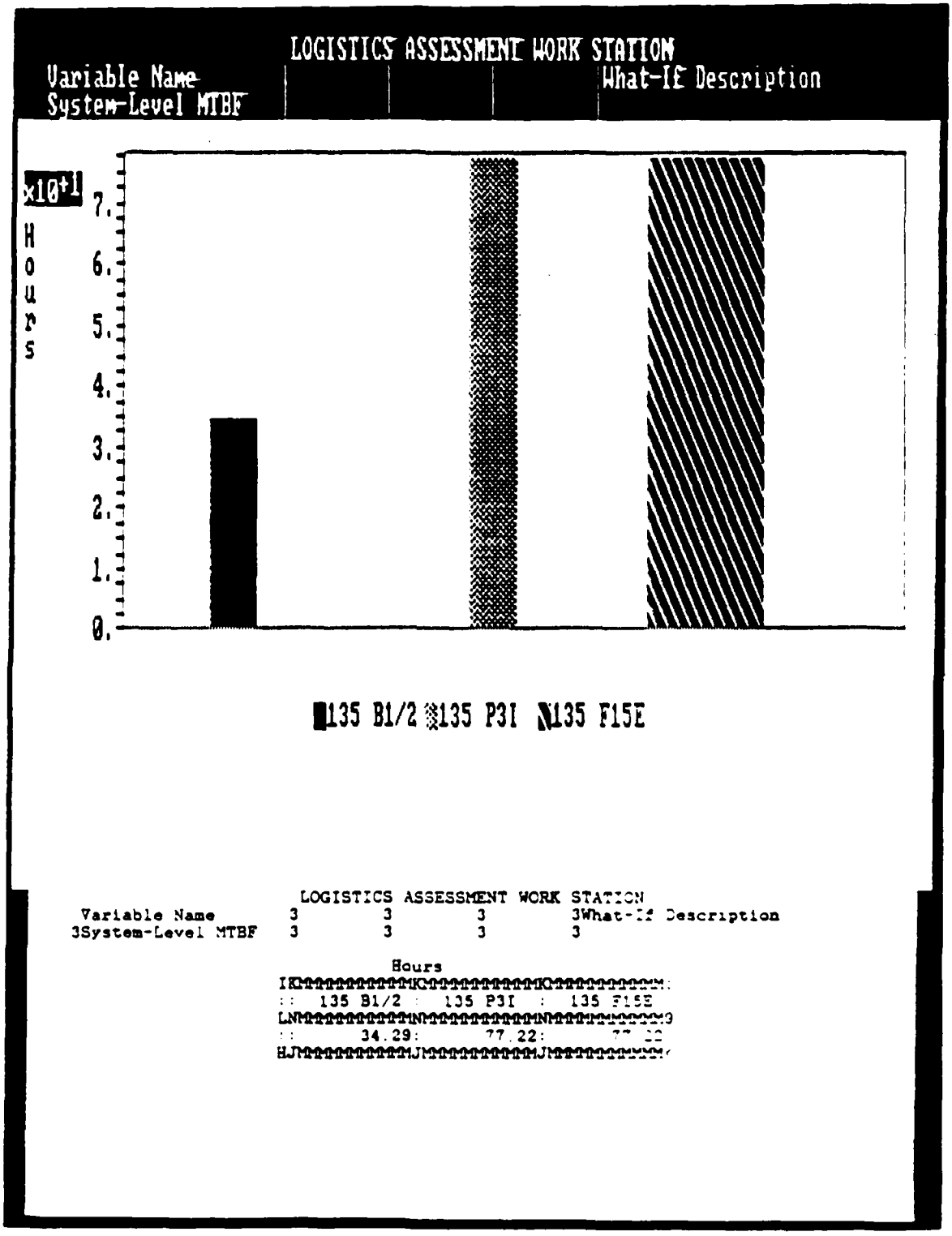


Fig. 30: Band 1/2, 135 P^3I, and 135 F-15E Versions: System-level MTBF (View C)

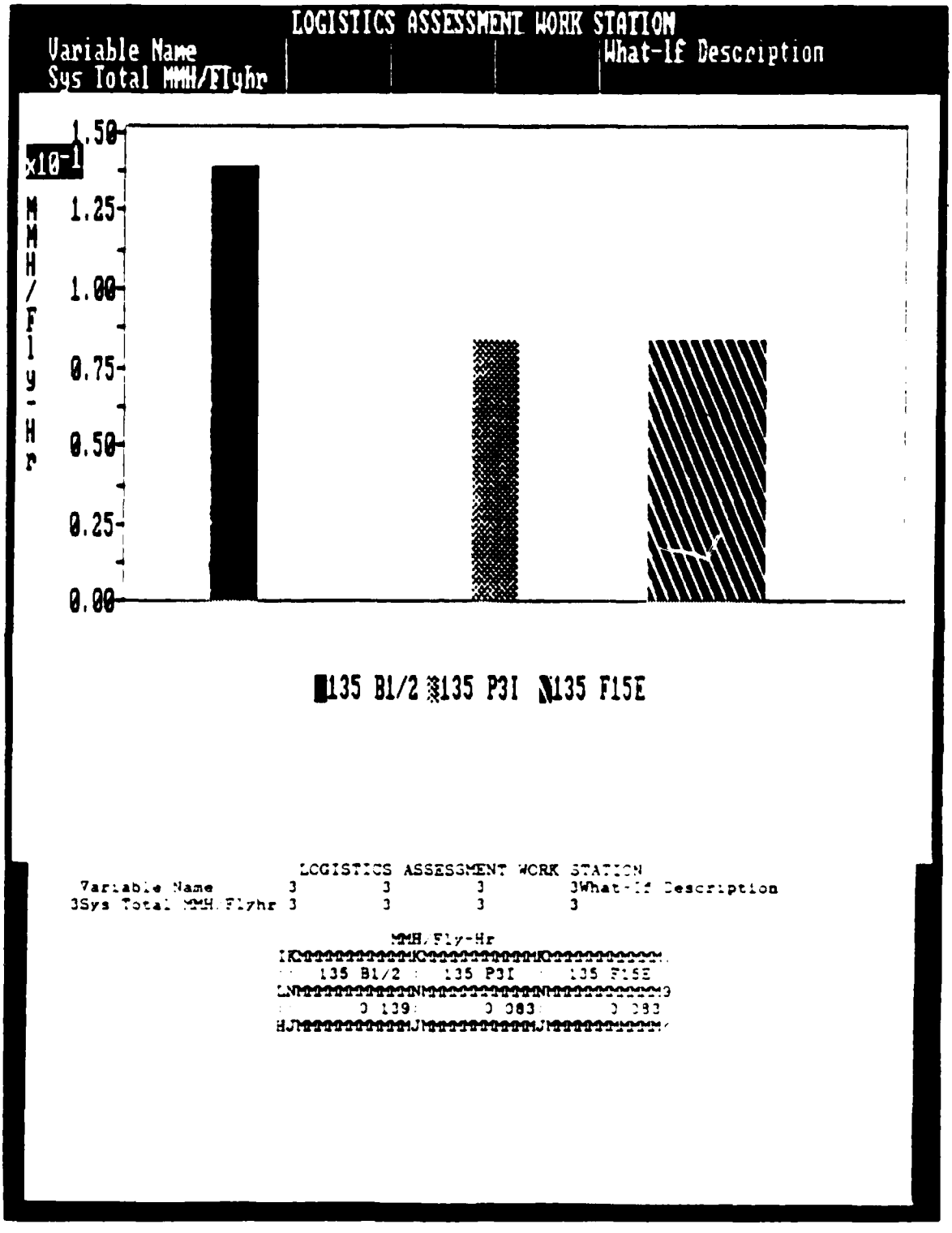


Fig. 31: Band 1/2, 135 P^3I, and 135 F-15E Versions: System-level MMH per Flight Hour (View C)

This initial 'quick look' comparison of the Band 1/2 and P^3I designs can be considered a backdrop for the remainder of the Sensitivity Analysis phase. From this point, the focus will be squarely on the P^3I design.

Design Variable Sensitivity. The next analysis steps focused on investigation of the sensitivity of P^3I design characteristics, categorized by the ten elements of integrated logistics support. Particular elements of interest (and hence specific LAMP input variables) were associated with the five supportability issues identified in Chapter 3. Those issues are listed again for convenience:

1. Are Northrop's projected maintenance characteristics (primarily MMH and NRTS) crucial to the maximization of R&M 2000 goals? What effect would some Repair-in-Place capability have?

2. How critical are projections about TISS and ALQ-135 BIT performance?

3. Are repair cycle times (base and depot) limiting factors in supportability of the ALQ-135?

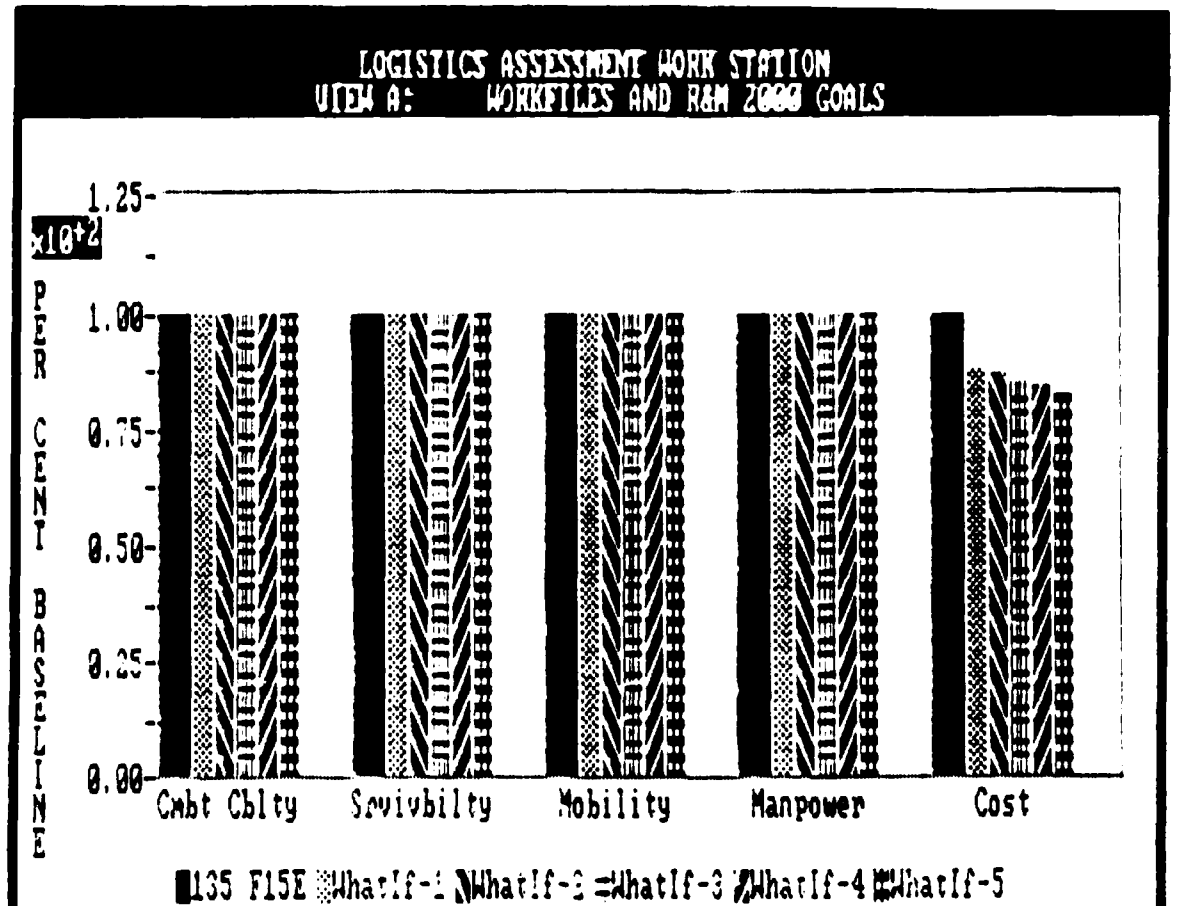
4. What if LRU MTBFs are less than predicted? How do changes in part utilization per sortie (MTBM-1 vs. MTBF) affect supportability?

5. How would changes to LRU weight, size, and unit cost affect the R&M 2000 goals?

View A provided the most comprehensive format for answers to each of these supportability questions. As was the case during direct comparison of ALQ-135 designs, other views were then called upon during this part of Sensitivity Analysis to provide more detailed supportability assessment where appropriate.

The first three supportability issues center around the sensitivity of maintainability characteristics. Maintainability in general is addressed in the first supportability issue. LAMP variables corresponding to Repair-in-Place (TRIP, #23), Not Repairable at This Station (TNRTS, #26), and Maintenance Manhours (MMH1, #50) were the ones determined most appropriate for analysis. The next series of illustrations (Figures 32-35) is related to general maintainability questions.

At present, there is no Repair-in-Place (RIP) capability planned for the ALQ-135. If some RIP capability could be developed it would probably add to the efficiency of the maintenance process. As shown in Figure 32, however, the only visible impact of the RIP concept was felt in the area of LCC. The line 'Comparison:135 F15E' (the solid bar in graphs) represents the same basic P^3I/F-15E characteristics as presented in the direct comparison section of this analysis. 'What-if (1)' represents in this case a hypothetical development of a 20% RIP rate for ALQ-135 failures. The resulting LCC savings was projected at over $20M. 'What-ifs' (2) through (5) stand for further improvements in the RIP rate of 10% each, each of which results in much smaller respective LCC savings as shown. Of course, any costs associated with the development of an RIP procedure for the ALQ-135 would have to be discounted from these LCC savings suggested by LAMP.



LOGISTICS ASSESSMENT WORK STATION
VIEW A WORKFILES AND R&M 2000 GOALS

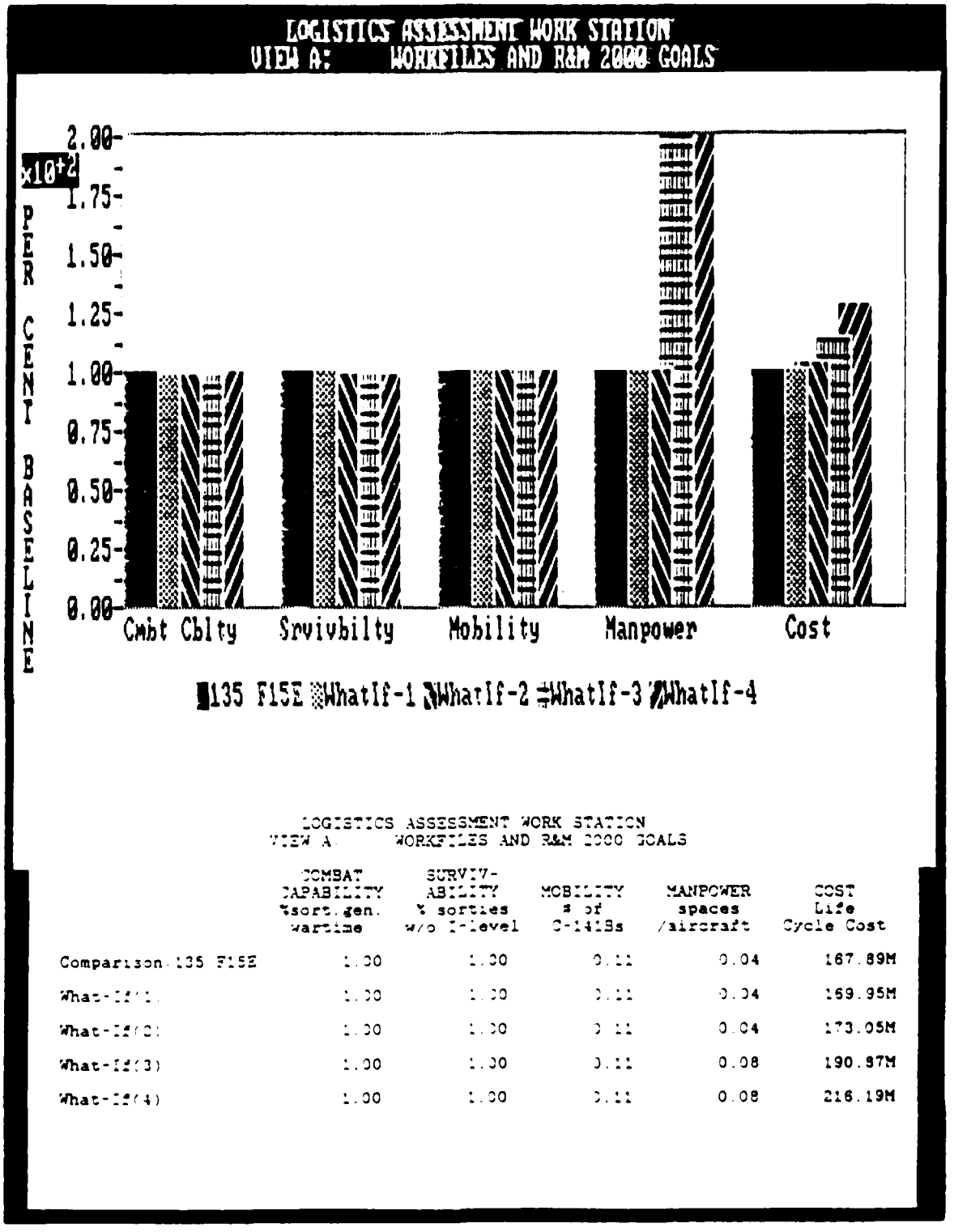
	COMBAT CAPABILITY %sort.gen. wartime	SURVIV-ABILITY % sorties w/o I-level	MOBILITY # of C-141Bs	MANPOWER spaces aircraft	COST Life Cycle Cost
Comparison 135 F15E	1.00	1.00	0.11	0.04	167.89M
What-If 1	1.00	1.00	0.11	0.04	147.66M
What-If 2	1.00	1.00	0.11	0.04	145.66M
What-If 3	1.00	1.00	0.11	0.04	143.45M
What-If 4	1.00	1.00	0.11	0.04	141.03M
What-If 5	1.00	1.00	0.11	0.04	138.37M

Fig. 32: 135 F-15E Version: Flightline RIP Comparison of 0, 0.2, and 10% Increases from 0.2 (View A)

How critical are ALQ-135 projected NRTS rates? Figure 33 illustrates the effects of incremental 50% increases over those assumed for the P^3I. Increases in LCC were at first quite small, but gradually became greater with higher NRTS rates. The NRTS rate would have to grow by virtually 150% ('What-if (3),' the 'plaid' bar) to impact the Manpower goal, which would in this case be felt at D-level, since no accompanying increase in Mobility requirements was seen.

Increases in MMH requirements for unscheduled maintenance could affect all five of the R&M 2000 goals. In the case of P^3I, increases of 20% in MMH impact Mobility, Manpower, and LCC goals as presented in Figure 34. Sortie demands and ALQ-135 R&M characteristics are evidently such that they are insensitive to MMH requirements over this range of values. LCC was relatively insensitive to MMH as shown in Figure 35, which is a sensitivity curve formulated through LAMP View E. The slope increase from 'What-if (3)' to 'What-if (4)' is associated with the additional manpower required at that point to meet the increasing workload.

The second supportability issue, the impact of changes in TISS performance and the degree of successful BIT design, were investigated by altering variables which describe Support Equipment downtime (SEDOWN, # 1) and the maintenance Can Not Duplicate (CND) rate (TCND, # 22). In general, these variables reflect the integration between the ALQ-135 subsystem and its SE. BIT fault isolation can also be reflected in required Maintenance Manhours (MMH1, #50) for



LOGISTICS ASSESSMENT WORK STATION
VIEW A WORKFILES AND R&M 2000 GOALS

	COMBAT CAPABILITY %sort.gen. wartime	SURVIV-ABILITY % sorties w/o I-level	MOBILITY # of C-141Bs	MANPOWER spaces /aircraft	COST Life Cycle Cost
Comparison 135 F15E	1.00	1.00	0.11	0.04	167.89M
What-If(1)	1.00	1.00	0.11	0.04	169.95M
What-If(2)	1.00	1.00	0.11	0.04	173.05M
What-If(3)	1.00	1.00	0.11	0.08	190.87M
What-If(4)	1.00	1.00	0.11	0.08	216.19M

Fig. 33: 135 F-15E Version: 50% Increases in Intermediate Shop NRTS (View A)

LOGISTICS ASSESSMENT WORK STATION
VIEW A WORKFILES AND R&M 2000 GOALS

	COMBAT CAPABILITY %sort gen wartime	SURVIV-ABILITY % sorties w/o I-level	MOBILITY # of C-141Bs	MANPOWER spaces aircraft	COST Life Cycle Cost
Comparison 135 F15E	1.00	1.00	0.11	0.04	167.89M
What-If(1)	1.00	1.00	0.11	0.09	168.24M
What-If(2)	1.00	1.00	0.11	0.08	168.50M
What-If(3)	1.00	1.00	0.16	0.08	177.16M
What-If(4)	1.00	1.00	0.17	0.13	177.67M
What-If(5)	1.00	1.00	0.17	0.13	178.10M

Fig. 34: 135 F-15E Version: 20% Increases in MMH for all tasks (View A)

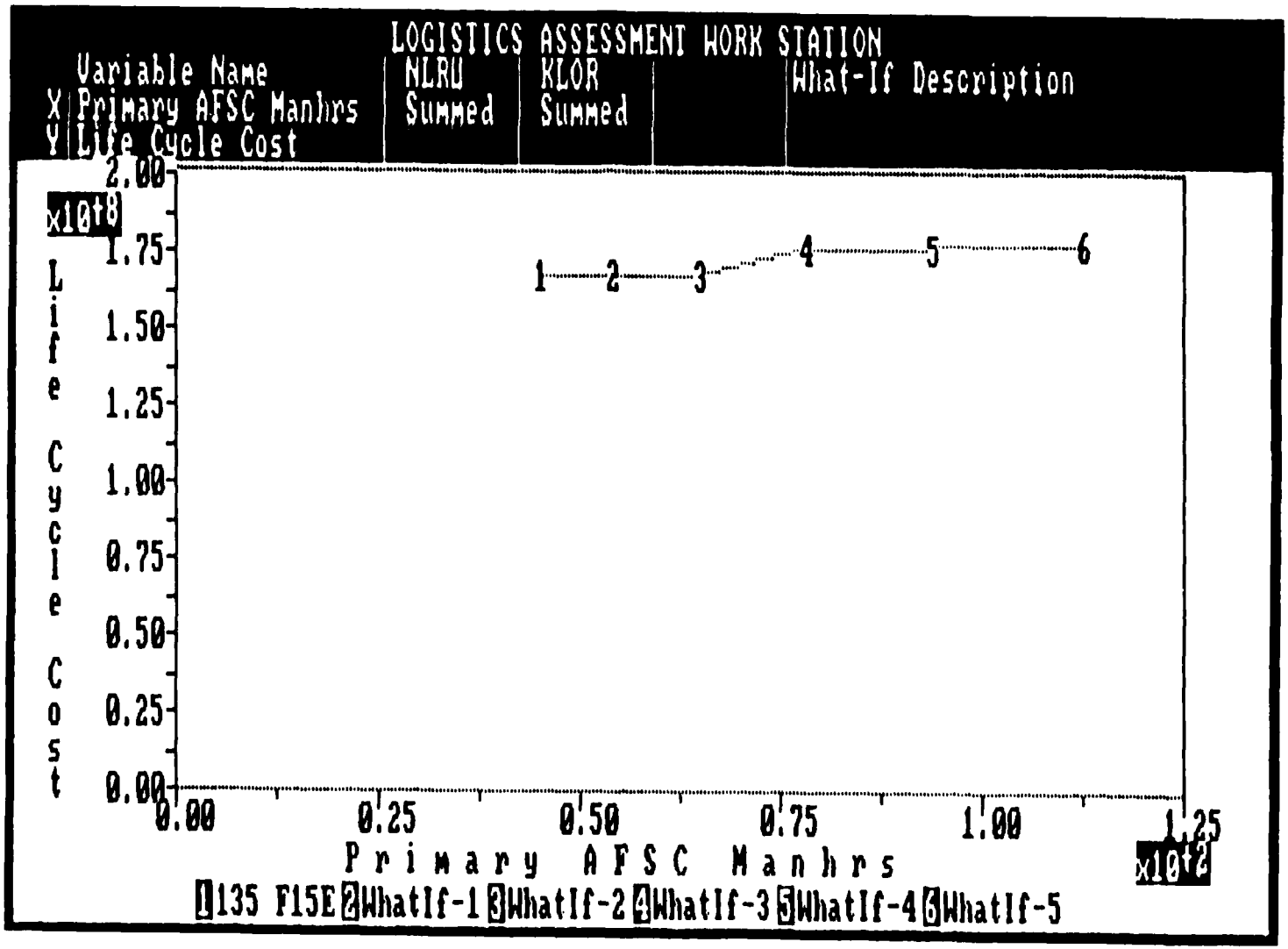


Fig. 35: 135 F-15E Version: Sensitivity of LCC to MMH (View E)

Fault Isolation, and in Intermediate- and Depot-level Inspection tasks. By testing these three variables, the sensitivity of the R&M 2000 goals to design-for-testability (DFT) capabilities were assessed (See Figures 36-40).

In light of past poor performance of ALQ-135 I-level SE, the sensitivity of ALQ-135 maintainability to TISS performance was determined by increasing TISS downtime in 20% increments (Figure 36). There was no impact for the first two degradations ('What-ifs' (1) and (2)), but the next two steps resulted in LCC and Mobility effects. The increase in the mobility load is due to the necessity of extra pieces of I-level SE to compensate for diminished capability of each unit. According to the output from the Support Equipment ILS Hierarchy (View C) shown in Figure 37, the TISS requirement given roughly an 80% increase in I-level SE downtime ('What-if (4)') would be four units per squadron versus the original one.

The P^3I design was insensitive to greater CND rates. Figure 38 shows successive 100% increases in the variable 'TCND.' One additional maintenance technician is needed (with an associated LCC increase) only when the CND rate reached approximately sixteen times its supposed base value of 5%.

To further focus on the importance of BIT/FIT performance, MMH requirements for Initial Test and Inspection tasks at all three levels of repair were increased in order to reflect hypothetically lower confidence in BIT. These input

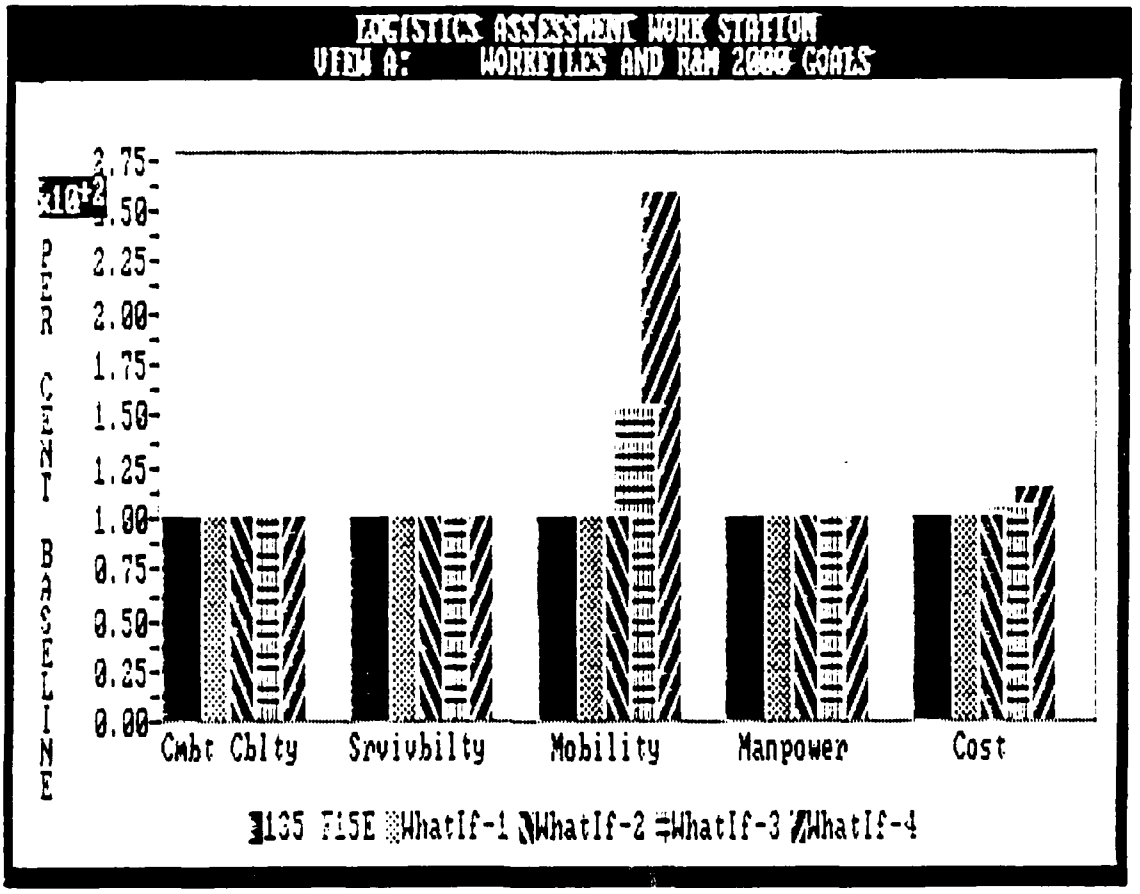


Fig. 36: 135 F-15E Version: 20% Increases in TISS Downtime (View A)

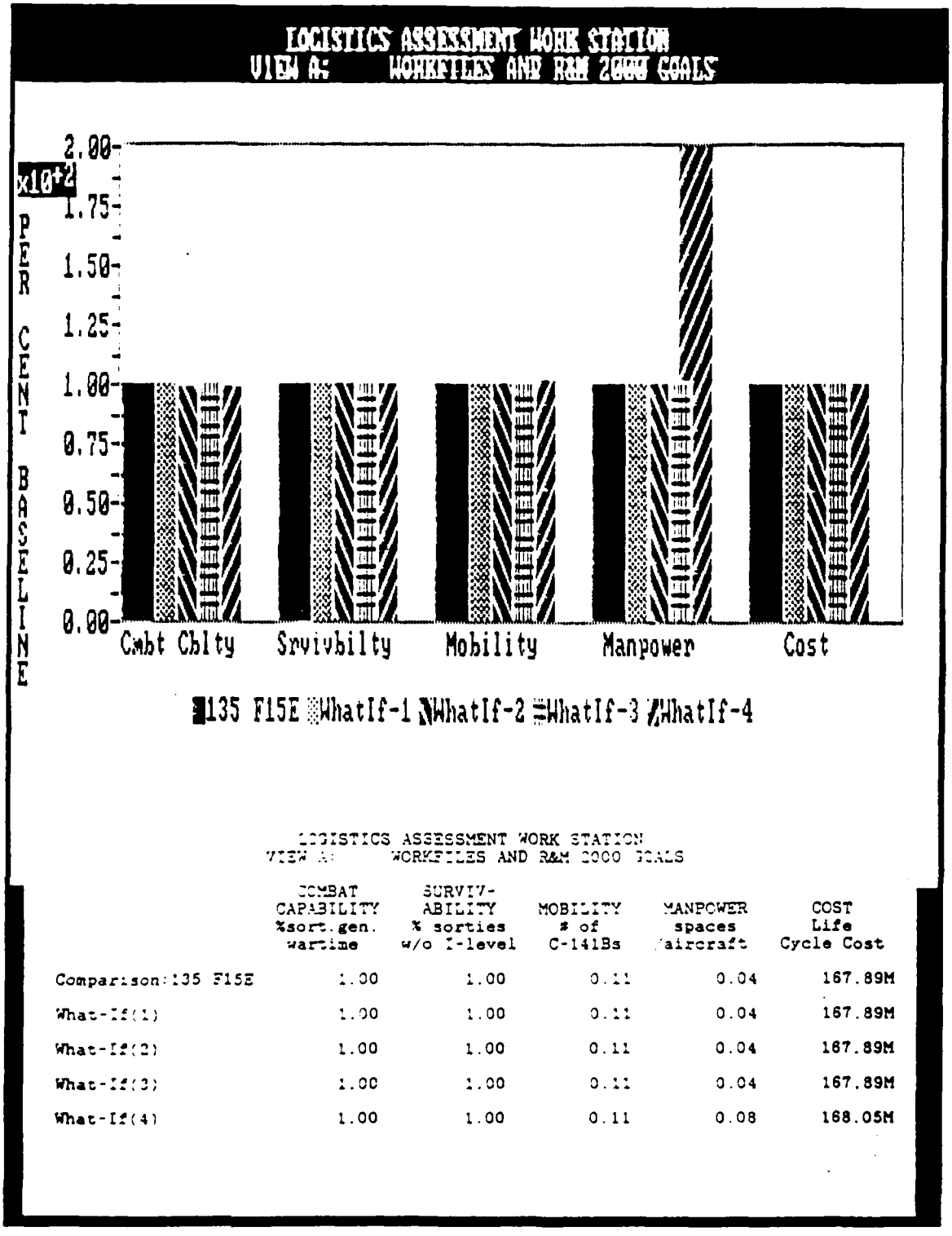
LOGISTICS ASSESSMENT WORK STATION

Variable Name	KSE			What-If Description
# of SE at Shop	TISS			

Support Equip.

135 F15E	WhatIf-1	WhatIf-2	WhatIf-3	WhatIf-4
1.000	1.000	1.000	2.000	4.000

Fig. 37: 135 F-15E Version: TISS Requirements, Given 20% Increases in TISS Downtime (View C)



LOGISTICS ASSESSMENT WORK STATION
VIEW A: WORKFILES AND R&M 2000 GOALS

	COMBAT CAPABILITY %sort.gen. wartime	SURVIV-ABILITY % sorties w/o I-level	MOBILITY # of C-141Bs	MANPOWER spaces aircraft	COST Life Cycle Cost
Comparison:135 F15E	1.00	1.00	0.11	0.04	167.89M
What-If(1)	1.00	1.00	0.11	0.04	167.89M
What-If(2)	1.00	1.00	0.11	0.04	167.89M
What-If(3)	1.00	1.00	0.11	0.04	167.89M
What-If(4)	1.00	1.00	0.11	0.08	168.05M

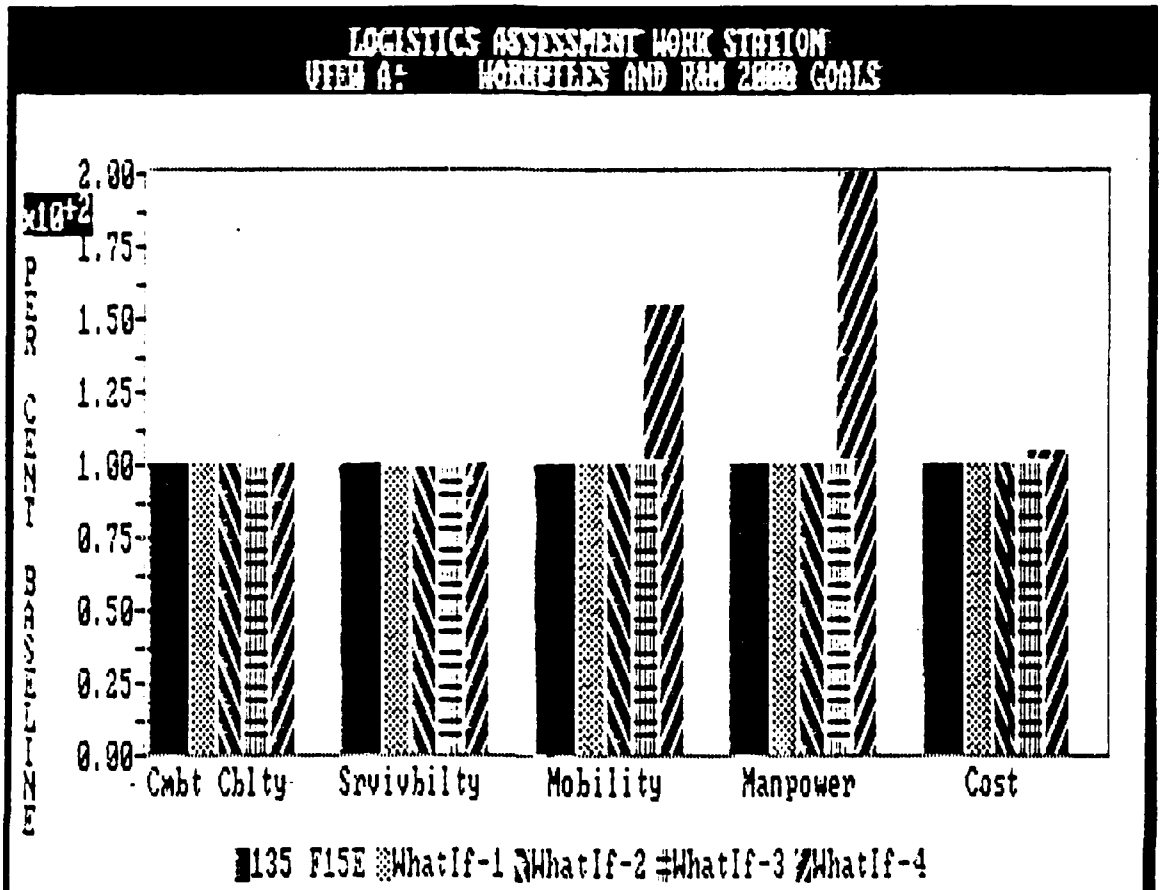
Fig. 38: 135 F-15E Version: 100% Increases in CND Rates (View A)

variables were increased by 20% in each of four 'What-ifs' as illustrated in Figure 39. Only after an increase of four steps in required MMH for these three variables was there any significant increase in Mobility, Manpower, or LCC requirements. An increased Mobility burden indicates that the Manpower increase comes at the O- and/or I-level. The sensitivity curve in Figure 40 provides a slightly different view of this weak LCC-MMH relationship.

The third supportability issue accounts for possible variations in the 'turnaround' or repair cycle times for I-level and D-level repairs as they relate to maintainability. The LAMP variables Flightline-to-Shop Time (SFBT, #43), Shop-Depot-Flightline Time (TOST, #44), and Base Repair Cycle Time (TBRT, #29) were varied to determine impacts on the R&M 2000 goals. Figures 41-49 are representative of outputs pertaining to this third supportability issue.

The time required to move a broken LRU from the flightline to the I-Shop was initially assumed to be one day or less. When this interval was increased in increments of 50% of base value (Figure 41), there was no impact on any of the R&M 2000 goals. Likewise, as depicted in Figure 42 a similar 'no change' effect resulted from 20% increases in the supposed 20-day I-Shop to Depot to Flightline response time.

In contrast to the other transportation/processing attributes, the Base Repair Cycle Time (LAMP variable TBRT, #29) was found to be critical to wartime capability and



LOGISTICS ASSESSMENT WORK STATION
VIEW A: WORKFILES AND R&M 2000 GOALS

	COMBAT CAPABILITY %sort.gen. wartime	SURVIV-ABILITY % sorties w/o I-level	MOBILITY # of C-141Bs	MANPOWER spaces /aircraft	COST Life Cycle Cost
Comparison:135 F15E	1.00	1.00	0.11	0.04	167.89M
What-If(1)	1.00	1.00	0.11	0.04	168.01M
What-If(2)	1.00	1.00	0.11	0.04	168.15M
What-If(3)	1.00	1.00	0.11	0.04	168.31M
What-If(4)	1.00	1.00	0.16	0.08	177.02M

Fig. 39: 135 F-15E Version: 20% Increases in MMH for Initial Test and Inspection Tasks (View A)

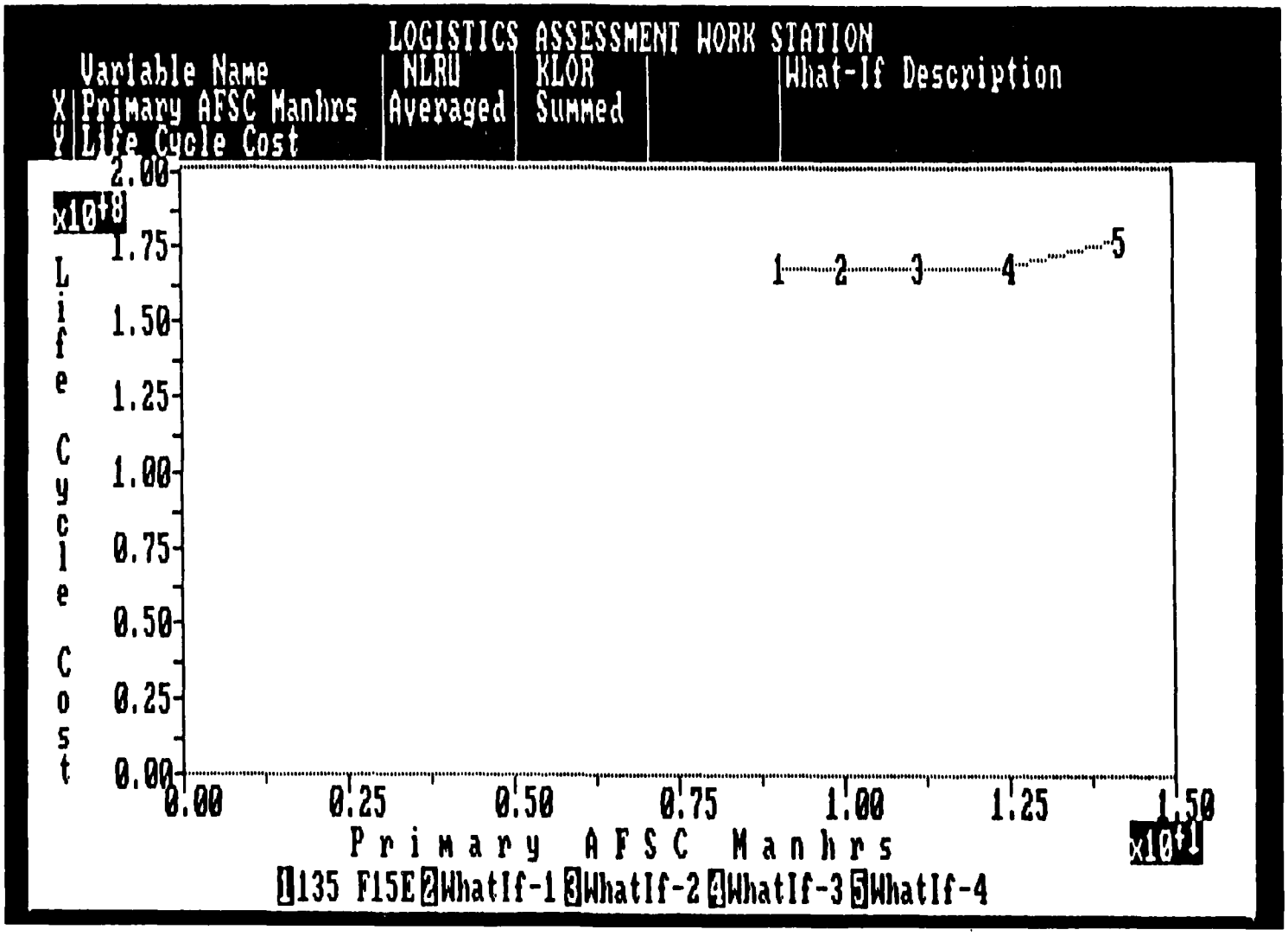


Fig. 40: 135 F-15E Version: Sensitivity of LCC to Test and Inspection Manhours (View E)

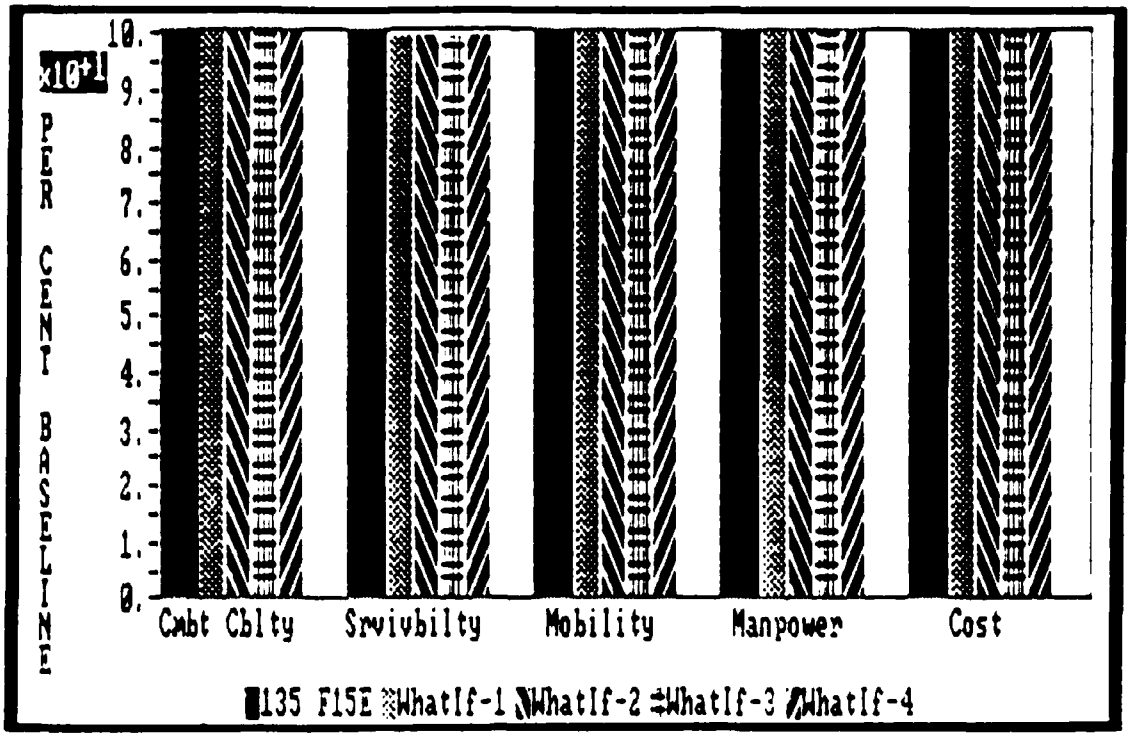


Fig. 41: 135 F-15E Version: 50% Increases in Flightline to Shop Transportation Time (View A)

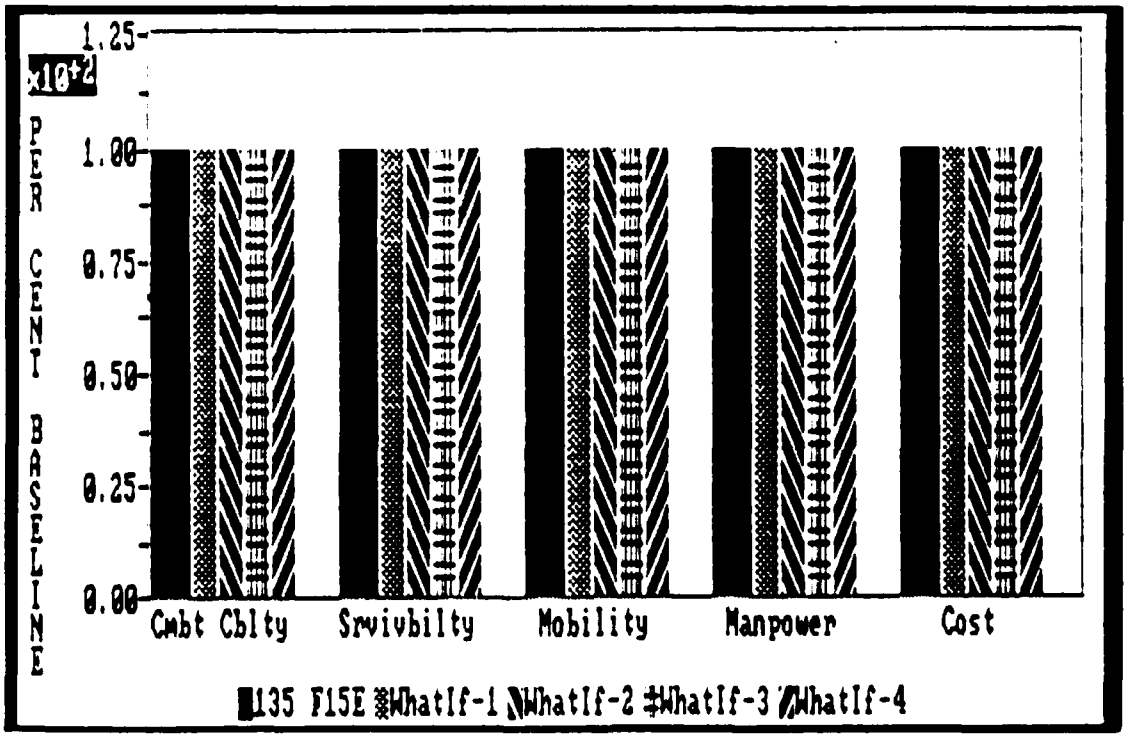


Fig. 42: 135 F-15E Version: 20% Increases in Shop to Depot to Flightline Order Response Time (View A)

peacetime cost-effectiveness. Figure 43 is LAMP View A which shows steps representing 20% increases in TBRT. The first two increases ('What-ifs' (2) and (3), attributable hypothetically to I-level 'bottlenecks') above the assumed starting values of 3 days (peacetime) and 2 days (wartime) are inconsequential. With further increases, however, impacts on Combat Capability, Survivability, and LCC quickly accumulate. A series of six Sensitivity Curves efficiently detail the effects of increased base-level turnaround.

The first of these curves, Figure 44, shows the negative correlation between the average expected daily wartime sorties and increased Base Repair Cycle Times. Figure 45 expresses a similar negative relationship in terms of the average number of FMC aircraft on each day of the war. Along with the detriments of lower sortie rates and fewer ready jets, LCC increases slightly and expected backorder rates go up dramatically as TBRT increases (Figures 46 and 47). The decreasing number of wartime sorties possible in the absence of I-level maintenance (lower Survivability) as TBRT values increase can be seen in the sensitivity curve of Figure 48. Finally, the adverse impact on Operational Availability related to longer Base Repair Cycle Times can be seen in Figure 49.

The fourth supportability issue addresses ALQ-135 reliability, specifically in terms of MTBF. Therefore, LAMP variable number 20 (SBMTBF), was altered to determine the impact on the R&M 2000 goals. Investigation of MTBF was

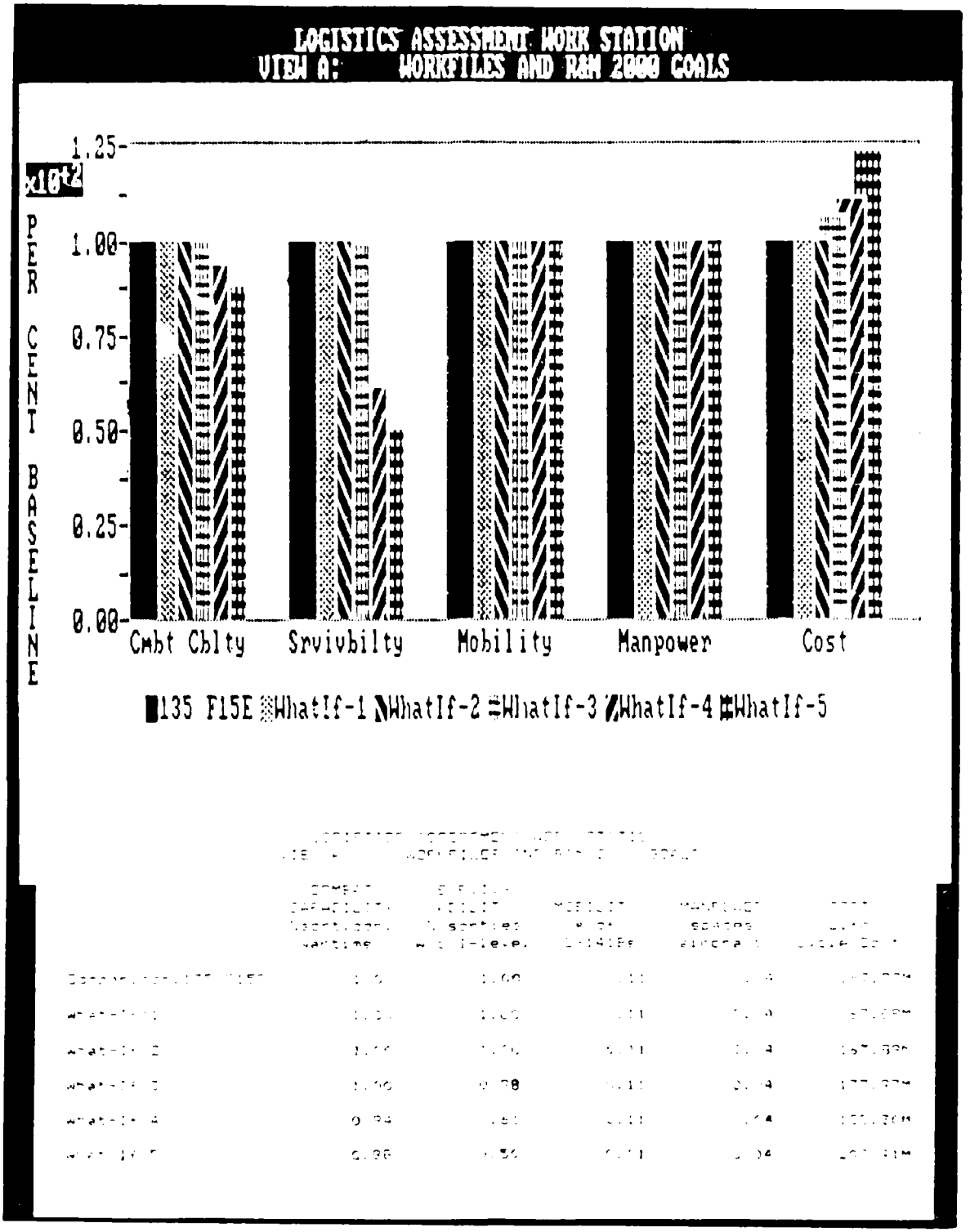


Fig. 43: 135 F-15E Version: 20% Increases in Base Repair Cycle Time (View A)

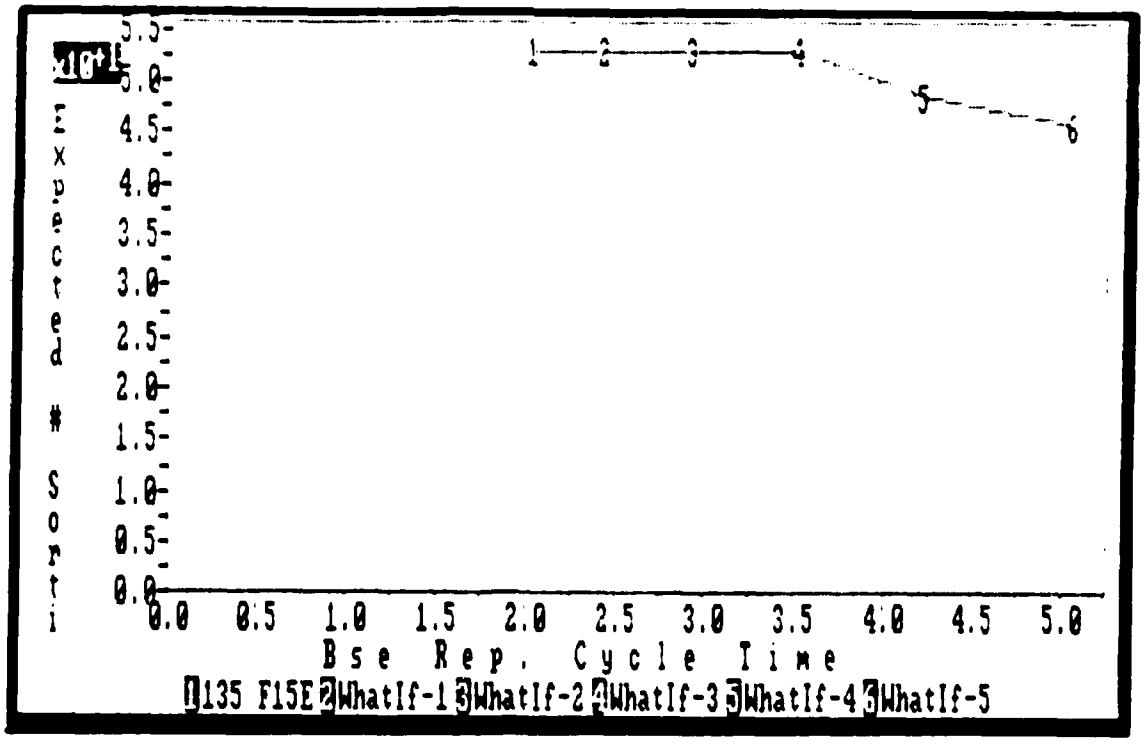


Fig. 44: 135 F-15E Version: Sensitivity of Expected Number of Sorties to Base Repair Cycle Time (View E)

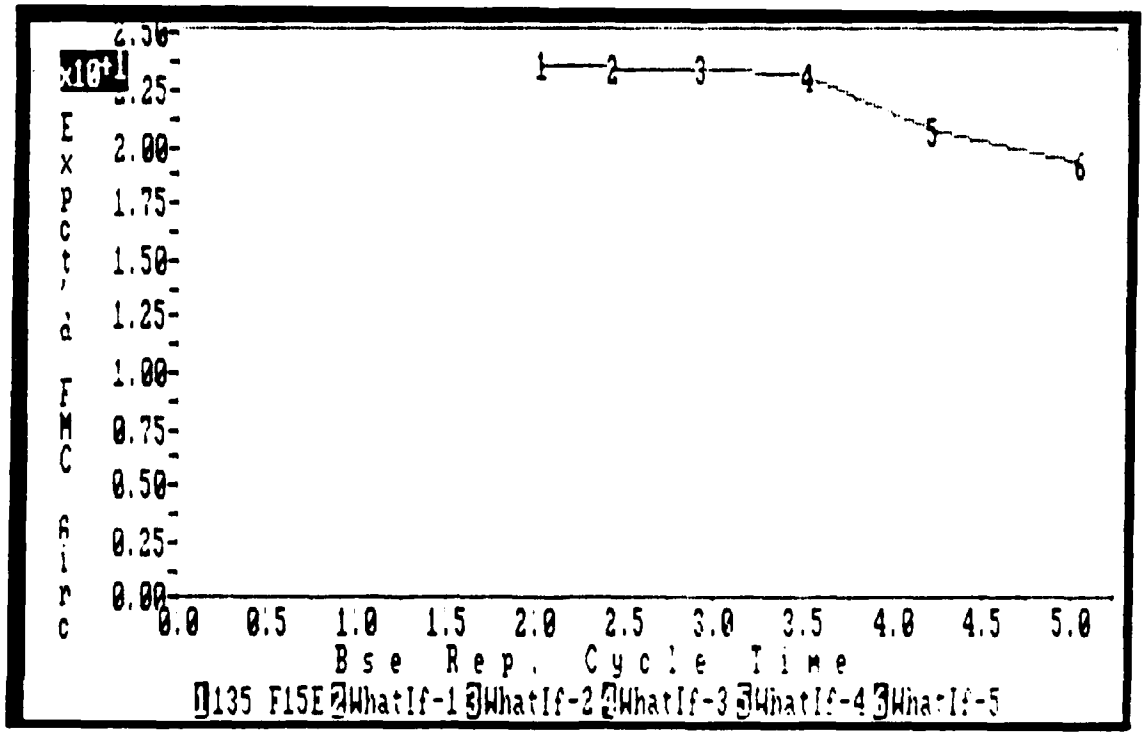


Fig. 45: 135 F-15E Version: Sensitivity of Expected FMC Aircraft to Base Repair Cycle Time (View E)

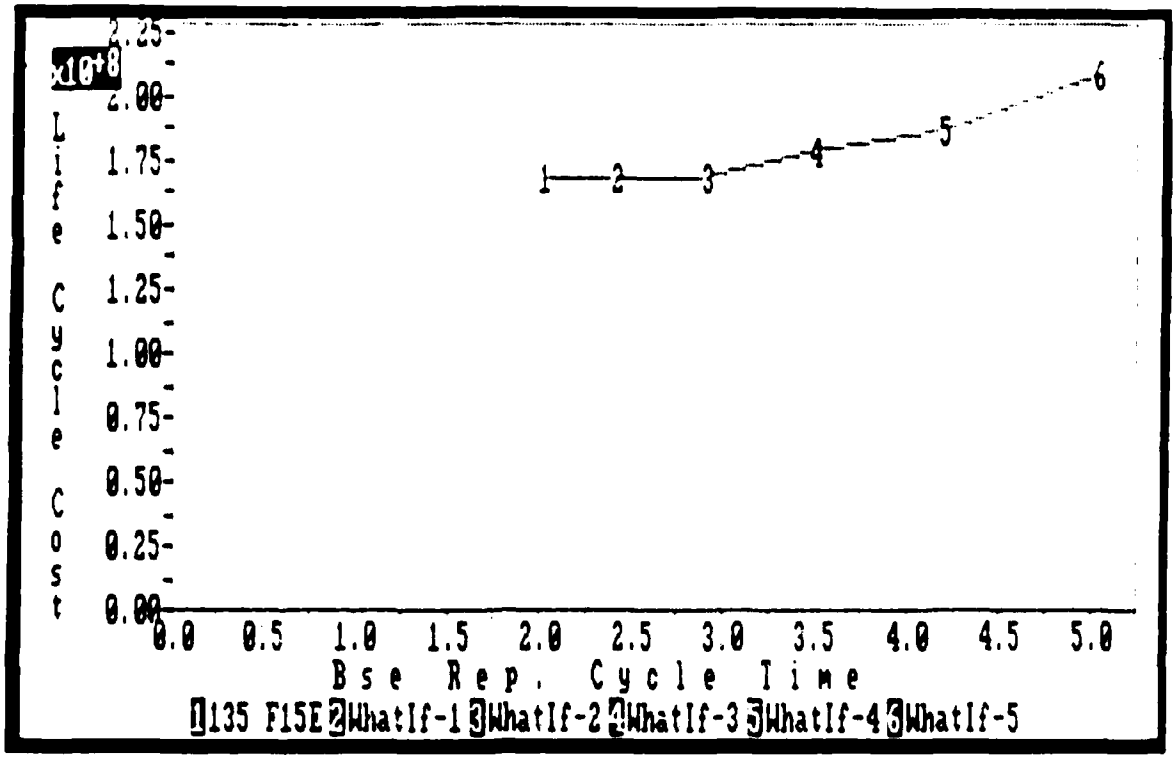


Fig. 46: 135 F-15E Version: Sensitivity of LCC to Base Repair Cycle Time (View E)

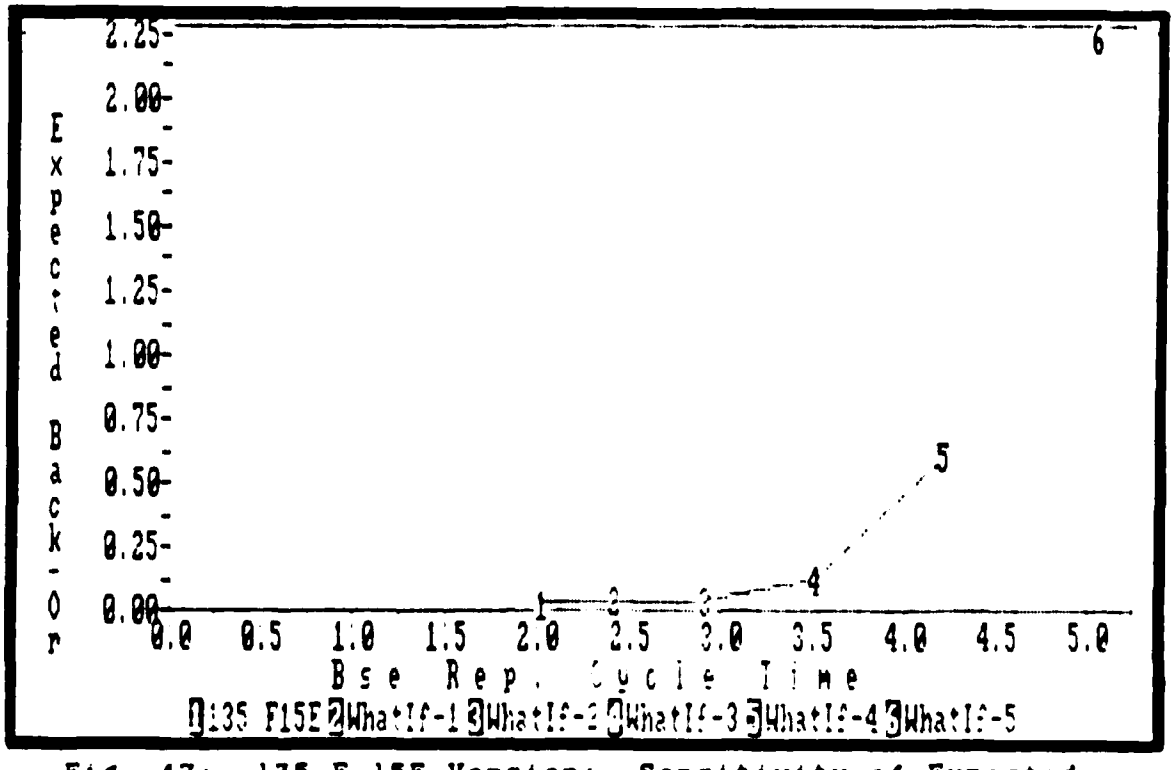


Fig. 47: 135 F-15E Version: Sensitivity of Expected Backorders to Base Repair Cycle Time (View E)

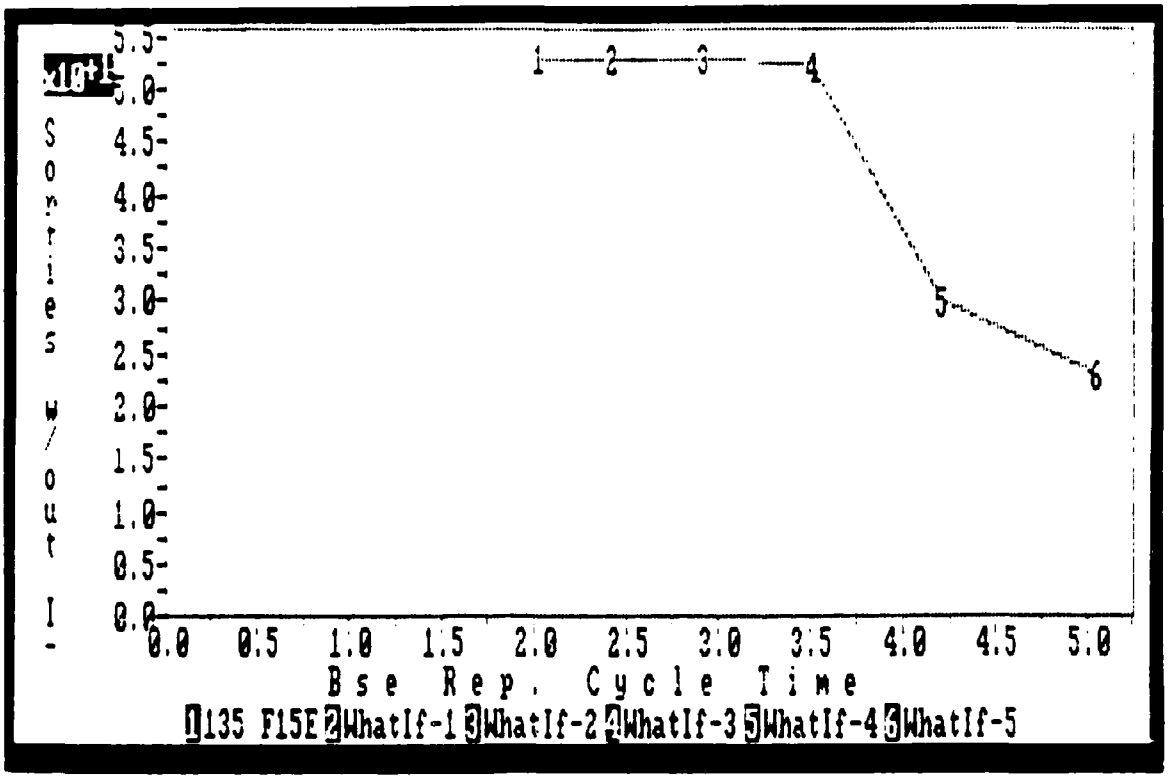


Fig. 48: 135 F-15E Version: Sensitivity of Sorties without I-level Maintenance to Base Repair Cycle Time (View E)

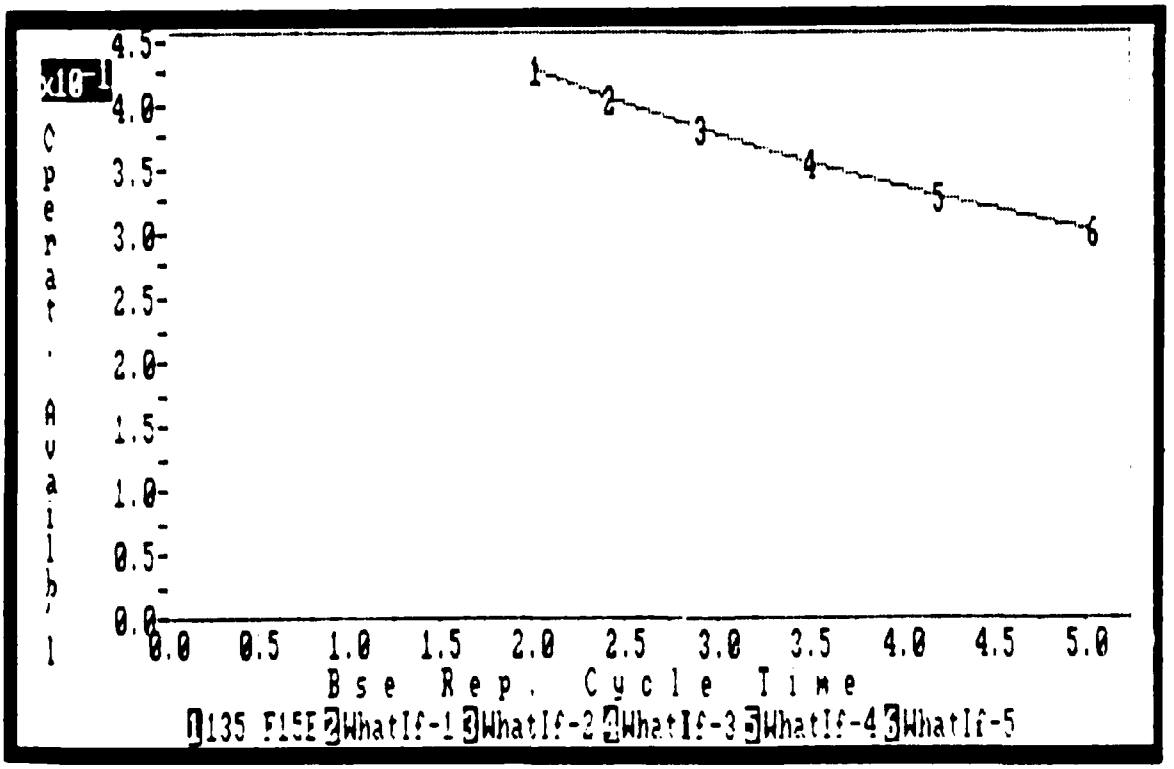
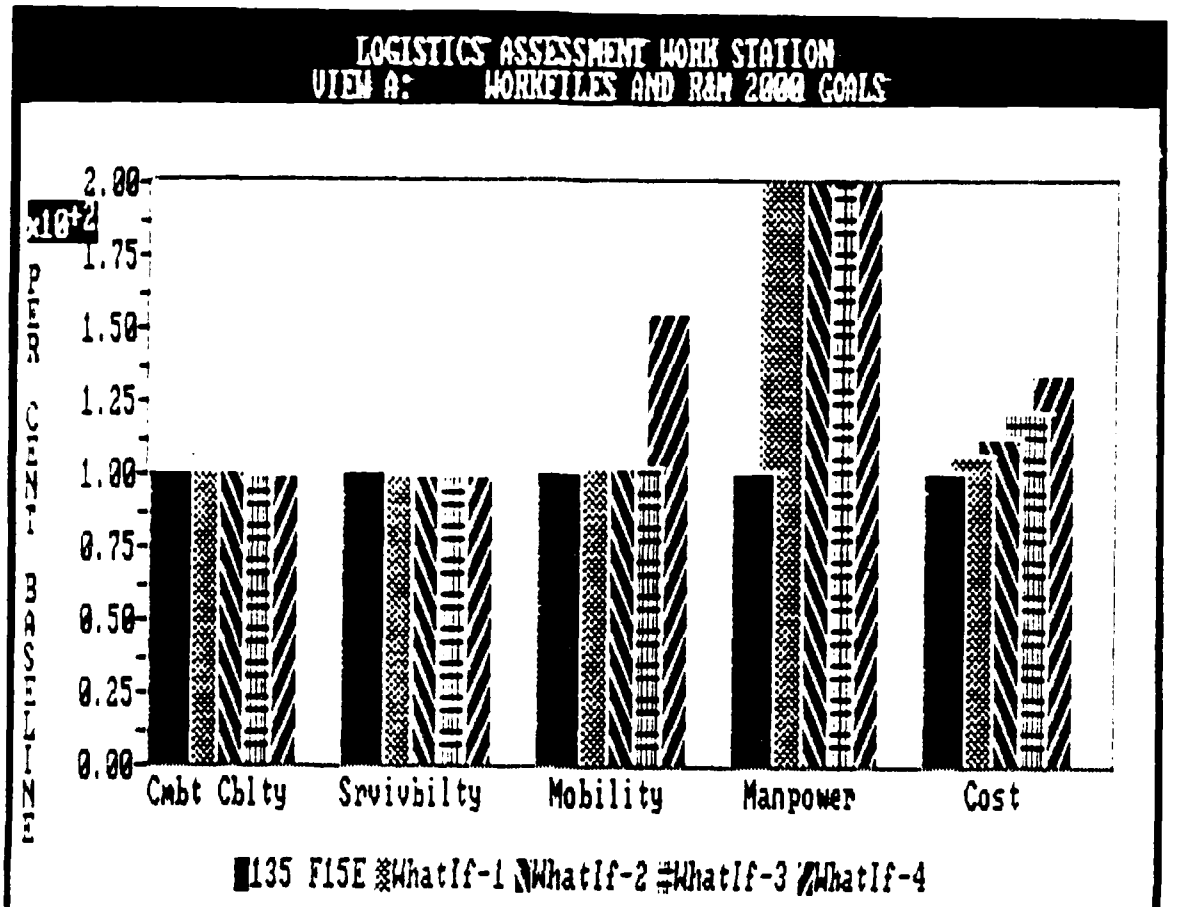


Fig. 49: 135 F-15E Version: Sensitivity of Operational Availability to Base Repair Cycle Time (View E)

an extensive process, the results of which can be seen in the next series of outputs, Figures 50-56.

LAMP View A provided the best initial look at R&M 2000 impacts due to decreases in MTBF. The major impact of hypothetical 10% reductions in LRU MTBFs came in the area of LCC, with smaller impacts on Mobility and Manpower goals (Figure 50). Figure 51 shows (sub)system-level MTBF values as they correspond to each 'What-if,' and lists (sub)system-level MTBMAs associated with each MTBF level. As might be expected from the constant 100% Combat Capability shown in View A, the average expected number of daily wartime sorties was insensitive to degraded LRU MTBFs (Figure 52). Figure 53 clearly shows, though, that LCC went down as averaged LRU MTBFs went up. The reason for the high 'averaged' MTBF on the X-axis in these latter two figures is the skewing caused by the high MTBF (10,875 hours) for the 'Preamp' LRU.

Since the LRU 'HI CTL O' (the Band 3 Control Oscillator) is the 'weak link' the P^3I design, it was considered prudent to isolate the impacts of changes in its MTBF. For an MTBF decrease of just 10% in this one LRU, ALQ-135 manpower requirements doubled. LCC increased roughly $5M for each 10% step (Figure 54). The impact of this LRU's reliability on (sub)system-level MTBF and (sub)system-level MTBMA can be seen in Figure 55. As exhibited by the curve in Figure 56, LCC was quite sensitive to MTBF changes in the LRU 'HI CTL O,' though of course not so severely as it is to lower MTBFs for all LRUs together.



LOGISTICS ASSESSMENT WORK STATION
VIEW A WORKFILES AND R&M 2000 GOALS

	COMBAT CAPABILITY %sort.gen. wartime	SURVIV-ABILITY % sorties w/o I-level	MOBILITY # of C-141Bs	MANPOWER spaces /aircraft	COST Life Cycle Cost
Comparison:135 F15E	1.00	1.00	0.11	0.04	167.89M
What-If(1)	1.00	1.00	0.11	0.08	178.46M
What-If(2)	1.00	1.00	0.11	0.08	190.04M
What-If(3)	1.00	1.00	0.11	0.08	202.91M
What-If(4)	1.00	1.00	0.16	0.08	225.56M

Fig. 50: 135 F-15E Version: 10% Reductions in MTBFs of all LRUs (View A)

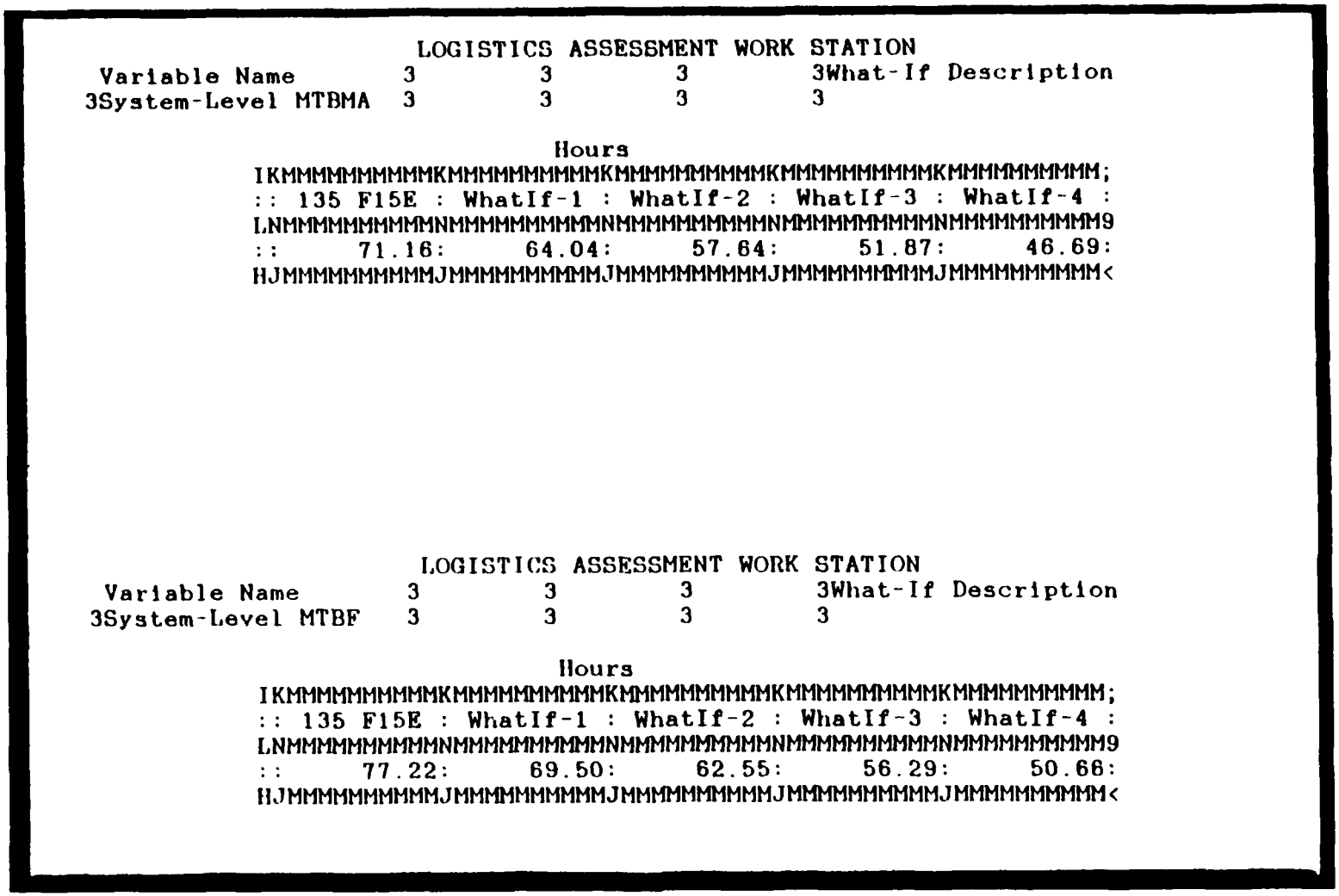


Fig. 51: 135 F-15E Version: System-level MTBF and MTBMA with 10% Reductions in LRU MTBFs (View C)

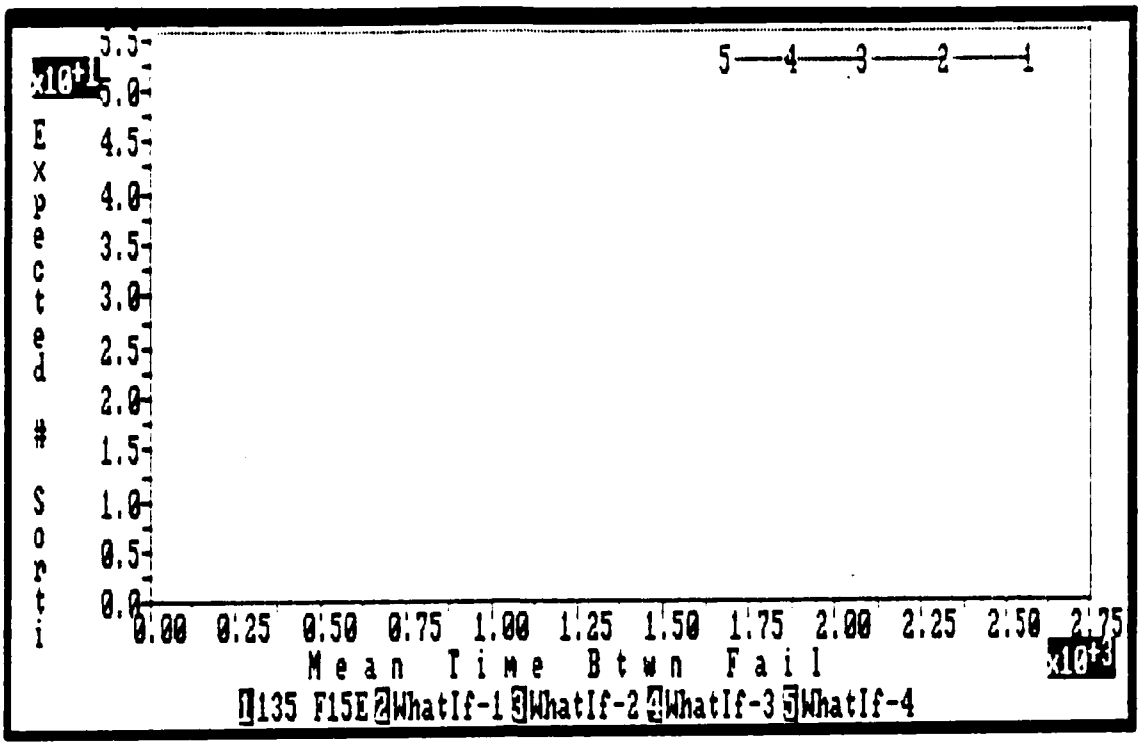


Fig. 52: 135 F-15E Version: Sensitivity of Expected Number of Sorties to MTBF (View E)

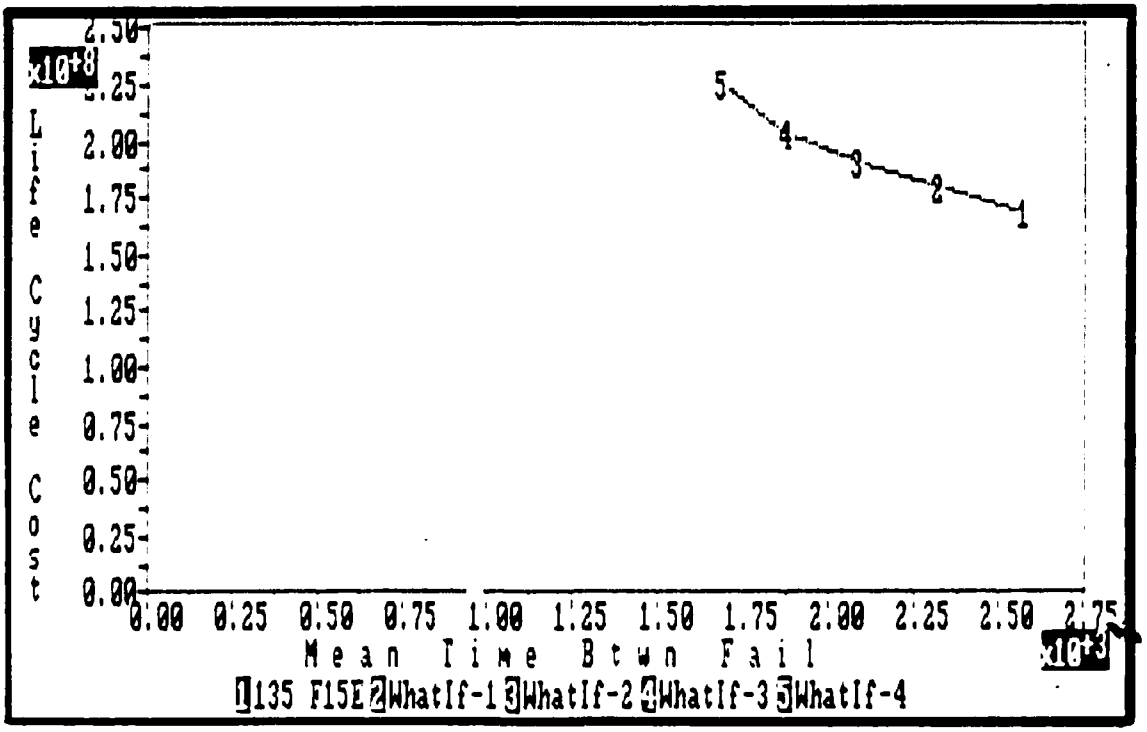
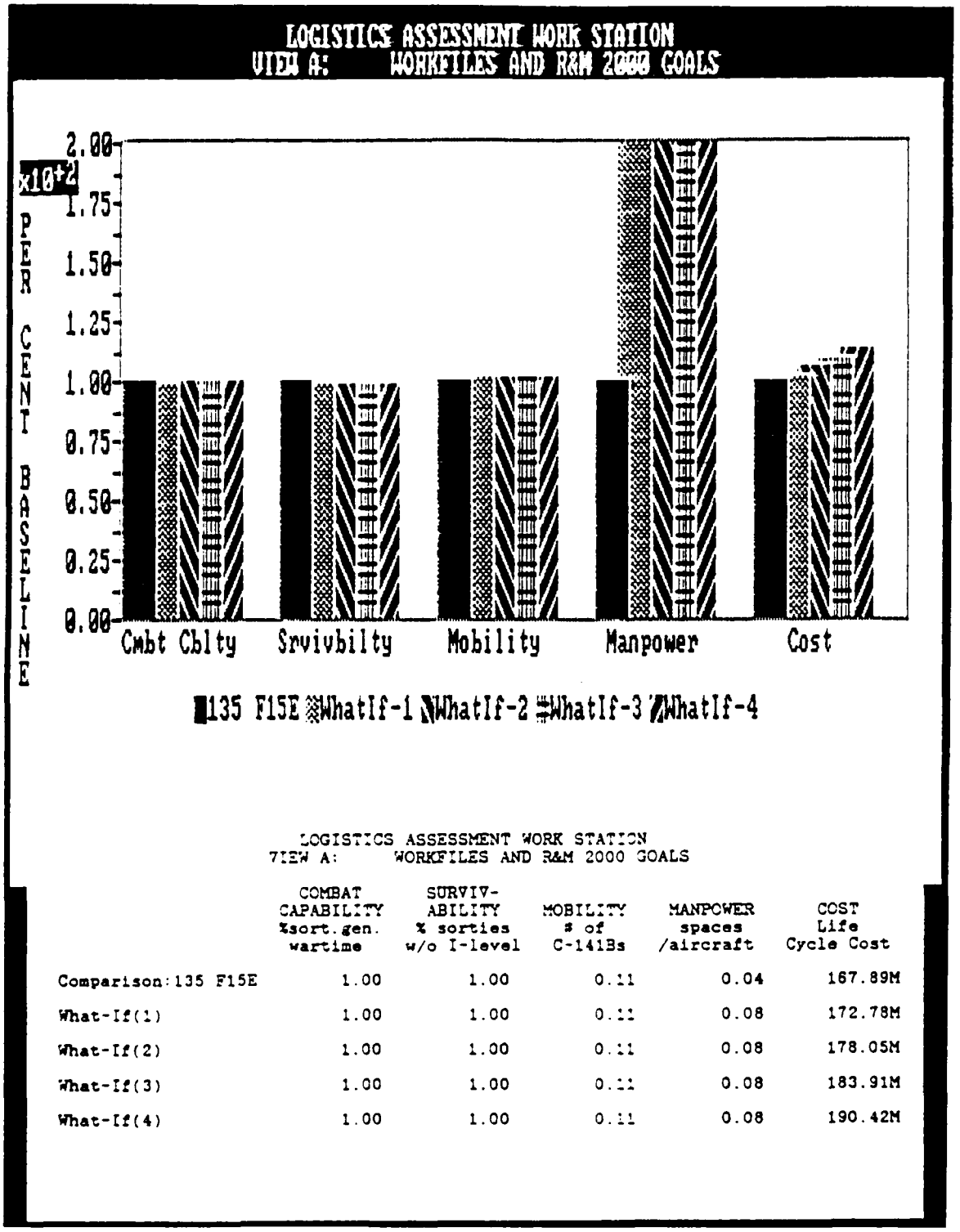


Fig. 53: 135 F-15E Version: Sensitivity of LCC to MTBF (View E)



LOGISTICS ASSESSMENT WORK STATION
VIEW A: WORKFILES AND R&M 2000 GOALS

	COMBAT CAPABILITY %sort.gen. wartime	SURVIV-ABILITY % sorties w/o I-level	MOBILITY # of C-141Bs	MANPOWER spaces /aircraft	COST Life Cycle Cost
Comparison:135 F15E	1.00	1.00	0.11	0.04	167.89M
What-If(1)	1.00	1.00	0.11	0.08	172.78M
What-If(2)	1.00	1.00	0.11	0.08	178.05M
What-If(3)	1.00	1.00	0.11	0.08	183.91M
What-If(4)	1.00	1.00	0.11	0.08	190.42M

Fig. 54: 135 F-15E Version: 10% Reductions in MTBF of Band 3 Control Oscillator only (View A)

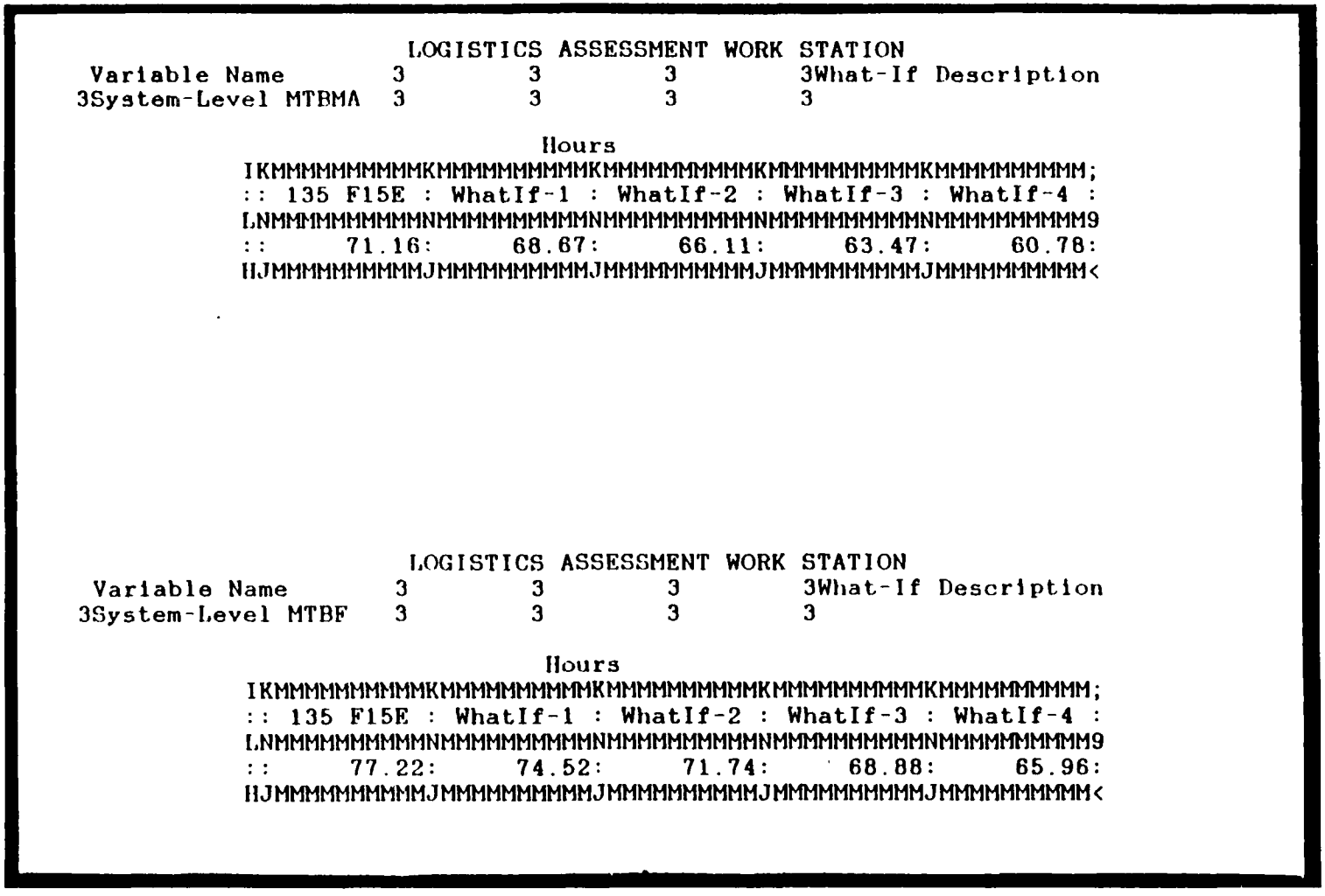


Fig. 55: 135 F-15E Version: System-level MTBF and MTBMA with 10% Reductions in MTBF of Band 3 Control Oscillator only (View C)

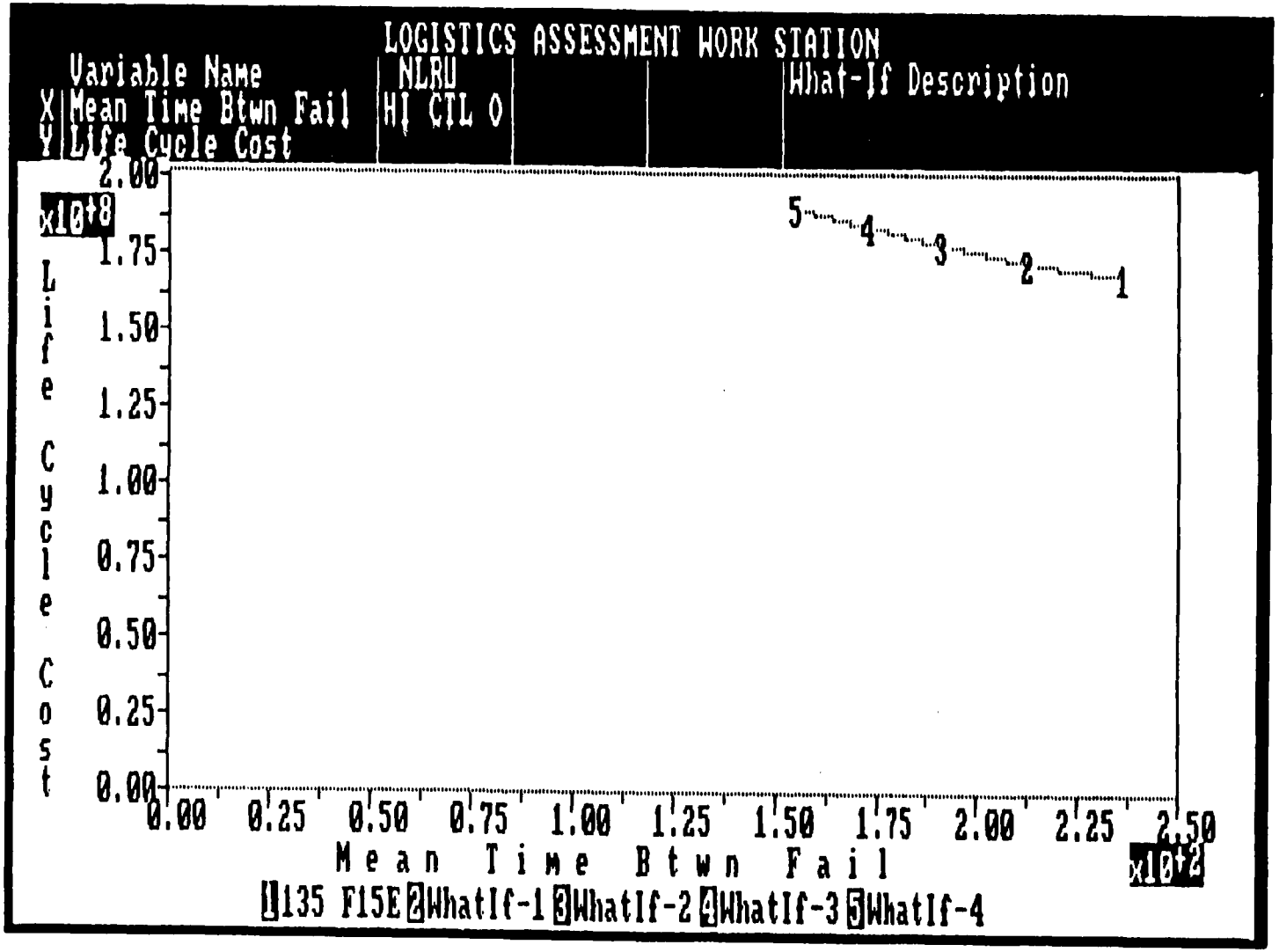


Fig. 56: 135 F-15E Version: Sensitivity of LCC to MTBF of Band 3 Control Oscillator (View E)

The fifth supportability issue is a 'miscellaneous' area which is involved with hypothetical changes in the size, weight, and cost of LRUs. In Figures 57-60, changes in the variables part size (SIZE, #18), part weight (WSTK, #17), and part unit cost (UC, #30) represent these eventualities.

For the P^3I design's LRUs, part weight is more restrictive than part size for mobility purposes. This condition remained true even when part size was increased up to approximately 40% of its original volume. As shown in Figure 57, all R&M 2000 goals are insensitive to changes in part size. As might be expected, increases in part weight result in small but noticeable increases in Mobility requirements (Figure 58).

Upfront and downstream increases in unit costs could be a possibility with any design. For the ALQ-135, Figure 59 shows the impact on LCC of four 10% increases in the cost of all LRUs in the P^3I design. (This representation assumes a 10% price increase in even the LRUs for the first group of aircraft.) Figure 60 is a 'parent-child' LCC bar chart from LAMP's View B. From this format, one can see the breakout of LCC cost into more specific elements, and how these proportions change in response to unit costs increases. As illustrated, these LRU unit cost increases had implications both for initial acquisition costs (ACQCST) and for later operations and support costs (TOSCST).

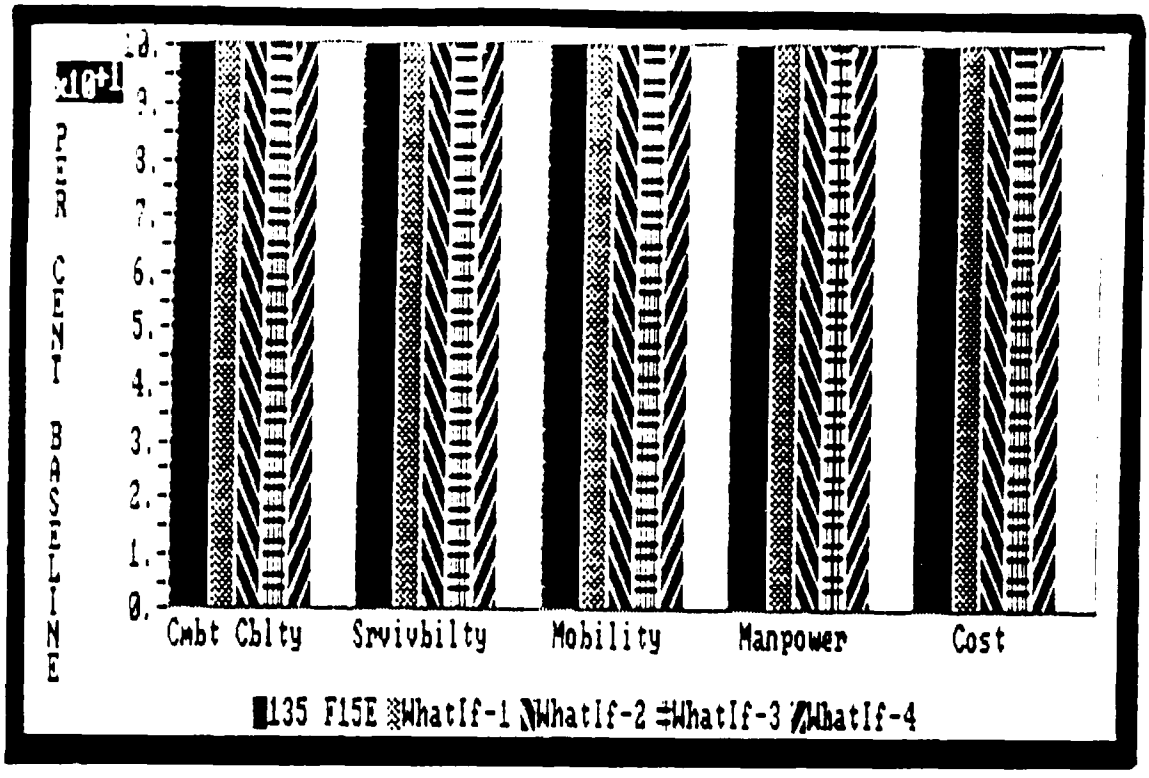


Fig. 57: 135 F-15E Version: 10% Increases in LRU Volume (View A)

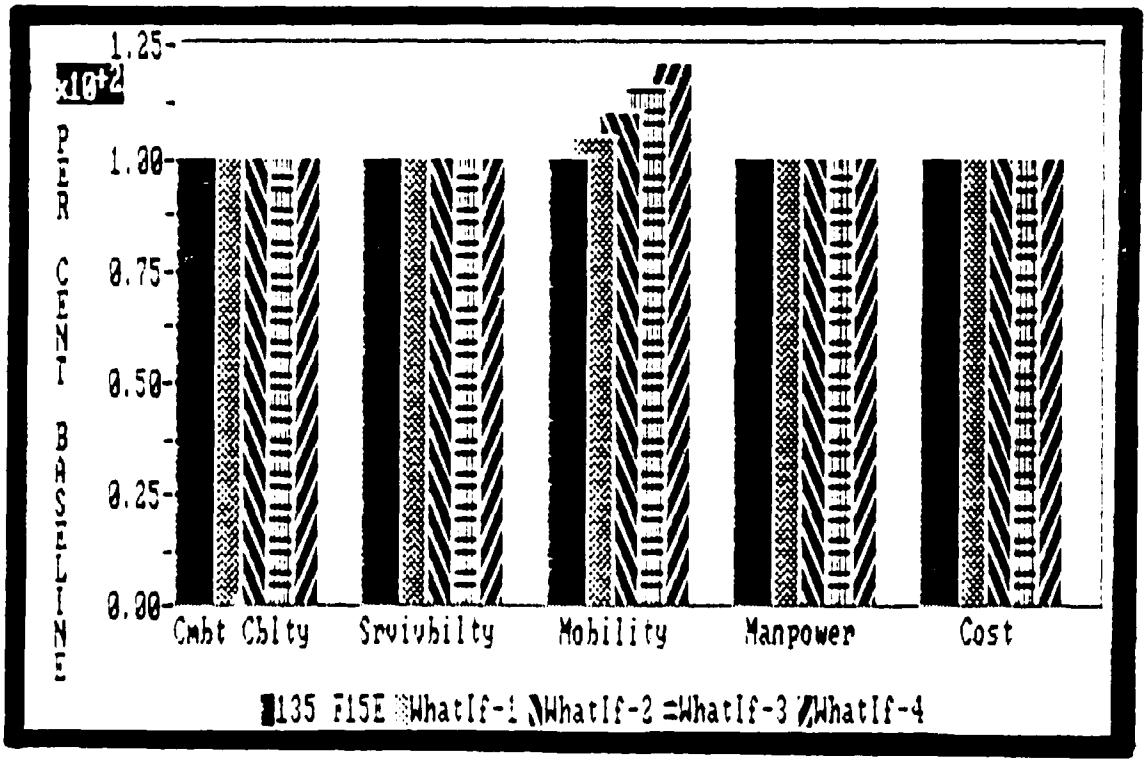
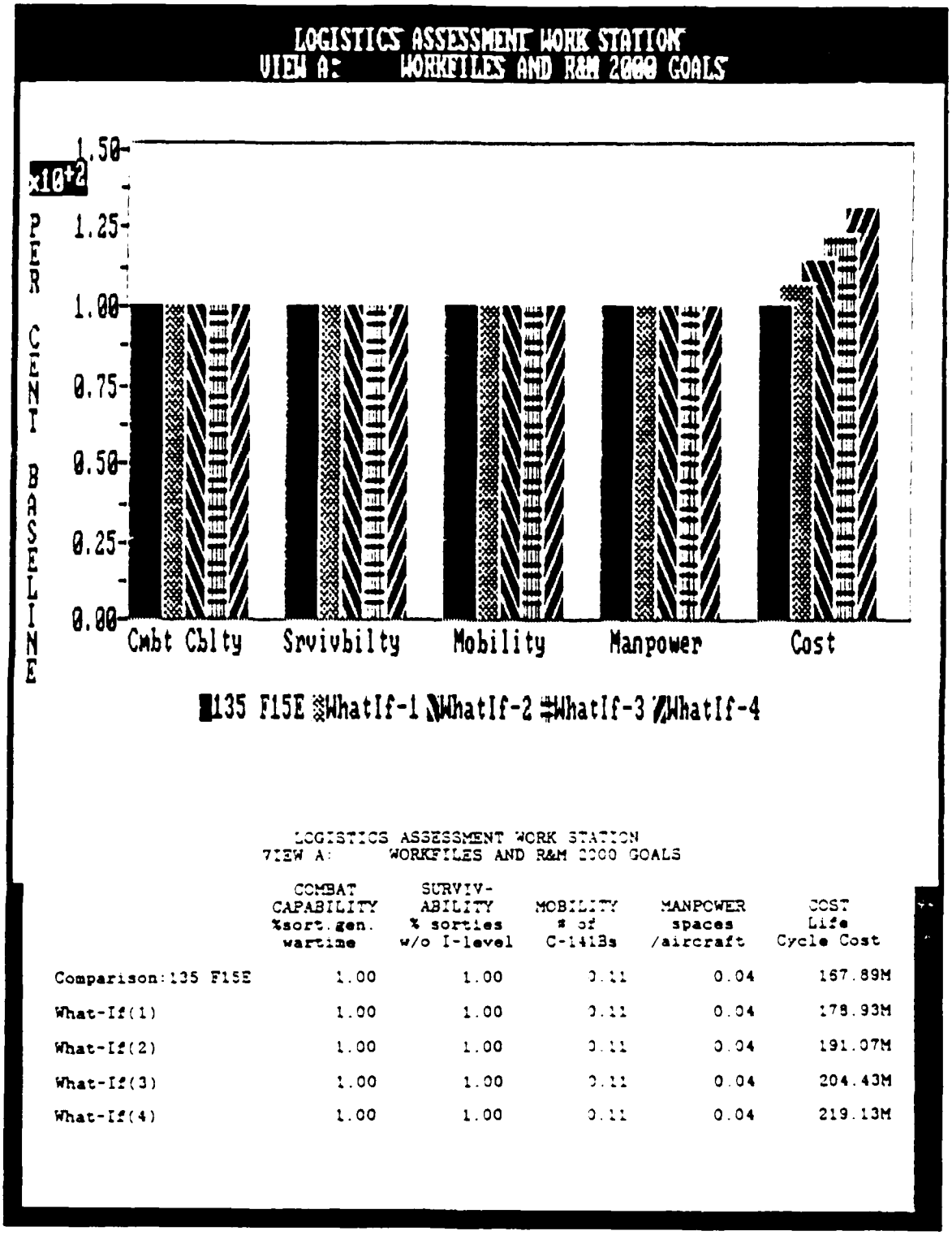


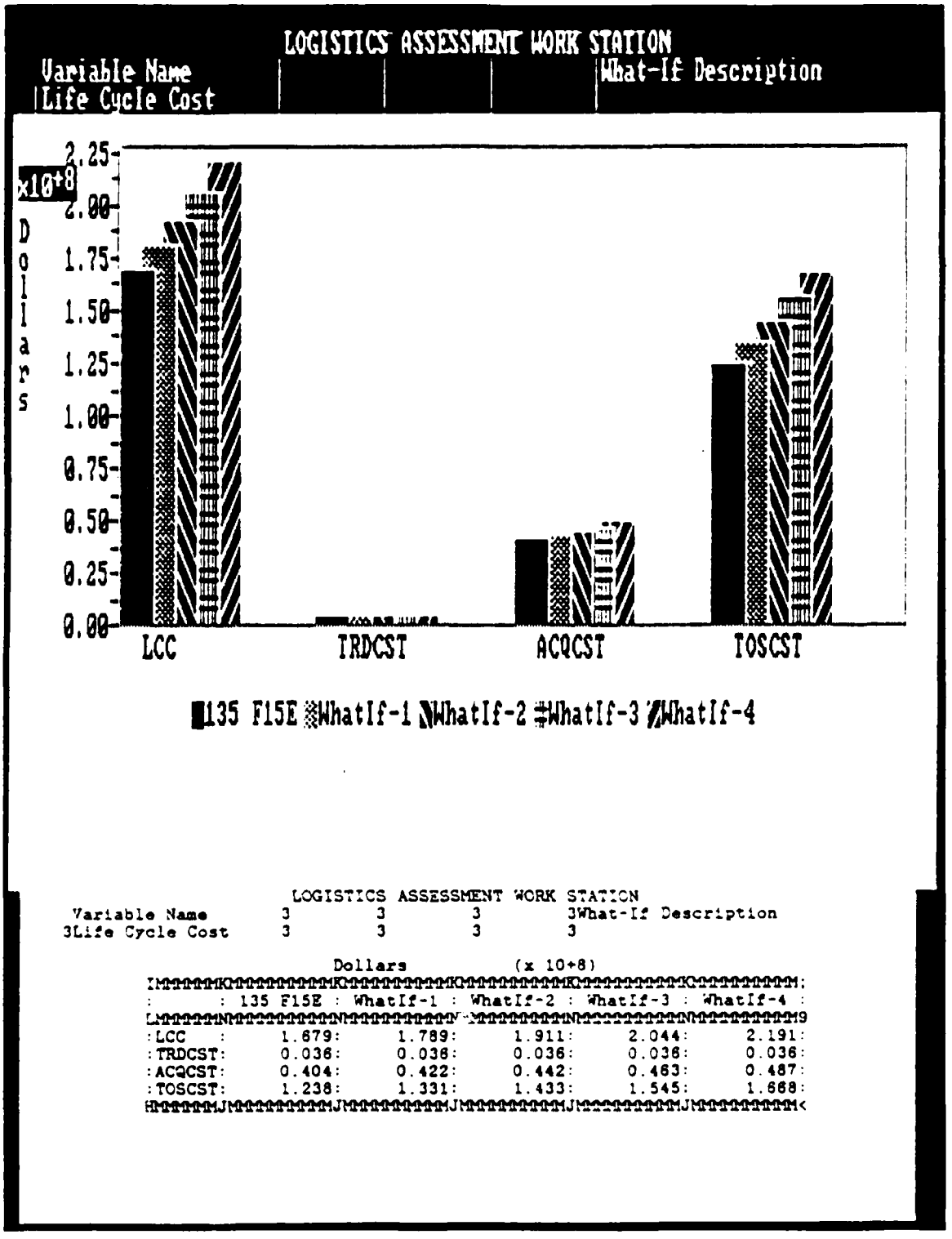
Fig. 58: 135 F-15E Version: 10% Increases in LRU Weight (View A)



LOGISTICS ASSESSMENT WORK STATION
VIEW A: WORKFILES AND R&M 2000 GOALS

	COMBAT CAPABILITY %sort.gen. wartime	SURVIV-ABILITY % sorties w/o I-level	MOBILITY # of C-141Bs	MANPOWER spaces /aircraft	COST Life Cycle Cost
Comparison:135 F15E	1.00	1.00	0.11	0.04	167.89M
What-If(1)	1.00	1.00	0.11	0.04	178.93M
What-If(2)	1.00	1.00	0.11	0.04	191.07M
What-If(3)	1.00	1.00	0.11	0.04	204.43M
What-If(4)	1.00	1.00	0.11	0.04	219.13M

Fig. 59: 135 F-15E Version: 10% Increases in LRU Unit Cost (View A)



LOGISTICS ASSESSMENT WORK STATION

Variable Name / Life Cycle Cost	3	3	3	3	What-If Description

Dollars (x 10+8)

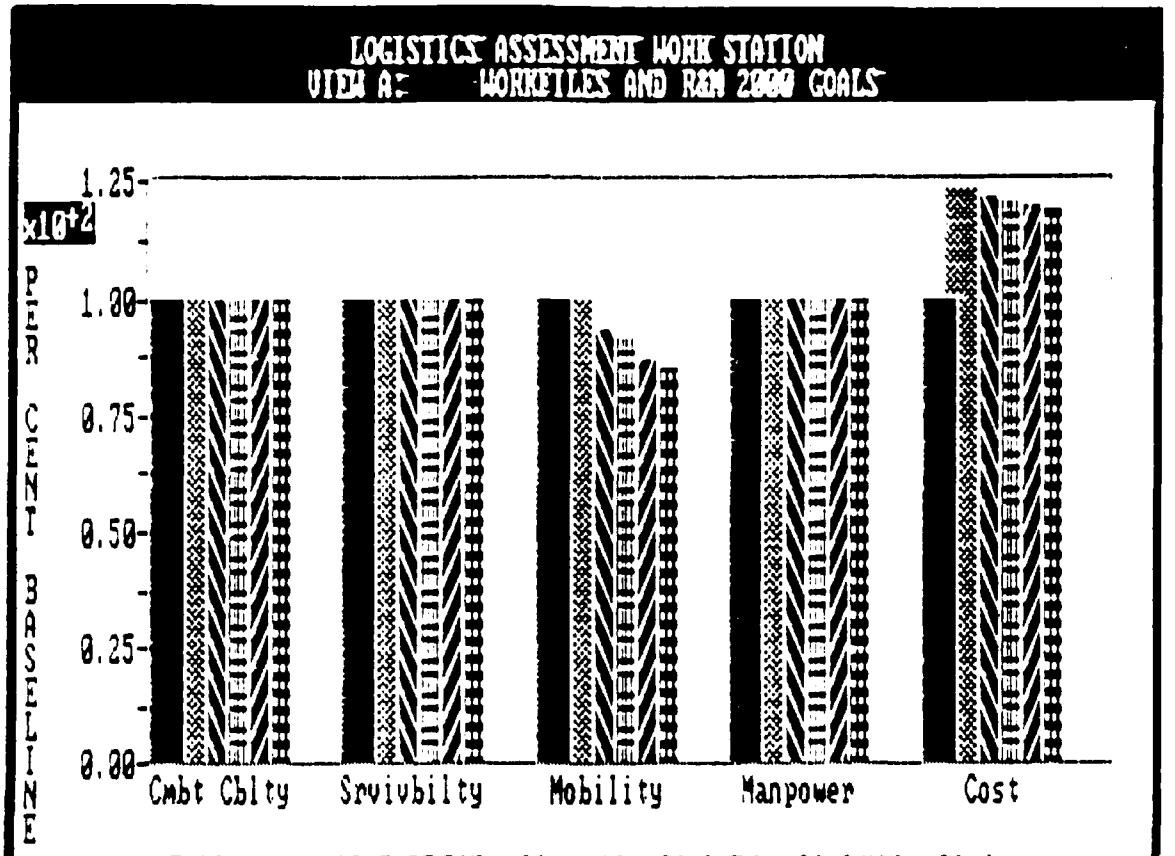
	135 F15E	WhatIf-1	WhatIf-2	WhatIf-3	WhatIf-4
LCC	1.679	1.789	1.911	2.044	2.191
TRDCST	0.036	0.038	0.036	0.036	0.036
ACQCST	0.404	0.422	0.442	0.463	0.487
TOSCST	1.238	1.331	1.433	1.545	1.668

Fig. 60: 135 F-15E Version: LCC Breakout for 10% Increases in LRU Unit Cost (View B)

Phase One Summary. The P^3I configuration represents significant supportability improvements over the Band 1/2 design. Mobility and Manpower goals are the ones most noticeably improved. LCC for the F-15E jammer will be much higher than the for the Band 1/2 version, but increased performance capabilities must be taken into account. The R&M 2000 goals Combat Capability and Survivability are very well satisfied in the P^3I design, and they remain mainly insensitive to negative changes in supportability variables.

Environmental Analysis Findings. In order to assess how the P^3I design might perform in more restrictive conditions, basic variables of the Design data set were held constant, and variables from the Support and Operational data sets were altered. Four variables identified for consideration were spares levels (TSTK, #61), attrition rate (ATTRIT, #59), requested sorties (TRS, #56) and maximum sorties (TMS, #57). For Figures 61-63, the P^3I flown at a 1.32 hour average sortie duration (the F-15C rate) is presented only as a benchmark for comparison (the solid bar); the basic F-15E Workfile (the shaded bar) is the starting point for LAMP 'What-ifs.'

Spares levels are almost certainly an important factor in the ALQ-135's support environment. As a starting point for investigation of this supposition, both the Peacetime Operating Stock (POS) and War Readiness Spares Kit (WRSK) quantities were reduced in increments of 10% (Figure 61).



LOGISTICS ASSESSMENT WORK STATION
VIEW A: WORKFILES AND R&M 2000 GOALS

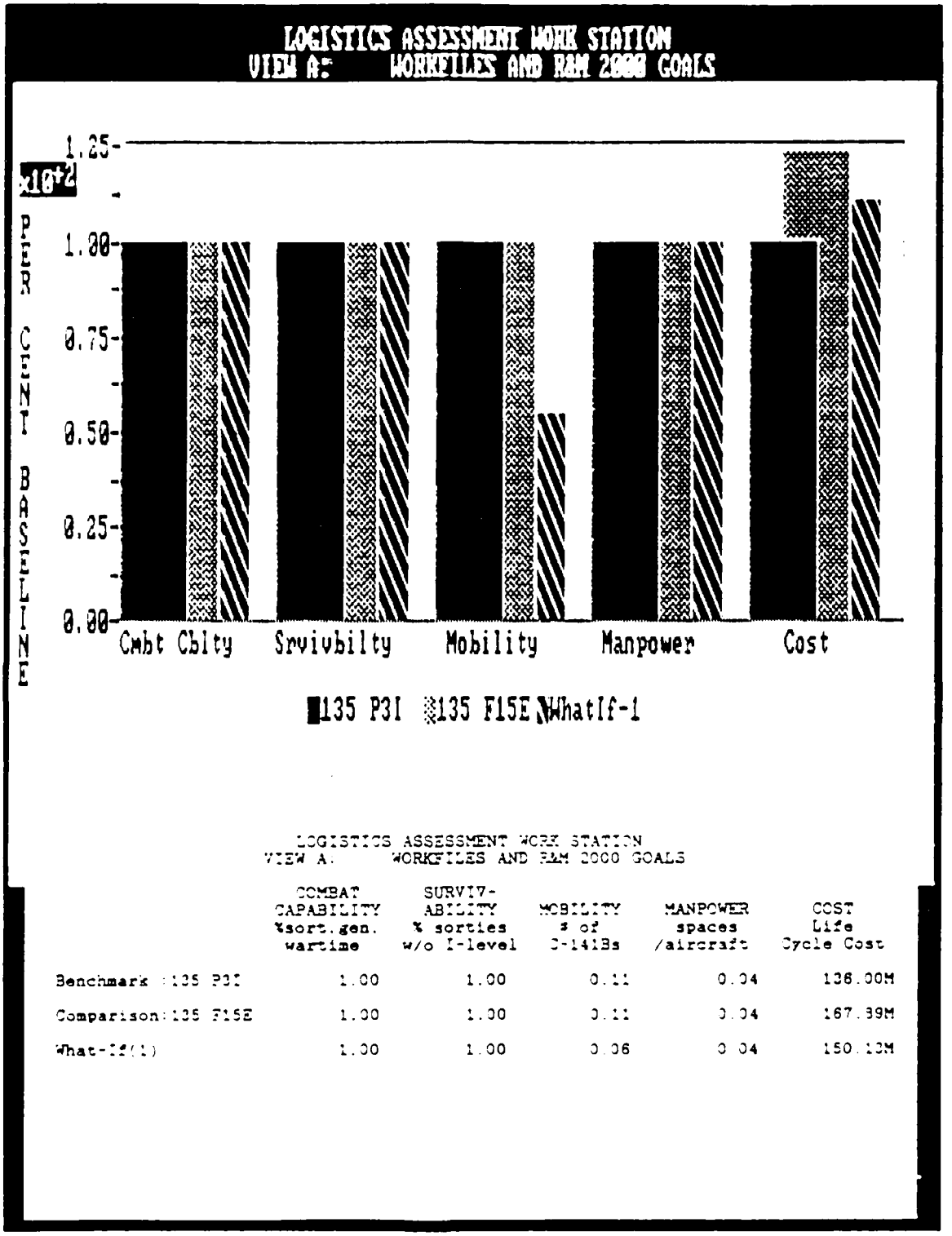
	COMBAT CAPABILITY %sort.gen. wartime	SURVIV-ABILITY % sorties w/o I-level	MOBILITY # of C-141Bs	MANPOWER spaces /aircraft	COST Life Cycle Cost
Benchmark :135 P3I	1.00	1.00	0.11	0.04	126.00M
Comparison:135 F15E	1.00	1.00	0.11	0.04	157.89M
What-If(1)	1.00	1.00	0.10	0.04	165.40M
What-If(2)	1.00	1.00	0.10	0.04	164.49M
What-If(3)	1.00	1.00	0.09	0.04	162.92M
What-If(4)	1.00	1.00	0.09	0.04	162.00M

Fig. 61: 135 F-15E Version: 10% Reductions in Peacetime and Wartime Spares (View A)

The LCC for '135 F15E' is higher than for '135 P3I' (the F-15C representation) solely due to the former's longer sortie duration. Decreases in the spares levels resulted in LCC and Mobility savings at no expense to Combat Capability and Survivability. In fact, information in Figure 62 suggests that the deletion of POS and WRSK parts entirely would not adversely affect Combat Capability or Survivability, but would allow LCC savings of some $17.76M.

Although the requested sorties can evidently be accomplished without spares support, they would come from a necessarily reduced number of FMC aircraft, as illustrated in Figure 63. This lower number of FMC jets would of course inhibit command flexibility, which is just one example of why the LAMP user should look beyond initial assessments provided by the View A format. One must also continually keep in mind LAMP's scope as a subsystem-level analytical device. The F-15 has many subsystems on board, and cumulative effects of even small impacts on subsystem FMC rates (as seen in Figure 63) for each would be substantial.

To assess the design's ability to function in a high-attrition operational environment (e.g., NATO general war), the LAMP input variable ATTRIT was increased drastically. (See Appendix C for actual values.) Figures 64-70 are direct comparisons of a low attrition rate, represented by the solid bar, with high attrition rates (the shaded bar).



LOGISTICS ASSESSMENT WORK STATION
VIEW A: WORKFILES AND R&M 2000 GOALS

	COMBAT CAPABILITY %sort.gen. wartime	SURVIV-ABILITY % sorties w/o I-level	MOBILITY # of C-141Bs	MANPOWER spaces /aircraft	COST Life Cycle Cost
Benchmark :135 P3I	1.00	1.00	0.11	0.04	136.00M
Comparison:135 F15E	1.00	1.00	0.11	0.04	167.39M
What-If(1)	1.00	1.00	0.06	0.04	150.13M

Fig. 62: 135 F-15E Version: 100% Deletion of Peacetime and Wartime Spares (View A)

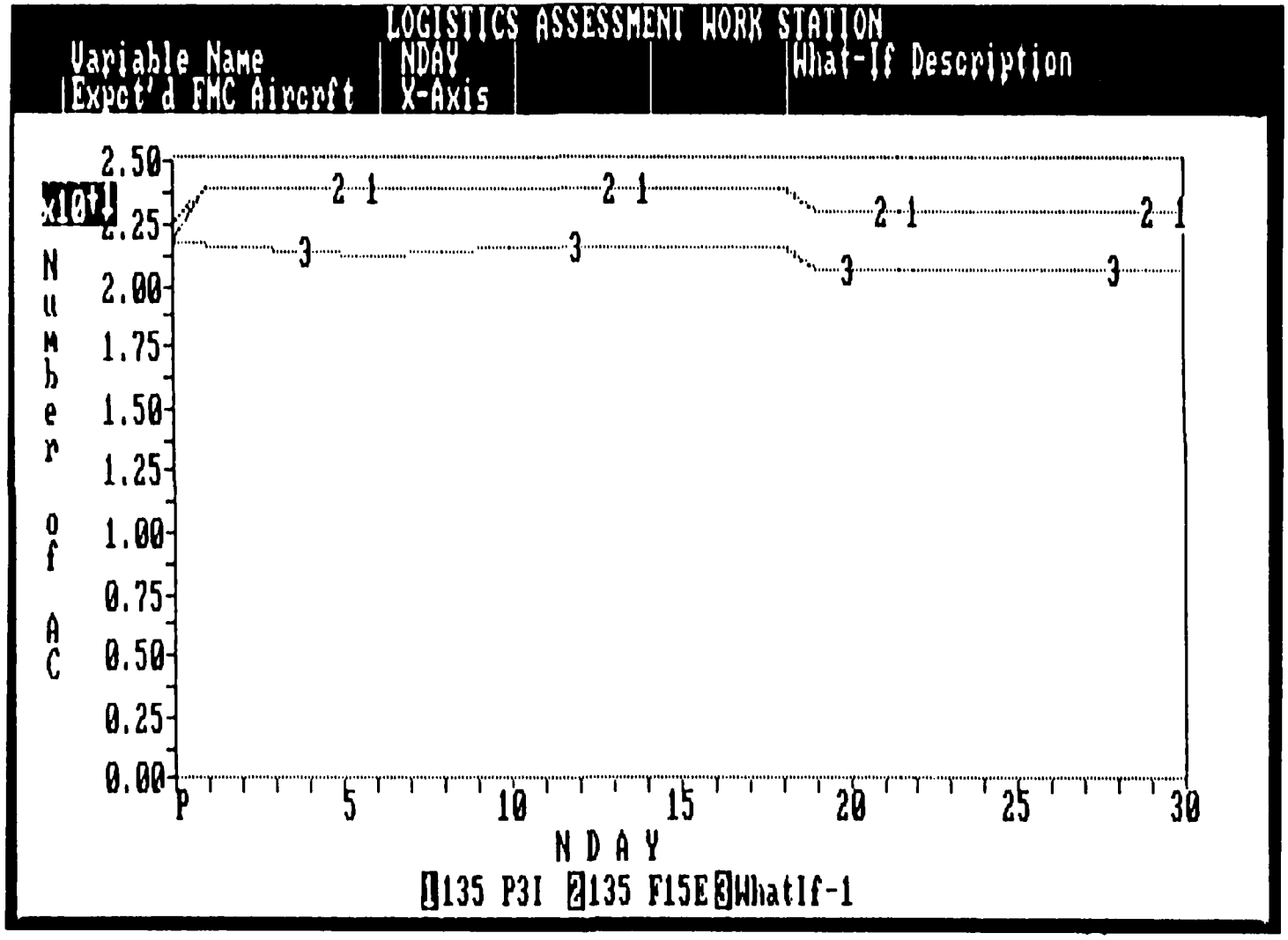
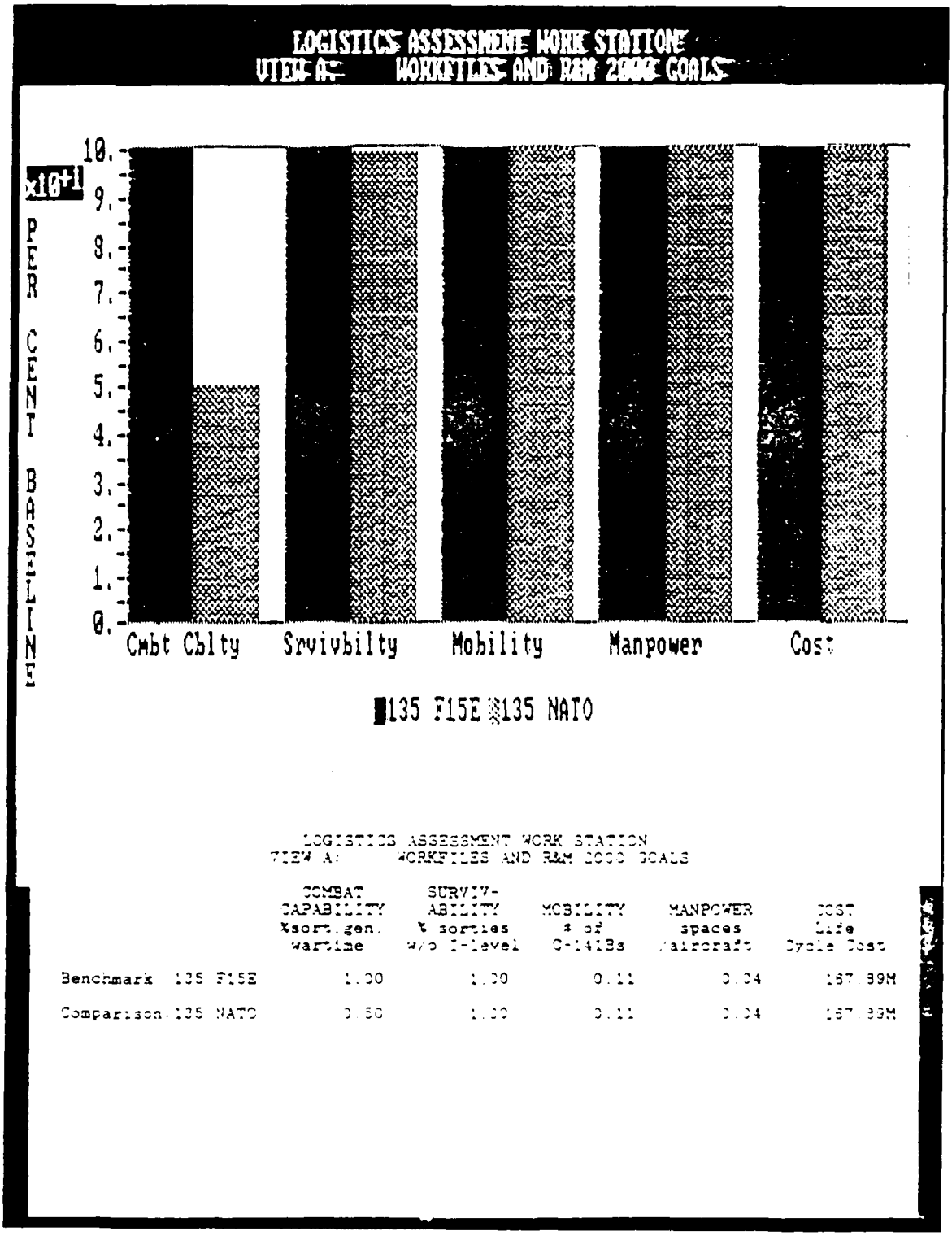


Fig. 63: 135 F-15E Version: Expected FMC Aircraft by Day, Comparison of Spares Levels (View B)

As shown in Figure 64, calculated Combat Capability for such a contingency (labeled '135 NATO') was reduced to 50%. Such a low level of sortie generation is due to battle losses and does not, as we have seen, reflect on ALQ-135 supportability characteristics. Survivability, the ability to function without I-level maintenance, remained high. (If flightline and depot resources alone were able to support the higher sortie rate, it stands to reason that there should be no problem in handling this lower maintenance load.) Cumulative aircraft attrition (from LAMP View B) for the Workfile '135 NATO,' as illustrated in Figure 65, would result in the loss of nearly half the squadron's aircraft by day four of the war. Remaining aircraft would only be able to support the daily sortie generation levels shown in Figure 66.

Under these high-loss conditions, the fleet (squadron) demand rate for spares actually decreased due to the inevitably lower sortie count (Figure 67). The drop in demand rate more than offset the fact that F-15s lost to battle attrition are not available as contributors to the 'cannibalization' pool. Accordingly, compared to the F-15E flown at a low attrition rate, the expected number of backorders went <u>down</u>, the number of LRUs on hand went <u>up</u>, and the quantity of parts in the repair pipeline <u>decreased</u> (Figures 68-70). Curiously, the lesson learned here is that the importance of supportability characteristics decreases as loss rates go up, since it is the number of jets themselves that is the limiting factor in sortie generation!



LOGISTICS ASSESSMENT WORK STATION
VIEW A: WORKFILES AND R&M 2000 GOALS

	COMBAT CAPABILITY %sort.gen. wartime	SURVIV-ABILITY % sorties w/o I-level	MOBILITY # of C-141Bs	MANPOWER spaces /aircraft	COST Life Cycle Cost
Benchmark: 135 F15E	1.00	1.00	0.11	0.04	167.89M
Comparison: 135 NATO	0.50	1.00	0.11	0.04	167.89M

Fig. 64: Direct Comparison of
135 F-15E and 135 NATO Workfiles (View A)

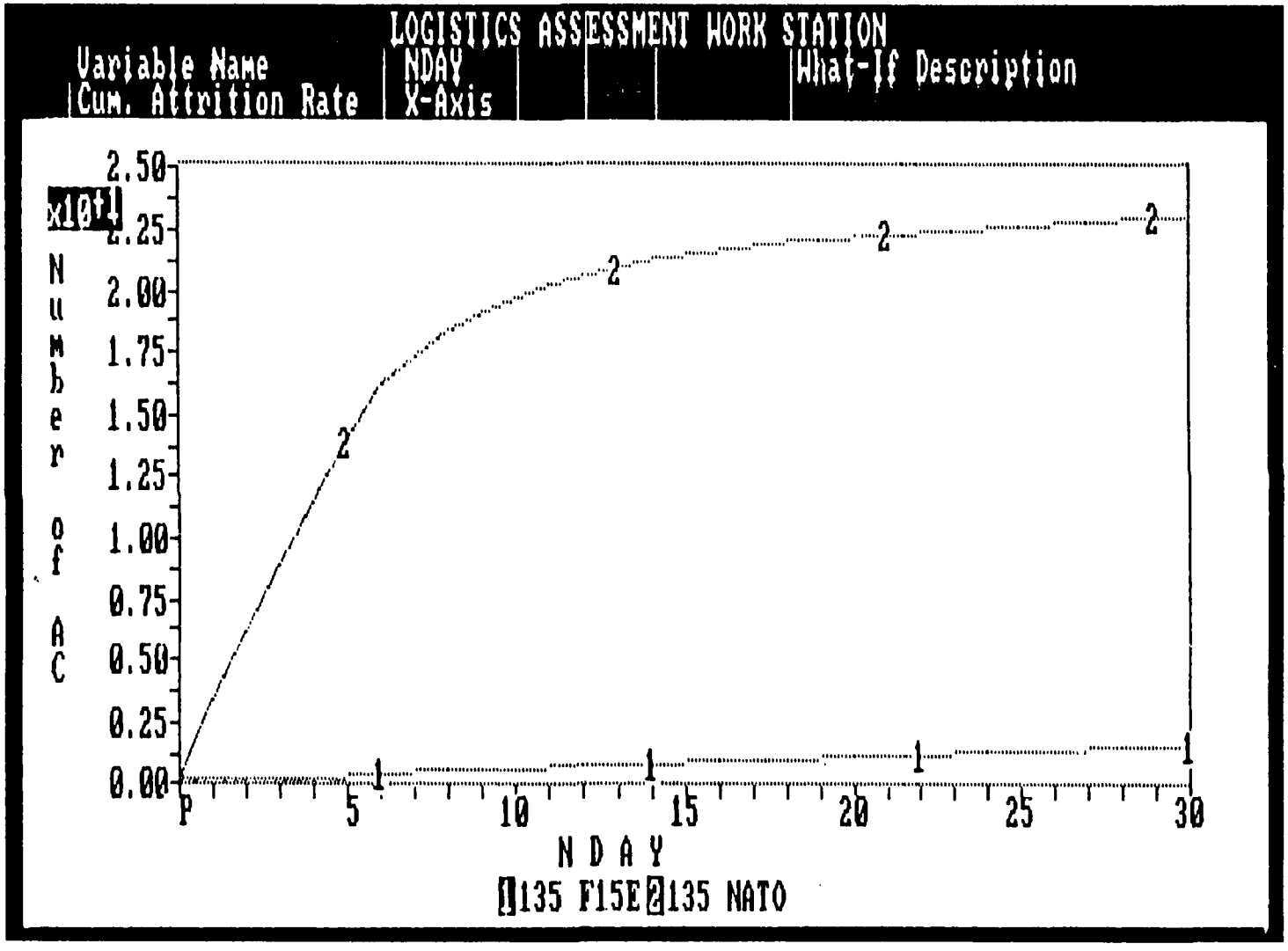


Fig. 65: 135 F-15E and 135 NATO Versions:
Cumulative Attrition by Day (View B)

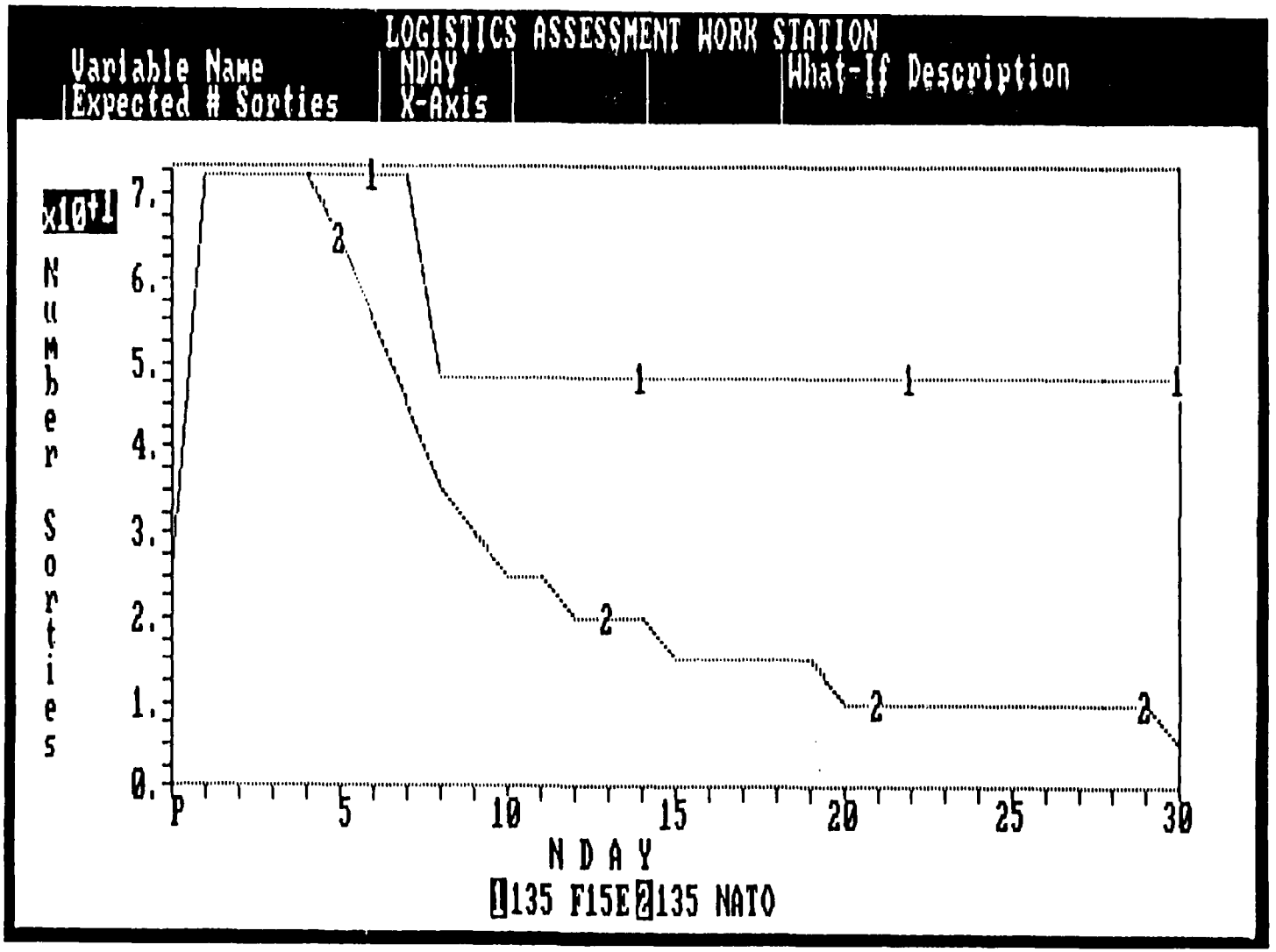
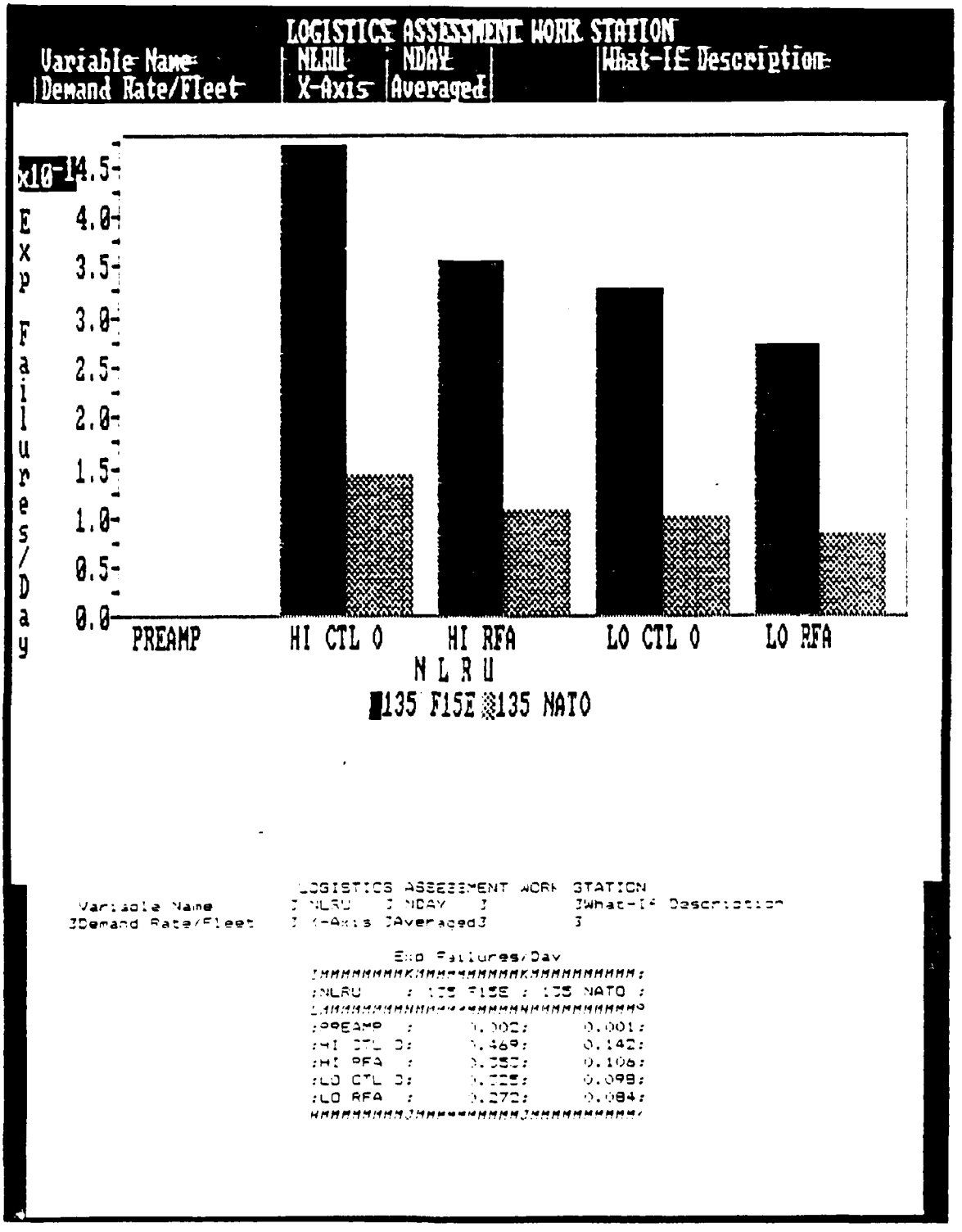


Fig. 66: 135 F-15E and 135 NATO Versions:
Expected Number of Sorties by Day (View B)



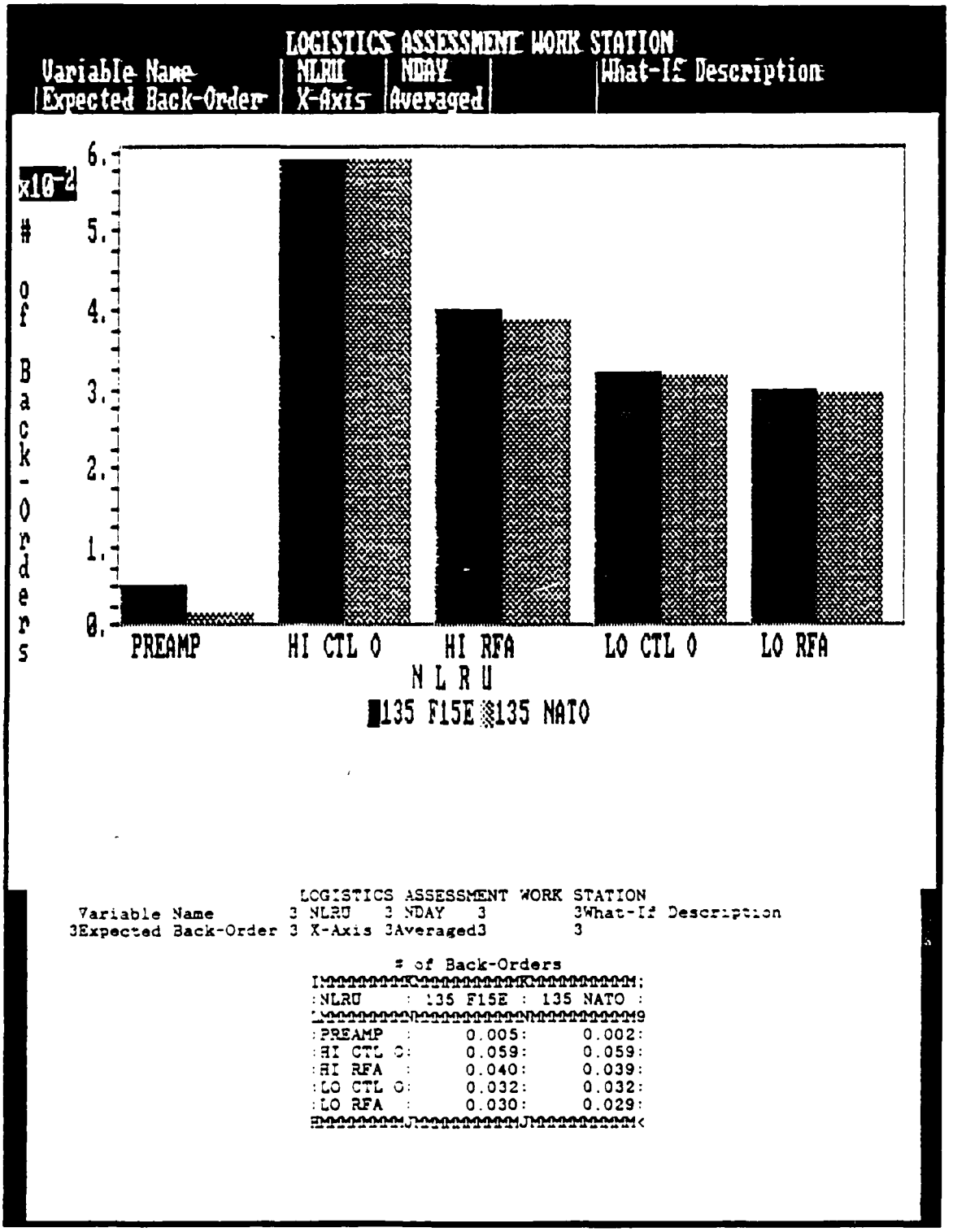
LOGISTICS ASSESSMENT WORK STATION

Variable Name | NLRU | NDAY | What-IF Description
Demand Rate/Fleet | X-Axis | Averaged |

Exp Failures/Day

NLRU	135 F15E	135 NATO
PREAMP	0.002	0.001
HI CTL O	0.469	0.142
HI RFA	0.350	0.106
LO CTL O	0.325	0.098
LO RFA	0.272	0.084

Fig. 67: 135 F-15E and 135 NATO Versions: Average Fleet Demand Rates by LRU (View B)



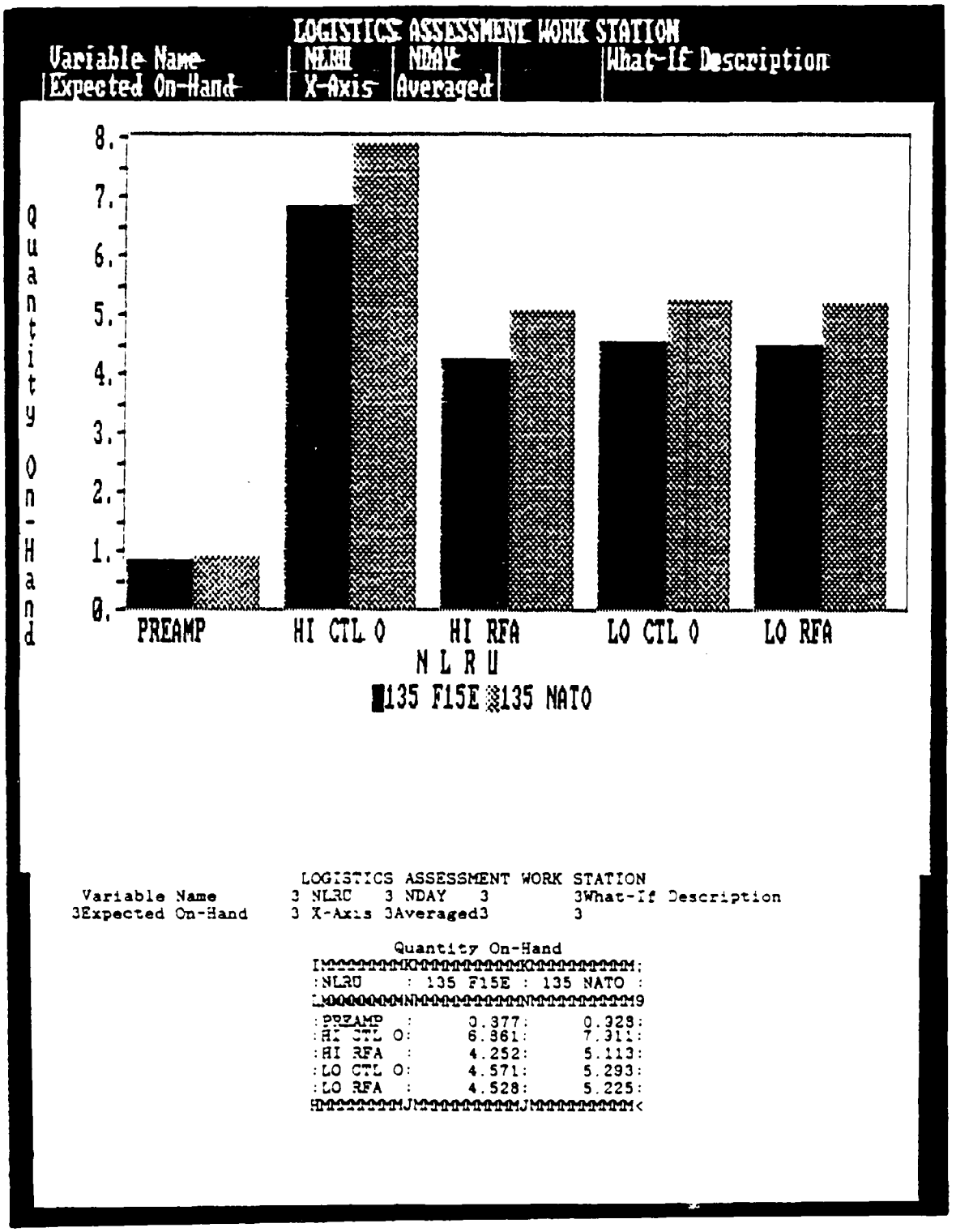
LOGISTICS ASSESSMENT WORK STATION

Variable Name	NLRU	NDAY	What-If Description
Expected Back-Order	X-Axis	Averaged	

# of Back-Orders

NLRU	135 F15E	135 NATO
PREAMP	0.005	0.002
HI CTL O	0.059	0.059
HI RFA	0.040	0.039
LO CTL O	0.032	0.032
LO RFA	0.030	0.029

Fig. 68: 135 F-15E and 135 NATO Versions: Average Expected Backorders by LRU (View B)



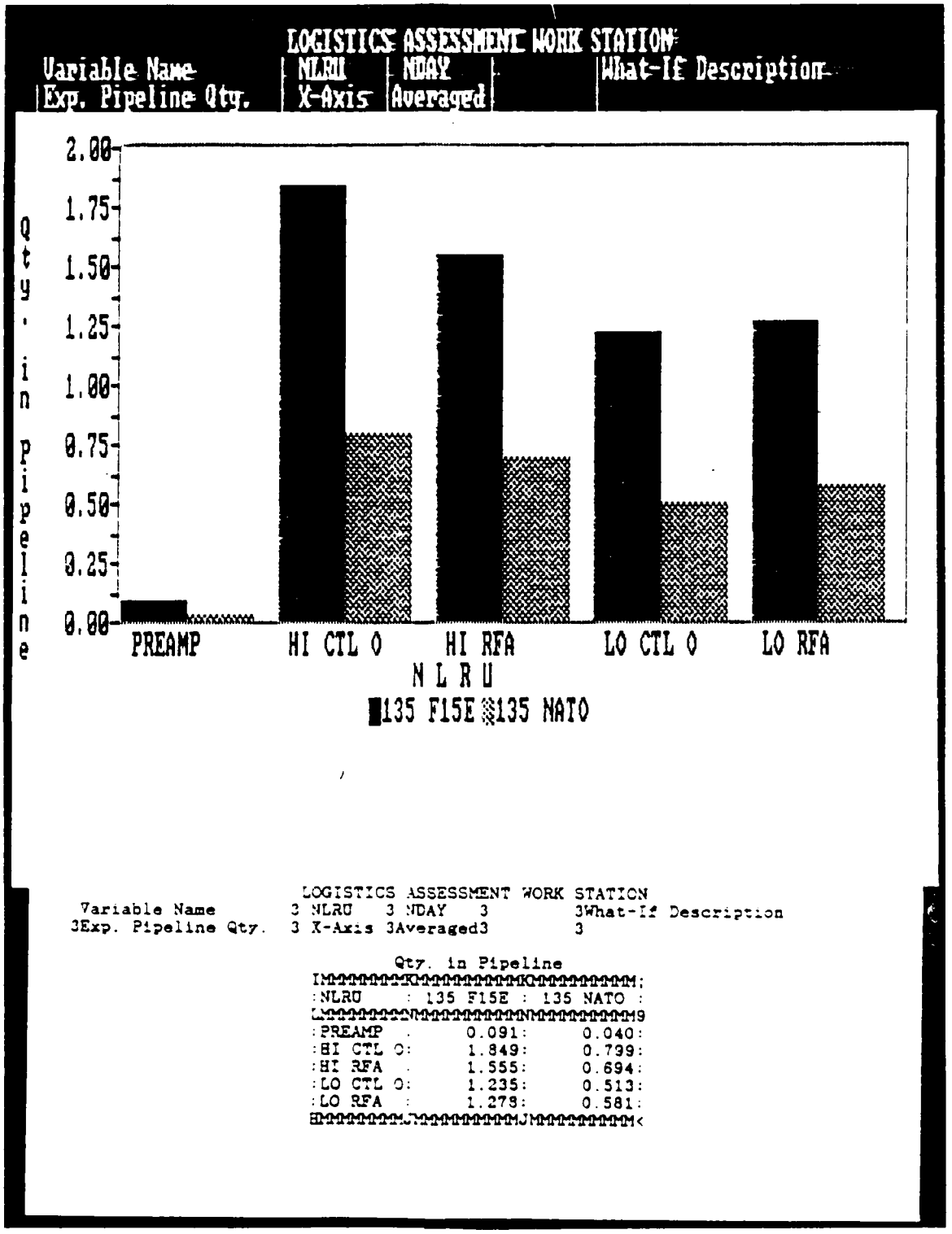
LOGISTICS ASSESSMENT WORK STATION

Variable Name / Expected On-Hand	NLRU / X-Axis	NDAY / Averaged	What-If Description
	3	3	3

Quantity On-Hand

NLRU	135 F15E	135 NATO
PREAMP	0.377	0.328
HI CTL O	6.861	7.311
HI RFA	4.252	5.113
LO CTL O	4.571	5.293
LO RFA	4.528	5.225

Fig. 69: 135 F-15E and 135 NATO Versions: Average Expected LRUs On-hand (View B)



LOGISTICS ASSESSMENT WORK STATION

Variable Name	NLRU	NDAY	What-If Description
Exp. Pipeline Qty.	X-Axis	Averaged	

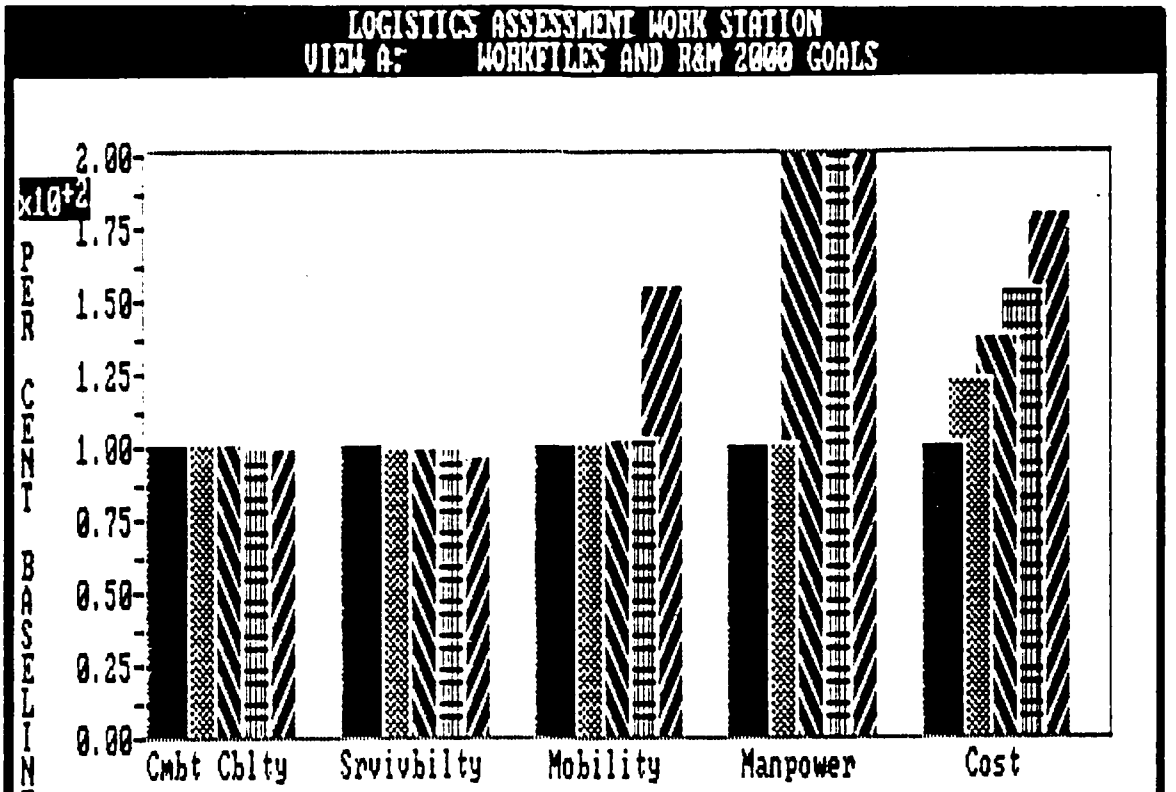
Qty. in Pipeline

NLRU	135 F15E	135 NATO
PREAMP	0.091	0.040
HI CTL O	1.849	0.799
HI RFA	1.555	0.694
LO CTL O	1.235	0.513
LO RFA	1.278	0.581

Fig. 70: 135 F-15E and 135 NATO Versions: Average Expected Repair Pipeline Quantities by LRU (View B)

Total requested (tasked) sorties is another significant determinant of the operational environment. As has been shown, P^3I supportability is quite high, and it may be reasonable to expect more of this subsystem than has been asked in the assumed operational plan. In this final series of LAMP outputs (Figures 71-75), '135 P3I' is again presented for reference, with hypothetical 'What-ifs' performed on the '135 F-15E' Workfile, which is represented by the shaded bar. (The wartime attrition rate has been reset to .001 losses per sortie.)

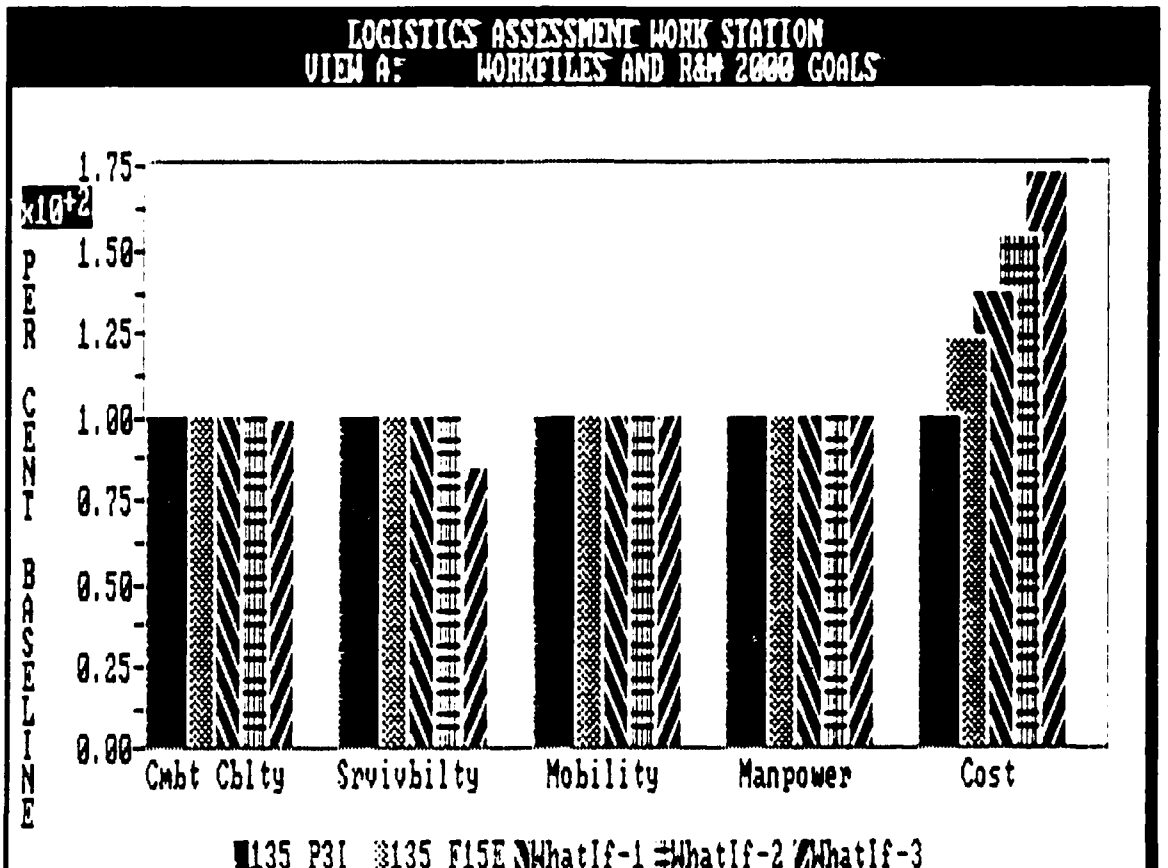
In Figure 71, each 'What-if' represents a 20% increase in the requested wartime sortie rate for the F-15E configuration. Additional maintenance personnel and an associated LCC increase were all that was required to sustain two 20% steps in sortie rate. The next 20% step required an additional SE (and associated LCC and Mobility increases), but resulted in the beginning of a drop off in Combat Capability and Survivability. Figure 72 shows the same comparative conditions, but with two exceptions: First, the increased sortie rate applied to peacetime as well as to the 30-day war. Second, by use of a user option, the level of support resources (SE, personnel, and spares) has been held constant. As a result, the Mobility and Manpower goals were unchanged. LCC is comparable to, and Survivability is somewhat lower than values shown in Figure 71 due to the constraints intentionally placed on manpower and spares.



LOGISTICS ASSESSMENT WORK STATION
VIEW A: WORKFILES AND R&M 2000 GOALS

	COMBAT CAPABILITY %sort.gen. wartime	SURVIV-ABILITY % sorties w/o I-level	MOBILITY # of C-141Bs	MANPOWER spaces /aircraft	COST Life Cycle Cost
Benchmark :135 P3I	1.00	1.00	0.11	0.04	136.00M
Comparison:135 F15E	1.00	1.00	0.11	0.04	167.89M
What-If(1)	1.00	1.00	0.11	0.08	186.80M
What-If(2)	1.00	0.99	0.11	0.08	209.31M
What-If(3)	0.99	0.96	0.16	0.08	244.68M

Fig. 71: 135 F-15E Version: 20% Increases in the Wartime Requested Sortie Rate (View A)



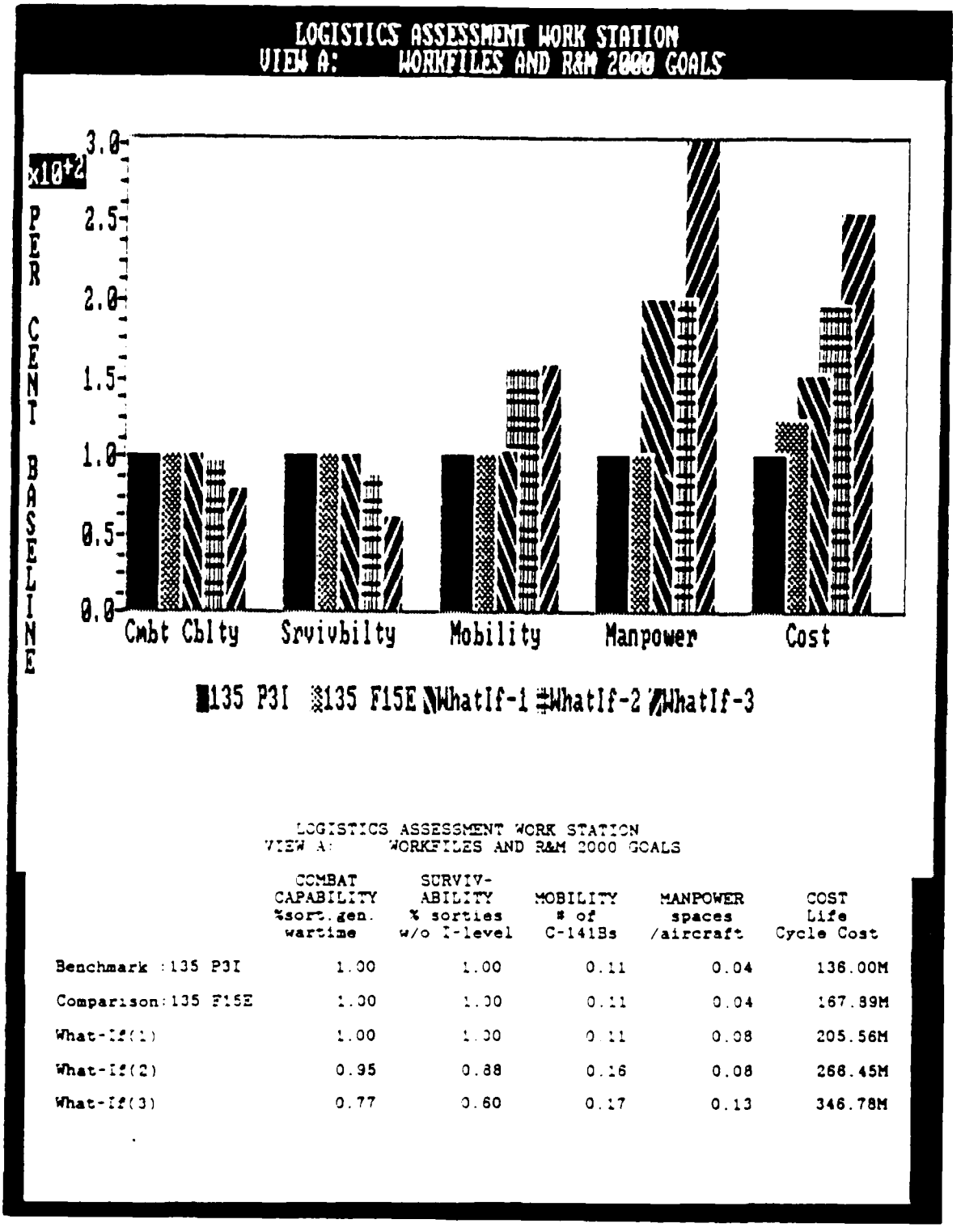
LOGISTICS ASSESSMENT WORK STATION
VIEW A: WORKFILES AND R&M 2000 GOALS

	COMBAT CAPABILITY %sort.gen. wartime	SURVIV-ABILITY % sorties w/o I-level	MOBILITY # of C-141Bs	MANPOWER spaces /aircraft	COST Life Cycle Cost
Benchmark :135 P3I	1.00	1.00	0.11	0.04	136.00M
Comparison:135 F15E	1.00	1.00	0.11	0.04	167.89M
What-If(1)	1.00	1.00	0.11	0.04	186.65M
What-If(2)	1.00	0.99	0.11	0.04	209.16M
What-If(3)	0.99	0.84	0.11	0.04	236.18M

Fig. 72: 135 F-15E Version: 20% Increases in the Requested Peacetime and Wartime Sortie Rates with Support Resources held Constant (View A)

To further investigate the issue of requested daily sorties, three increments of 40% increases in requested sorties (wartime only) were commanded. The resulting adverse effects on the R&M 2000 goals is shown in Figure 73. The rather weak correlation between the number of F-15E P^3I FMC aircraft and requested sortie rates is revealed in Figure 74. Apparently the F-15E P^3I can handle quite an impressive wartime tasking, even though the nature of its mission is unlikely to require (and crew limitations are unlikely to allow) such a high sustained sortie rate.

The final determining feature of the operational environment to be examined was the limitation on maximum daily sorties (LAMP variable TMS, #57). This variable represents the 'upper limit' of what each individual F-15 can fly per day in order to compensate for non-FMC jets and thereby contribute to the overall requested sortie rate. When this upper, per-aircraft limit (for peace and war) was cut in three increments of 10% as indicated in Figure 75, there was no adverse impact whatsoever on the R&M 2000 goals for the P^3I version. This finding suggests that the sortie load at any given time is spread across a wide portion of the squadron's aircraft.



LOGISTICS ASSESSMENT WORK STATION
VIEW A: WORKFILES AND R&M 2000 GOALS

	COMBAT CAPABILITY %sort.gen. wartime	SURVIV-ABILITY % sorties w/o I-level	MOBILITY # of C-141Bs	MANPOWER spaces /aircraft	COST Life Cycle Cost
Benchmark :135 P3I	1.00	1.00	0.11	0.04	136.00M
Comparison:135 F15E	1.00	1.00	0.11	0.04	167.89M
What-If(1)	1.00	1.00	0.11	0.08	205.56M
What-If(2)	0.95	0.88	0.16	0.08	268.45M
What-If(3)	0.77	0.60	0.17	0.13	346.78M

Fig. 73: 135 F-15E Version: 40% Increases in the Requested Sortie Rate (Wartime only) (View A)

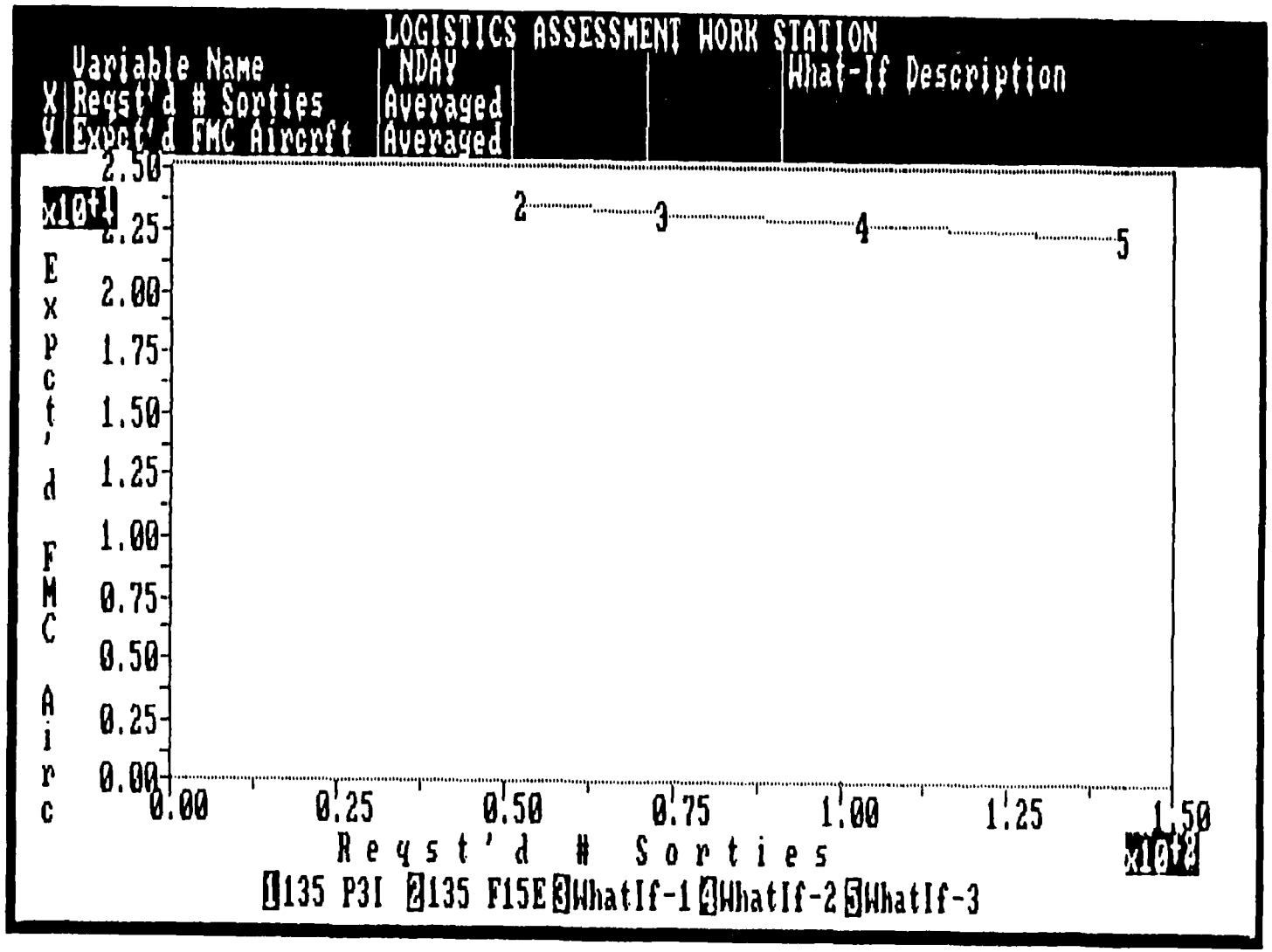
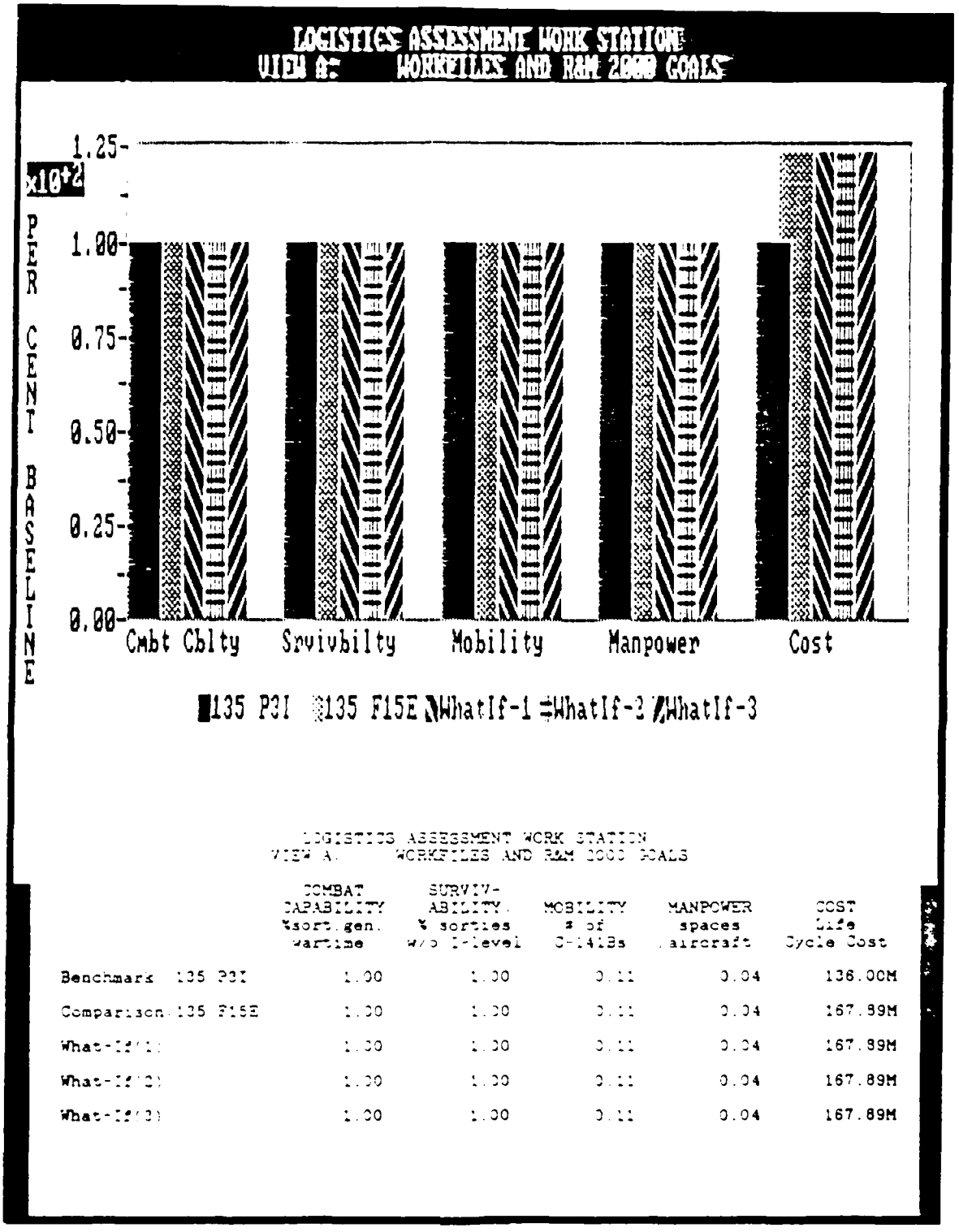


Fig. 74: 135 F-15E Version: Sensitivity of Expected FMC Aircraft to the Requested Wartime Sortie Rate (View E)



LOGISTICS ASSESSMENT WORK STATION
VIEW A: WORKFILES AND R&M 2000 GOALS

	COMBAT CAPABILITY %sort.gen. wartime	SURVIV-ABILITY % sorties w/o I-level	MOBILITY # of C-141Bs	MANPOWER spaces aircraft	COST Life Cycle Cost
Benchmark: 135 P3I	1.00	1.00	0.11	0.04	136.00M
Comparison: 135 F15E	1.00	1.00	0.11	0.04	167.89M
What-If(1)	1.00	1.00	0.11	0.04	167.89M
What-If(2)	1.00	1.00	0.11	0.04	167.89M
What-If(3)	1.00	1.00	0.11	0.04	167.89M

Fig. 75: 135 F-15E Version: 10% Reductions in Maximum Allowable Sorties (View A)

Phase Two Summary. In responding to various demands which were placed on the ALQ-135 by its support and operational environment, the P^3I design performed well. LCC and Mobility impacts were as could have been intuitively expected. Manpower requirements were relatively insensitive to Support and Operational factors. Combat Capability and Survivability were completely insensitive over the range of variables tested, except for the upper end of the range of requested sortie rates.

LAMP: A User's Evaluation

In addition to several brief remarks made at appropriate points in the text thus far, the employment of LAMP in this supportability assessment has revealed many considerations which should be brought to the attention of decision makers and future LAMP users. The remainder of this chapter offers some fairly 'general,' overall comments; several positive and negative points regarding the choice of LAMP as an analysis tool; and some suggestions for future enhancements of the product.

Overall comments. As noted in all DRC documentation associated with LAMP, a thorough understanding of the technology under analysis is an important prerequisite to successful LAMP use. Such an understanding allows a valid, complete analysis and enables the user to cross-check outputs that intuitively 'just don't look right.'

More than simply a working familiarity with LAMP itself is also important. There are critical subtleties within the

logic and assumptions of LAMP, and it is important that the user recognizes when he is operating on the edge of model limits.

As with any modeling process, LAMP depends on valid data inputs to provide reasonable outputs. There are large quantities of data required to perform an all-encompassing study of the type seen in this thesis. This volume problem may be compounded by reliance on non-F-16 CDS data bases and sources, as was the case with this study, and by the need to ensure that definitions of such data are compatible with LAMP assumptions. It is crucial to realize that just because a computer can efficiently process all of these inputs doesn't necessarily mean that the resulting outputs are accurate and meaningful.

LAMP has several inherent capability limitations, due to constraints which exist partly by virtue of its being intended as a microcomputer-based tool. The program can handle no more than 10 parts (in the case of this study, LRUs) in each design being analyzed. The logic within the program is limited to subsystem-level (as opposed to weapon system) analysis, and is capable of looking at only a single subsystem at a time. As a consequence, each analysis is performed as if the unit under study is isolated from other aircraft systems. A prime example of how this assumption can be a problem is in the difficulty of dealing with resources (SE and manpower) shared between subsystems. Also, the cannibalization logic employed overlooks the

likelihood that candidate airframes may be out flying in non-FMC status instead of sitting on the ramp contributing to the spare parts pool.

One collateral and perhaps unintended feature of LAMP is its value as a logistics teaching tool. Through the application of LAMP to real-world acquisition problems, the user quickly learns basic tradeoffs between the R&M 2000 goals and interrelationships between supportability elements (input and calculated variables, in LAMP terms).

Positive Features. LAMP has a number of encouraging features. Its user-friendliness can safely be described as 'moderate.' Paths through internal software menus and so forth are only slightly less than self-explanatory, and they are easily learned. After a few trial runs, data can be competently loaded into the data base structure, Workfiles formed, and outputs produced. A major caution at this point is the already-mentioned need to ensure that those outputs are valid, meaningful, and based on solid data inputs.

On-line references are excellent. The LAWS 'Help' function is particularly noteworthy as it provides a great deal more actual help than most comparable 'Help' routines. In addition, a 'Browse' function allows momentary review or checking of various data base elements with minimum interruption to whatever task is in progress. On-line definitions and variable descriptions are thankfully convenient, as there are a lot of terms and acronyms within the program which are difficult to quickly master.

The 'stand alone' output formats, examples of which have been seen in this chapter, are outstanding. User options for level of detail and format choices are quite versatile. Scale dimensions and axis labels are applied automatically. The clarity of presentation (provided the user understands the basic LAMP measures of merit for the R&M 2000 goals) is an appropriate finishing touch which highlights the capabilities of LAMP. One drawback observed in the course of obtaining hardcopy was the difficulty of configuring various printers to produce these high-quality graphics.

Specific Shortcomings. As this program is still in a prototype status, there are a few software 'glitches' which are disruptive and restrictive to the analysis process. LAWS equipment has little 'spare' memory; accumulated Workfiles and/or graphics files quickly consume available space which inhibits and eventually overloads processing. Some input variables were inexplicably 'unsensitizable' due to unexpected dead ends in the 'What-if' options. Apparent difficulties in integrating LAMP's many models have created complications in the functioning of a potentially powerful 'Actual vs. Required' capability which was, with one exception, unused in this analysis. Finally, in one case the sum of sub-categories of a breakout chart (Figure 26, a LCC parent-child bar chart) did not equal the quantity indicated by the total.

Some of the variable definitions presented in the software are incorrect. Others are correct but unclear. In some cases definitions given in the Data Collection Guide do not agree with those provided on-line by LAWS.

Although on the whole LAWS is a very usable instrument, there are some tasks and outputs which are not exactly self-explanatory. An improved User's Guide due out soon from DRC should alleviate much of this shortcoming.

Suggestions for Improvement. There are several features that should be considered as LAMP evolves into a truly efficient and useful assessment tool. The Input Variable/R&M 2000 Goal Contribution Matrix (Appendix E) and the Hierarchies for the R&M 2000 Goals (such as the one in Appendix D), and those for the ILS Elements should be published in future LAMP User's Guides. These visual aids would add immensely to the user's understanding of the variables' and goals' interrelationships. In the same vein, it should be possible to develop a tutorial program which would walk a novice user through various Data Development and Data Analysis tasks. Similarly, an on-line function which could 'suggest' or 'guide' the user to likely or appropriate areas for further investigation would expedite the analysis process.

There are a few minor 'niceties,' the ideas for which arose while in the heat of LAMP use, which could be useful.

First, some form of 'batch' trial sensitization would be helpful. The user would be able to quickly command, say, two 10% increments up and/or down in the entire data base or any subset thereof. Such a capability would have significantly shortened the length of time necessary to conduct the 'raw' sensitization described in Chapter III.

Second, a related convenience would allow the user to change any given variable in the Parts file for all parts simultaneously. The current procedure requires moving to each part individually to make changes which might apply to all.

Third, the value of the (already powerful) sensitivity curves could be enhanced by allowing the user to sensitize any of the five R&M 2000 goals against other LAMP variables. In the current program version, the only major R&M 2000 goal which may be selected as a View E axis is LCC.

Fourth, the input variables for Flightline to Shop Transportation Time (SFBT, #43) and Shop to Depot to Flightline Order Response Time (TOST, #44) should be moved from the input Parts file to the Support file. These variables are more representative of the support environment than of the inherent maintainability of the design itself.

Summary

The content of this Chapter was divided into two parts. In the first part supportability characteristics of the Band 1/2 design were compared directly with those of the P^3I

configuration. More detailed analysis sought to establish the sensitivity of the supportability characteristics for the P^3I design, and to evaluate the design's suitability in various environmental scenarios. User-oriented LAMP 'lessons learned' from this particular application and suggestions for program improvement were presented. Overall project conclusions can be found in Chapter V.

V. Conclusions and Recommendations

As specified in Chapter I, the purpose of this research was twofold. First, a supportability assessment of the AN/ALQ-135 was to have been performed. Second, an evaluation of LAMP's usefulness would be completed. Accordingly, this chapter will summarize the research in two separate concluding sections which address ALQ-135 supportability and LAMP utility. Following these summary remarks, several recommendations concerning the use of LAMP are listed.

AN/ALQ-135 Supportability

The following conclusions are highly dependent on the validity of available primary data as gathered and listed in Appendix B. Although this point has already been stressed, it bears repeating yet again for additional emphasis.

The clearest way of providing conclusions concerning ALQ-135 supportability is to continue to adhere to the two-part analysis format. As outlined in Chapters 3 and 4, this framework differentiated design features from operational and support contingencies.

Sensitivity Analysis Conclusions. The P^3I design features big supportability improvements over its predecessor, the Band 1/2 jammer. When utilized at the same 1.32 hours-per-sortie rate, its supportability is superior to that of the Band 1/2 configuration with respect to all

five R&M 2000 goals except for LCC, which (as has already been brought out) is difficult to directly compare. With the P^3I design, the Tactical Air Forces can expect two and one-half times the number of sorties without maintenance, a lower spare parts demand rate, much less dependence on intermediate-level maintenance, a mobility burden reduced by 20%, twice the operational availability, system-level MTBMA and MTBF improvements on the order of 100%, and almost half of the necessary MMH per flight hour.

The reader will recall that the remainder of the Sensitivity Analysis phase dealt with uncertainties in the design. Summary answers to each of the five supportability issues identified will now be presented.

1. **Are Northrop's projected maintenance characteristics (primarily MMH and NRTS) crucial to the maximization of R&M 2000 goals? What effect would some Repair-In-Place capability have?**

If a 'cost-free' RIP maintenance capability could be adopted for some failed components, there would be significant LCC savings, but no measurable impact on other R&M 2000 goals. The design is also relatively insensitive to less-favorable NRTS rates. Manpower and Mobility needs, however, are quite dependent on MMH needs. LCC is for the most part not impacted by MMH needed for corrective maintenance.

2. **How critical are projections about TISS and ALQ-135 BIT performance?**

For small degradations in TISS capability, Mobility and LCC measures are unaffected. Larger inadequacies in TISS SE performance, however, require more units to cover the shortfall, and the Mobility and LCC goals are affected accordingly. Likewise, only at very high levels of CND, BIT, and FIT unreliability is there any significant effect on any of the R&M 2000 goals.

3. Are repair cycle times (base and depot) limiting factors in supportability of the ALQ-135?

According to the LAMP model, the success of the P^3I design is apparently insensitive to increases in base-level and round-trip depot-level transportation times. The goals Combat Capability, Survivability, and LCC, though, are very sensitive to even moderate increases in base repair cycle times. If the wartime base repair cycle time increases from the assumed two days to just three days, measures of expected sorties and expected FMC aircraft begin to suffer. Even less-severe increases in base repair cycle time would have implications for higher LCC and much higher parts backorders. Also, the number of sorties possible without I-level maintenance and operational availability in general are greatly reduced if the base repair cycle time were to increase.

4. What if LRU MTBFs are less than predicted? How do changes in part utilization per sortie (MTBM-1 vs. MTBF) affect supportability?

In the event MTBFs are lower than predicted, one could expect Manpower requirements and LCC to increase. Combat

Capability, Survivability, and Mobility goals were unaffected by MTBF decreases over the range examined. (The impact of decreases in part utilizations per sortie would be identical to corresponding increases in MTBF).

5. How would changes to LRU weight, size, and cost affect the R&M 2000 goals?

The impacts of these uncertainties on Mobility and LCC goals are as could be intuitively expected. LAMP is able to account for the fact that increases in LRU unit costs affect operations and support costs as well as the nearer-term acquisition cost.

Overall, then, the P^3I design is reasonably tolerant of hypothetical deterioration of the logistics support elements. The most critical logistical determinant of Combat Capability and Survivability is the base repair cycle time for corrective maintenance. The logistics challenge for this new version of the ALQ-135 will be to maintain its high level of Combat Capability and Survivability while maintaining and further reducing its Mobility, Manpower, and LCC requirements.

Environmental Analysis Conclusions. Four aspects of the environment were investigated. Environmental Analysis considered impacts on the ALQ-135 due to spares levels, F-15 attrition rates, requested sorties, and maximum sorties.

As defined by LAMP, there would be no adverse impact on Combat Capability if spares levels were decreased; Mobility and LCC goals, though, would be supported by reduced spares

quantities. Combat sorties would have to be flown by a reduced pool of aircraft due to LRU shortages, however, so reduced spares levels might not be a preferred objective.

Increased aircraft attrition rates cause demand rates, backorders, and pipeline quantities to go down. These so-called logistical 'benefits,' though, are paradoxical, as they are the result of aircraft battle losses, not enhanced supportability.

The P^3I design is fairly well able to respond to and support a heavier requested sortie demand. LCC would go up with such higher sortie rates. Mobility and Manpower requirements would increase as well, but on the whole, Combat Capability and Survivability measures are rather insensitive to reasonable increases in operational tasking.

Finally, R&M features of the P^3I design are apparently such that, if the ability of FMC aircraft to fly compensating extra sorties to recoup lost sorties due to non-FMC jets is cut, there is no impact. The ability to spread sortie loads over all assigned aircraft is indicative of good supportability and contributes to operational readiness and flexibility.

LAMP Utility

LAMP is worthy of continuing USAF attention as a promising analysis tool. Data and model complexities, though, mean that the concept has some distance to go prior to becoming self-supporting. For the immediate future,

analytical and technical support to be provided by the proposed Combat Supportability Information and Analysis Center (CSIAC) would be crucial to making this methodology useful to System Program Offices.

It must be remembered that LAMP would be only one factor in acquisition-phase decision making, not the determining input. Necessary assumptions and simplifications are inevitable in any modeling endeavor such as LAMP, and conditions which are not dealt with by the computer program may be the overriding concerns as far as the Program Manager is concerned.

Applications of LAMP to the ALQ-135 case was a more complex undertaking than was initially anticipated. Again, the establishment of a CSIAC to provide LAMP expertise would greatly lessen the height of obstacles present due to LAMP's complexities.

An important final remark regarding the evaluation of LAMP as an analysis tool is an appropriate mention of DRC-provided support. The company was available in every instance where help was needed to quickly iron out ambiguities, answer questions, research software problems, and provide hardware. DRC was open-minded and receptive to user-oriented feedback. The high level of competence observed, particularly in engineers Kevin Deal and Eric Davis, was an intangible which contributed greatly to the completion of this effort.

Recommendations

The following recommendations come to mind at the completion of this project. All of these suggestions apply to the future of the LAMP concept.

LAMP should be further developed to ensure its validity and realism. The usability features suggested in Chapter 4, as well as others, would enhance the interactive process, and should be considered for incorporation into the program. Efforts should be made to expand the LAMP concept into system-level (whole aircraft) applications. The application of LAMP to systems outside the Tactical Fighter environment should also continue to be developed.

An effort should be made to objectively compare LAMP to similar supportability assessment methods. Relevant qualitative and quantitative processes used by military and contractor organizations would serve as benchmark or competitive methodologies.

Current efforts to use LAMP as a logistics educational tool should be continued and possibly expanded. LAMP's comprehensive and interactive nature make it a good example of a decision support system, and a potentially excellent teaching aid for illustrating the interrelationships between logistics elements and objectives. The application of LAMP to textbook cases would be suitable content for acquisition logistics course work.

Appendix A:
Dollar Value Conversion Factors

Extracted from AFR 173-13, (2 September 1986)

Air Force Regulation 173-13, (US Air Force Cost and Planning Factors), provides cost conversion factors which allow inflation-adjusted comparison of dollar amounts. These factors vary by the type of purchase under consideration, for example, Research and Development (R&D), procurement, construction, 'special,' and so forth. For LAMP data, R&D and procurement conversions were required to make comparisons between Band 1/2 and P3I with validity. The following conversion factors were extracted from Table 5-1, 'USAF Raw Inflation Indices' (173:92), and applied to the input variables shown:

For base year 1987:

Input variable	Procurement Factor	R&D Factor
2. CAB: SE Unit Cost	.496 (1977)	
16. RDCOST: LRU R&D Cost		.474 (1975)
30. UC: Average LRU Unit Cost	.631 (1980)	

Appendix B:
Data Collection Form for Input Variables

Part I: Input Variables for AN/ALQ-135 Predecessor (Band 1/2 System)

(The numbers in the left-hand column are for purposes of cross-reference with text notation and other appendices only.)

REFERENCE FILES:

		SUPPORT EQUIPMENT:	I-level (TITE)	D-level (ALM205/206)
1.	SEDOWN	Support Equipment Percentage Downtime	.68	.43
2.	CAB	Support Equipment Unit Cost	$1.53M	$4.45M
3.	COB	Percent of Unit Cost to Operate/yr	.15	.15
4.	WSE	Weight per Unit	3946 lbs	5229 lbs
5.	SIZESE	Volume per Unit	333 cu ft	253 cu ft
6.	SESQFT	(Floor) Area Required	25.2 sq ft	44.1 sq ft

		MANPOWER:	O-/I-level (326XX)	D-level ("CIV TECH")
7.	BLR	Base Labor Rate	$7.285/hr	N/A
8.	DLR	Depot Labor Rate	N/A	$28.33/hr
9.	TCS	Tech School Course Cost per Graduate	$1200.00	$1200.00

		FACILITIES:	(O-Shop)	(I-Shop)	(D-Shop)
10.	FACOST	Total Cost of Facility	N/A	N/A	N/A
11.	FACFT	Area of Facility	N/A	0 sq ft	0 sq ft
12.	FMTCST	Maint Cost per Facility/yr.	N/A	N/A	N/A
13.	FSHPWT	Shipping Weight	N/A	N/A	N/A
14	FSHPCC	Shipping Volume	N/A	N/A	N/A

PARTS FILES: *	CO B2	RFA B2	CO B1	RFA B1
DESIGN INTERFACE:				
15. UF Fractional Utilization/sortie	1.0	1.0	1.0	1.0
16. RDCOST R&D Cost	$281.4K	$241.2K	$281.4K	1185.9K
17. WSTEK Part Weight	50 lbs	60 lbs	50 lbs	60 lbs
18. SIZE Part Size	1.39 cuft	1.17 cuft	1.39 cuft	1.17 cuft
19. SUBQPA Sub-Ass'y Quantity	1	1	1	1
20. SBMTBF	157 hrs	239 hrs	241 hrs	256 hrs
SCHEDULED MAINTENANCE:				
21. SMI Sched. Maint. Interval	N/A	N/A	N/A	N/A
UNSCHEDULED MAINTENANCE:				
22. TCND Flightline CND Rate	.10	.10	.10	.10
23. TRIP Flightline Repair in Place Rate	N/A	N/A	N/A	N/A
24. BCOND I-Shop Condemn Rate	N/A	N/A	N/A	N/A
25. TBCS I-Shop Re-Test OK	.05	.05	.05	.05

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* Input variables numbered 15 to 53, 60, and 61 must be defined for <u>each</u> of the four LRUs used in the ALQ-135 Band 1/2 configuration. In some cases the values will be the same for all LRUs; in others, each LRU characteristic for a given variable is unique. A functional description of ALQ-135 components is presented in Chapter II, pages 28-32.

		CO B2	RFA B2	CO B1	RFA B1
26. TNRTS I-Shop NRTS Rate		.06	.10	.05	.12
27. DCOND Depot Condemn Rate		.02	.03	.04	.04
28. FI Fault Isolation		1	1	1	1
29. TBRT Base Repair Cycle Time	P:	3 days	3 days	3 days	3 days
	W:	2 days	2 days	2 days	2 days
SUPPLY SUPPORT:					
30. UC Cost per Part		$26,941	$22,725	$26,941	$111,727
31. BMR Cost of I-level Consumables		0	0	0	0
32. DMR Cost of D-level Consumables		0	0	0	0
33. BMC % Cost of Part to perform I-Shop Repair		.03	.03	.03	.03
34. DMC % Cost of Part to perform Depot Repair		.05	.05	.05	.05
35. BSMC Supply Management Cost per Part/yr		$150	$150	$150	$150
SUPPORT EQUIPMENT:					
36. SESCH/SCHHR SE for Sched Maint.		N/A	N/A	N/A	N/A

	CO B2	RFA B2	CO B1	RFA B1
37. SEUSCH1/USCHR1 SE for Unsched Maint: % Utilized for tasks				
Initial Test (FL)	N/A	N/A	N/A	N/A
Remove and Replace	N/A	N/A	N/A	N/A
Repair in Place	N/A	N/A	N/A	N/A
Insp/Fault Iso (I)	1.0	1.0	1.0	1.0
Repair	0	0	0	0
Insp/Fault Iso (D)	1.0	1.0	1.0	1.0
Repair	0	0	0	0
PACKAGING, HANDLING, TRANSPORTATION:				
38. WRAT Weight Ratio (Packed vs Unpacked)	1.25	1.25	1.25	1.25
39. CPC Packaging Cost/lb	$2.21	$2.21	$2.21	$2.21
40. VPI % Incr in Volume (Packed)	1.50	1.50	1.50	1.50
41. FSTCST Flt Line to Shop Transport Cost/lb	0	0	0	0
42. OSTCST Shop to Depot Transport Cost/lb	$3.67	$3.67	$3.67	$3.67
43. SFBT Flt Line to Shop Transport Time	1 day	1 day	1 day	1 day
44. TOST Shop to Depot to Flightline Time	20 days	20 days	20 days	20 days
TECHNICAL DATA:				
45. ANPTD Associated Number of pages Tech Data	3318	3318	3318	3318
46. NPY # of pp. updated/yr	664	664	664	664

	CO B2	RFA B2	CO B1	RFA B1
47. CPY Cost per Updated Page	$350	$350	$350	$350

FACILITIES:

48. FACTYP
Type Facility at each Repair Level:

Flightline:	N/A
Intermediate Shop Facility:	'I-Shop'
Depot Facility:	'Depot'

MANPOWER AND TRAINING:

49. MOSSCH/SMH AFSC fo Sched Maint.	N/A	N/A	N/A	N/A
50. MOSUS1/MMH1 AFSC for Unsched Maint: ManHours required for tasks				
Initial Test (FL)	.02	.02	.02	.02
Remove and Replace	.9	.9	.9	.9
Repair in Place	N/A	N/A	N/A	N/A
Insp/Fault Iso (I)	2.0	3.0	2.0	3.0
Repair	N/A	N/A	N/A	N/A
Insp/Fault Iso (D)	10.0	5.6	10.0	5.6
Repair	10.0	6.0	10.0	6.0

COMPUTER RESOURCES:

51. NLC # of Lines of Computer Code Developed/yr	1000	0	1000	0
52. DCPLC Development Cost per Line of Code	$1000	0	$1000	0
53. SCPLC Support Cost per Line of Code	$2.37	0	$2.37	0

DATA SETS:

OPERATIONAL DATA SET:

54. TNA Number of Aircraft Assigned per Squadron 24

55. AVAIL Peacetime Fully Mission Capable Rate .7

56. TRS Requested Sorties per assigned Aircraft per day

Peacetime:	1
War Days 1-7:	3
War Days 8-30:	2

57. TMS Maximum Sorties per assigned Aircraft per day

Peacetime:	3
War Days 1-30:	5

58. TFH Expected Flying Hours per Sortie 1.32

59. ATTRIT Attrition Rate per Sortie

Peacetime:	.0001
War Days 1-30:	.001

	B2 CO	B2 RFA	B1 CO	B1 RFA
DESIGN DATA SET:				
60. QPA Quantity of each part utilized in the design	2	2	1	1
SUPPORT DATA SET:				
61. TSTK Peace (POS):	9	6	3	5
War Days 1-30 (WRSK):	28	32	10	16

Quantity of LRUs available as Peacetime Operating Spares (POS) and War Reserve Supply

Flightline Support Resources

62. FLSE/NFLSE: N/A

63. FLMP/NFLMP: 326XX/4

64. FLFAC/NFLFAC: N/A

Intermediate Shop Support Resources

65 SHSE/NSHSE: TITE/1

66. SHMP/NSHMP: 326XX/2

67. SHFAC/NFLFAC: I Shop/1

Depot Support Resources

68. DPSE/NDPSE: ALM-205/206/1

69. DPMP/NDPMP: CIVTECH/25

70. DPFAC/NDPFAC: Depot/1

Part II: Input Variables for
AN/ALQ-135 Alternative (P3I System)

REFERENCE FILES:

SUPPORT EQUIPMENT:			I-level (TISS)	D-level (ALM205/206)
1.	SEDOWN	Support Equipment Percentage Downtime	.43	.43
2.	CAB	Support Equipment Unit Cost	$2.20M	$4.45M
3.	COB	Percent of Unit Cost to Operate/yr	.14	.15
4.	WSE	Weight per Unit	3946 lbs	5229 lbs
5.	SIZESE	Volume per Unit	333 cu ft	253 cu ft
6.	SESQFT	(Floor) Area Required	25.2 sq ft	44.1 sq ft

MANPOWER:			O-/I-level (326XX)	D-level ("CIV TECH")
7.	BLR	Base Labor Rate	$7.285/hr	N/A
8.	DLR	Depot Labor Rate	N/A	$28.33/hr
9.	TCS	Tech School Course Cost per Graduate	$1200.00	$1200.00

FACILITIES:			(O-Shop)	(I-Shop)	(D-Shop)
10.	FACOST	Total Cost of Facility	N/A	N/A	N/A
11.	FACFT	Area of Facility	N/A	0 sq ft	0 sq ft
12.	FMTCST	Maint Cost per Facility/yr.	N/A	N/A	N/A
13.	FSHPWT	Shipping Weight	N/A	N/A	N/A
14.	FSHPCC	Shipping Volume	N/A	N/A	N/A

PARTS FILES: *	PREAMP	HI CTL O	HI RFA	LO CTL O	LO RFA
DESIGN INTERFACE:					
15. UF Fractional Utilization/sortie	1.0	1.0	1.0	1.0	1.0
16. RDCOST R&D Cost	$.13M	$1.287M	$.449M	$1.290M	$.467M
17. WSTEK Part Weight	12 lbs	110 lbs	90 lbs	110lbs	90 lbs
18. SIZE Part Size	.11 cuft	1.39	1.17	1.17	1.17
19. SUBQPA Sub-Ass'y Quantity	1	1	1	1	1
20. SBMTBF	10875 hrs	237	630	341	790
SCHEDULED MAINTENANCE:					
21. SMI Sched. Maint. Interval	N/A	N/A	N/A	N/A	N/A
UNSCHEDULED MAINTENANCE:					
22. TCND Flightline CND Rate	.05	.05	.05	.05	.05
23. TRIP Flightline Repair in Place Rate	N/A	N/A	N/A	N/A	N/A
24. BCOND I-Shop Condemn Rate	N/A	N/A	N/A	N/A	N/A
25. TBCS I-Shop Re-Test OK	.03	.03	.03	.03	.03

* Input variables numbered 15 to 53, 60, and 61 must be defined for <u>each</u> of the five LRUs used in the ALQ-135 P^3I configuration. In some cases the values will be the same for all LRUs; in others, each LRU characteristic for a given variable is unique. A functional description of ALQ-135 components is presented in Chapter II, pages 28-32.

	PREAMP	HI CTL O	HI RFA	LO CTL O	LO RFA
26. TNRTS I-Shop NRTS Rate	.05	.06	.10	.05	.12
27. DCOND Depot Condemn Rate	.02	.02	.03	.04	.04
28. FI Fault Isolation	1	1	1	1	1
29. TBRT Base Repair Cycle Time	P: 3 days W: 2 days	3 days 2 days	3 days 2 days	3 days 2 days	3 days 2 days
SUPPLY SUPPORT:					
30. UC Cost per Part	$92.5K	$916.1K	$319.3K	$918.4K	$332.2K
31. BMR Cost of I-level Consumables	0	0	0	0	0
32. DMR Cost of D-level Consumables	0	0	0	0	0
33. BMC % Cost of Part to perform I-Shop Repair	.03	.03	.03	.03	.03
34. DMC % Cost of Part to perform Depot Repair	.05	.05	.05	.05	.05
35. BSMC Supply Management Cost per Part/yr	$150	$150	$150	$150	$150
SUPPORT EQUIPMENT:					
36. SESCH/SCHHR SE for Sched Maint.	N/A	N/A	N/A	N/A	N/A

	PREAMP	HI CTL O	HI RFA	LO CTL O	LO RFA
37. SEUSCH1/USCHR1 SE for Unsched Maint: % Utilized for tasks					
Initial Test (FL)	N/A	N/A	N/A	N/A	N/A
Remove and Replace	N/A	N/A	N/A	N/A	N/A
Repair in Place	N/A	N/A	N/A	N/A	N/A
Insp/Fault Iso (I)	1.0	1.0	1.0	1.0	1.0
Repair	1.0	1.0	1.0	1.0	1.0
Insp/Fault Iso (D)	1.0	1.0	1.0	1.0	1.0
Repair	0	0	0	0	0
PACKAGING, HANDLING, TRANSPORTATION:					
38. WRAT Weight Ratio (Packed vs Unpacked)	1.25	1.25	1.25	1.25	1.25
39. CPC Packaging Cost/lb	$2.21	$2.21	$2.21	$2.21	$2.21
40. VPI % Incr in Volume (Packed)	1.50	1.50	1.50	1.50	1.50
41. FSTCST Flt Line to Shop Transport Cost/lb	0	0	0	0	0
42. OSTCST Shop to Depot Transport Cost/lb	$3.67	$3.67	$3.67	$3.67	$3.67
43. SFBT Flt Line to Shop Transport Time	1 day	1 day	1 day	1 day	1 day
44. TOST Shop to Depot to Flightline Time	20 days	20 days	20 days	20 days	20 days
TECHNICAL DATA:					
45. ANPTD Associated Number of pages Tech Data	3318	3318	3318	3318	3318

		PREAMP	HI CTL O	HI RFA	LO CTL O	LO RFA
46.	NPY # of pp. updated/yr	664	664	664	664	664
47.	CPY Cost per Updated Page	$350	$350	$350	$350	$350

FACILITIES:

48. FACTYP
Type Facility at each Repair Level:

Flightline:	N/A
Intermediate Shop Facility:	'I-Shop'
Depot Facility:	'Depot'

MANPOWER AND TRAINING:

49.	MOSSCH/SMH AFSC for Sched Maint.	N/A	N/A	N/A	N/A	N/A
50.	MOSUS1/MMH1 AFSC for Unsched Maint: ManHours required for tasks					
	Initial Test (FL)	.02	.02	.02	.02	.02
	Remove and Replace	.9	.9	.9	.9	.9
	Repair in Place	N/A	N/A	N/A	N/A	N/A
	Insp/Fault Iso (I)	3.0	3.45	3.92	3.29	2.7
	Repair	2	2	2	2	2
	Insp/Fault Iso (D)	2.1	2.1	.6	2.1	.6
	Repair	2	2	.5	2	.5

COMPUTER RESOURCES:

51.	NLC # of Lines of Computer Code Developed/yr	0	5350	0	5350	0
52.	DCPLC Development Cost per Line of Code	0	$1000	0	$1000	0
53.	SCPLC Support Cost per Line of Code	0	$2.37	0	$2.37	0

DATA SETS:

OPERATIONAL DATA SET:

54. TNA Number of Aircraft Assigned per Squadron 24

55. AVAIL Peacetime Fully Mission Capable Rate .7

56. TRS Requested Sorties per assigned Aircraft per day
Peacetime: 1
War Days 1-7: 3
War Days 8-30: 2

57. TMS Maximum Sorties per assigned Aircraft per day
Peacetime: 3
War Days 1-30: 5

58. TFH Expected Flying Hours per Sortie 1.32

59. ATTRIT Attrition Rate per Sortie Peacetime: .0001
War Days 1-30: .001

	PREAMP	HI CTL O	HI RFA	LO CTL O	LO RFA
DESIGN DATA SET:					
60. QPA Quantity of each part utilized in the design	1	1	2	1	2
SUPPORT DATA SET:					
61. TSTK Peace (POS):	0	3	2	2	2
War Days 1-30 (WRSK):	1	9	6	6	6

Quantity of LRUs available as Peacetime Operating Spares (POS) and War Reserve Supply

Flightline Support Resources

62. FLSE/NFLSE: N/A

63. FLMP/NFLMP: 326XX/4

64. FLFAC/NFLFAC: N/A

Intermediate Shop Support Resources

65 SHSE/NSHSE: TISS/1

66. SHMP/NSHMP: 326XX/2

67. SHFAC/NFLFAC: I Shop/1

Depot Support Resources

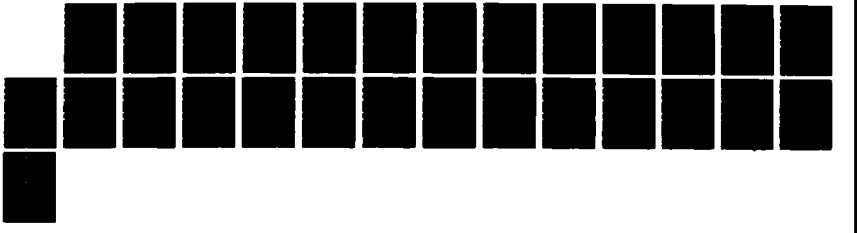
68. DPSE/NDPSE: ALM-205/206/1

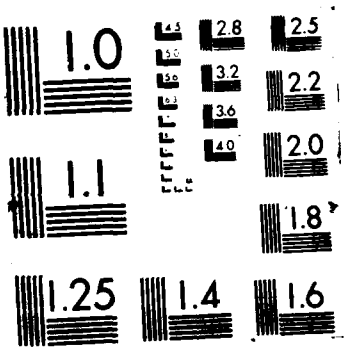
69. DPMP/NDPMP: CIVTECH/25

70. DPFAC/NDPFAC: Depot/1

AD-A186 474 USING THE LOGISTICS ASSESSMENT METHODOLOGY PROGRAM FOR SUPPORTABILITY ANA (U) AIR FORCE INST OF TECH WRIGHT-PATTERSON AFB OH SCHOOL OF SYST G L TOVREA

UNCLASSIFIED SEP 87 AFIT/GLM/LSM/87S-77 F/G 15/5 NL

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Part III: Scalar Values for Band 1/2 and P3I Systems

71.	RAQ	Acquisition Cost of Recruits (ea)	$3200.00
72.	BOHR	Base Overhead Rate (per worker per hour)	$28.347
73.	DOHR	Depot Overhead Rate (per worker per hour)	$19.02
74.	BAMH	Base Available Manhours (per worker per day)	18
75.	DAMH	Depot Available Manhours (per worker per day)	8
76.	ATOR	Annual Personnel Turnover Rate	.2436
77.	UPG	AFSC Upgrade Rate (per year)	.2
78.	TTHS	Transients, Trainees, Holdees, and Students (Unavailable Manhours)	0
79.	MANWT	Average Weight of a Person (lbs)	173
80.	MANCC	Average Volume of a Person (cu ft)	12
81.	BAA	Daily Availability of SE (hrs,wartime)	24
82.	CCC141	Vol. Capacity of C141B Transport (cu ft)	113,900
83.	WTC141	Weight Capacity of C141B Transport (lbs)	71,105
84.	ACPTD	Acquisition Cost per Page of Tech Data	$588.00
85.	MRO	Manhours Req'd to Complete on-equipment form	.08
86.	SR	Manhours Req'd to Complete Supply Trans form	.25
87.	TR	Manhours Req'd to Complete Transport form	.16
88.	MRF	Manhours to Complete off-Equipment form	.24

Appendix C:
Input Variable Background Information

Note: All SE values are 63% of their basic value to reflect the fact that the ALQ-135 is to consume 63% of total TEWS SE demand.

1. SEDOWN (Support Equipment Percentage Downtime)

For I-level TITE, an estimate of 10-15%, provided by Warner Robins Air Logistics Center (WR-ALC) (33) has been modified to reflect TITE field problems related by HQ TAC/LGMA. According to Capt Earl Shafer, Holloman AFB reported an inadequacy rate of 60% for TITE-related repairs from January to June 1987, and Langley AFB reported a rate of 68% from January to December 1986. Northrop contract personnel and equipment have been required to fill the shortfall at many F-15 bases (47).

WR-ALC also provided the historical downtime for the ALM-205/206 SE. The Logistics Branch of the F-15 SPO (TAFL) estimated this value is a reasonable projection for future ALM-205/206 downtime (39).

For TISS (I-level), the value shown is a design goal, modified slightly to reflect realistic expectations (43).

There is another piece of SE associated with the AN/ALQ-135, the Memory Loader Verifier, or MLV. This item is not considered in this study because it is a constant between the two comparative systems, it is used for O-level Operational Flight Program (OFP) installation and verification only, and the other pieces of SE can perform MLV functions if called upon (43,39).

2. CAB: (Support Equipment Unit Cost)

TITE unit cost is $1.2M each (1977 dollars), or $2.42M each (1987 dollars) (54). (Dollar values were converted to 1987 amounts using R&D or Procurement dollar conversion factors in AFR 173-13. See Appendix A.) TISS cost is projected to be $3.5M each (43). The difference between TITE and TISS cost can be attributed partly to the greater capability of TISS.

ALM 205/206 unit cost is constant between Band 1/2 and P^3I. The value represents combined cost of ALM-205 ($2.4M each) and ALM-206 ($1.1M each), or $3.5M total (1977 dollars) (39) converted to $7.06M 1987 dollars.

Honeywell is the prime contractor for all ALQ-135 SE.

3. COB: (Percent of Unit Cost for Annual SE Operation)

TISS O&S cost was estimated at $500K/yr, or 14% of unit cost (43). TITE and ALM-205/206 O&S costs were assumed to be similar proportions due to similar function and technology; 15% is used.

4. WSE: (Weight per Unit of SE)
TISS SE weighs 6263 lbs (43). TITE weight was estimated as the same as TISS. ALM-205/206 weight is the total of 5000 lbs (ALM-205) and 3300 lbs (ALM-206) (39).

5. SIZESE: (Volume per Unit of SE)
TISS volume is 529 cu ft (43). TITE volume was estimated as the same as TISS (39). ALM-205/206 volume is the total of 284 cu ft (ALM-205) and 118 cu ft (ALM-206) (39).

6. SESQFT: (Floor Area Required for Placement of SE)
The ALM-205/206 footprint is 70 sq ft (39). TISS and TITE footprints were derived from the ALM-205/206 size/weight ratio, which yields a conversion factor of 3.4.

7. BLR: (Base Labor Rate)
Default value used.

8. DLR: (Depot Labor Rate)
Default value used.

9. TCS: (Tech School Course Cost Per Graduate)
Default value used. It is assumed to be approximately equal for military and civilian technicians.

10. FACOST: (Total Cost of Facility)
Assumed to be negligible, or zero.

11. FACFT: (Area of Facility)
Assumed to be negligible, or zero.

12. FMTCST: (Annual Maintenance Cost per Facility)
Assumed to be negligible, or zero.

13. FSHPWT: (Facility Shipping Weight)
N/A, or zero.

14. FSHPCC: (Facility Shipping Volume)
N/A, or zero.

15. UF: (Fractional Utilization of Part per Sortie)
For the F-15 overall, part utilization times were considered to average 1.33 times actual flight hours (1). This 1.33 to 1 ratio reflects the 'gap' between MTBMA (which is measured in flying hours) and MTBF (which is measured in equipment operating hours). However, in contrast to radar and navigation equipment, for instance, EW subsystems are unlikely to be operating over the entire duration of a mission, especially in peacetime. Since extra-flight operations and in-flight 'off' times offset one another, a compromise (and probably worst-case) UF of '1' was used.

16. RDCOST: (Research and Development Cost)

For the Band 1/2 version, R&D costs, including 8 pre-production sets, was given by Northrop Defense Systems Division (NDSD) as $30M (1975 dollars) (42), an equivalent 1987 cost of $63.3M. This total was allocated over 757 F-15 A and C models (18:7) at 24 aircraft per squadron for an ALQ-135 Band 1/2 total R&D cost of $2.01M per squadron. LRU unit costs given by WR-ALC (33) were used to assign proportions of the R&D cost over each of four LRUs as shown:

LRU	Unit Cost ($1987)	Proportion of Total
B2 CO	27.7K	.14
B2 RFA	23.4K	.12
B1 CO	27.7K	.14
B1 RFA	114.8K	.59
Total cost:	193.6K	

These proportions were used to 'weight' the overall ALQ-135 R&D cost per squadron to arrive at per-squadron R&D costs of $281.4K (B2 CO), $241.2K (B2 RFA), $281.4K (B1 CO), and $1185.9K (B1 RFA).

The contract CCP94 R&D amount for P^3I R&D is listed as $121M (assumed to be 1987 dollars) (48). This contract applies to 409 F-15Cs and 392 F-15Es, for an F-15E 'share' of 48.9%, or $59,2M. For 392 aircraft at 24 aircraft per squadron, the per-squadron R&D cost for the F-15E P^3I version is $3.62M. LRU proportions were derived as follows:

LRU	Unit Cost ($1987)	Proportion of Total
PREAMP	92.5K	.036
HI CTL O	916.1K	.355
HI RFA	319.3K	.124
LO CTL O	918.4K	.356
LO RFA	332.2K	.129
Total cost:	2578.5K	

Using proportional LRU weights, the per-squadron R&D costs used are $.130M (PREAMP), $1.287M (HI CTL O), $.449M (HI RFA), $1.290M (LO CTL O), and $.467M (LO RFA).

17. WSTEK: (Part Weight)

Provided by NDSD (54).

18. SIZE: (Part Volume)

Cubic size was calculated from length-width-height dimensions provided by ASD/TAF (2). Band 1/2 dimensions are identical to those of the P^3I design (54).

19. SUBQPA: (Subassemblies and Quantity)

N/A, LRUs are considered as whole units only.

20. SBMTBF: (LRU Mean Time Between Failures)
For Band 1/2, MTBFs were provided by WR-ALC (33) based on historical data from June 1986 to June 1987.
MTBFs for P^3I were projected in NDSD's Reliability Predictions Report dated 26 September, 1986. (MTBFs for fore and aft RFAs in each band are slightly different, so single 'average' MTBF values were used for Band 1.5 and Band 3 units (10:23).

21. SMI: (Scheduled Maintenance Interval)
All values were set at zero to reflect the absence of a scheduled maintenance requirement for both ALQ-135 versions.

Note: All unscheduled maintenance action rates were assumed to be the same for wartime and peacetime.

22. TCND: (Flightline 'Cannot Duplicate' Rate)
WR-ALC estimates the Band 1/2 CND rate at .05 to .1 for all LRUs. It is difficult however, to break out O-level CNDs from I-level RTOKs. The CND rate would be higher according to one AIS assistant shop chief, except that even though the original malfunction may not be duplicable, there is always some 'tweaking' of the system which can be done (4). 10% is the value used.
Although NDSD predicts P^3I CND to be approximately the same as historical experience suggests, the SPO expects that Built-in-Test (BIT) improvements will uncover 95% of possible fault modes(23:Sec 2,45). Therefore, the P^3I CND rate was estimated at .05.

23. TRIP: (Flightline Repair-in-Place Rate)
N/A, no RIP is possible for the ALQ-135.

24. BCOND: (Base Level Condemnations Rate)
0, since condemnation is not authorized at base level.

25. TBCS: (I-Shop Bench Check Serviceable, or RTOK, rate)
The value was estimated by an AIS assistant shop chief at .05. For P^3I, the estimate is .03, which is an achievable USAF target for technologies of this type (31).

26. TNRTS: (I-Shop 'Not Repairable at This Station' rate)
Band 1/2 values were calculated from WR-ALC historical data by dividing total recorded NRTS cases by total writeups (by LRU) (33). Values for P^3I were projected on the basis of Band 1/2 experience (48): The HI CTL O was considered analogous to the B2 CO, etc. (The PREAMP value is arbitrary, but it is unlikely to be relevant in light of its predicted MTBF of over 10,000 hours.)

27. DCOND: (Depot Level Condemnation Rate)
Values for Band 1/2 were calculated from WR-ALC historical data by dividing total condemnations by total NRTS (by LRU) (33). P^3I values should be on the same order as for Band 1/2 (48).

28. FI: (Fault Isolation)
It is held constant at '1' by LAMP models (30).

29. TBRT: (Base Repair Cycle Time)
3 days (peacetime) and 2 days (wartime) is typical (6).

30. UC: (Unit Cost per LRU)
For Band 1/2, costs were provided by WR-ALC in 1980 dollars, converted to 1987 dollars using a Procurement conversion factor from AFR 173-13.
For P^3I, LRU costs were supplied by ASD/TAFE (32).

31. BMR: (Average Cost of I-level Consumables per Repair)
Considered negligible, or zero (47).

32. DMR: (Average Cost of Depot Consummates per Repair)
Considered negligible, or zero (47).

33. BMC: (Avg % of LRU Unit Cost to do I-Shop Repair)
3% is considered reasonable (33).

34. DMC: (Avg % of LRU Unit Cost to do Depot Repair)
Estimated by WR-ALC at 5%. Depot repair costs are higher due to overhead costs and the typically more sophisticated repairs performed at depot (33).

35. BSMC: (Annual Supply/Inventory Mgt Cost per item)
The value used is an estimate, but the impact of this particular variable is negligible.

36. SESCH/
SCHHR: (SE use for Scheduled Maintenance)
N/A, there is no scheduled maintenance required for the ALQ-135.

37. SEUSCH1/
USCHR1: (SE use for Unscheduled Maintenance)
N/A for flightline. For I-Shop and Depot, SE use is 100% for tasks requiring SE (33,6).

38. WRAT: (Weight Ratio (Packed to Unpacked))
The value used is an estimate, confirmed by NDSD (54).

39. CPC: (Packaging Cost per Pound)
Default Value Used.

40. VPI: (Volume Ratio (Packed to Unpacked))
The value used is an estimate, confirmed by NDSD (54).

41. FSTCST: (Transportation Cost per Pound, Fltline to Shop)
Zero, since the I-Shop is collocated with Flightline.

42. OSTCST: (Transportation Cost per Pound, I-Shop to Depot)
Default value used.

43. SFBT: (Transportation Time, Flightline to I-Shop)
LAMP's minimum allowable value was used.

44. TOST: (Shop to Depot Response and Transportation Time)
WR-ALC estimates 17 days, (33) plus three days processing time expected at Depot.

45. ANPTD: (Number of Tech Data Pages Associated with LRUs)
ASD/TAFL projects 16,589 pages of technical data associated with P^3I (35). If divided across five LRUs, the figure becomes 3318 pages for each. For Band 1/2, 3318 pages per LRU is a reasonable estimate.

46. NPY: (Number of Tech Data Pages Updated Annually)
ASD/TAFL expects that 20% of technical data pages (664 per LRU) for the P^3I version will be updated each year (35). The same number is used for Band 1/2 LRUs.

47. CPY: (Cost per Updated Page)
ASD/TAF estimated current technical data update costs at $350 per page (35).

48. FACTYP: (Type of Repair Facility at Each Repair Level)
N/A for Flightline. 'I-Shop' and 'Depot' are arbitrary labels for I- and D- level repair facilities.

49. MOSSCH/
SMH: (AFSC Use for Scheduled Maintenance)
N/A, there is no scheduled maintenance required for the ALQ-135.

50. MOSUS1/
MMH1: (AFSC Use for Unscheduled Maintenance)
At Flightline: The NDSD Critical Design Review panel predicted that average P^3I on-aircraft initial fault isolation and test time will be .02 hours (8:177). .02 hours was also assumed a reasonable value for the Band 1/2 system. The CDR-predicted R&R are much lower than the values used, but they exclude panel access, safety wiring, and repair verification, etc. (8:173). Therefore, a WR-ALC historical statistic of .9 hours was used for each LRU (33). The ASD ALQ-135 PM projects that P^3I R&R times will vary by LRU, but on the average they will be similar to those of the Band 1/2 version (38). RIP for the ALQ-135 is N/A.

At Intermediate Shop: Band 1/2 values were provided by an AIS Assistant Shop Chief. All I-level repair is done using TITE SE; there are no 'off-TITE' repair tasks, so the figure under 'I-Shop Repair' is reflected as zero (4). For P^3I, NDSD predictions are shown under Fault Isolate, & Repair. These values do not include such tasks as fault detection/ isolation, electrical tests, and post-repair performance confirmations (8:173), so an arbitrary 2 hours has been added under 'I-Shop Repair' to account for these tasks. No predictions were available for PREAMP repairs, so an arbitrary 5 hours was supposed, although the MTBF is sufficiently high to make the actual value insignificant.

At Depot: Band 1/2 MMH times are from WR-ALC. Inspection and Fault Isolation account for roughly half of an average 20 MMH per CO at depot and 11.6 MMH per RFA. 'Off-ALM' repair accounts for the other portion of total MMH at Depot (33). Predictions for D-level repair include all subtasks, and the values shown are directly from CDR panel projections (8:177).

51. NLC: (# of Lines of Software Code Developed per Year)
2,000 lines of Band 1/2 Code (which actually reside in the ALR-56C RWR) were recently developed in an annual update. The 2,000 lines represent 10% of approximately 20,000 lines total for the Band 1/2 System. The code is associated with the COs, so 1000 lines each was used (48). 107,000 lines are associated with the P^3I COs (2) (assumed 53,500 each). 10% of 53,500 lines is 5,350 lines, which is the assumed annual update for each CO.

52. DCPLC: (Development Cost per Line of Computer Code)
One ASD/TAFE estimate is $1000 per line of code (2).

53. SCPLC: (Annual Support Cost per Line of Computer Code)
During a recent annual update of Band 1/2 software, $76,000 was spent to update (support) 10% of 32,000 lines of ALR-56C/ALQ-135 combined software (45). The ALQ-135 share of those 3,200 updated lines is 62.5%, or $47,500 considered allocable over the ALQ-135's entire 20,000 lines of code. Annual support cost per line, therefore, was calculated to be $2.37.

54. TNA: (Number of Aircraft Assigned to a Squadron)
There are normally 24 F-15s per squadron.

55. AVAIL: (Peacetime Fully Mission Capable Rate)
The Default value of .70 is realistic.

56. TRS: (Rqstd Sorties per Assigned Aircraft per Day)
The peacetime value of 1 is realistic. Wartime values shown are generic.

57. TMS: (Maximum Sorties per Assigned Aircraft per Day)
The peacetime value of 3 is realistic. Wartime values shown are generic.

58. TFH: (Average Flying Hours per Sortie)
The default value was used for both ALQ-135 versions. The F-15E average sortie duration (ASD) is projected to be 2.0 hours (8:299), but the F-15C value of 1.32 hours was used where appropriate and as explained in the findings.

59. ATTRIT: (Attrition Rate per Sortie)
The peacetime value shown is typical. The wartime rate is higher, but still includes only mechanical malfunctions and not battle-induced losses. The wartime rate of .001 is generic, and may be considered representative of a low-threat environment. A realistic 'standard' NATO wartime attrition rate (non-aircraft specific) might be expressed as:

Day 1:	5%
Days 2-6:	4%
Days 7-9:	3%
Days 10-15:	2%
Days 16-30:	1% (49,6)

60. QPA: (Quantity of Each LRU Utilized in the Design)
Quantities shown are for standard SPJ configurations.

61. TSTK: (Qty of Spare LRUs Available as POS and in WRSK)
(WRSK levels were reflected in the spares quantities for wartime flying days.) For Band 1/2, figures shown are provided by HQ TAC as listed (per squadron) for Bitburg, but are typical of F-15 squadrons worldwide (47).
POS and WRSK P^3I quantities are 'to be determined' (23:18), so spares quantities were calculated from a self-derived 'provisioning function' which is based on Band 1/2 reliability characteristics and actual spares levels. The actual quantity of Band 1/2 spares for each LRU happens to correspond roughly to the following relationship:

$$\text{Spares Qty} = \frac{(\text{\# of operating units}) \times (\text{operating hours/month})}{1.33 \times (\text{LRU MTBF})}$$

For the case of the P^3I version, the appropriate peacetime spares quantity for the HI CTL O, for example, would be:

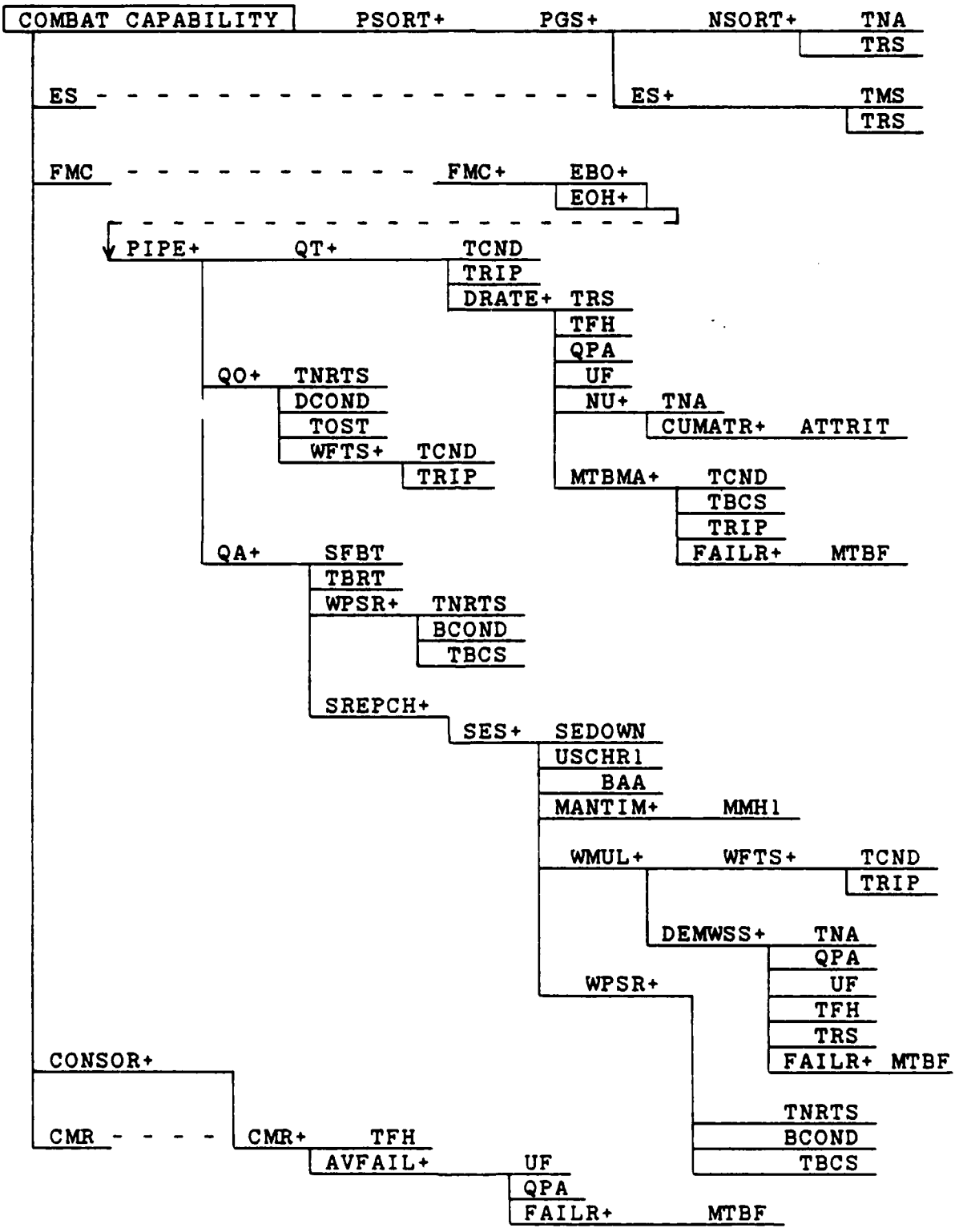
$$SQ = \frac{(24 \text{ units/sqdn}) \times (1.32 \text{ hrs/sortie} \times 30 \text{ sorties/mo})}{1.33 \times (237 \text{ hours})} = 3$$

WRSK quantities are approximately three times POS quantities (47), and in LAMP the models assume that the POS units are in various 'repair pipeline' locations for day one of the war (6).

62 - 70. Typical types and quantities of SE, Manpower, and Facilities at each level of repair were provided by ASD/TAFL (39) and WR-ALC (33).

71 - 88. Sources for scalar value defaults are listed in DRC's LAMP Data Collection Guide. Variable number 74, BAMH, was changed to 18 hours per day to reflect wartime conditions. Variable number 81, BAA, was changed to 24 hours per day, again to account for realistic wartime conditions.

Appendix D:
Sample LAMP View A Hierarchy Paths
for the R&M 2000 Goal "Combat Capability"



Appendix E:
Input Variable/R&M 2000 Goal Contribution Matrix

VARIABLE:	R&M 2000 GOALS				
	CC	SRV	MOB	MPW	LCC
1. SEDOWN	X	X			
2. CAB					X
3. COB					X
4. WSE			X		
5. SIZESE			X		
6. SESQFT			X		X
7. BLR					X
8. DLR					X
9. TCS					X
10. FACOST					X
11. FACFT			X		X
12. FMTCST					X
13. FSHPWT			X		
14. FSHPCC			X		
15. UF	X	X			X
16. RDCOST					X
17. WSTEK			X		
18. SIZE			X		
19. SUBQPA	X	X			X
20. SBMTBF	X	X			X
21. SMI					X
22. TCND	X	X			X
23. TRIP	X	X			X
24. BCOND	X	X			X
25. TBCS	X	X			X
26. TNRTS	X	X			X
27. DCOND	X	X			X
28. FI					
29. TBRT	X	X			
30. UC					X
31. BMR					X
32. DMR					X
33. BMC					X
34. DMC					X
35. BSMC					X
36. SESCH/SCHHR					X
37. SEUSCH1/USCHR1	X	X			
38. WRAT					X
39. CPC					X
40. VPI			X		
41. FSTCST					X
42. OSTCST					X

VARIABLE:	R&M 2000 GOALS				
	CC	SRV	MOB	MPW	LCC
43. SFBT	X	X			
44. TOST	X	X			
45. ANPTD					X
46. NPY					X
47. CPY					X
48. FACTYP	X	X	X	X	X
49. MOSSCH/SMH					X
50. MOSUS1/MMH1	X	X			X
51. NLC					X
52. DCPLC					X
53. SCPLC					X
54. TNA	X	X		X	X
55. AVAIL	X	X			
56. TRS	X	X			X
57. TMS	X	X			
58. TFH	X	X			X
59. ATTRIT	X	X			X
60. QPA	X	X			X
61. TSTK	X	X	X		X
62. FLSE/NFLSE			X		X
63. FLMP/NFLMP			X	X	X
64. FLFAC/NFLFAC			X		X
65. SHSE/NSHSE			X		X
66. SHMP/NSHMP			X	X	X
67. SHFAC/NSHFAC			X		X
68. DPSE/NDPSE					X
69. DPMP/NDPMP				X	X
70. DPFAC/NDPFAC					X
71. RAQ					X
72. BOHR					X
73. DOHR					X
74. BAMH	X	X		X	X
75. DAMH				X	X
76. ATOR					X
77. UPG					X
78. TTHS					X
79. MANWT			X		
80. MANCC			X		
81. BAA	X	X			
82. CCC141			X		
83. WTC141			X		
84. ACPTD					X
85. MRO					X
86. SR					X
87. TR					X
88. MRF					X

Appendix F: Input Variable Sensitization

These sensitizations were accomplished on the P^3I ALQ-135 data to determine the criticality of input variable accuracy. They were performed assuming the generic Operational Plan with 1.32 hours average sortie duration as discussed in Chapter III. In terms of LAMP details, the Actual/Required setting was 'on' for all sensitizations, except where noted otherwise. The sensitizations apply to all configuration parts, SE, and manpower, and to peacetime and wartime days, except where noted otherwise.

The base values for the R&M 2000 goals are:

COMBAT CAPABILITY (CC) % sort. gen. wartime	SURVIVABILITY (SRV) % sorties w/o I-level	MOBILITY (MOB) # of C-141Bs	MANPOWER (MPW) spaces/ aircraft	COSTS (LCC) life cyc $ costs
1.00 (max)	1.00 (max)	.11	.04	136.0M

The following list shows the results of individual input variables raw sensitization:

VARIABLE:	CHANGE COMMANDED:	EFFECT ON R&M 2000 GOAL(S):
1. SEDOWN	10% incr times 5	No change
2. CAB	20% incr twice	LCC: incr to 137.7 to 139.7
3. COB	20% incr twice	LCC: incr to 137.3 to 138.7
4. WSE	20% incr twice	MOB: incr to .12 to.13
5. SIZE	20% incr twice	No change
6. SESQFT	20% incr twice	No change

VARIABLE:	CHANGE COMMANDED:	EFFECT ON R&M 2000 GOAL(S):
7. BLR	20% incr twice	LCC: incr to 136.1 to 136.1
8. DLR	20% incr twice	No change
9. TCS	20% incr twice	LCC: incr to 136.1 to 136.1
10-14. FACOST, FACFT, FMTCST, FSHPWT, FSHPCC: All N/A		
15. UF	20% incr twice	LCC: incr to 148.4 to 163.3
16. RDCOST	20% incr twice	LCC: incr to 136.7 to 137.4
17. WSTEK	20% incr twice	MOB: incr to .12 to .13
18. SIZE	20% incr twice	No change (WSTEK is LimFac)
19. SUBQPA:	N/A	
20. SBMTBF:	20% incr twice 20% decr twice	LCC: decr to 125.7 to 117.1 MPW: incr to .04 to .08 LCC: incr to 151.5 to 171.0
21. SMI:	N/A	
22. TCND:	20% incr twice	No change
23. TRIP:	changed to .2	LCC: decr to 122.7
24. BCOND:	changed to .01	LCC: incr to 153.8
25. TBCS	20% incr twice	LCC: incr to 136.1 to 136.1
26. TNRTS	20% incr twice	LCC: incr to 136.6 to 137.2
27. DCOND	20% incr twice 20% decr twice	No change No change
28. FI: N/A		
29. TBRT	100% incr twice	CC: decr to 1.0 to .74 SRV: decr to 1.0 to .53 LCC: incr to 136.0 to 180.5
30. UC	20% incr twice	LCC: incr to 151.8 to 170.8
31. BMR	changed to #500 then 50% incr three times	LCC: incr to 137.4 to 138.1 to 139.1 to 140.7

VARIABLE:	CHANGE COMMANDED:	EFFECT ON R&M 2000 GOAL(S):
32. DMR	changed to $500 then 50% incr three times	LCC: incr to 136.2 to 136.2 to 136.3 to 136.4
33. BMC	50% incr twice	LCC: incr to 163.2 to 204.0
34. DMC	50% incr twice	LCC: incr to 139.4 to 144.5
BMC % DMC	changed to 0	LCC: decr to 74.9
35. BSMC	20% incr twice	No change
36. SESCH/SCHHR:	N/A	
37. SEUSCH1/ USCHR1:	20% decr twice	No change
38. WRAT	20% incr twice	MOB: incr to .12 to .13
39. CPC	20% incr twice	No change
40. VPI	20% incr twice	No change (WRAT is LimFac)
41. FSTCST:	N/A	
42. OSTCST	20% incr twice	No change
43. SFBT	20% incr twice	No change
44. TOST	50% incr times 3	No change
45. ANPTD	20% incr twice	LCC: incr to 138.0 to 140.3
46. NPY	20% incr twice	LCC: incr to 140.7 to 146.3
47. CPY:	Reflected in NPY	
48. FACTYP:	N/A	
49. MOSSCH/SMH:	N/A	
50. MOSUS1/ MMH1:	20% incr twice	LCC: incr to 136.2 to 136.3
51. NLC	20% incr twice	LCC: incr to 138.3 to 141.0
52. DCPLC	20% incr twice	LCC: incr to 138.2 to 140.7
53. SCPLC	20% incr twice	LCC: incr to 136.1 to 136.3
54. TNA:	constant, N/A	

VARIABLE:	CHANGE COMMANDED:	EFFECT ON R&M 2000 GOAL(S):
55. AVAIL	10% decr twice	No change
56. TRS	20% incr twice	LCC: incr to 148.4 to 163.3
	20% incr twice (war days only)	No change
57. TMS	30% decr twice	CC: decr to 1.0 to .94
58. TFH	20% incr times 3	LCC: incr to 148.4 to 163.3 to 181.2
59. ATTRIT	100% incr times 5 (war days only)	CC: decr to 1 to 1 to 1 to .85 to .56 SRV: decr to 1 to 1 to 1 to 1 to .99
60. QPA: constant, N/A		
61. TSTK	25% decr times 4	MOB: decr to .10 to .08 to .08 to .07 LCC: decr to 132.6 to 127.7 to 126.7 to 124.2
	changed to 0	MOB: decr to .06 LCC: decr to 118.3
	changed to 0 (war days only)	MOB: decr to .06 LCC: decr to 118.3
62. FLSE: N/A		
63. FLMP/NFLMP: Unable to sensitize		
64. FLFAC/NFLFAC: N/A		
65. SHSE/ NSHSE	20% decr twice	No change
66. SHMP/ NSHMP	25% decr twice	No change
	changed to 0 (with actual/required setting 'off')	MPW: decr to 0
67-68. SHFAC/NSHFAC/DPSE/NDPSE: Fixed, N/A		
69. DPMP/NDPMP: Unable to sensitize		
70. DPFAC/NDPFAC: Fixed, N/A		

Appendix G: Categorized Input Variables for the AN/ALQ-135

FIXED	MODIFIABLE	INSENSITIVE
7. BLR	4. WSE	1. SEDOWN
8. DLR	15. UF	2. CAB
9. TCS	17. WSTEK	3. COB
28. FI	20. SBMTBF	5. SIZESE *
54. TNA	23. TRIP	6. SESQFT
60. QPA	29. TBRT	10. FACOST
68. DPSE/NDPSE	30. UC	11. FACFT
70. DPFAC/NDPFAC	33. BMC	12. FMTCST
71. RAQ	38. WRAT	13. FSHPWT
72. BOHR	56. TRS	14. FSHPCC
73. DOHR	57. TMS	16. RDCOST
74. BAMH	58. TFH	18. SIZE *
75. DAMH	59. ATTRIT	19. SUBQPA
76. ATOR	61. TSTK	21. SMI
77. UPG	63. FLMP/NFLMP	22. TCND
78. TTHS	66. SHMP/NSHMP	24. BCOND
79. MANWT		25. TBCS
80. MANCC		26. TNRTS
81. BAA		27. DCOND
82. CCC141		31. BMR
83. WTC141		32. DMR
84. ACPTD		34. DMC **
85. MRO		35. BSMC
86. SR		36. SESCH/SCHHR
87. TR		37. SEUSCH1/USCHR1
88. MRF		39. CPC
		40. VPI *
		41. FSTCST
		42. OSTCST
		43. SFBT
		44. TOST
		45. ANPTD
		46. NPY
		47. CPY
		48. FACTYP
		49. MOSSCH/SMH
		50. MOSUS1/MMH1
		51. NLC
		52. DCPLC
		53. SCPLC
		55. AVAIL
		62. FLSE/NFLSE
		64. FLFAC/NFLFAC
		65. SHSE/NSHSE
		67. SHFAC/NSHFAC
		69. DPMP/NDPMP

* WSE, WSTEK, and WRAT are the limiting (driving) factors.
** DMC would be a factor under a two-level maintenance plan.

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VITA

Captain 'GT' Tovrea was born in Manhattan, Kansas on 3 December 1956. After growing up 'in the military,' he graduated from high school in Colorado Springs, Colorado in 1974. He was awarded the degree of Bachelor of Science in International Affairs from the United States Air Force Academy in 1978. He received his Navigator wings at Mather AFB, California in March 1979 and completed Electronic Warfare Training in September of the same year.

His first operational assignment was as an Electronic Warfare Officer in the 563rd Tactical Fighter Squadron (F4G 'Wild Weasel') at George AFB, California from October 1980 to April 1983. He was then stationed at Spangdahlem AB, Germany in the 81st and 480th Tactical Fighter Squadrons (F4G/F4E), where he upgraded to Instructor Electronic Warfare Officer and Flight Examiner. He returned from overseas duty in April 1986 to enter the School of Logistics, Air Force Institute of Technology, in May 1986.

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Thesis Chairman: Robert D. Materna, Lieutenant Colonel, USAF
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Abstract

The purpose of this research was to demonstrate how weapon system supportability can be assessed through the use of the Logistics Assessment Methodology Program (LAMP) during acquisition and modification. The F-15E's AN/ALQ-135 self-protection jammer was used as the subject aircraft subsystem in this qualitative and quantitative anlaysis.

Reliability and Maintainability (the main factors in system supportability), general F-15 program logistics objectives, and specific AN/ALQ-135 acquisition program projections are discussed as background information. LAMP is presented as a potentially helpful decision-making aid to be used in the pursuit of AN/ALQ-135 supportability goals.

The two main thrusts of this adapted methdology are an investigation of the sensitivity of supportability goals with respect to design characteristic uncertainties and a determination of supportability goal impacts due to potential changes in operational and support environments.

Overall, the research findings indicate that the AN/ALQ-135's new P3I design offers significant supportability improvements over its predecessor, the Band 1/2 self-protection jammer. In particular, benefits in configuration. The P3I design was found to be reasonably folerant to posited deterioration in relevant and support environments, P3I availability was found to be nearly insensitive to reductions in spares levels. The cumulative effects of battle attritiion reduced the importance of most supportability elements, and system capabilities remained high even in the advent of increased sortie demands.

LAMP was seen as a promising tool for supportability assessment. Several suggestions for improvements and extension of the program are listed. The thesis closes by recommending further development of the LAMP concept, an objective comparison of LAMP relative to similar methodologies, and expansion of the idea of using LAMP as an educational aid.

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