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AIR FORCE AVIONICS STANDARDIZATION: AN EXAMINATION OF IMPLEMENT--ETC(U)

MAR 77 S BAILY, G F HARRISON, A SAVISAAR F09603-76-A-3231

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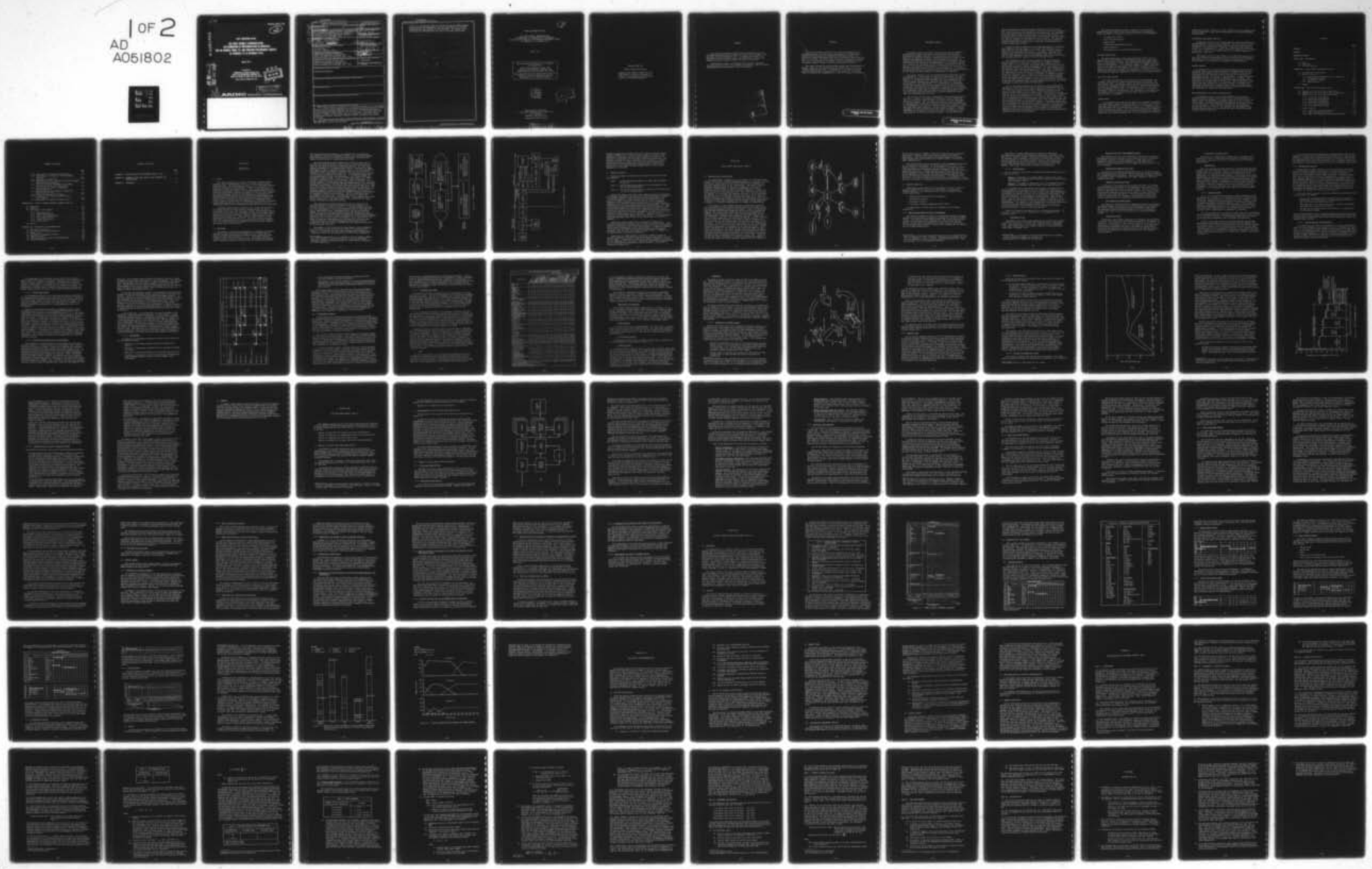

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FINAL ENGINEERING REPORT

AIR FORCE AVIONICS STANDARDIZATION: AN EXAMINATION OF IMPLEMENTATION ALTERNATIVES FOR AN AVIONICS FORM, FIT, AND FUNCTION PROCUREMENT CONCEPT (18 FEBRUARY TO 15 DECEMBER 1976)

March 1977

Prepared for

AERONAUTICAL SYSTEMS DIVISION (ASD)
DEPUTY FOR AERONAUTICAL EQUIPMENT (AE)
WRIGHT-PATTERSON AIR FORCE BASE, OHIO 45433

under Contract F09603-76-A-3231

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This report presents the results of a continuing examination of a procurement concept, currently being implemented by the Aeronautical Systems Division's Deputy for Aeronautical Equipment (ASD/AE), for acquiring a standard medium-accuracy inertial navigation system (INS) for the U.S. Air Force. The report deals with issues of equipment qualification, test and integration, precurement policy, configuration control, alternative support concepts, incentives, and penalty provisions.

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FOREWORD

This report was prepared by ARINC Research Corporation for the Aeronautical Systems Division's Deputy for Aeronautical Equipment (ASD/AE) under Contract F09603-76-A-3231. It presents the results of an examination of a procurement concept and implementation strategy for acquiring inertial navigation systems for the U.S. Air Force.

ARINC Research wishes to acknowledge the excellent cooperation received from the airlines, the equipment manufacturers, and the military representatives who participated in the investigation.

ABSTRACT

This report presents the results of a continuing examination of a procurement concept, currently being implemented by the Aeronautical Systems Division's Deputy for Aeronautical Equipment (ASD/AE), for acquiring a standard medium-accuracy inertial navigation system (INS) for the U.S. Air Force. The report deals with issues of equipment qualification, test and integration, procurement policy, configuration control, alternative support concepts, incentives, and penalty provisions.

The report reviews the lessons learned during open forum meetings to develop a form, fit, and function (F^3) specification for an Air Force standard medium-accuracy INS. A management tool for identifying other avionics standardization opportunities is also described. The report offers conclusions and recommendations in each of the areas investigated.

MANAGEMENT SUMMARY

The United States Air Force has taken decisive steps to implement a standardization concept that departs significantly from traditional Government procurement practices. To a large extent, the decision to embark on this approach is based on attractive potential economic returns inferred from commercial parallels. These benefits are difficult to translate quantitatively in the military acquisition environment; however, the evidence, both qualitative and quantitative, is sufficiently provocative to warrant the investment of both Government and industry in the new approach. The successful implementation of the form, fit, and function (F^3) INS program promises benefits for both users and producers. The lessons learned in the program may provide additional insight into the attractiveness of the concept for other potential F^3 standardization candidates.

The concept centers on four interrelated business practices: (1) the establishment of a single agency to consolidate requirements and procure avionics for the Air Force when an attractive market situation becomes apparent; (2) relaxation of the government role in configuration control so as to promote technological innovation with regard to reliability, maintainability, and producibility; (3) establishment of a maintenance concept that provides for contractor support during the first few years of operation, which provides an incentive for such innovations and defers the acquisition of AGE until the equipment is matured; and (4) articulation of an acquisition policy that provides for periodic procurements rather than sole-source multiyear awards, thus sustaining competitive forces until all requirements have been met.

The Air Force F^3 INS is not a "standard" in the conventional sense of the word. It would be a prohibitively formidable task to standardize, even at the interface level, to meet all avionics interface requirements of existing aircraft. The philosophy adopted early in the development of the procurement concept was to develop a specification that would meet the requirements of at least one existing aircraft and, possibly, a second, both with large market potential. Industry would be induced to develop equipments for these applications and carry them to maturity. In future development of aircraft (e.g., ATF, RF-X, FAC-X), the "standard" would then represent an attractive baseline equipment. Aircraft developers would be motivated to configure avionics interfaces to the Air Force F^3 INS. While the connector pin assignment on the anticipated initial application (F-16) leaves little flexibility at the present time, the employment of the MIL-STD-1553A MUS bus offers promise for future applications. It is expected that as future aircraft move to more extensive digital concepts, pins will be available for assignment to other functions. The potential for using the standard in other existing aircraft with minor hardware or software changes and the possibility of intertype interchangeability are attractive additional benefits.

"Growth" capability other than anticipated improvement in reliability, maintainability, and performance is not a technical objective; it is, in fact, counter to the philosophy of the concept, which requires rigorous control of the interfaces and functions. For example, the addition of computer functions within the Inertial Navigation Unit (INU) for tasks such as stores management cannot be contemplated under this concept because the interfaces would be unique for that aircraft application.

The resemblance of this military program to the very successful practices that have evolved in the commercial air transport industry is strong; however, it is important to recognize the differences in the environments. Military avionics technology changes very rapidly and often provides the impetus for commercial adaptation. Lot sizes ordered in the two procurement environments ordinarily differ by an order of magnitude, and there are other, more subtle differences. Thus there is justification for establishing a unique military F^3 standardization approach. It is significant that there is no universal procurement implementation approach in the air transport industry. Each airline and each airframe supplier adapts the standardization concept to suit its own operating philosophy. It is a testimony to the validity of the approach that there is sufficient flexibility to accommodate these different perspectives without sacrificing fundamental economic and operational advantages.

One of the difficult aspects of the analysis of the implementation approach for the F^3 INS was the lack of applicable quantitative data on the impact of the technical and business innovations entailed in this program. The experimental nature of this program was recognized by DoD planners at the inception of the concept, and it should be kept in mind that the nature of the program has not changed. The benefits to be realized from the successful implementation of the F^3 INS in one or more aircraft are to be measured at a force-wide rather than aircraft-program level. The first tangible evidence of the program's success will come at the time when bids are solicited for the production contracts. Conclusive evidence will not be available until several years' experience in the operational environment is obtained. In view of the uncertainty entailed in this sequence of activities, ARINC Research believes that the incremental implementation approach, which has been described in this document, is practical and appropriate and that the potential benefits justify the development-program initiatives that have been undertaken.

The following paragraphs present a synopsis of the conclusions reached during the course of this effort and related recommendations. These are grouped to correspond to the six major areas of investigation:

- The Open Forum Process
- The F^3 INS Specification
- Market Forces
- Configuration Management Practices
- Support Concepts
- New Opportunities in Avionics Standardization

THE OPEN FORUM PROCESS

The open forum activity, which was sponsored by the Air Force to develop the F^3 specification, was an endeavor responsibly supported by both the military and industry. This organizational achievement should serve as encouragement for other military avionics procurements initiated along the same approach. It is important, however, to budget sufficient time for the orderly accomplishment of the forum's iterative process. A period of at least one year should be allowed for the definition of the mechanical, electrical, software, and environmental interfaces for avionics with technical complexity comparable to that of inertial navigation systems.

THE F^3 INS SPECIFICATION

The F^3 INS specification is consistent with the philosophical and technical concept of the commercial counterparts where advisable. The specification calls out extensive quality assurance procedures that are not a part of commercial (ARINC) Characteristics; however, ARINC Research believes that the extreme range of environmental conditions that must be met to accommodate the variety of aircraft operations in the military environment justifies this departure. The employment of a multiplex data bus (MIL-STD-1553) should provide considerable flexibility for future applications of the standard.

MARKET FORCES

A procurement policy that sutains competition throughout the acquisition period offers economic returns estimated at 38 percent of acquisition costs when contrasted with conventional sole-source procurements. The near-term market size is large enough to sustain two or three manufacturers and to consider split awards. Cost histories of selected reprocurements analyzed by ARINC Research suggest that sustaining production on identical units with two or more manufacturers is not a prerequisite to sustaining competition; however, competition is more credible and the performance data are more comparable if more than one manufacturer is delivering equipment simultaneously.

CONFIGURATION MANAGEMENT PRACTICES

Configuration control of the product baseline should be transferred to the manufacturer under a warranty arrangement. This will enable the manufacturer quickly to institute changes that improve reliability and maintainability. The manufacturer's incentive to implement these changes at no cost to the Government is to reduce the cost of repairing units returned to the plant. There is very little incentive if Government approval is delayed for a long time.

Configuration control of the changes to the functional baseline (i.e., form, fit, function, and testability) must be retained by the Government. Any changes to the functional baseline should be resisted since this will have an impact on the potential for equipment interchangeability.

SUPPORT CONCEPTS

A long-term (up to five years) initial warranty or similar form of contractor support with economic incentives is recommended so that costs associated with equipment infant mortality and changes to AGE that may be expected from all potential sources during the first few years of operational use will not be borne by the Government. A model reliability improvement warranty is presented in Appendix A of this report. Consideration of an organic support concept should begin approximately two years prior to the expiration of the warranty. Several transition alternatives have been discussed in the report; however, the economic and operational attractiveness of these concepts cannot be determined until the number and location of equipments has been established and detailed cost information is supplied by the manufacturer.

NEW OPPORTUNITIES FOR AVIONICS STANDARDIZATION

A preliminary review of the data accumulated for the Avionics Planning Baseline document reveals other avionics requirements with a market attraction comparable to or greater than that of the INS over the next 15 years. The data need refinement through an iterative review process among users before detailed recommendations can be made; however, it is believed that a useful analytic tool for avionics development planning has been set in motion. We recommend that development of the Avionics Planning Baseline be continued, and that a three-to-six-month revision cycle be instituted.

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CHAPTER ONE

INTRODUCTION

1.1 SCOPE

This report summarizes the results and findings of ARINC Research technical activities sponsored by the U.S. Air Force under Contract F09603-76-A-3231. This work entailed joint U.S. Air Force/ARINC Research efforts in developing and implementing a form, fit, and function (F^3) procurement concept for military avionics. The initial application was chosen by the sponsoring agency to be a standard medium-accuracy inertial navigation system (INS), currently referred to as the Air Force Standard INS. The procurement concept for the Standard INS incorporates an F^3 standardization technical approach and business procedures adapted from commercial airline practices. This report describes the development of the Air Force F^3 interface specification and the accompanying set of business practices proposed for its implementation in military procurement. Related ARINC Research activities in developing management tools for identifying other avionics standardization opportunities are also described.

Preliminary ARINC Research findings on the concept are contained in the related reports: *Air Force Avionics Standardization: An Initial Investigation into an ASD INS Procurement Concept,* ARINC Research Publication 1269-01-1-1427, May 1976; and *Summary of Efforts: ASD (RWSV) Standardization and Avionics Subsystem Interface,* ARINC Research Publication 1269-01-1-1449, August 1975. These reports described efforts for the period April 1975 through January 1976. This report focuses on those activities undertaken during the period February 1976 through December 1976. The earlier work will be summarized to preserve report continuity and enhance clarity of exposition.

1.2 BACKGROUND

The decision to examine the applicability of commercial procurement practices to the military avionics community can be traced back to several government acquisition and logistics policy studies performed between 1971 and 1974 (References 1, 2, 3). The studies noted the extremely rapid increase in military avionics procurement and operating costs. When these costs were projected into the future and contrasted with anticipated austere budgets, it was apparent that new approaches were needed to assure that an adequate military force could be maintained. Those involved with earlier studies were particularly intrigued by the success of the airlines in controlling avionic costs.

The airline approach, which evolved over a period of many years, is a process involving innovation in both technical and business practices. There are two essential aspects of commercial practice: (1) joint user-producer development of an interface specification* that meets the common requirements of the air transport industry, and (2) a set of qualification/procurement practices permitting individual small-lot buys that sustain competitive forces among industry suppliers. The major activities involved in this process are depicted in Figure 1-1. It is generally agreed that this approach benefits both user and producer. The Airlines Electronic Engineering Committee (AEEC), chaired by Aeronautical Radio, Inc. (ARINC), performs a coordinating role in this process. Users and producers are brought together in an open forum under the auspices of the AEEC. For those systems selected for air transport community standardization, the mechanical, electrical, environmental, and software interfaces are developed in a cooperative effort that considers both user needs and production constraints. The producer is allowed virtually unlimited latitude in the internal design and production approach to meet the interface requirements, both during the production-proposal period and during the equipment maturation process while the equipment is under initial warranty. This is an important aspect of the commercial practices since it provides motivation to improve the producibility and reliability of the equipments. Both customers and vendors benefit from a larger, more stable market, with alternatives for supply sources throughout the acquisition process.

ARINC Research has provided assistance to the U.S. Air Force in adopting these basic concepts to military avionics procurements. The Air Force concept is depicted in Figure 1-2. The open forum process that led to the development of the Air Force medium-accuracy F^3 INS took place over an eight-month period. Representatives of the Air Force Systems Command, the Air Force Logistics Command, major INS manufacturers, and other interested military and industry organizations convened periodically during this time to discuss changes and additions to a specification "strawman" prepared by the Air Force prior to the meetings. At the conclusion of the forum, at least three INS manufacturers indicated that they were ready to proceed through a qualification program at the Central Inertial Guidance Test Facility (CIGTF) at Holloman AFB and integration tests with an airframe prime contractor.

The sequence of activities the Air Force expects to occur subsequent to qualification testing is shown to the right of the dashed line in Figure 1-2. The program calls for multiple awards, made periodically on a competitive basis, for the production of the INS and an accompanying

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*Or an ARINC Characteristic as it is referred to in the industry; ARINC's role in this process is described in detail in *Airline Procurement Techniques*, Technical Perspective Number 26, ARINC Research Corporation, July 1976 (Reference 4).

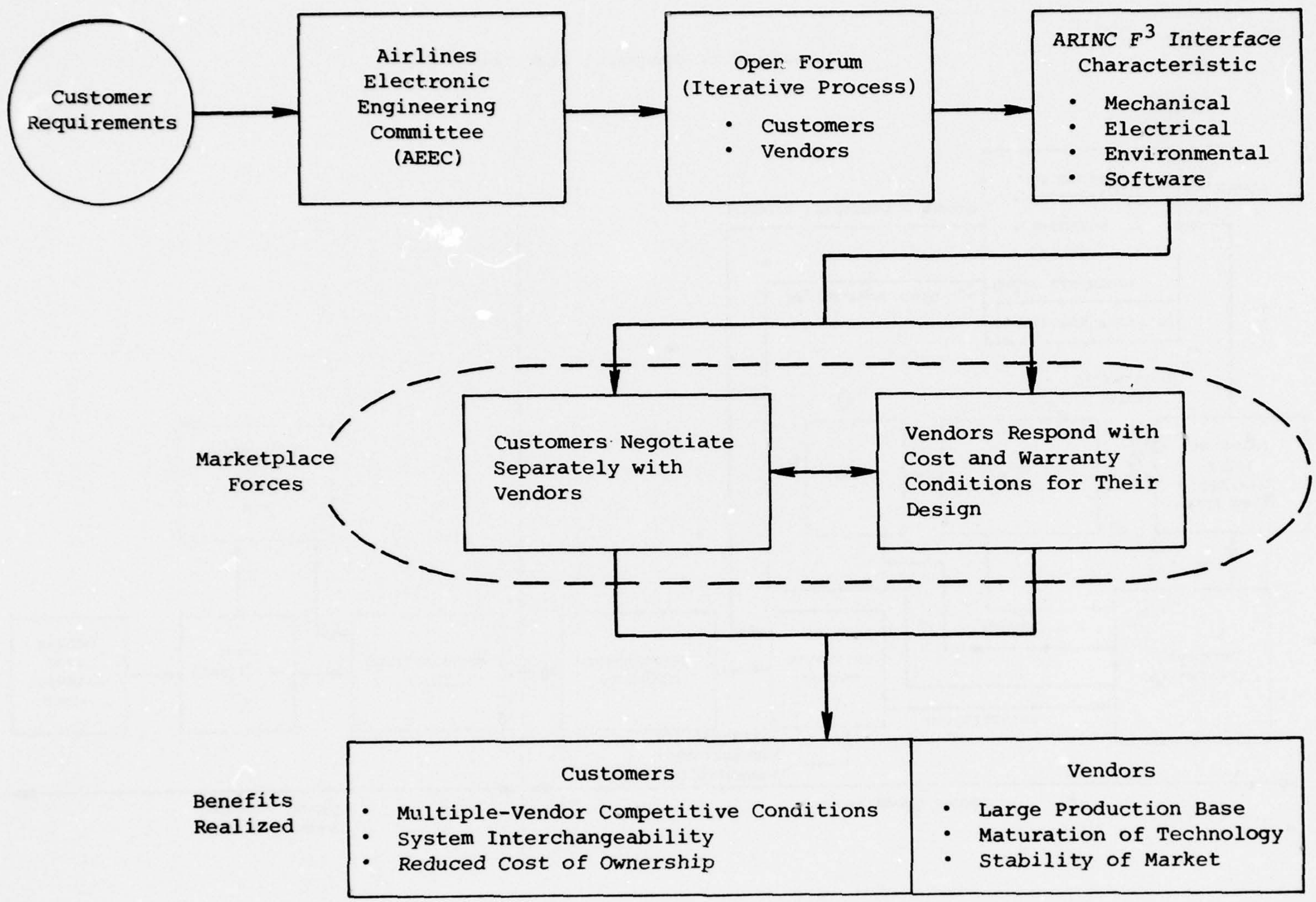

Figure 1-1. AIRLINE APPROACH

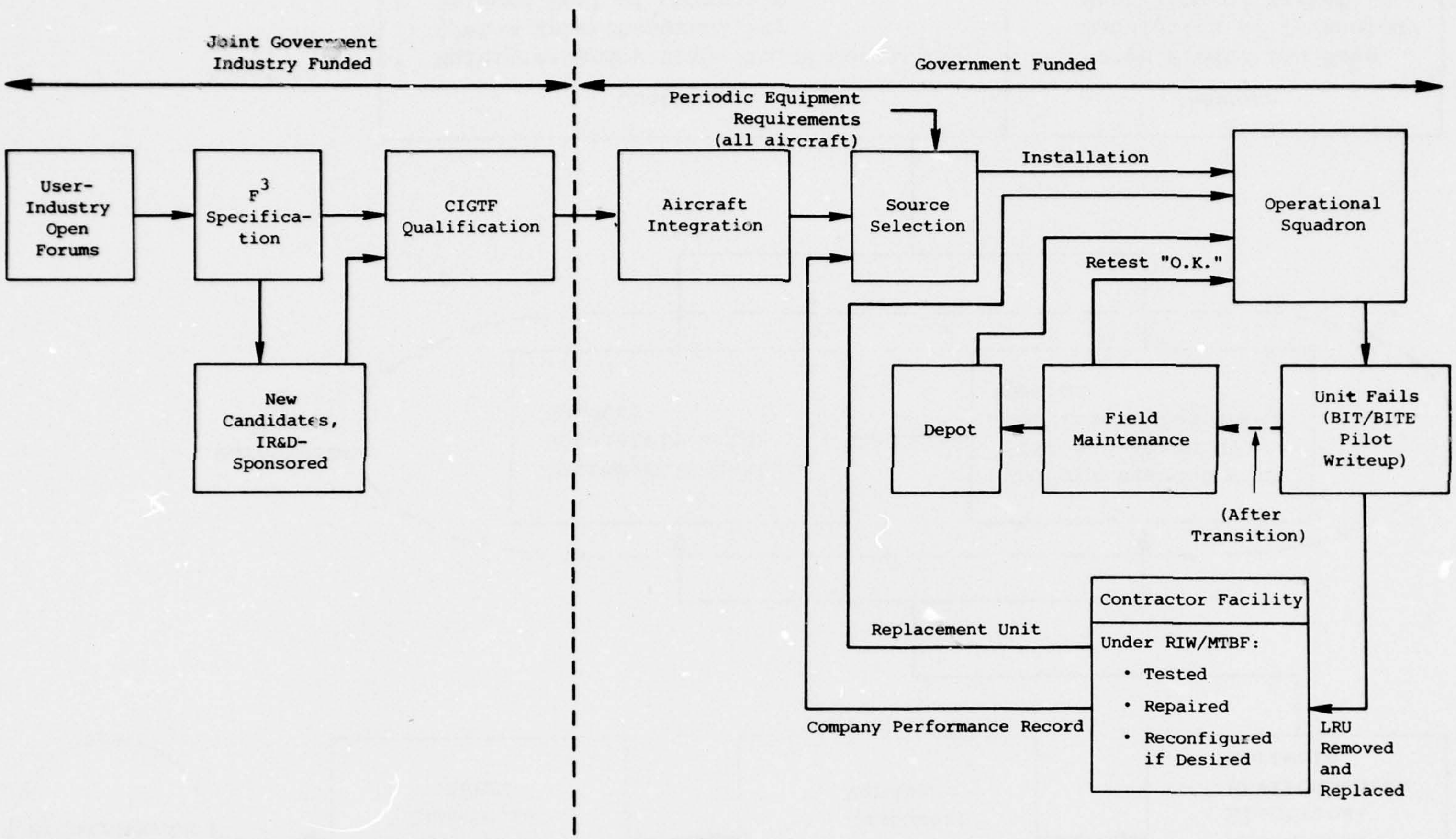

Figure 1-2. USAF F^3 STANDARD INS PROGRAM

Reliability Improvement Warranty (RIW) and a Mean Time Between Failures Guarantee (MTBFG). For an initial period (probably five years) after operational introduction, the units will probably be repaired by the contractor in accordance with the terms of an equipment warranty. The eventual transition to organic maintenance will be made on a schedule determined by life-cycle costs (LCC) and operational considerations. The overall plan was developed during the period April 1975 through January 1976. This report focuses on examinations of implementation approaches for this plan.

1.3 TECHNICAL APPROACH

Three broad tasks were defined for the technical activities under this contract:

Task I - Provide Engineering Support for Future INS Procurement Activities

Task II - Provide Engineering Support for the Development of the INS Interface Specification

Task III - Provide Engineering Support in Analyzing New Opportunities in Avionics Standardization

Engineering support under Task I was centered primarily on developing the necessary quantitative and qualitative information needed to assemble a procurement package for the initial operational application of the Air Force Standard INS. ARINC Research reviewed both military and commercial policies regarding the acquisition of avionic equipments. Alternatives for modifying current military policies to achieve greater consistency with airline acquisition practices were developed. The impact of such changes was assessed where supporting data were available. Areas investigated included test requirements, configuration control, market division, and warranty provisions. This support was provided to the newly formed USAF single agency for INS procurements, the Avionics and Aircraft Accessories System Program Office (ASD/AEA). Highlights of these activities are reported in Chapter Two of this report. A model Reliability Improvement Warranty (RIW) for use by the single agency is presented in Appendix A.

Engineering support under Task II consisted of technical and secretariat assistance throughout the Air Force open forum process. ARINC Research reviewed the F^3 INS specification during each stage of preparation and provided recommendations to the forum chairman. A comparative analysis of the military and commercial INS interface specifications was also performed. This activity is described in Chapter Three. A summary of the specification is presented in Appendix B.

Under Task III, ARINC Research performed a systematic review of official documentation related to Air Force avionics requirements over the next 15 years. A presentation format was developed to enhance the utility of this information for the user in identifying standardization opportunities and in conducting other development planning analyses. This effort is described in Chapter Four.

CHAPTER TWO

SINGLE-AGENCY ORGANIZATION (TASK I)

2.1 ORGANIZATIONAL RELATIONSHIPS

The single-agency organization is a key aspect of the ASD procurement concept. The need for a central management authority to coordinate testing, procurement, and modification activities throughout the equipment life cycle was recognized early in the investigation. Some senior technical management representatives in the airline industry believe that the pervasive corporate memory of commercial enterprises is the chief contributor to the success of the air transport community in controlling avionics acquisition and operating costs. In at least one major airline, for example, it is a policy that engineers who play a role in introducing new avionics into the commercial fleet are also a part of the team that devises solutions to any technical problems that might arise. This is in contrast to conventional military practices, in which system responsibility is transferred among major commands from development through acquisition to support, or originates simultaneously in a number of organizations.

The disparity in size between military and commercial operations limits the degree of organizational emulation that is practical; however, the essential management concept can be adopted. Figure 2-1 depicts the organizational relationships established for the Air Force Standard INS Program. The Avionics and Aircraft Accessories System Program Office (ASD/AEA) is the designated single agency for the acquisition of future INS requirements, including the F^3 medium-accuracy INS. ASD/AEA uses the technology background of ASD Engineering (ASD/EN), the USAF laboratory system, and the test experience of the Central Inertial Guidance Test Facility (CIGTF) as the technical basis for assessing new entries in the INS market. Following the operational introduction of the Standard INS, field experience is fed back to the single agency from the using commands through the item manager at Oklahoma City Air Logistics Center. Initial market requirements are determined through the existing USAF Air Staff validation procedures. The single agency's INS procurements for new aircraft are coordinated through the aircraft System Program Office (SPO). Arrangements with integration contractors for retrofitting installations are made through the appropriate Air Logistics Center (ALC). Logistics concepts and impact assessments of planned procurements are supplied by the recently formed Air Force Acquisition Logistics Division (AFALD) of

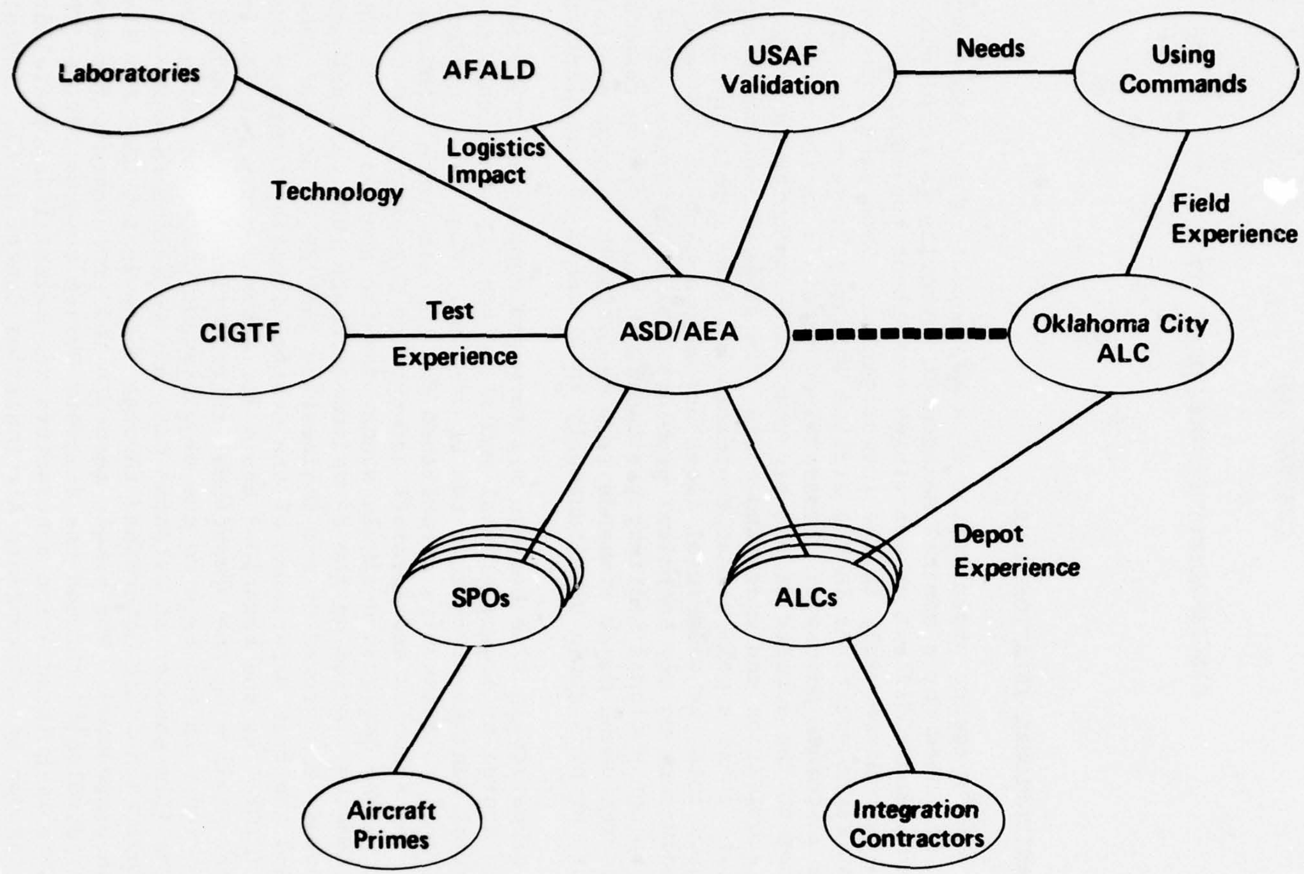

Figure 2-1. SINGLE-AGENCY ORGANIZATIONAL RELATIONSHIPS

the Air Force Logistics Command. Within ASD, engineering and procurement assistance is supplied to the single agency through the ASD matrix organization. Policies and procedures governing communication between these organizations are described in the ASD/AE document, "Single Agency Plan", dated May 1976.

This organizational concept incorporates several fundamental attributes of the commercial counterparts. The single agency does not "go out of business" after the installation of the equipment; it continues to monitor field performance and incorporates pertinent information into other INS procurement activities. Through continuing coordination with the Air Staff, market requirements can be "smoothed" and unified in much the same way as the membership of the Airlines Electronic Engineering Committee (AEEC) achieves a consolidated statement of requirements. If INS manufacturers have built to a single interface specification and the procurement is accompanied by a warranty, the equipment and the production process mature rapidly.

2.2 BUSINESS PRACTICES

ARINC Research participated in the development of a set of business practices appropriate for use by the single agency in procuring the Standard Navigator. We concentrated on four areas of primary interest to the single agency:

- Qualification/Requalification of Equipments
- Configuration Controls
- Maintenance Concepts
- A Strategy to Sustain Competitive Market Forces

Our examinations of these areas are discussed in the following subsections.

2.2.1 Qualification/Requalification of Equipments

The equivalent commercial practice for qualifying inertial navigation systems is not a completely satisfactory precedent for the ASD procurement concept. The Federal Aviation Administration (FAA) certification process may take up to 18 months and is peculiar to an aircraft type and FAA region. A formal Technical Standard Order (TSO) was never established for inertial navigation systems.* Qualification standards are not spelled out in an ARINC Characteristic.

*Since current certification requirements have been met, compelling motivation for completing the TSO is lacking. Performance requirements are now a part of Appendix G, Federal Aviation Regulation (FAR) Part 121. They are oriented to an airline operating structure.

The extent of testing required by the customer to demonstrate performance and reliability is determined subjectively, primarily on the basis of the customer's judgment concerning the manufacturer's record with the equipment type in question. The sharing of testing costs by buyer and seller appears to be standard industry practice. The proportion of costs assumed by each party is negotiable. The equipment manufacturer provides INS equipment meeting the interface specification at his own expense. This is part of his "price of entry" into the market.

2.2.1.1 Qualification

The Air Force has stated that a two-phase procurement approach for the F^3 INS will be used:

Phase I - Procurement of a limited number (five or more) of pre-production units from multiple sources for purposes of qualification and integration testing

Phase II - Procurement of production units for Government-Furnished Aeronautical Equipment (GFAE) delivery to the prime contractor

It is planned that an abbreviated test program for engineering prototypes provided by each manufacturer will be conducted at CIGTF prior to the preproduction contract award in order to assure that those manufacturers representing the smallest technical risk in producing a qualifiable F^3 INS will be selected for the first phase of the procurement. These tests, as currently envisioned include laboratory performance and limited flight tests. They will permit an assessment of the degree of conformity to the F^3 specification and the technical risks associated with correcting areas of nonconformance. For example, if the equipment does not meet the form factor, are significant technical developments necessary or is it a matter of routine repackaging? This information may be supplied to the source-selection authority to assist in the award decision.

Major test categories are explained in the following paragraphs. The decision to evoke any or all of these tests is a prerogative of the procuring agency.

Performance Tests

Performance tests comprise both laboratory and flight tests conducted by CIGTF and are similar to Project 688G* testing normally conducted by CIGTF. The various tests are specified in Appendix IV of the ASD/ENACA "Final Draft Characteristic for a Moderate Accuracy Inertial Navigation System (INS)", September 1976.**

*Project 688G is a Department of Defense-funded program for certifying inertial equipments proposed for military use.

**See Appendix B for a summary of this document.

Qualification Tests (Environmental Tests)

Environmental tests are to be conducted to determine the equipment's performance and fatigue resistance to the effects of natural and induced environments peculiar to military operations. These tests will be conducted in accordance with MIL-STD-810C, with some modification to reflect the special requirements of the Standard INS program and the known F-16 environment.

Combined Environmental Test (CET)

The purpose of the Combined Environmental Test is to evaluate system design from engineering failure data obtained while the system is operating in a simulated service environment. CETs are performed in chambers designed to reproduce a range of temperatures, altitudes, humidities, and other expected conditions.

Production Verification Test

The purpose of the Production Verification Test (PVT) is to expose design deficiencies and defects due to inadequate quality control, introduction of new production lines, or design changes. Each delivered set could be required to pass a PVT, which will consist of a series of random vibration and temperature-altitude cycles similar to those conducted for reliability tests under MIL-STD-781. Fifteen sequential failure-free tests are required prior to acceptance, a failure being defined as any incident that precludes the satisfactory demonstration of performance.

Maintainability Demonstration

The purpose of the Maintainability Demonstration Test is to determine the median equipment repair times at the organizational and intermediate shop levels. While the initial maintenance philosophy is LRU removal and replacement under manufacturer warranty, it will be necessary to estimate these times to plan for transition to an organic maintenance concept.

Reliability Tests

Reliability testing during production in accordance with MIL-STD-781 is planned. This requirement may be modified somewhat if an RIW/MTBFG is imposed on the manufacturer, since economic penalties are incurred by the manufacturer for equipments found to be unreliable in field experience. No reliability requirement was cited in the interface specification, because it was believed that competitive forces would provide incentive for reliability maturation in much the same way as in the commercial avionics process.

Integration and Flight Tests

The INS will be integrated with other avionics and tested on the ground and in flight. These tests will determine the Standard INS's compatibility with the aircraft and its adherence to the performance specification.

Observations

While this qualification and integration test program is much more extensive than that which has evolved in civil aviation, ARINC Research believes that it is justified. Military procurements must adhere to a "lowest cost" concept unless compelling technical factors can be demonstrated in a controlled test procedure. The airlines and airframe manufacturers may substitute a "corporate memory" prerogative in passing over low bidders with questionable technical reputations without such formal technical criteria. In addition, it should be recognized that the range of environmental conditions to which the military systems are subjected is extreme in comparison with the air transport operating environment. It would be imprudent not to gather information on the performance of the equipments over this range early in the procurement process.

2.2.1.2 Requalification

The Air Force Standard INS procurement concept encourages the INS manufacturer to institute no-cost engineering changes that improve the reliability, maintainability, or producibility of the equipment. Under the concept, changes not affecting form-fit-function or testability may be implemented without contractual approval if the current concept is approved. Configuration control is then performed by the manufacturer with minimum Government attention. This raises the question of how to determine whether manufacturer-instituted changes have progressed to the point where requalification of equipments is necessary.

Two control mechanisms are expected to reduce the risk of introducing, without Government approval, technology changes warranting requalification: (1) a contractual provision that configuration audits may be performed at any time by the Government, and (2) economic considerations.

Informal discussions between ASD program management and the INS manufacturers have greatly reduced the concern over the possible need for requalification. Economic considerations limit the extent of changes that may be introduced into a production process during the procurement intervals planned for the Standard INS program. If any significant technology changes were contemplated for a subsequent procurement, the manufacturer would probably not take the economic risk without a qualification reevaluation.

If it were found that the manufacturer had significantly modified the hardware or software and the modification invalidated previous qualification inspection, a qualification reevaluation would be indicated. This reevaluation should be based on the extent of product or specification changes and the examination of contractor design and test data. Performance tests should verify that the item continues to meet all of the specification requirements.

2.2.2 Configuration Controls

The procurement concept features a five-year reliability improvement warranty following equipment installation in an operational unit. Extensions of contractor support may be sought if the RIW is economically attractive. Configuration control during the period of contractor maintenance is the responsibility of the INS manufacturer. The rationale for this departure from current Air Force configuration-management policy is that contractor awareness of the delays involved in Government approval of Engineering Change Proposals tends to restrain initiative for instituting no-cost changes to improve reliability, maintainability, or producibility. If the approval process can be circumvented for changes that do not affect the product functional configuration, then early economic returns can be realized by the manufacturer. Thus incentive is produced for technical initiatives that benefit the military in the long run.

There are, however, several troublesome implementation problems entailed in this concept, for example:

- How does the Government determine whether a unit that has been reconfigured by the manufacturer is substantially the same as the test unit that was previously qualified?
- What impact will such changes have on test equipment requirements upon transition to organic maintenance?
- How does the Government prevent a proliferation of configurations in the logistics system?

The following sections present a recommended approach for addressing these concerns; this approach provides some Governmental controls while allowing the manufacturer considerable latitude for instituting product changes that promise economic returns.

2.2.2.1 Product Baseline and Testability

The product baseline should be determined by a physical configuration audit of a unit nominated by the manufacturer prior to equipment qualification. It is fully expected that changes to this baseline will occur during the test and integration process currently planned for the prototype units; however, if the manufacturer is required to maintain configuration control by serial number throughout the prototype and production process, the configuration differences between operational units and those which were qualified should be readily ascertainable.

The establishment of testability can be deferred until production award. Many of the changes that might be expected to result from the integration tests will change test standards. The manufacturer should be allowed to propose both test procedures and the method of configuration control in his response to the production unit request for proposal. The manufacturer's equipment design concept and administrative structure may suggest unique policies that offer savings over standardized procedures.

2.2.2.2 Engineering Changes

Any contemplated changes to the functional baseline as established by the interface specification should be governed by MIL-STD-480. Changes of this nature would be extremely rare under a form, fit, and function specification concept; however, it might be to the Government's benefit to consider such a change if the INS were to be employed on an aircraft with peculiar interface requirements and if interchangeability were not a consideration.

Changes to the product baseline may be commonplace under an RIW or RIW/MTBFG acquisition concept. If such changes were proposed as cost-reimbursable, the provisions of MIL-STD-480 would apply. It is envisioned that operational experience with the INS may suggest changes to the product baseline that will provide near-term return to the manufacturer under the terms of the RIW. In these cases, provided such changes do not affect form, fit, function, testability, or safety-of-flight, it is to the Government's best interests to permit the changes to be made at no cost to the Government. Changes undertaken at the contractor's expense may be assumed to produce significant reductions in the cost of either maintenance or production. A portion of the benefits of such changes will eventually accrue to the Government, either upon transition to organic support or in a subsequent procurement. If testability is affected, the Government should ensure that the effects of the change on the planned organic support concept are not adverse. The warranty, if employed, should stipulate that Government disapproval of such changes does not reduce the manufacturer's liability under the contract.

2.2.2.3 Preventing Proliferation of Configurations

Proliferation of configurations while the equipment is under manufacturer warranty is of little concern to the Government under a form, fit, and function acquisition concept. Penalties for peculiar test equipment, increased piece-parts sufficiency levels, and training imposed by such proliferation are borne by the contractor during the warranty period. The manufacturer should be encouraged to institute such changes both during production and when failed equipments are repaired. After a reasonable period for product maturity, however, the manufacturer must be required to bring all units produced under a single award to the same reliability/maintainability (R/M) configuration. Assuming a field reliability of about 300 hours (fighter environment) and a low "retest OK" rate, each equipment would be recycled through the manufacturer's facilities approximately every two years. The contractor should therefore be required to select a single configuration after about three years in a five-year warranty. This practice should provide ample time to incorporate changes indicated by field experience. The manufacturer should also be required to provide kits for the limited number of sets in the unselected configuration that are not returned before the end of the warranty period. Again, economics will limit the number of changes necessitating such kits.

If more than one production contract is contemplated, provisions should be made to control proliferation between production lots for the same manufacturer. Figure 2-2 illustrates two plausible procurement scenarios. In the first case, RIW terms of diminishing length are negotiated with a single-source manufacturer to achieve a simultaneous transition to organic at the end of the first warranty period. The contractor may select a final configuration at any point during the first three years of this initial warranty. Ideally, he will select this configuration in time to influence the production line of one of the subsequent options. He should be required to begin reconfiguring returned units within three years after the initial installation.

In the second case, it is assumed that the initial producer is not guaranteed a subsequent production contract. In this example, a second competitor receives an award. A simultaneous transition is not possible if the same period of maturity is allowed for both products. However, it is entirely possible that the first competitor may, with the benefit of a year's operational experience, be in a more favorable bidding position on the third award. In this latter scenario, it should be understood by all parties that the configuration selected in the first warranty period will govern all subsequent awards to that manufacturer within a stated period of time. This should not be a constraint on the design flexibility of the manufacturer, since historically the greater part of reliability growth is achieved in the first three years after equipment installation.

2.2.2.4 Observations

In summary, the recommended configuration control policy consists of the following key aspects:

- Definition of the product baseline during the qualification process
- Definition of testability coincident with the proposal for production award
- Definition of functional baseline by the interface specification
- Tailoring of configuration control procedures by the manufacturer with Government approval (control by serial number a firm requirement)

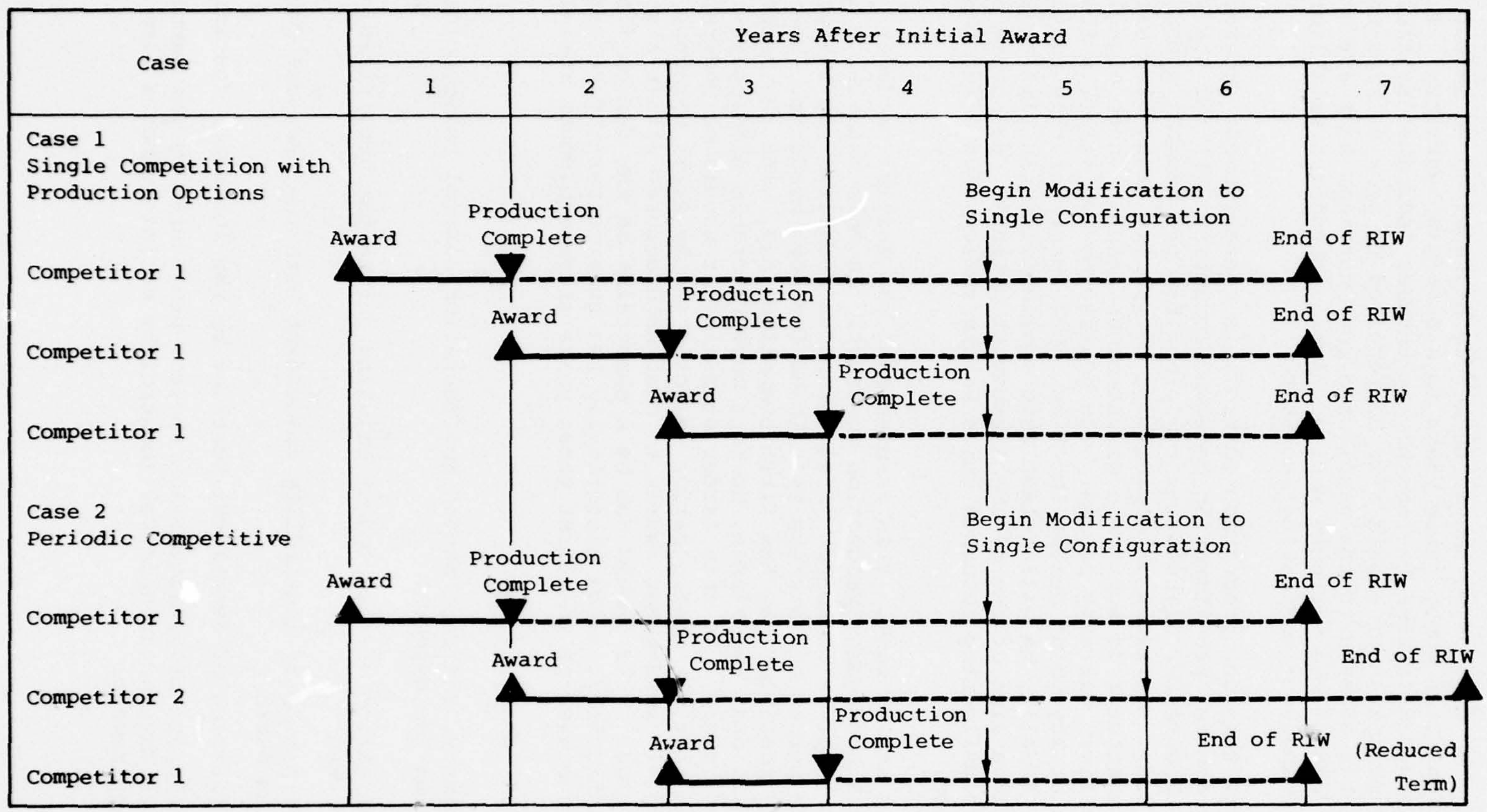

Figure 2-2. PROCUREMENT SCENARIOS

- Use of MIL-STD-480 formatted proposals for changes affecting functional baseline, including testability
- Establishment of contractual obligation to bring each manufacturer's equipments to latest R/M configuration or provide modification kits prior to expiration of warranty (time phasing dependent on procurement scenario)

ARINC Research believes that these policies represent reasonable departures from standard military practices and are consistent with the procurement concept. It is unlikely that the major INS manufacturers participating in this program would institute procedures radically different from those identified in MIL-STD-480; however, flexibility should be permitted. There are philosophical as well as practical motivations for this approach. The purpose of this new USAF acquisition concept is to promote product improvement to the mutual benefit of user and producer. Traditional ECP procedures, even "record only" (Class II) ECPs, suggest Government "business as usual" encroachment on the design initiatives of the manufacturer. Removing unnecessary administrative procedures of this nature will provide convincing evidence to the avionics manufacturing community of the Government's commitment to the new practices.

2.2.3 Maintenance Concepts

The departures from conventional procurement practices described in the preceding sections have substantial impact on the maintenance philosophy for the INS. Organic maintenance concepts are not attractive for the initial operational period of equipments with different, continually changing internal configurations. The alternatives are indefinite contractor support under a cost-reimbursable arrangement, a commercial-type warranty that ensures against infant mortality, or an RIW. Of these three alternatives, the RIW has clear advantages. It permits much more effective cost controls and it motivates the contractor to improve reliability.

The Air Force currently plans to employ some form of warranty during the first five years of the program. Cost estimates of alternative support concepts should be determined prior to the award; however, this early estimation is of value more in determining the economic attractiveness of the F^3/warranty concept than in establishing a viable procurement alternative. Many advantages of the approach are lost if warranty penalties/incentives are not applied in the acquisition phase.

The airlines normally employ a warranty during the initial period of employment of an avionic system, lessening the economic impact of infant mortality as well as acquainting operational personnel with the characteristics of a new system. The airlines eventually transition to organic maintenance. There are several factors involved in this decision. First, contractual relations between supplier and user in the warranty may become an administrative burden. For example, the determination of fault in a failed LRU with a broken seal represents a troublesome negotiation process. Next, there are "tweaking" procedures that are better performed by airline maintenance personnel. Employment of avionics is peculiar to the airline's route structure, fleet composition, and maintenance philosophy. Finally, there are union-management relations to be considered. Unions are becoming vocal in categorizing extended warranty conditions as "work-arounds" to union agreements. Thus, there are strong parallels to the military policies that result eventually in organic maintenance. The following sections describe the recommended warranty conditions and the provisions for transition to organic support.

2.2.3.1 Warranty Provisions

The Air Force has not yet decided on all of the features of the RIW contract for the INS. Bids for the warranty will be solicited to accompany the production award. Thus there is adequate time to develop the warranty and other support alternatives, such as a form of commercial warranty or a cost-reimbursable service contract. It is, however, very likely that many of the terms and conditions currently imposed or contemplated in the RIWs in force for other large avionics procurements, such as the OMEGA navigation receiver and the selected avionics in the F-16, will be a part of whatever form of contractual support the Government elects for the Standard INS.

It is in the best interests of the Government to develop a dialogue with industry regarding the planned warranty provisions far in advance of the solicitation. In this way, features that are unclear or are perceived by industry to be unreasonable can be resolved in time for a revised offering. The risk factor incorporated in the manufacturer's bid should be smaller if there is clarity in the contract, and the reduced risk may be reflected in a lower warranty cost to the Government. With this objective in mind, ARINC Research was asked to develop a "strawman" RIW to serve as a point of departure for Government-industry discussions.

Appendix A presents a full description of an RIW that is compatible with the Standard INS procurement concept and meets current DoD guidelines on the use of warranties. The limited experience provided by the recent procurements summarized in Table 2-1, particularly the OMEGA navigation receiver and selected F-16 components, was considered in the structuring of this instrument. To the extent possible, the contract language is modeled after the OMEGA RIW because it has received considerable recent scrutiny by Government legal experts. Several major departures from the OMEGA approach were indicated by the differences in technology, by differences in acquisition concept (F^3), and by recent DoD policy changes regarding warranties. The following paragraphs provide an overview of the resulting "strawman".

Term

The term of the RIW is for a five-year period commencing with the Government's acceptance of the first complete production INS. This is one year longer than previous INS RIWs and two years longer than most commercial avionics warranties. The extended term was selected to provide more time for the manufacturer to show economic returns for no-cost

Table 2-1. RIWS STRUCTURED FOR USE IN CURRENT OR RECENT MILITARY PROCUREMENTS 1/

Component under Contract

Element of Contract 2/	ARN-118(V) TACAN	F-111 Gyro	ARN-123, R-1963 VOR/ILS/MB	APN-194 Altimeter	Inertial Navigation System	Attitude and Heading Reference System	Klystron Electron Tube	APN-209 Altimeter	2171 Gyro	F-14 Hydraulic Pump 3/	Low Cost Omega Receiver	APN-99 Omega Receiver 4/	C-130 Hydraulic Pump 3/	Airspeed Indicator	FMS ARN-118 TACAN 4/	F-16 Components 4/	AV-8A Hydraulic Pump 4/	Lightweight Doppler Navigation System 4/	UTTAS 4/	APN-154/	AYK-14 Computer 4/	CH-53E AFCS 4/
Contracting Agency																						
Army			X					X										X	X			
Navy				X					X	X		X					X			X	X	X
Air Force	X	X			X	X	X				X		X	X	X	X						
Contract Status																						
Being Negotiated																X		X				
Awarded			X		X	X		X			X										X	
Equipment Deployed	X			X			X			X			X	X								
Completed		X							X													
Contract Type																						
Firm Fixed Price	X	X	X	X	X	X	X	X	X	X	X		X	X		X		X				
Fixed Price Incentive																					X	
Other																						
RIW Was																						
Sole Source							X	X	X	X			X	X								
Competitive	X	X	X			X					X					X		X				
Warranty Period Specified In																						
Years or Hours - (e.g., 5 years or 2000 hours)		X		X			X		X	X			X			X					X	
Hours Only																						
Years Only (number)	5		4		4	5		4			5			5				4				
Warranty Separately Priced	X	X	X	X	X	X	X	X	X	X	X		X			X		X			X	
Warranty Data Separately Priced		X	X	X	X	X		X						X				X			X	
Warranty Payment																						
In Full with Delivery	X					X	X	X					X	X				4/			X	
Time-Phased over Warranty Period		X	X						X	X	X					X						
Lost/Damaged Units																						
Partial Warranty Price Refund	X	X	X	X					X					X		X		X			X	
Extend Warranty on Another Unit					X	X		5/		5/	X		5/									
MTBF Guarantee																						
Single Value Specified					X	X												X				
Different Values Over Time Periods	X		X								X					X						
LRU/SRU MTBF Apportionment Required	X				X	X					X					X						
Penalties/Requirements																						
Engineering Analysis of Failures	X	X	X		X	X			X	X	X			X		X		X			X	
Corrective Action Design Change	X	X	X		X	X			X	X	X			X		X		X			X	
Consignment Spares	X				X	X					X					X						
Reliability Testing	X		X																			
Other																		5/				
Exclusions Defined	X	X	X		X	X	X	X	X		X			X		X		X			X	
Failure Definition																						
Any Removal					X	X				X			X									
Verified by Contractor	X	X	X	X			X		X		X			X		X		X			X	
Unverified Failure Adjustment Provision	X		X		X	X		X			X							X				
Repair Pipeline																						
Repair and Return		X	X	X					X				X	X							X	
Central Government Storage							X	X														
Contractor Bonded Storage	X				X	X				X	X					X		X				
Repair Turnaround Time Requirement																						
Number of Days	15	45	20	45		22	120				15		10	30		22					10	
Other					5/			5/	5/									5/				
Turnaround Time Penalty																						
Consignment Spares					X	X					X					X						
Dollar Payment	X		X	X							X							5/				
Warranty Extension								X		X			X									
Warranty Marking on Units Required	X	X	X	X	X	X	X	X	X	X	X		X	X		X		X			X	
ETI Required	X	X	X	X	X	X	X		X		X					X		5/			X	
Seals Required	X		X	X	X	X			X		X			X		X		X			X	
Operating-Hour Adjustment	X				X	X		X			X					X		X				
Backup Repair Facility Required	X															X						
Government Pays Shipping	X	X	X	X	X	X	5/	X	X	X	X		X	X		X		X			X	
Approved Shipping Containers Required	X	X	X	X	X	X	X	X	X	X			X	X		X		X			X	
ECP/Configuration Control																						
No-Cost ECP Provision	X	X	X	X	X	X		X	X	X	X		X	X		X		X			X	
Modification of New and Returned Units	X	X	X	X	X	X		X	X	X	X		X	X		X		X			X	
No-Cost Modification Kits	X				X	X				X	X		X			X						
Retrofit Entire Population		X		X	X	X			X		X			X		X					X	
Contractor Records Required																						
On Units by Serial Number	X	X	X	X	X	X	X	X	X	X	X		X	X		X		X			X	
Unit Cycle Times	X	X	X	X	X	X		X	X	X	X			X		X		X			X	
Failure Cause	X	X	X	X	X	X		X	X	X	X		X	X		X		X			X	
Parts and Material Usage	X	X	X	X	X	X		X	X	X	X			X		X		X			X	
Repair Man-Hours	X	X	X	X	X	X		X	X	X	X			X		X		X			X	
Warranty Data Reporting																						
Quarterly Warranty Reports			X	X	X	X		X	X				5/								4/	
Semi-Annual Warranty Reports	X	X			X	X				X	X			X		X		X				
Annual Warranty Effectiveness Reports	X	X	X		X	X		X	X	X	X			X				X				
Repair Concept after Warranty																						
Not Specified	X	X		X	X	X	X		X		X		X	X							X	
Option to Extend Warranty			X													X						
Option on Organic Requirements								X		X								X				

1/ This matrix, prepared by ARINC Research Corporation under Air Force Contract F33657-76-C-0701, is intended only as a general guide to the provisions included in the listed contracts.
2/ An X indicates that the element listed is applicable to the contract.
3/ Equipment provided to contractor as GFE.
4/ Analysis not yet completed; or RIW in solicitation but contract not yet awarded.
5/ Other requirement or special provision (see contract).

(to the Government) reliability engineering changes over the first few years of operational experience and thus incentivize product improvements. Recent experience with a new commercial INS source suggests that the significant advances in maturing the product occur during the first three years of product use. The extended term also allows the Government to postpone AGE acquisition and training decisions until the changes have "settled out", thus reducing expensive modification costs normally incurred in such programs.

RIW terms much longer than five years are considered unadvisable because of industry reluctance to commit for such long periods. Their ability to plan in terms of labor issues, material availability, and general economic conditions is poor even for a five-year period. This uncertainty is sure to be reflected as a cost, even when traditional escalation clauses are made part of the contract.

Applicability of Warranty

The language regarding warranty applicability is similar to all of the recent military avionics RIWs. Normal exclusions for damage by combat action, unauthorized repair actions, etc., are considered. The warranty is made for two LRUs: the Inertial Navigation Unit (INU) and the mount. The mount is provided with a cavity for a battery, which is required for some applications (e.g., F-16). ARINC Research recommends that the battery be excluded from the warranty since it fails to comply with the DoD guidelines for warranty (i.e., falls in the category of consumable items).

MTBF Guarantee

An option is given for a guaranteed MTBF on the INU. This is a priced option as called for in recent DoD guidelines. An elapsed-time indicator (ETI) would be provided for on the INU. The mount contains no electronic or mechanical moving parts and is therefore not a logical candidate for an MTBF guarantee.

Configuration Control

Configuration control by serial number is the primary responsibility of the manufacturer, as described in Section 2.2.2.

Liability Limit

Contractors have a liability limit in processing "no defect found" INUs. The contractor will be reimbursed at a fixed-bid dollar amount for processing all "no defect found" INUs in excess of 0.3 times the total number of all INUs returned to him for repair during a six-month measurement period. Since he must process the first 30 percent of "no defect found" INUs, the contractor has an incentive to provide accurate BITE. At the same time, the contractor is protected from unnecessary returns -- such as would occur, for example, if a squadron took advantage of an extended stand-down to "clean up" all of its INUs. The 30-percent limit value was selected following a review of operational experience with two avionics equipments having similar technology.

Procedures

The general concept of operation under the RIW is portrayed in Figure 2-3. Organizational maintenance is limited to LRU removal and replacment. Built-in test equipment (BITE) of the manufacturer's own design is the only equipment used to determine a unit malfunction. There is no intermediate-level test equipment.* When a malfunction is indicated either by the BITE or by a new write-up, the squadron maintenance officer draws a spare (if available) and immediately notifies the manufacturer of the action. The manufacturer, within one working day, is required to ship a replacement unit to the location specified in the message. When the pulled unit is returned, the manufacturer will run tests on the factory test equipment. If the unit tests "O.K.", the manufacturer will return it to bonded storage. The manufacturer is obligated to repair or replace a malfunctioning unit within the period negotiated in the warranty (normally about 15 to 20 days) and then place the unit in bonded storage.

The repair locations and storage areas are selected by the manufacturer with the consent of the Government. It may be more economical for the manufacturer initially to place senior engineering personnel with suitable test equipment near the location of the operational bases during the first few years of maintenance experience. In this way, his pipeline time can be controlled and problems that are traceable to integration rather than to system failure can be isolated. The Air Force has stated that it intends to permit wide latitude in the implementation of the RIW procedures among the competing manufacturers.

2.2.3.2 Transition to Organic Support

Whatever the term of the initial warranty or contractor support, it is anticipated that the Government will eventually transition to an organic logistics concept. This decision should be made approximately two years before the contractual support contract expires, to provide sufficient time to procure the necessary AGE, spare parts, and data, and conduct an orderly training program for maintenance personnel. The equipment should mature at a reasonable rate within the first few years of use, yielding better information for determining the provisioning concept. The following additional decisions must be made at the same time:

- Should test equipment be procured for the organizational and intermediate levels or should the organic maintenance concept parallel the RIW concept (i.e., BIT/BITE only at organizational level with all repair activities at a centralized location such as the Aerospace Guidance and Metrology Center (AGMC)?
- To what degree can factory test equipment be substituted for MIL-qualified AGE in these alternatives and how can prices be established?

*The F-16 maintenance concept includes INS test stations for the Avionics Intermediate Shop (AIS) automatic test equipment. In the event that warranty is selected for the INS, the F-16 program office contemplates using this (with suitable adapters) for an intermediate-level go/no-go test.

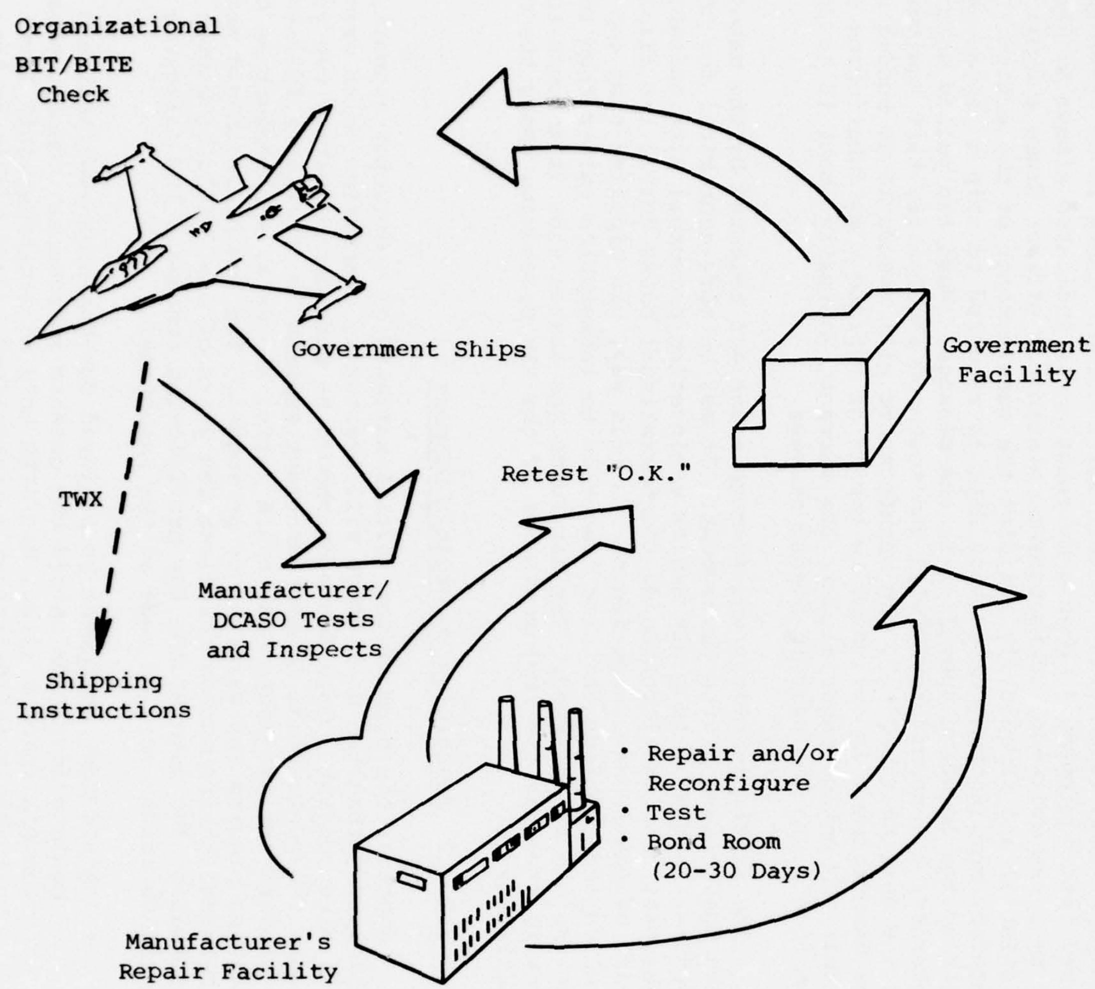

Figure 2-3. LOGISTICS CONCEPT UNDER RIW

- If more than one INS supplier and more than one aircraft type are involved, is the logistics situation improved if the equipment of each manufacturer is configured (through software reprogramming and card changes) so that predominantly one manufacturer's equipment is used for each aircraft type, or at least within a generic aircraft type (e.g., fighter)?

The information needed to address these and other critical issues relating to transition will not be available until the prototype test program is well under way. Much of this information can be developed as subtasks in the prototype contract. However, it is possible to construct some plausible organic logistics scenarios on the basis of our current understanding of the design approaches of the competing manufacturers.

There is the possibility that, with multiple INS suppliers for a single aircraft type, repair parts would proliferate upon transition to organic maintenance. If only one aircraft application is implemented, this situation is unattractive logistically relative to "business as usual" (one aircraft type, one INS manufacturer). However, a number of aircraft applications are envisioned. In a "business as usual" acquisition philosophy, there would normally be a peculiar INS for each aircraft type, with attendant parts proliferation at the force level. The F^3 acquisition strategy can reduce proliferation at the force level by controlling the interfaces across aircraft types, and a *single manufacturer's equipment* may remain compatible with a number of aircraft types. LRU proliferation is therefore reduced, and piece-part proliferation should be no worse than under previous acquisition policies.

The important point to be drawn from the foregoing discussion is that life-cycle-cost analyses of the benefits of alternate logistics scenarios should consider these alternatives at the force level rather than at the aircraft program level.

2.2.4 Market Forces

One of the more appealing features of the F^3 standardization concepts is that the interface specification allows a great many design approaches and therefore permits a larger number of manufacturers to offer equipment to meet a given requirement. In contrast to conventional multiple-year avionics procurements, in which the initial winner is drawn into a sole-source position, any manufacturer who has designed and qualified equipments that meet the interface requirements is a potential future supplier. This approach has been found to place substantial competitive pressure on avionics suppliers in the commercial air transport industry. However, there are significant differences in procurement practices between the military and commercial markets. It will be necessary to modify some current military acquisition policies to take full advantage of the F^3 standardization concept's potential for acquisition-cost reduction. The basis for ARINC Research Corporation's recommendations on the nature of these modifications is presented in the following subsections.

2.2.4.1 Market Outlook

There are two aspects of the market forces that may be influenced by the F^3 standardization concept:

1. An initially larger demand for a single product, brought about by the concerted action of the potential users to establish a common requirement. The AEEC performs this function for commercial avionics users. The single-agency concept is intended to function as the military counterpart.
2. An attractive long-term market potential, brought about by the existence of a standard and the tendency of future requirements to be tailored to that standard.

The military INS market outlook as might be perceived by the major suppliers is depicted in Figure 2-4. This information was derived from the Avionics Planning Baseline document* supplemented by scheduling information provided by the aircraft System Program Offices (SPOs) where available. It can be seen that the requirements rise to a steep peak over the next few years, primarily as a result of the coincidental delivery schedules of new military aircraft.

The portion of the market occupied by identified Air Force requirements for medium-accuracy INSs is significant. If the Standard INS were available immediately, there would be a demand for almost 4,000 INSs over the next eight years. With a little "smoothing" of installation (retrofit) schedules, this would be sufficient to sustain a production requirement for up to three manufacturers through this period. If this occurred, it is almost certain that many of the other aircraft programs would be attracted to the F^3 standard. Thus competitive forces would become self-sustaining.

Unfortunately, the fabrication and testing of a new product in the inertial industry entails considerable time. Because of a long lead time for INS components and stringent safety-testing requirements, it is unlikely that deliveries could begin before fiscal year 1980. If current schedules are maintained, more than 40 percent of the identified USAF requirements that could be satisfied with the Standard INS must be satisfied with an existing design. While the remaining Standard INS requirement is still sizable, it does not present the commanding market attractiveness. The existing USAF medium-accuracy requirements in the 1980-1985 time period consist principally of F-16 and A-10 installs. However, changing defense requirements do show major growth patterns for the next five to seven years, with lowered levels beyond that.

2.2.4.2 Effects on Acquisition Prices

The foregoing suggests that the near-term requirement is not large enough to sustain more than two manufacturers in production for the Standard

*See Chapter Four for a description of this source.

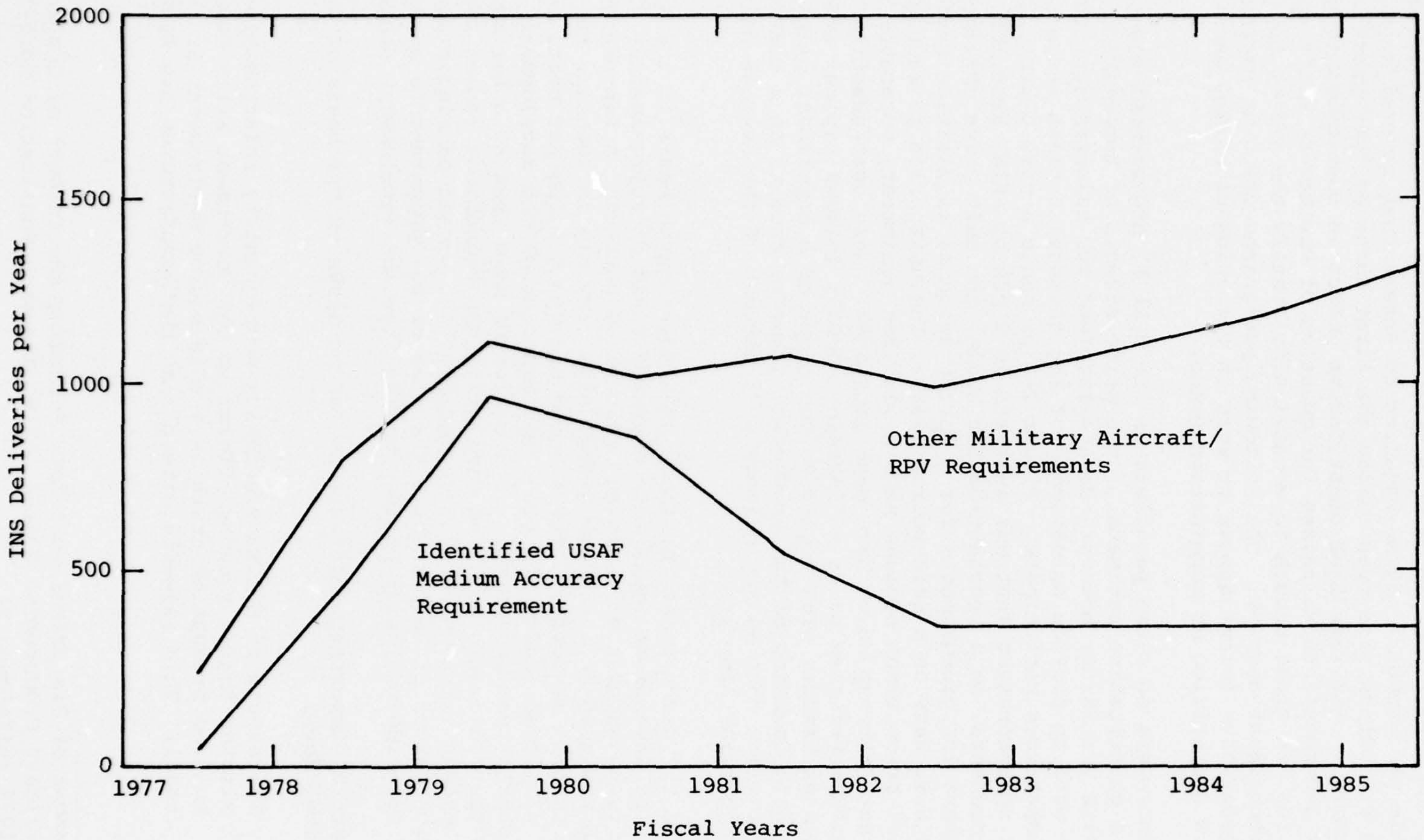

Figure 2-4. MARKET OUTLOOK FOR MILITARY AIRCRAFT INERTIAL NAVIGATION SYSTEMS

INS at the same time. In fact, a split buy (two or more smaller awards on a single procurement) may be required to assure that several manufacturers keep a production line open during the first three or four years of the requirement. The resulting quantitative impact on cost-quantity discounts bid by the manufacturer raises the question of whether or not the market pressures are great enough to economically justify the effort to implement the procurement concept. The following paragraphs offer an explanation of how competitive forces appear to work in the avionics market and the effects of this competition on acquisition price.

There are no close parallels to the USAF F^3 procurement concept from which a quantitative estimate of the price effects of competition can be made with precision; however, data maintained for selected reprocurements can be used to provide an estimate of the savings in cases where only a few competitors participate. Figure 2-5 presents a case history of a recent reprocurement that was analyzed in depth by ARINC Research.* The curve presents, on a constant-dollar basis, the unit price obtained in subsequent lot procurements for a recent avionics acquisition performed by the U.S. Navy on a sole-source basis. The unit price is reduced in each lot procurement because some production equipment, personnel training, and other start-up costs have been amortized. This cost/quantity relationship (often referred to as a "learning curve") follows typical avionics procurement history with regard to the slope of a log-linear plot of the data. Each doubling of the production quantity results in a cost/quantity discount price that is approximately 94 percent of the average unit price for the previous lot size.

Had the procurement continued on a sole-source basis in the sixth award, the Government would have expected a bid of approximately $34,000 per unit, based on the "learning" rate of 94 percent. A reprocurement package was used on the sixth award, significantly influencing the manufacturers' responses. The winning bid was $25,000 per unit, approximately 27 percent below the projected midpoint of the development contractor's learning curve. In a series of more than 40 other avionic system reprocurements analyzed similarly, the reductions ranged from 20 to 69 percent, with an average saving over the projected single-source "learning curve" of 38 percent. The size of the procurements analyzed ranged from 100 to 18,337 units procured from the development contractor.

Several important observations can be drawn on the basis of the historical data:

- The nature of military avionics cost/quantity relationships demonstrates that discounts offered to the Government after several hundred production units in a sole-source environment are very small. This suggests either that the manufacturer has factored

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*"*Assessment of Historical Cost Data Regarding the Effects of Competition on DoD/Military Procurement Costs*", ARINC Research Publication 6411-1555, June 1976 (Reference 5).

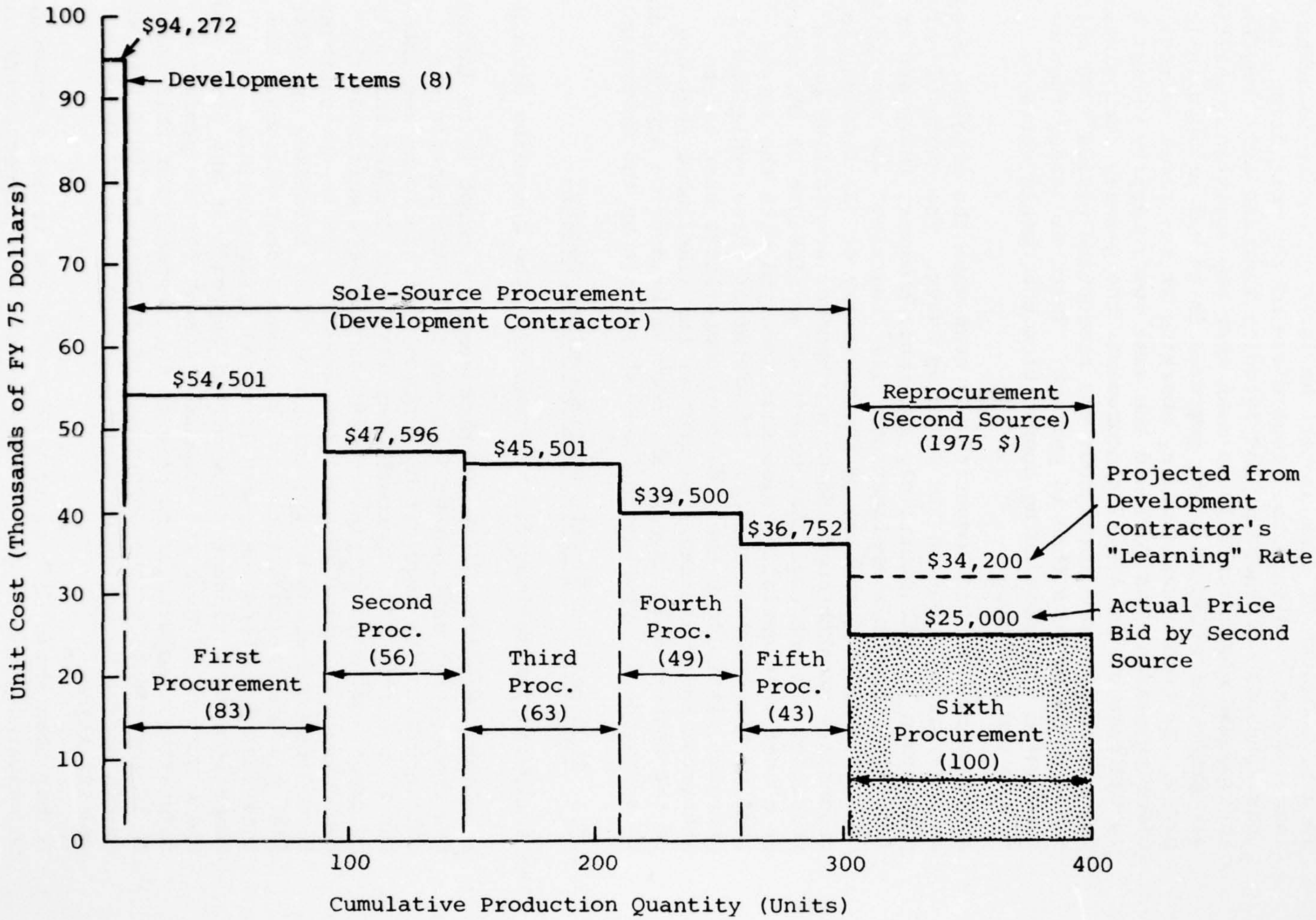

Figure 2-5. ASW-27 PROCUREMENT HISTORY

in a high degree of risk or that he lacks incentive to grant larger quantity discounts. Regardless of the motivation, the characteristic flatness of the avionics learning curve may be interpreted quantitatively to mean that buy-splitting penalties are small for avionics being procured in normal production-lot sizes. If both manufacturers, starting at identical initial offering prices, had followed the same cost/quantity offering in the case of the ASW-27 procurement, the penalty for maintaining two competitors throughout the production period (200 units each) would be less than 14 percent. There are other factors associated with continuing competition that would serve to reduce the penalty.

- A new source can bid competitively even when the original manufacturer is well out on his learning curve. The cause of this phenomenon is not intuitively apparent; however, there are at least two plausible explanations: (1) "learning" was accomplished on a related product line of the new entry or (2) a production technology breakthrough and/or a component acquisition price reduction was achieved that permitted manufacture of the product at a cost substantially below that incurred with the method used by the original source. If either of these explanations prevails, it follows that the more competitors that can be attracted and sustained, the greater the likelihood that one of the sources will develop an improved production approach and thus provide an opportunity for cost savings by the Government.

2.2.4.3 Implications for the F^3 Procurement Concept

The following conclusions can be drawn from the preceding discussion.

- A central objective of the F^3 procurement concept is to influence the competitive environment in a way that will benefit the military avionics acquisition process. It should be realized that the F^3 specification approach does little or nothing initially to *create* competition since competition always exists at the beginning of a major avionics procurement. It is the sustaining forces brought about by the existence of an interface specification that produce the potential for acquisition-cost savings. The interface specification makes it technically possible for a competitor to introduce a new design approach at any time; however, there must be a large and authentic market for the product to induce the manufacturer to develop the design. For this reason, it is important for the Government to announce at this time which awards are to be set aside for procurement to an F^3 interface specification.

- It has been shown that sustaining production is not a prerequisite to sustaining the threat of competition. The reprocurement history illustrates that competitive prices can be obtained from manufacturers who are not concurrently in production for the avionics system. Reprocurement forces the new competitor to produce an exact replication of the equipment previously produced by the development contractor. It follows that the design/production freedom permitted by the F^3 concept should permit even easier market reentry. It is important, however, that the time at which reentry is possible not be made too late in the acquisition period. An extended exclusion might discourage an otherwise interested source. Further, if the initial award winner achieves production economies during the first several years, there is no motivation to pass these on to the buyer until the recompetition takes place.

- Splitting the buy, if permitted by procurement regulations, serves several purposes. The threat of competition is much more credible if several manufacturers are in production at the same time. In addition, performance data on the alternate equipments can be compared under similar operating conditions early in the acquisition cycle. Should one of the equipments fail to perform as desired, the alternate source(s) can be brought in before the bulk of the production requirements have been procured. The penalties in initial acquisition price resulting from shorter learning curves are small compared with the potential for lowering subsequent lot prices.

The impact of this kind of procurement scenario on life-cycle costs is difficult to forecast. It is a generally accepted premise that contemporary technology advances such as solid-state electronics and large-scale integration have greatly improved the reliability and maintainability of most currently produced avionic systems. These advances have reduced the proportion of the total life-cycle cost that is contributed by the operational and support (O&S) costs. Military planners have typically used a value equal to twice the acquisition costs as an estimate of the ten-year life-cycle costs for avionic systems; however, this rough rule of estimation was based on experience with avionic systems having reliability performance on the order of tens of hours. INS equipments used in the commercial environment now have demonstrated MTBFs of over 1,000 hours. Reliability performance for similar equipments in the extreme military environments on the order of several hundred hours is entirely plausible. Thus the importance of reducing acquisition costs in INS procurements is particularly significant in the current technology environment. Parametric analyses performed by ARINC Research in the preliminary analysis of the INS procurement concept indicated that when reliability performance exceeded approximately 500 hours MTBF, the life-cycle costs were dominated by acquisition costs.

The foregoing discussion is not intended to suggest that reliability considerations should not be a concern. The potential for maturing the reliability of the product by restricting changes to the functional baseline is central to the program objectives. The reliability impact of changing suppliers precipitously in the reprocurements that were analyzed is not currently available. In the case of the F^3 INS periodic procurement scenario, it is essential that a contractual economic incentive, such as an RIW, accompany the award so as to reduce the cost risk to the Government of introducing a new supplier.

2.3 SUMMARY

In summary, ARINC Research finds the military F^3 procurement approach described in this chapter to be a practical implementation of a concept that has excellent potential for economic returns. Risks identified in the initial potential applications (F-16, A-10) are related to the tight schedule imposed by the production program, rather than to fundamental technical issues. Through a program encompassing multiple-equipment qualification, periodic procurement, and economic controls in the form of warranties, the Government can reduce the risk that an unreliable equipment will be acquired or that delivery schedules will not be met.

CHAPTER THREE

THE OPEN FORUM PROCESS (TASK II)

This chapter discusses the Air Force open forum process for developing a specification for a medium-accuracy inertial navigation system, which is to be the standard INS for future USAF aircraft. The chapter is organized as follows:

Section 3.1 describes the results of the open forum process.

Section 3.2 describes the implementation of the open forum process.

Section 3.3 summarizes the open forum history.

Section 3.4 presents the lessons learned and other observations.

3.1 RESULTS OF THE AIR FORCE OPEN FORUM PROCESS

The product of the open forum process was the final drart of *Characteristic for a Moderate Accuracy Inertial Navigation System (INS)*, dated September 1976.* This specification states the form, fit, and function (F^3) requirements for the standard inertial navigation systems to be installed on future USAF aircraft applications requiring medium navigation accuracy.

The standard INS is composed of three line-replaceable units (LRUs): (1) Inertial Navigation Unit (INU), (2) Control Display Unit (CDU), and (3) INU Mount.

The specification states the system performance requirements and the physical, electrical, environmental, and functional interface requirements that must be met to affort LRU interchangeability between manufacturers. Because of time limitations on the open forum, the CDU requirements are not detailed in the specification. The CDU control/readout function is performed by the Fire Control/Navigation Panel in the F-16 application.

*The Air Force changed the nomenclature from "moderate accuracy" to "medium accuracy" subsequent to the issuance of the final draft. Within the context of this report, the two terms are synonymous.

An F-16 addendum to the specification covers the changes to the basic specification required to meet the specific F-16 requirements.

Appendix B is a summary of the specification.

3.2 IMPLEMENTATION OF THE AIR FORCE OPEN FORUM PROCESS

The evolution of the specification followed the approach shown in Figure 3-1.

In 1974, the Air Force identified the need for inertial system standardization, to halt the proliferation of different systems with little commonality to fulfill similar mission objectives. After considerable background study, a decision was made to prepare a standard USAF INS specification, using an open forum process modeled after the business practices of the Airlines Electronic Engineering Committee (AEEC). To this end, in early 1975, the Directorate of Avionics Engineering at ASD, ASD/ENA, was appointed the subgroup chairman and given the responsibility for preparing the initial draft of the strawman specification, using material from the Air Force users and from the inertial industry. ASD/ENA prepared the strawman specification in cooperation with ASD/AES, the Directorate of Avionics Standardization and Systems Architecture, and issued it for review by Air Force units and private industry. The basic model for the strawman specification was the General Dynamics specification for the F-16 inertial system.

An initial public meeting was held to explain the intended open forum process to all interested parties in DoD and private industry. This was followed by five open forums extending from December 1975 to July 1976. ARINC Research provided assistance in specification updating and secretariat activities. Activities up to and including the first two open forum meetings were reported in ARINC Research Publication 1269-01-2-1497, but they will also be reviewed in the following summary of the open forum history.

3.3 SUMMARY OF THE AIR FORCE OPEN FORUM HISTORY

3.3.1 First Open Forum Meeting

The first of the five open forum meetings at ASD was held on 2, 3, and 4 December 1975 and was attended by 58 representatives of private industry, the Air Force, the Army, and the Navy. The major tasks were to define the scope of the specification, gain an understanding of Air Force market objectives for the standard INS, and develop a priority list of issues that needed subsequent treatment.

3.3.2 Second Open Forum Meeting

As a result of the first open forum meeting, the specification was completely rewritten by ASD/ENA and ASD/AES. Commentary was added to

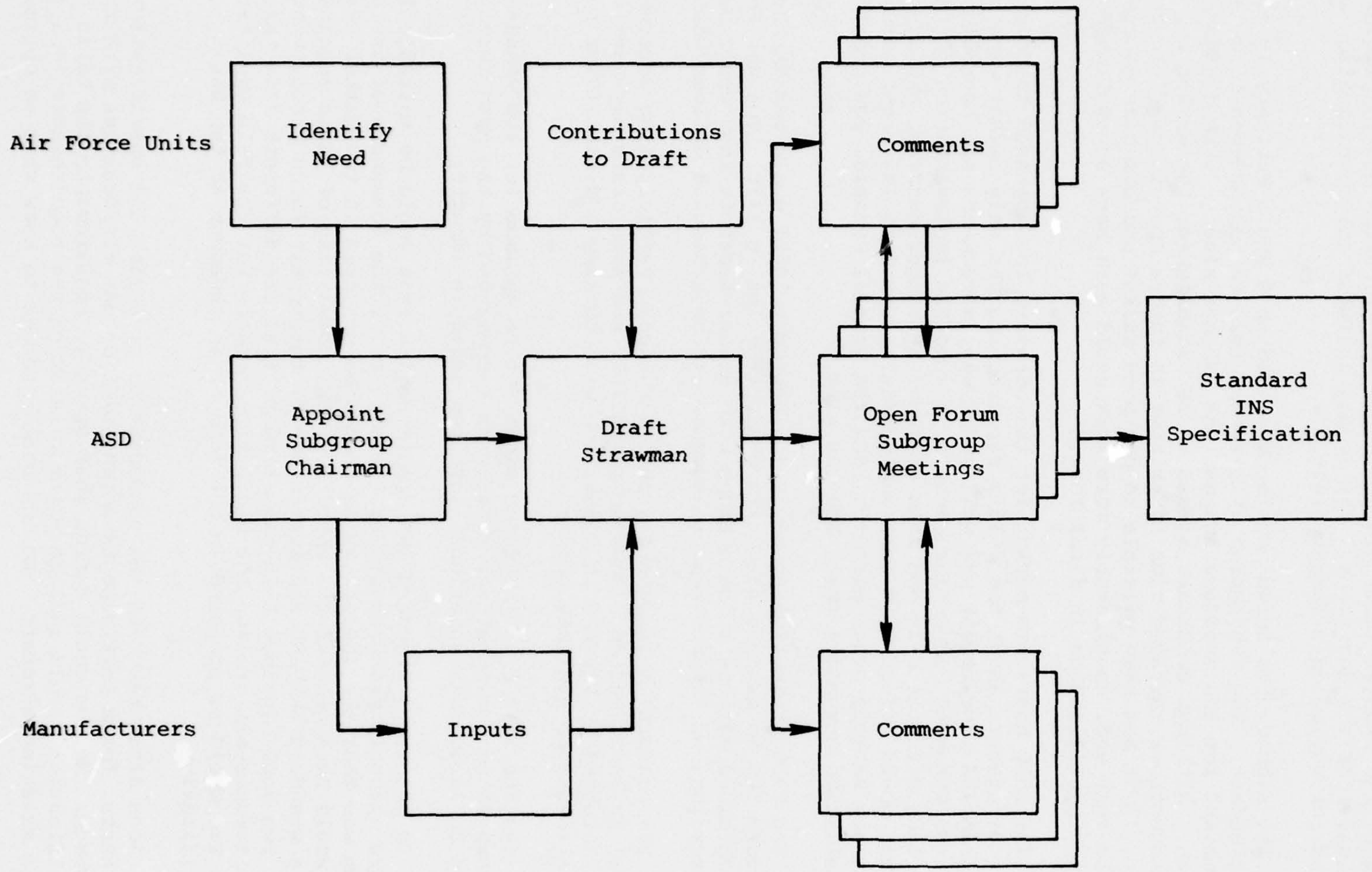

Figure 3-1. EVOLUTION OF AN AIR FORCE SPECIFICATION

annotate the changes incorporated in the specification and to provide rationale for the decisions. The second draft of the specification was issued for review on 5 January 1976.

The second open forum meeting was held on 4 and 5 February 1976, with 52 attendees. The two topics of greatest concern to the open forum -- the market for the standard INS and the INU box size -- were discussed at length. Although consensus seemed to be established, the market and box-size questions surfaced time after time in future open forums. In retrospect, if it had been possible to postpone market and box-size discussions to the very end, considerably more work could have been accomplished to put the specification in final form.

The only near-term market for the standard INS appeared to be the F-16. Areas of concern about the F-16's representing the only market were that the F-16 INS procurement was well under way, agreements had been signed with the European consortium members, a specific implementation of the interface with the F-16 had been designed by Singer-Kearfott and any changes would affect F-16 cost and schedule, the F-16 INS requirements might not satisfy other aircraft, and the General Dynamics equipment installation assumed a small INU box size.

The F-16 production schedule (in February 1976) would permit the standard INS to satisfy the third production lot in 1978. The Air Force had obtained various price options with Singer-Kearfott that would have to be exercised or dropped well in advance of the scheduled delivery dates.

The consortium agreement with the European Participating Governments (EPGs) is based on the Singer-Kearfott INS, and some costs may have already been incurred by the EPG in connection with tooling and facilities for the specific Singer-Kearfott hardware.

The specific F-16 interface might not be optimum for the standard INS. If changes to the interface were to be recommended by the open forum, there would be large (but undefined) cost and schedule impacts.

To prepare a standard INS specification that would be suitable for all future aircraft procurements by the Air Force, the consensus of the open forum was that the specification should be prepared in two parts. Part One would be a general INS specification, consisting of basic requirements for a standard INS and applicable to all future Air Force procurements. Part Two would include F-16 requirements that are different from the basic requirements and replace the basic requirements for the F-16 application. Part Two would be prepared in the form of an addendum to the basic specification.

Soon after reaching the consensus on preparing the specification in two parts, forum participants began pointing out difficulties with this approach. No one could define what specific requirements the basic specification should include without relating the requirements to a specific existing aircraft. No one could pretend to know what an optimum set of requirements should be for future aircraft. It was widely recognized that a purely theoretical standard is not suitable for application to any specific, existing aircraft.

The second topic of greatest concern, the INS physical size and form factor, was related to the market restrictions in that the only near-term application was the F-16. The F-16 inboard profile was constrained to the small size of the Singer-Kearfott INU (7.531" × 7.625" × 15.187"). General Dynamics stated that very little volume reserve was left in the F-16 and any avilable unused space should be reserved for future growth. General Dynamics further emphasized that any changes to the F-16 INU would result in large cost and schedule impacts on the entire F-16 program.

Proponents of a larger-size INU argued that the larger size must be specified in order to create effective competition for the standard INS and allow for the introduction of new technologies. For example, if the Singer-Kearfott size were to be adopted as standard, the Honeywell Ring Laser Gyro (8.62" × 10.12" × 20.6") would be ruled out.

No definite consensus could be reached on INU box size. The tentative consensus was that multiple (or alternate) box sizes were acceptable as long as all functions and interfaces remained identical. This would permit at least one-way interchangeability by the F-16 units, while allowing extended competition for future standard INS markets. The specification was to identify alternate sizes and any necessary adapter units.

Other issues addressed in the second open forum were as follows:

- Battery requirements. It was decided to define the battery as capable of powering the INU through a 10-second power outage. The INU should also be capable of accepting power from an external 30-minute battery. Drawings of the Autonetics battery, having the largest power capacity, were made available for review for compatibility with the F-16 installation.
- Performance accuracy requirements. The second specification draft had minor differences between the military and civilian aviation accuracy requirements. These differences were discussed, and it was decided to change the specification to combine the civil and military accuracy requirements into a single set representing the tighter of the two.
- Digital interface. More definition of the digital interface was required, over and above MIL-STD-1553, which has already been imposed. The forum decided that this additional detail could be made available by reference to the General Dynamics F-16 interface specifications. The interface requirements must be expressed in great detail in order to provide LRU interchangeability among vendors. For any application using an ARINC 575 interface, the MIL-STD-1553 interface circuit boards would be replaced by ARINC 575 interface circuit boards since having both sets of interface boards installed would be too expensive and would require additional volume.

- Analog interface. INU instrument drive outputs should be in analog format since inexpensive digital instruments will not be available for some time. The F-16 set of analog signals should be considered representative, while the KC-135 (an all-analog tanker aircraft) set of analog signals should be considered as the worst case.
- Back-up multiplex (MUX) bus control. The INU must include a MIL-STD-1553 MUX bus control function for autonomous operation of the inertial subsystem when not installed in the aircraft. In addition, the INU bus control function is required for the F-16 as a back-up to the prime F-16 MUX bus control.
- Attitude mode. Minor clarifications should be added to the specification requirements for the back-up attitude mode.

3.3.3 Third Open Forum Meeting

The third draft of the specification was issued for review on 9 March 1976. The third open forum meeting was held 30 and 31 March, and 1 April 1976. There were 55 attendees, including 31 from private industry and 24 from DoD. Inertial manufacturing companies represented were Delco, Ferranti-Scotland, General Electric, Honeywell, Lear Siegler, Litton, Rockwell, and Singer-Kearfott. Airframe manufacturing companies represented were Douglas Aircraft and Northrup Corporation. In addition to ASD/EN and ASD/AE, Air Force organizations represented were AGMC, CIGTF, MAC, SAC, F-15 SPO, F-16 SPO, Avionics Laboratory, and Oklahoma City ALC. An Army Avionics Laboratory representative was also in attendance.

The key discussions are summarized in the following paragraphs.

There was a continuation of discussions about the philosophy of the standard INS specification with regard to the market, which had occupied considerable time at the second open forum. Again, no consensus could be established. The trend of the opinion was that there should be two specifications in one -- the first priority being an F-16 reprocurement specification, and the second being a common, future Air Force standard INS specification.

The F-16 portion of the specification is tied to inflexible F-16 aircraft interface constraints in such characteristics as physical interface (size), electrical interface, cooling-air interface, power interface, and operating interface. General Dynamics indicated that there was no latitude of freedom within the F-16 constraints. The goal of the open forum was declared to be the improvement of the General Dynamics F-16 INS specification in the areas that do not affect the F-16 constraints.

The portion of the specification that defines the future Air Force standard INS should be modeled along the general lines of the F-16, for lack of a better model. The market for this future Air Force standard INS was still not known. The A-10 (close-support aircraft) was mentioned as one candidate. The size of the standard was set as one ATR*, extra long and tall, in order to avoid stifling technology. (The one ATR, extra long and tall size, was chosen to accommodate the current Ring Laser Gyro technology.) Considerable opposition was expressed to this large size, based on the arguments that the F-16 size represents the current state of the art and a smaller size would attract a larger market. By specifying a large size, the Air Force would rule out the employment of the standard in future state-of-the-art aircraft.

A basic Air Force goal is to minimize the INU life-cycle costs. The consensus was to include life-cycle-cost considerations as specification requirements and to furnish a life-cycle-cost model as part of the specification for guidance of the vendors.

The Air Force has experienced general disillusionment with the standard reliability tests and wants to replace them with Combined Environment Reliability Tests (CERTs). The CERT approach has come into vogue because of successful (but limited) experience in applying CERT to the F-111 radar and using CERT on three competitive OMEGA systems currently (at the time of the third open forum) under test. CERT tests are of questionable value in supplying reliability data but may be effective in providing an early indication of expected service reliability at much lower cost than the standard reliability tests.

A widespread industry opinion was that the environmental control specified for the F-16 INU is inadequate and that, with the given amount of cooling air, the F-16 INU may not provide reliable performance. Industry representatives discussed their analysis of the cooling-air inadequacy and cited experiences that demonstrated strong correlation between adequate cooling air and high MTBF. The industry desire expressed was that the cooling-air volume be greatly increased (by a factor of two or three) for the future Air Force standard INU.

After extended discussion, it was decided not to incorporate a specific MTBF requirement in the specification. In many instances the Air Force has found that following the expenditure of considerable time and funds in extensive reliability testing, the operational system reliability is unacceptable. For the standard INS, the hope is that competition will foster improved reliability. During the forum, it was emphasized that the Air Force expects to impose contractual arrangements (some form of Reliability Improvement Warranty incentive) to assure the desired MTBF.

With regard to maintainability requirements, it was explained that AGMC was preparing a maintainability test plan and AGMC would run tests to evaluate the equipment maintainability for organic depot maintenance.

*ATR is a standard form factor employed by the air transport industry. The initials are derived from Air Transport Radio, reflecting the early applications. The standard is now applied to avionics in general; thus the expansion of the initials is no longer used in the technical community.

There was considerable discussion of the role of the Central Inertial Guidance Test Facility (CIGTF) at Holloman AFB. The plan is to submit the INUs of all candidate vendors to gating tests at CIGTF, before admitting the vendors for source selection. A flyable prototype (rather than a production model) will be acceptable for CIGTF tests if the prototype is of the specified size and form factor. The CIGTF gating tests will probably be limited to navigation performance flight tests unless CIGTF is directed to enlarge its test facilities. At the time of the third open forum, the schedule was to start CIGTF tests in October 1976 and to issue the RFP in January 1977. The vendors expressed reservations about having to bear considerable costs in passing the CIGTF test gate.

Because of difficulties encountered in detailing battery characteristics, it was decided to leave the battery loosely defined at the time of this forum.

By general agreement, it was decided to add commentary to the specification to emphasize the requirement for LRU interchangeability among vendors. The INU mount will be considered a part of the aircraft, and LRU interchangeability will be required at the mount interface.

3.3.4 Fourth Open Forum Meeting

The fourth draft of the specification was issued for review by all past participants in the INS open forums on 11 May 1976. The major revisions included incorporation of the CIGTF performance-test procedures as an appendix and a complete rewrite of the quality-assurance section.

The fourth open forum was held 2-4 June 1976, with 55 attendees. A summary of the discussion is presented in the following paragraphs.

Considerable discussion, continued from the previous forums, was held on the philosophy of the F^3 specification and the market for the standard INS. The consensus of the fourth open forum was that the only near-term market for the standard INS was the F-16 and that the specification should be changed to allow only the F-16 INU box size. While the small-size requirement may stifle some competition, this is the only viable approach for the standard INS to gain a broad future market base.

The F-16 application is the main driving factor for the F^3 specification; thus the specification should include all F-16 interface constraints (physical, electrical, and environmental). The F-16 APO cautioned the forum that any departures from the General Dynamics interface requirements might cause problems in the use of the F^3 specification for F-16 procurements.

The Environmental Control System (ECS) requirements were revised largely on the basis of suggestions from ASD/EN. It was decided that the pilot should not be afforded the capability to override the automatic overtemperature shutoff.

The forum participants decided to leave the specification without any reliability-design or reliability-test requirements. The specification commentary explains that it is difficult to specify definitive reliability characteristics and that the vendors should strive for reliable equipment in order to obtain future business. The omission of reliability test requirements was caused by general Air Force dissatisfaction with reliability tests. It was recognized that the omission of reliability tests is contrary to current Air Force regulations (AFR 80-5, MIL-STD-785). Changes will be required to the ways in which the Air Force conducts business.

In the fourth revision of the specification, the Combined Environment Reliability Tests (CERTs) were changed to the Combined Environment Tests (CETs). It was agreed by the participants that the use of CERTs to obtain reliability data for INS equipments was questionable.

The Combined Environment Tests (CETs) will remain essentially as written for the fourth draft of the specification. The CET portion is optional and may or may not be imposed by the contract. No accept/reject criteria are specified for CET, and the equipment will pass CET by undergoing the tests regardless of any failures. The objective of CET is to provide data on the environmental performance of the INS.

Performance accuracy requirements were left in the form of separate civil and military requirements, which are expressed somewhat differently and with minor differences between the civil and military numerical values. This was done, in spite of criticisms expressed at past forums, according to the rationale that the forum has no power to change preexistent requirements. The civil requirements must be met to obtain FAA certification, while the military requirements reflect F-16 design. Commentary will be added to direct the employment of the Rayleigh distribution in accuracy calculations. However, even with the given distribution, the forum could not agree on the precise interpretation of the specification in making calculations of the rms value of performance accuracy.

Consensus could not be reached on how to specify the performance limit for "pilot squawks". The performance accuracy is basically specified as 0.8 nm/hr CEP, which allows half of the flights to exceed the 0.8 nm/hr drift rate. There is a possibility that a pilot will consider any performance exceeding 0.8 nm/hr drift rate as a failure of the INS.

There may be a variation in AGE equipment among vendors. To preclude damage, the INU AGE connector will have pins reserved for equipment identification.

The INS uses single-phase prime power, with heaters connected to the other two phases. Dc power is used only for the CDU panel lighting and for flag outputs.

The CIGTF tests prior to source selection will consist of the normal 688G CIGTF performance tests that have been run on all INS systems in the past, and these tests are not included in the specification. The CIGTF performance tests described in the specification, paragraph 4.2.3 and Appendix IV, are optional tests performed after contract award at CIGTF, if the program manager chooses to impose these tests (depending on the availability of the requisite funds).

Burn-in tests were left up to the discretion of the vendor, and burn-in was deleted from the Production Verification Tests (PVTs). Upon request by the vendors, the vibration test in PVT was changed to an operating test in order to provide more data.

There was insufficient time to discuss the CDU requirements. It was decided to schedule the fifth and final forum for four days to provide time to discuss the CDU.

3.3.5 Fifth Open Forum Meeting

The fifth draft of the F^3 specification was issued for review on 18 June 1976. The fifth and final open forum was held 20-23 July 1976, with 58 participants. The major areas of discussion are summarized in the following paragraphs.

The F-16 digital interface requirements for the INU, imposed by General Dynamics, cite the original MIL-STD-1553 (USAF) with amendments. At the time the F-16 contract was signed, the tri-service version (MIL-STD-1553A) was not yet published. Both MIL-STD-1553 (USAF) and MIL-STD-1553A are fairly general digital-data-bus discipline specifications, not detailed design specifications; and more detailed definition is required to establish a specific interface. It was decided to impose the General Dynamics interface specification in the F-16 portion of the F^3 specification and to impose MIL-STD-1553A in the future standard USAF portion of the F^3 specification. The INS vendors recognize that MIL-STD-1553A is a broad document that requires additional detail for a specific aircraft interface.

The consensus (with some dissensions) was to eliminate the battery from the future standard USAF portion of the F^3 specification. The standard INS will operate off the aircraft emergency dc bus, which is normally supported by the aircraft battery. The elimination of the INU battery for the standard INS is based on the troublesome history of INU batteries, showing batteries to be expensive to maintain, requiring expensive AGE and frequent maintenance, and exhibiting poor reliability performance. In addition, battery characteristics must be specified in considerable detail in order to achieve interchangeability between vendors. The detailed battery definition would have consumed more time than was available for this final open forum. It was decided to specify the F-16 battery for the F-16 INU in the F-16 portion of the F^3 specification, since General Dynamics does not allow the INU to be connected to the aircraft battery.

No reliability requirements or tests are incorporated in the standard INS portion of the F^3 specification. This leaves the vendors free to choose whatever reliability goals they consider necessary to capture the market. The procurement contract may impose some reliability requirements. The F-16 addendum to the F^3 specification will include the reliability requirements and tests of the General Dynamics contract.

The life-cycle-cost (LCC) model, included in the fifth draft of the specification, was deleted on the basis of the arguments that there is no guarantee that this specific model will be used for vendor evaluation, that the LCC model may change, and that the Air Force cannot specify the numerical value of many of the constants in the LCC model. Also, for the F-16 application, it is too late in the F-16 design cycle for the LCC model to affect the design.

The control-display unit (CDU) requirements were not spelled out in the F^3 specification, primarily because the time for the open forum expired. In addition, it is difficult to predict future aircraft CDU needs, even from a functional man-machine interface viewpoint. The F-16 Fire Control and Navigational Panel (FCNP) specification will be included in the F-16 addendum.

The open forum encountered considerable difficulty in establishing a common, baseline test plan for all tests in the specification, which would be the same for all candidate INS vendors. The normal Air Force practice is to assign the vendor,the responsibility for preparing test plans and procedures, subject to Air Force approval. Normally, there is no detailing of test plans in the specification; the specification merely states that performance tests shall verify compliance with the specification. The forum made a serious attempt to spell out a performance test plan for the standard INS that would be common to all the vendors. This attempt was unsuccessful because no consensus could be reached on what should be included in the test plan. It would have taken a considerably longer time than was available to prepare a test plan of performance tests.

Considerable controversy was encountered in precisely defining the detailed performance requirements. The specification will be issued with the requirements for performance accuracy stated in terms of CEP, but there were strong arguments for the 90-percentile and three-sigma bases of measurement. The specification will be issued with the requirement for averaging accuracy data over time, but there were strong arguments for using time-slice analysis. The specification will require velocity accuracy on a per-channel basis, versus the radial accuracy basis expounded by some participants. In addition to the military performance requirements, the specification includes FAA requirements relating to navigation accuracy, which were left in the form specified by the FAA. The FAA requirements differ in a minor way from the military performance requirements in the statistical basis of accuracy. The basic cause of the controversy over the statistical basis of specifying performance accuracy is that there are differences between the error distributions of the various vendors' inertial systems and the specific statistical test method may distort the performance accuracy. For example, a particular INS may satisfy the accuracy on the CEP basis but fail on the three-sigma basis.

The built-in-test (BIT) function will be specified with 95-percent effectiveness of fault detection and 2-percent false failure indication in the body of the specification. These values are achievable within the state of the art in the opinion of the forum. The F-16 requirements for 95-percent effectiveness of fault detection and 1-percent false failure indication are to be incorporated in the F-16 addendum. For purposes of defining BIT effectiveness, failure of performance accuracy is included in the definition of a fault. Fault isolation to the SRU level will not be fully automatic and will require operator control. The requirement is that SRU fault isolation be unambiguous.

It was recognized that the INS environment might be outside the normal range for short periods of time and, as a result, INS performance accuracy might exceed the required limits. As an example, the ground cart is used to cool the cockpit in the tropics and to heat the cockpit in polar regions for periods up to 30 minutes, during which time the rate of temperature change will be very high and may affect INS performance accruacy. In addition, during start-up transients and for short periods during flight, the environmental control system will undergo transient abnormal conditions. The fifth draft of the specification allowed a qualitative degradation of performance accuracy and life during these transient conditions. Attempts by the open forum to quantify the allowed performance degradation were unsuccessful, probably because of variations in the performance degradation with the particular technique of INS implementation and the fact that INS vendors, for competitive reasons, did not want to discuss the details of their implementation. Because the allowed performance degradation during ECS transients could not be quantified, it was decided to delete the qualitative allowance for performance degradation altogether. Normally, such quantification takes place during contract performance.

The aircraft prime contractors affirmed that, for most aircraft, the prime power goes outside the MIL-STD-704B limits for short periods. It was decided not to reflect this departure in the specification requirements, in order to avoid overdesign of the INS power supply.

For greatest flexibility in aircraft installations, it would be desirable to have the capability to orient the INU 0°, 90°, or 180° with respect to the direction of flight. The forum considered the 90° orientation not to be cost-effective. The specification will require only 0°/180° orientation, by external jumpering of connector pins, as in ARINC Characteristic 561.

To provide for INU interchangeability among vendors without requiring rebalancing of the ECS for the allowed volume of cooling air when the INU is replaced, the total pressure drop caused by the INU and rack must be held to ±10 percent of the Singer-Kearfott pressure drop. This requirement forces other vendors to duplicate the Singer-Kearfott pressure drop. An alternative approach is to install adjustable orifices on all F-16 INU racks.

The consensus was that there should be no automatic mode switching from NAV to ATT when the pilot selects NAV before the expiration of the prescribed alignment time (such selection may occur in case of a scramble).

The F^3 specification is not in compliance with a number of Air Force regulations governing normal Air Force procurement practices. For example, reliability requirements are excluded from the specification. The test to see if the specification can be used for procurement will occur in the Air Force cycle of specification approval.

3.3.6 Final Specification Draft

The final specification draft, which incorporated the results of the fifth forum, was issued for review by participants in September 1976. Appendix B is a summary of the INS F^3 specification.

3.4 LESSONS LEARNED

This section presents some lessons learned, as well as some general observations made by open forum participants in developing the USAF medium-accuracy INS specification.

3.4.1 Difficulty of Gauging Consensus

As a fundamental prerequisite to the open forum process, consensus must be reached on the requirements to be incorporated in the specification; that is, each individual specification requirement should reflect the convergent trend of opinion, or the consensus. During the USAF INS F^3 specification open forum process, it was observed in many instances that consensus is difficult to gauge. On controversial topics, diametrically opposite viewpoints were expressed and it was difficult to establish which represented the majority. Further, the forum participants sometimes changed sides and the consensus then changed.

An example of the nebulous nature of consensus was the question of INU box size. Early arguments on the large versus the small INU established two divergent trends of opinion. By the time the third open forum was held, consensus seemed to favor the large INU, and this was reflected in the fourth draft of the specification, on the basis of allowing maximum competition. However, the fourth open forum reversed this trend, and the final specification draft called for a small box size since this would attract a broader market base.

3.4.2 Time to Establish Consensus

While there sometimes appeared to be divergent trends of opinion and consensus could not be established, and while the consensus sometimes changed, the general experience was that, with sufficient time for full analysis of the weight of the pertinent arguments, opinions converged and consensus was established.

3.4.3 Ample Time Allowance for Open Forum Process

In the commercial environment, it takes approximately one year for the AEEC open forums to develop the average ARINC Characteristic, and this follows considerable experience with the open forum process. In some instances there has been a shorter preparation time, when the equipment has been essentially "off the shelf". The Air Force F^3 INS specification was scheduled for completion in approximately six months, which was most optimistic considering that this first open forum process included an initial learning period and the preparation for the open forum process was limited. The short schedule was dictated by the F-16 procurement schedule and the desire to be able to satisfy the third F-16 production lot in 1978 with the standard INS procured in a competitive environment. The five INS open forum meetings were actually conducted over a period of approximately eight months (December 1975 through July 1976); and the final specification draft was released for review in September 1976, 14 months after issuance of the first strawman specification in August 1975. Because there was insufficient time available for the INS open forum process, a consensus could not be established in some areas. The main unfinished areas were as follows: (1) the Control Display Unit (CDU) requirements for the standard INS were not included in the specification (for the F-16 application, the General Dynamics Fire Control and Navigation Panel specification was included in the F-16 addendum); (2) the test plan for performance tests was not included; and (3) the statistical basis for measuring performance was judged unsatisfactory by some forum participants.

As a general recommendation, future F^3 specification open forum plans should allow ample time to allow reaching consensus on all major issues. It is recognized that the driving factor in scheduling a specific open forum process is the schedule of the corresponding market base. Therefore, planning for the open forum process should start as soon as a candidate market is identified.

3.4.4 Limitations on Controversial Discussions

A number of controversial topics were repeatedly brought up for discussion, and these proved to be time-consuming. Because of the tight schedule for the INS specification, the forum chairman tried to limit discussion when widely divergent opinions were expressed. Even with limitations imposed, a few controversial topics consumed a disproportionate amount of time. These topics were the basic philosophy of the F^3 specification in relation to the market base, the INU box size, and the INU battery.

Experience showed that consensus could be established through discussion on some topics that were moderately controversial; however, on topics that elicited widely differing viewpoints, extended discussion did not always achieve consensus but did serve to illuminate differing viewpoints. The passage of time between open forum meetings gave the participants the opportunity to analyze the arguments, and this tended to reduce the gap in viewpoints.

3.4.5 Requirements for Changes to USAF Procurement Practices

A number of Air Force regulations covering Air Force procurement practices must be reviewed for any changes that may be required to permit competitive procurement using the F^3 specification. For example, AFR 80-5 and MIL-STD-785 require that the specification include requirements for reliability design criteria and reliability tests, which are not included in the F^3 specification. The specification approval cycle will establish what changes may be required to USAF procurement regulations.

3.4.6 Importance of Market Base

The motivation for conducting an open forum process of F^3 specification preparation is that a market base is clearly foreseeable for the particular system. The larger the market base, the larger the number of open forum participants and the greater the motivation for specification preparation. The key specification requirements will be determined by the key necessities of the market. If certain requirements have been predetermined as inflexible for the particular market, any latitude in specification development is greatly curtailed.

3.4.7 Requirement for Prior Analysis to Provide Available Approaches and Alternatives

While the AEEC open forum is developing an ARINC Characteristic, analytical work is being conducted by the technical representatives of the airlines and industry to conduct trade-offs to be used in advancing the proposed alternatives. The analyses deal with the best and most economical solutions, consistent with both the stipulated requirements and the intended application, and are generally consistent with the various manufacturers' product lines. The market base in these situations is generally well defined: the fleet of aircraft is either already owned or being bought, or plans are under way to acquire a specific airframe in the near future. Also, the airframe lineage and the avionics accommodations (racking, space, wiring, etc.) in the commercial environment are relatively stable. As a result, the necessary analytical trade-offs can be made on the deliberate schedule allowed to develop its Characteristic. In a military open forum, industry representatives cannot greatly influence military decisions, thereby constraining trade-off flexibility. The military homework must therefore be conducted in advance to define which items are inflexible and which can be traded.

While an airline representative can make company decisions concerning design considerations that may affect requirements, schedules, cost, and performance, and an industry representative can make recommendations affecting those decisions in relatively short periods, the military representative cannot. The requirements process yields a documented set of needs that is relatively fixed, making the process of trade-offs and accompanying decisions rather long and involved. As a result, it is very difficult for trade-offs that affect military requirements to be accomplished in the relatively short periods (60 days) between open forum meetings. In other words, there is some inconsistency between the requirements process and the relatively more flexible open forum process. This difference can be resolved by performing early requirements/applications analyses to gain an appreciation for the basic kinds of requirements changes that may be necessary during the conduct of an open forum process, and to prepare for those possible changes in a reasonable time.

3.4.8 Need for Continued Involvement of All Major Participants in the Open Forum Process

In the AEEC open forum, all participating organizations know the value of being present at meetings and having the opportunity to present their ideas. If they do not attend the meetings, they fully understand the implications of having to conform to an ARINC Characteristic which they may not have helped generate and with which they may not fully agree. The industry will build to the Characteristic whether the nonparticipant agrees or not. If a user is the nonparticipant, he either accepts someone else's requirements as the baseline or pays a premium to the vendor for the differences he wants. If a vendor is the nonparticipant, he puts himself in the position of having to build equipment which may not include features or characteristics he would have preferred to include or which may include features that put him at a disadvantage. His other alternative is to build his own unique product line and try to compete with the industry, knowing full well that equipment described by the ARINC Characteristic is the user's preference and that his position in the market may be weak.

Air Force open forums have to engender this same philosophy: nonparticipants may later balk at following the specification on the grounds that their contributions are lacking. In the military environment, of course, this can be overcome by decree but, with the increased authority of the Program Managers, such action is usually not taken. It would be preferable, therefore, to insist from the outset that potential users contribute to the open forum on a regular basis so that the resulting specification has the benefit of their experience and needs.

3.4.9 Two-Part Specification to Accommodate Market Differences

If there are foreseeable differences between the future, general market and an existing, specific market, the most viable approach to satisfying the needs of both is to prepare a two-part specification. After considerable discussion, this approach was adopted for the standard

USAF INS specification, with the body of the specification intended to cover future, undefined USAF INS procurements and an F-16 addendum describing the specific F-16 procurement. As an example, the digital interface for future Air Force inertial systems was specified as the tri-service MIL-STD-1553A, while the F-16 addendum describes the particular General Dynamics interface -- essentially the basic MIL-STD-1553 (USAF) with minor modifications.

3.4.10 Impracticability of Designing a Standard for Hypothetical Aircraft

It would be convenient to tailor the F^3 specification for future generations of aircraft, but this is impossible since no one can predict which aircraft will be produced in the future. This became evident in the attempt to define the Control Display Unit (CDU). No consensus could be reached on what the functional man-machine interface should be. The danger of writing the specification for a hypothetical aircraft interface is that it may not fit any actual aircraft interface, thus requiring some changes to the interfaces of all aircraft. The specification should be tailored for one or more specific aircraft, and subsequent interfaces of other aircraft should be made to conform to this standard. The choice of the F-16 as the model aircraft for the standard INS was considered a good choice since the F-16 represents modern, state-of-the-art design and its operating environment represents a good current set of bounding conditions.

After at least one major application for the standard has been established, it is possible to make general accommodations for other potential uses. For example, additional test requirements and the provision for Universal Transverse Mercator (UTM) coordinates were added to the F^3 INS specification so that U.S. Army helicopter requirements could be met.

3.4.11 Effects of Smaller Size on Market

Lengthy and recurring discussions were held at each of the five open forum sessions regarding the size of the INU. Some manufacturers believed that they would be forced out of the inertial business if the future Air Force standard specification required a small INU. It was also pointed out that specifying a small size would inhibit the introduction of new technology such as the Ring Laser Gyro (RLG) development since it would be many years before the RLG technology could be miniaturized. However, the overpowering arguments for small size were that the F-16 application mandated the small size and that the future market would be attracted to the small size. Since equipment size is often an important factor in aircraft installations, a small-size INU would also favor more aircraft applications in the future.

It was also pointed out that the natural trend in equipment design is toward smaller equipment. For example, in the commercial sector, ARINC 561 INU size was changed from two ATRs (in the original 561, dated 1 June 1967) to one ATR (in 561-8, dated 30 June 1972).

3.4.12 Incorporation of Definitive Test Plans in Specification

One of the USAF ground rules in preparing specifications is that for each design requirement, there shall be a corresponding test requirement. This rule was followed in the preparation of the F^3 INS specification, and each design requirement was matched by a test requirement. However, since the time for specification preparation was severely limited, some of the test requirements are not fully definitive, particularly in the area of performance accuracy. In discussions of the test plan for performance accuracy, it came to light that there were different interpretations of the same performance-accuracy requirements.

The recommendation for future open forum activities is that definitive test plans be included in the first strawman specification draft, that adequate time be allowed for discussion of test plans, and that USAF experts on test plans be available for consultation to represent USAF interests.

3.4.13 Requirement for Analog Instrument Drives

It is foreseen that future aircraft instruments will accept digital input drives, which would eliminate the INS digital-to-analog converters and result in lower inertial system costs. However, the state of the art in digital aircraft instruments has not advanced to the point where digital instruments are cost-effective. Therefore, analog instrument drives must be provided.

CHAPTER FOUR

AVIONICS PLANNING BASELINE DOCUMENT (TASK III)

4.1 BACKGROUND

The requirement for a systematic method of collecting and displaying planning data for Air Force avionics was identified at the outset of the ARINC Research standardization studies. There was no single document containing quantitative information on existing avionics installations, planned modifications/demodifications, and funding considerations for Air Force tactical and strategic aircraft. This information was considered essential as a first step toward identifying avionics standardization opportunities. Accordingly, the development of a collection procedure and a suitable display format was made a part of the ARINC Research 1976 avionics standardization efforts. This work was accomplished as a cooperative endeavor with the Directorate of Avionics Standardization and Systems Architecture, ASD/AES, and with the cognizant Air Staff program monitor, AF/RDPV.

The results of the initial data collection have been published as a separate document entitled "Avionics Planning Baseline", dated 30 September 1976. This document is classified SECRET because similarly classified source materials were used in some instances. The general nature of the document will be described in an unclassified fashion in this chapter in order to promote an understanding of its contents over a broader distribution than that achieved in the official distribution list, and thus encourage general use. Copies of the Avionics Planning Baseline document may be requested from Headquarters, USAF, Attention: AF/RDPV.

4.2 APPROACH

The Avionics Planning Baseline document is designed to display all pertinent avionics planning information available on each model of Air Force aircraft that exists or is planned to be in the inventory through fiscal year 1991. The document is intended to be used as an avionics planning baseline from which information can be derived to assist in effective avionics planning in such areas as development requirements, instituting or justifying development programs, or establishing modification funding scenarios or installation schedules.

So that this document could be prepared within the contractual period and resources allocated, it was decided to compile the information from existing source documents that were available at Headquarters, USAF. These were considered to be representative of the categories of information necessary for a planning document of this scope. Table 4-1 presents the sources identified as pertinent. No field visits or new investigations were undertaken to collect or verify data. It is intended that this initial version of the Avionics Planning Baseline serve as a "strawman" vehicle which, following repeated review and updating, will accurately reflect the latest avionics data available throughout the Air Force.

Table 4-1. PRINCIPAL SOURCES USED IN PREPARATION OF AVIONICS BASELINE DOCUMENT

1.	Rand Corporation Report, *Listing of Avionics for USAF Aircraft*, July 1970 (Confidential); source: HQ ASD/AESS.
2.	AFLC Report, *Aircraft Electronic Equipment*, RCS: LOG-E19 (OT), undated, source: HQ USAF/RDPV.
2a.	Listing of C-130H Avionics; source: HQ USAF/LGYY, Lt. Col. Reed, undated.
3.	ARINC Research Report, *Navigation Equipment Integration Handbook*, March 1976.
4.	LMI Report, *DoD Demand for Selected Avionic Assemblies, Vol. II: MDS/Avionics Functional Requirement/Equipment Cross Reference -- Air Force*, June 1976; source: HQ USAF/RDPV.
5.	XOOG Letter, "USAF Aircraft Configuration/Force Structure", 4 March 1976 (SECRET).
6.	Approved Modification Maintenance Program, February 1976, distributed by HQ AFLC/LORE (SECRET).
7.	Aircraft Class V Modification Funding Plan, 7 May 1976; source: HQ USAF/XOOE.
8.	HQ USAF/LGYY TACAN program documentation, AFLC Form 48, 18 February 1976.
9.	*Procurement Plan for NAVSTAR GPS User Equipment*, undated (SECRET); source: HQ USAF/RDQPS.
10.	RDQPS Letter, "JTIDS Class V Aircraft and Groud Equipment Modification Requirements", 19 February 1976 (Confidential).
11.	*OMEGA Class V Mod Proposal T-2934*, 2 April 1976; source: HQ USAF/RDPV.
12.	*Air Force Fifteen Year Navigation Plan: 1976 (Draft)*, 17 March 1976 (SECRET); source: HQ USAF/RDQPS.
13.	"ROC Status Report", 1 May 1976 (SECRET); source: HQ USAF/RDQM.
14.	HQ AFLC/LOA Letter, "Realignment of ARC-164 UHF Radio Program", 30 July 1976 (SECRET); source: HQ USAF/LGYY.
15.	Available ROC documents; source: HQ USAF/RDQM.

By displaying a wide variety of avionics information on a single sheet for each aircraft, as depicted in Figure 4-1, this document enables the planner to correlate the existing equipments, requirements for new or improved equipments, existing or needed R&D programs, and modification funding and scheduling needs or priorities. Since the document is a compilation of diverse activities by different organizations over different time periods, it does not always reflect the results as coordinated activity. Consequently, there may appear to be some conflicts, omissions, or planning errors. Most of these can be resolved by a simple correction of data that may be outdated

PLANNING INFORMATION ONLY

	Code	Existing Avionics [1,2,3,4,5]	Nomenclature	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91
				Programmed and Planned Avionics Changes (Fiscal Years)														
1	C	UHF	ARC-51															
2	C	VHF-AM	WILCOX 807A															
3	C	VHF-FM	FM-622A															
4	C	HF	618 T-3															
5	N	TACAN	ARN-52															
6	N	RADIO COMPASS	ARN-6				[	GPS DEMOD			]							
7	N	VOR	51 R-6															
8	N	ILS	51V-4A															
9	N	RADAR BEACON	557-181X															
10	ID	IFF	APX-72															
11	IN	COMPASS SYSTEM	ASN-75															
12	EW	RWR	ALR-46															
13																		
14																		
15																		
16																		
17																		
18																		
19																		
20		ONGOING MODIFICATIONS [6]	FY76 & PRIOR															
21	F1516	MOD "X"	6	50	70	?	?		(226 ACFT)									
22																		
23																		
24																		
25																		
26																		
27																		
28																		
29		CL V MOD PLANNING FUNDS [7]																
30	F2784	AFSATCOM					14.4	8.2										
31																		
32																		
33																		
34																		
35																		
36		OTHER PLANNED AVIONICS																
37		TACAN (ARN-118)		113	113		[	GPS DEMOD			]							
38		UHF (ARC-164)				226		(226 KITS) [14]										
39		GPS (CLASS C)						75	75	76		(226 ACFT) [9,12]						
40																		
41																		
42																		
43		CURRENT ROCS, STATUS [13,15]																
44	TAF	324-72 "IMPROVED AIRCRAFT TACAN SET" TO BE INSTALLED BEGINNING FY-77 (15 APRIL 1975), LINES 5, 37																
45																		
46																		
47																		
48																		
49																		
50																		
			Fiscal Year	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91
			Force Structure Profiles (Total Inventory), FY [illegible] 78-3) FY 84-91 (EPA)															
			Quantity	226	226	226	226	226	226	226	226	215	200	180	150	100	40	0

CODES
C – COMMUNICATIONS
N – NAVIGATION
WD – WEAPON DELIVERY
ID – IDENTIFICATION
IN – INSTRUMENTATION
EW – RHAW CHAFF JAMMERS
R – RECONNAISSANCE
M – OTHER MISSION EQUIP
FL – FLIGHT CONTROLS
EN – ENGINE CONTROLS
EL – POWER DISTRIBUTION

▼—▼ DEMOD ▲—▲ INSTALL [ ] OPTION

AVIONICS PLANNING BASELINE
for the
(FICTITIOUS SAMPLE)
as of 3/31/77

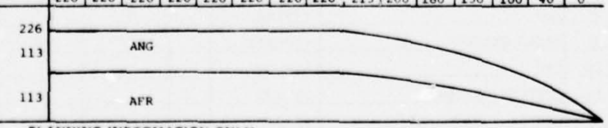

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Figure 4-1. SAMPLE AVIONICS PLANNING BASELINE or in error; others may reflect valid issues that require action or decision for resolution. The document has been widely distributed to all Air Force organizations. Each reader has been requested to review carefully all information in his functional area of interest and recommend changes to assure data currency, accuracy, and consistency. It is believed that once this Avionics Planning Baseline is reviewed, updated, and considered complete and accurate, it will provide a valuable tool for all future avionics planning and implementation activities.

4.3 DESCRIPTION OF THE DOCUMENT

The aircraft categories and models considered in the document are presented in Table 4-2. Six categories of avionics information are displayed for each Active Duty, Air Force Reserve, and Air National Guard aircraft in the inventory: (1) Existing Avionics (or, in the case of future aircraft, Functional Requirements); (2) Ongoing Modifications; (3) Class V Mod Planning Funds; (4) Other Planned Avionics; (5) Current ROCs and Status; and (6) Force Structure Quantities and Profiles. A generalized version of a single aircraft planning sheet is presented in Figure 4-1 to illustrate the format and types of information presented in the document. The six sections are described in detail in the following subsections.

4.3.1 Existing Avionics

This section, at the top of each sheet, lists the major avionic systems and subsystems on the aircraft that have been previously documented in Sources 1 through 5 of Table 4-1.* Each listed equipment is preceded by a code reflecting the equipment's function: communications (C), navigation (N), identification (ID), etc. A key of the various codes is given at the lower left corner of each sheet, immediately above the title block. Nomenclatures reflect the variety of equipments documented, although no attempt was made in the preliminary draft to determine whether multiple nomenclatures indicate redundant equipments or multiple configurations.

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	Code	Existing Avionics [1,2,3,4,5]	Nomenclature	Programmed and Planned Avionics Changes (Fiscal Years)														
				77	78	79	80	81	82	83	84	85	86	87	88	89	90	91
1	C	UHF	ARC-51															
2	C	VHF-AM	WILCOX 807A															
3	C	VHF-FM	FM-622A															
4	C	HF	618 T-3															
5	N	TACAN	ARN-52															
6	N	RADIO COMPASS	ARN-6						GPS DEMOD									
7	N	VOR	51 R-6															
8	N	ILS	51V-4A															
9	N	RADAR BEACON	557-181X															
10	ID	IFF	APX-72															
11	IN	COMPASS SYSTEM	ASN-75															
12	EW	RWR	ALR-46															
13																		

*Each reference number is used as a superscript notation throughout the planning document.

Table 4-2. AVIONICS PLANNING BASELINE SECTIONS

1. Attack/FAC

A-7D
A-10A
AT-28D
A-37B
AC-130A/H
O-2A/B
OV-10A

2. Bomber

B-1
B-52D
B-52G
B-52H
B-57C
FB-111A

3. Cargo/Tanker

C-5A
VC-6A
C-7A
C-9A/VC-9C
C-12A
YC-14/15
KC-97L
C-118A
C-123K
C-130A
C-130B
C-130D
C-130E
C-130H
HC-130H/N/P
C-131B
N/VC131H
C/NC-135A
C-135B/C
KC-135A/Q
VC-137B/C
VC/C-140A/B
C/NC-141

4. Electronic

E-3A
E-4A/B
EB-57B
B/EB-57E
EC-121C/S
EC-121G/T
EC-135A/C/G/H/J/K/L/P
EC-135N
EF-111A

5. Fighter

F-4C
F-4D
F-4E
F-4G
F-5A/B/E/F
F-15A
F-16A/B
F-100D/F
F-101B/F
F/TF-104G
F-105B/D/F/G
F-106A/B
F-111A
F-111D
F-111E
F-111F

6. Helicopter

HH-1H
T/UH-1F/N/P
CH/HH-3B/E
CH/HH-53B/C

7. Reconnaissance

DC-130A/E/H
RC-130A
RC-135A/D/M/S/T/U/V
RF-4C
RF-101C
SR-71A/B
WC-130B/E/H
WC-135B

8. Trainer

T-33A
T-37B
T-38A
T-39A/B/F
T-41A/C
T-43A

9. Utility

U-2
U-4B

10. Undesignated

AC-X
APF
ASTA
ATCA
ATF
AV-X
FAC-X
FOI
RF-X

It should also be noted that these lists do not contain individual system components such as actuators, servos, indicators, etc., which are part of or augment a system or subsystem.

4.3.2 Ongoing Modifications

The information in this section is taken directly from Source 6 in Table 4-1 which shows currently approved modifications and their implementation schedule through FY78, as well as the total number of aircraft to receive the modification. Prior-year schedules and those beyond FY78 were not shown but can be inferred in some cases. Where inference was not possible, question marks are substituted for quantities in the schedules. For example:

19											
20		ONGOING MODIFICATIONS[6]	FY76 & PRIOR								
21	F1516	MOD "X"	6	50	70	?	?	Δ	(226	ACFT)	
22											
23											

The modification described on line 21 in the sample is Mod F1516 (short title, MOD X), which is to be installed on a total of 226 aircraft. Six aircraft were modified in FY76 and prior; 50 will be modified in FY77 and 70 in FY78. In this example, it was assumed that the remaining 100 modifications would require two additional years to install, although it is possible that all 100 could be completed in FY79. The question marks reflect this uncertainty.

Where modifications replace existing equipments, a corresponding demodification of the existing equipment is indicated. This example does not reflect a corresponding demodification of existing equipment, indicating that it is most likely a new, additional equipment.

4.3.3 Class V Mod Planning Funds

This section shows the planning funds (in millions of dollars) that are allocated for Class V modifications by the Priority Review Group in the Air Staff and are documented in Source 7. The funds shown do not generally reflect ongoing modifications that have already been approved and funded and that were discussed in the preceding paragraphs. Rather, they show funds expected to be used for modifications that have been prioritized and are awaiting approval and implementation.

28											
29		CL V MOD PLANNING FUNDS[7]									
30	F2784	AFSATCOM					14.4	8.2			
31											

The funds are generally documented for a particular series of aircraft and were not always broken out by model (e.g., B-52 rather than B-52G, F-4 rather than F-4D, etc.). Accordingly, the funds shown in the Avionics Planning Baseline for a particular aircraft model are calculated by dividing total funds by representative quantities of aircraft involved. For example, if a modification was found to have a value of $1 million and it was determined to apply to 25 B-52Gs and 75 B-52Hs, the allocated funding for G models would be shown at $0.25M and for H models at $0.75M.

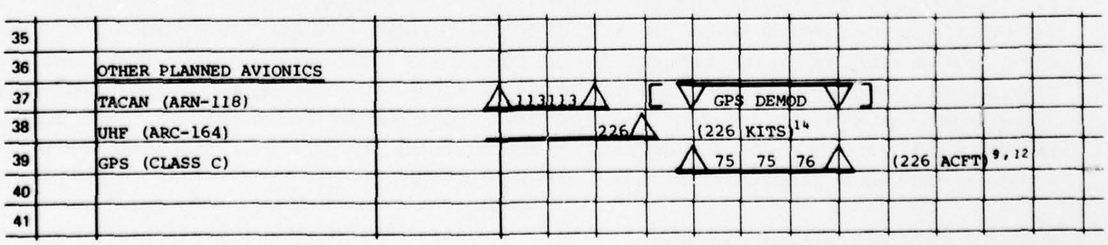
4.3.4 Other Planned Avionics

This section addresses ongoing avionics activities that were not included in the previous sections but merit attention because of their cost impact or importance. Principal systems reflected in this first issue include:

- ARN-118 TACAN
- ARC-164 UHF
- OMEGA
- Global Positioning System (GPS)
- Joint Tactical Information Distribution System (JTIDS)

Other R&D programs that have high modification-cost impacts -- e.g., Advanced Landing System (ALS), Secure Voice Communications, EW Developments, etc. -- should be included in this section in future issues, as soon as they can be identified with specific airframe applications.

The ARN-118 and ARC-164 were shown as ongoing modifications in some aircraft, but implementation schedules are largely open because current production delivery schedules are indefinite and because many kit installations will be performed in the field by using-command personnel. Consequently, many of the schedules shown in this section reflect funding-cycle dates rather than actual installation schedules. For example:



As shown in this example, most ARC-164 schedules cover the period FY76 or earlier to FY79, with all quantities shown in the last year. The reason for using this method is that delivery schedule data were not available, but the depicted schedule shows the time open between first funding (FY76 or prior) and last anticipated installation (FY79). Correlation between proposed programs and possible trade-off options were also displayed in this section and in conjunction with other sections -- for example, the following typical GPS situation displayed in the document:

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	Code	Existing Avionics [1,2,3,4,5]	Nomenclature	Programmed and Planned Avionics Changes (Fiscal Years)											
				77	78	79	80	81	82	83	84	85	86	87	88
1	C	UHF	ARC-51												
2	C	VHF-AM	WILCOX 807A												
3	C	VHF-FM	FM-622A												
4	C	HF	618 T-3												
5	N	TACAN	ARN-52												
6	N	RADIO COMPASS	ARN-6				[	GPS	DEMOD		]				
7	N	VOR	51 R-6												
8	N	ILS	51V-4A												
9	N	RADAR BEACON	557-181X												
10	ID	IFF	APX-72												
11	IN	COMPASS SYSTEM	ASN-75												
12	EW	RWR	ALR-46												
13															
35															
36		OTHER PLANNED AVIONICS													
37		TACAN (ARN-118)		113	113		[	GPS	DEMOD		]				
38		UHF (ARC-164)				226		(226	KITS)[14]						
39		GPS (CLASS C)						75	75	76		(226	ACFT)[9,12]		
40															
41															

This sample shows an ARN-118 installation and a corresponding ARN-52 demodification. The subsequent GPS installation shows that demodification options exist for both the old ARN-6 and the newly installed ARN-118. This information reflects both an achieved decision (TACAN "swap-out") and the need for a future decision on demodification that will occur when GPS is installed. Program actions and options were displayed in this fashion to illustrate possible issues clearly and to provide information that could be used in formulating decisions. Sources 8, 9, 10, 11, 12, and 14 were used to develop information in this section.

4.3.5 Current ROCs, Status

Each Required Operational Capability (ROC) document dealing with avionics that could be assigned by airframe was included in this section. Sources 13 and 15 were the primary documents used. In general, the status commentary provided represents the latest pertinent status carried in the ROC Status Reports. Dates are included in parentheses to show when the

42		
43		CURRENT ROCS, STATUS[13,15]
44	TAF	324-72 "IMPROVED AIRCRAFT TACAN SET" TO BE INSTALLED BEGINNING FY-77 (15 APRIL 1975), LINES 5, 37
45		
46		

status commentary was included in the ROC Status Report. Other commentary or status was extracted from the ROC itself, where appropriate, or based on discussions with Air Staff personnel concerning program status and other pertinent planning information. Line numbers shown indicate direct correlation between the ROC and other items of information shown on the sheet.

4.3.6 *Force Profiles*

The last category of information is the force structure data presented at the bottom right of each page. Quantities are shown numerically by fiscal year and graphically for the entire period. The profiles are divided into two sections: the period FY77-83, covering POM data; and the period FY84-91, covering planning data.

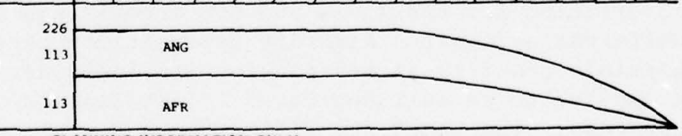
41		
42		
43		CURRENT ROCS, STATUS[13,15]
44	TAF	324-72 "IMPROVED AIRCRAFT TACAN SET" TO BE INSTALLED BEGINNING FY-77 (15 APRIL 1975), LINES 5, 37
45		
46		
47		
48		
49		
50		

CODES
C - COMMUNICATIONS
N - NAVIGATION
WD - WEAPON DELIVERY
ID - IDENTIFICATION
IN - INSTRUMENTATION
EW - RHAW, CHAFF, JAMMERS
R - RECONNAISSANCE
M - OTHER MISSION EQUIP
FL - FLIGHT CONTROLS
EN - ENGINE CONTROLS
EL - POWER DISTRIBUTION

DEMOD — INSTALL — [ ] OPTION

Fiscal Year	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91
Force Structure Profiles (Total Inventory): FY 77-83 (PA78-3) FY 84-91 (EPA)															
Quantity	226	226	226	226	226	226	226	226	215	200	180	150	100	40	0

AVIONICS PLANNING BASELINE
for the
(FICTITIOUS SAMPLE)
as of 3/31/77



PLANNING INFORMATION ONLY
UNCLASSIFIED

Profiles are for active force aircraft unless otherwise identified as Air Force Reserve (AFR) or Air National Guard (ANG). These profiles are useful in determining aircraft life, and hence the value of proposed avionics changes, and in drawing comparisons between quantities of aircraft and quantities of each modification planned.

4.4 RESULTS

Data have been accumulated and formatted for 151 USAF aircraft types or series designations. These included both existing inventory and planned developments through 1991. It is now possible to gain insight into trends in avionics developments on a force-wide basis with a high degree of assurance in the consistency of the data. Opportunities for applying standardization or other acquisition concepts can be made visible more readily through a straightforward manipulation of the data contained in the Avionics Planning Baseline document.

In Figure 4-2, for example, it is apparent that the avionics units for the ARC-164 UHF Radio and the Global Positioning System (GPS) present commanding market situations over the next 15 years. The acquisition strategy for GPS has not been completely formulated as yet. The ARN-118 TACAN and the ARC-164 UHF radios are being procured under central management, standardization-unit procurement approaches. In this example, which is a limited sample of data, the Joint Tactical Information Distribution System (JTIDS) and Inertial Navigation System (INS) stand out as other opportunities for market force exploitation. One approach to exploiting the market forces in the case of the INS purchases is described in preceding chapters of this report.

Insight into other candidates for standardization or for other innovations in acquisition strategy may be derived from the document, but not from such straightforward manipulation of the data. For example, there are scattered requirements for secure-speech transceivers in various communications bands -- UHF, VHF, and HF. It is technically feasible to build a single unit that will meet all of these requirements; however, the economic attractiveness of such a concept depends to a large extent on the market base and its uniformity, as well as on the technical considerations. Thus the planner must employ judgment in selecting and organizing the data from the document.

Another major use of the document for planning purposes is in identifying conflicts or inconsistencies in modification, demodification, or installation schedules. Figure 4-3, for example, presents the planning information for the TACAN and GPS avionic equipments by year for three different aircraft. Aircraft designations have been omitted because of possible security classification implications. The schedule for aircraft A appears to be well conceived. Installation of the ARN-118 TACAN is in progress. The TACAN demodification and replacement with GPS is scheduled for fiscal year 1983. The slight negative slopes to both schedules indicate a slow aircraft phase-out throughout the period.

The validity of the schedules for aircraft B and C is questionable and probably reflects the lack of coordination between the planners concerned with these avionics installations. Both of these aircraft have existing TACAN equipment. In both of these examples, it is not certain whether or not the ARN-118 TACAN should be installed. Rather, consideration should be given to postponing the action until the GPS is available.

Issues such as these are now being resolved in the Air Force. The Avionics Planning Baseline document has provided an instrument for displaying and correcting planning problems that have arisen. It is

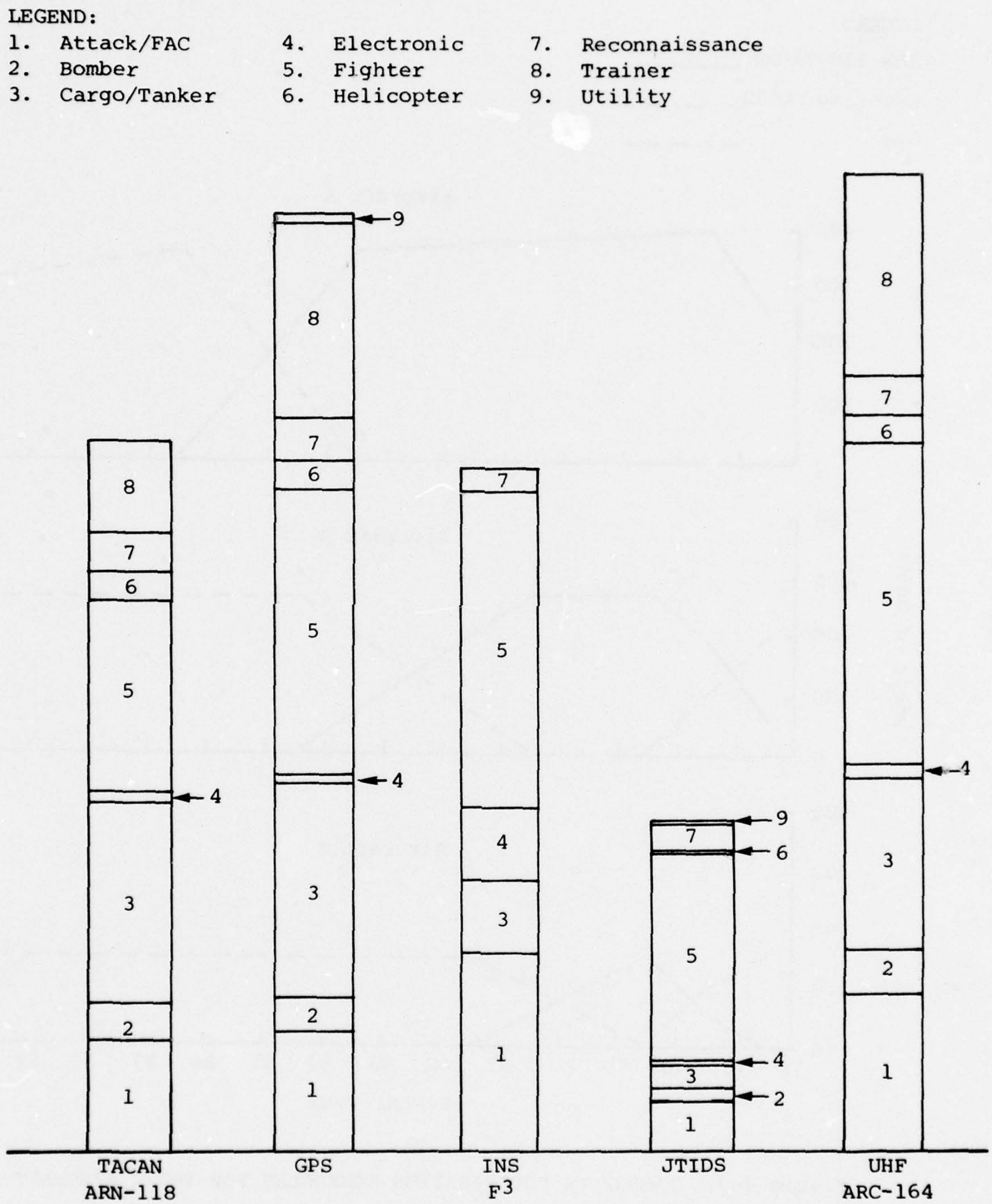


Figure 4-2. MAJOR USAF AVIONICS PROGRAMS BY TOTAL EQUIPMENT ACQUISITION QUANTITY (Scale Removed Because of Security Classification Considerations)

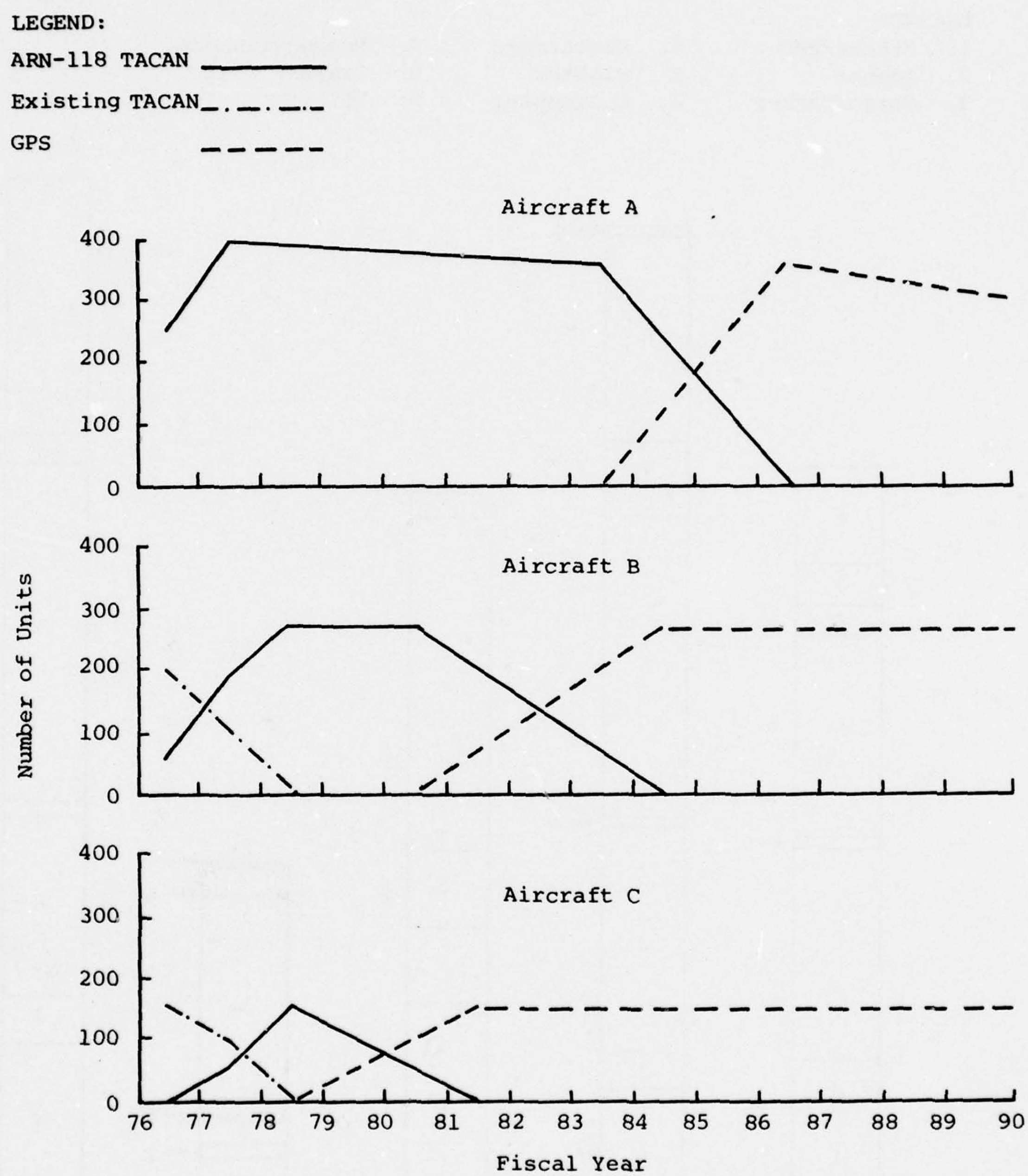


Figure 4-3. TACAN/GPS MODIFICATION SCHEDULES FOR THREE AIRCRAFT

important that the data in the document be reviewed on a formalized cycle of about three to six months to assure its validity for planning purposes. There are additional sources and categories of data that should also be considered for inclusion in the document -- for example, avionics in remotely piloted vehicles. Nevertheless, the existing accumulation of information provides a useful starting point for examining high-potential areas for avionic acquisition and support cost reductions.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

The preceding chapters have developed details of lessons learned and observations regarding specific elements of the USAF INS procurement approach, the open forum activity, and a management tool for investigating other avionics standardization opportunities. This chapter consolidates those findings into a set of general conclusions and recommendations. To some extent, inferences may be drawn from the Standard INS experience regarding the applicability of the approach to other avionics acquisitions planned by the Air Force. These observations are drawn for the six major areas of investigation by ARINC Research: (1) the open forum process, (2) the F^3 INS interface specification, (3) marketplace forces, (4) configuration management practices, (5) support concepts, and (6) new opportunities in avionics standardization.

5.1 THE OPEN FORUM PROCESS

There was genuine concern at the initiation of the INS open forum as to whether industry could be induced to participate productively during the period expected to be required for development of an F^3 INS specification. It is now apparent that representatives of manufacturers with a broad range of technical approaches will work together to develop an interface characteristic accommodating these technologies, even when there is considerable uncertainty about the military's intention to implement the resulting characteristic. The process could be steamlined somewhat by implementing procedural rules in such areas as time limitations on discussions and subcommittee assignment of issues, e.g., performance measurement, applicable military specifications, etc. However, a total period of at least one year should be allowed because of the need for each representative to discuss the evolving characteristic with technical experts at his own organization. It is recommended that a core secretariat of Government representatives be nominated to retain the experience base developed in this and subsequent forums if the F^3 specification concept is to be applied to a wide range of military procurements.

The principal lessons learned and observations relating to the open forum process which may be of value to future military open forums are:

(1) Consensus is difficult to gauge and consensus may change.

(2) Consensus can be established with time.

(3) One year or more should be allowed to establish the interface specifications.

(4) Procedural rules should be devised to control discussion on controversial topics.

(5) Changes to USAF procurement practices are required.

(6) The market base may restrict latitude in specification development.

(7) Prior requirements/applications analyses should be performed to provide alternate approaches and trade-off alternatives.

(8) Continued involvement of participants should be stressed.

(9) A two-part specification provides an approach to differences in market requirements.

(10) Developing standards for hypothetical aircraft serves no purpose.

(11) Smaller box size increases market appeal but may restrict initial competition.

(12) Test plans should be defined early in the forum process.

(13) Analog as well as digital instrument drives are required.

5.2 THE F^3 INS INTERFACE SPECIFICATION

The F^3 INS interface specification resulting from the open forum process represents an impressive organizational and technical achievement. It is consistent with the concept of its commercial counterparts in permitting a broad range of design approaches. While a great number of military specifications and standards are cited, this practice is used for the sake of brevity (e.g., test environments, connectors), not to specify technical design. MIL-E-5400 is evoked for nonstandard parts and processes; this constraint is more philosophical than practical since most major manufacturers utilize parts suppliers that build to the military specification.

The form factor (F-16-sized) has been subject to legitimate criticism. The smaller 3/4 ATR size pushes technology to some extent, thus limiting competition. On the other hand, if the standard cannot meet the F-16 requirements, more severe criticism is invited by the exclusion of this major share of the potential market. This latter consideration, together with the military and commercial trend toward better utilization of premium avionics space, provides strong rationale for this approach. All other technical aspects of the system are representative of mature technologies and are thus appropriate for F^3 implementation.

5.3 MARKET FORCES

The historical evidence is that sustaining production is not a prerequisite to sustaining competition. An articulated Air Force policy as to which future procurements are designated for F^3 competitive awards should suffice for sustaining competition, providing the potential market is attractive (large and stable). The quantitative benefits of these market forces are estimated at 30 to 40 percent of acquisition costs.

A wide range of procurement strategies is open to the Government, e.g., periodic competitive awards for all aircraft applications; initial competitive awards for each aircraft application with additional production options; split buys within a single award for either of these first two approaches; and variations on these concepts such as an initial split buy, narrowing to a single vendor after several years' operational experience. Additional cost and technical data are required before each concept can be quantitatively evaluated. These data are planned to be developed during the prototype test period. Positive evidence of the benefits and/or drawbacks of the selected-approach will not be available until the concept has been implemented for several years.

Several broad characteristics of the procurement strategy can be qualitatively inferred at this time. In order to take advantage of market pressures for lowering acquisition costs, it is imperative that commitments not be made for purchasing many years' production output at a time. Otherwise, the contractor is not motivated to pass on savings brought about by a production-technology innovation. Split buys are attractive because the competitive threat is more credible. Further, field performance data for competing sources are more comparable if the equipments are flown on the same aircraft type. This approach would, however, require an exemption to current Government procurement regulations, which call for "lowest cost" acquisition. Further, the market base should be large enough to keep several manufacturers' production rates close to an optimum monthly capacity (nominally 15 to 20 per month). Thus the technical feasibility of evoking the F^3 INS for aircraft other than the F-16 becomes a key issue.

A production gap of a year or so for a supplier should not place him at a serious pricing disadvantage. Under the procurement approach, production "learning" could very well occur on a parallel production line for a similar (either commercial or military) avionics unit of the same family. Since the manufacturer has considerable freedom in internal design, any innovative feature developed in the parallel production process could theoretically be incorporated into the USAF Standard INS.

5.4 CONFIGURATION MANAGEMENT PRACTICES

Configuration control of the functional baseline (interface level), including testability, should be rigorously enforced. If applications of the Standard INS extend to other existing aircraft, there will be a well founded pressure to utilize "growth" potential within the LRU or to otherwise modify the equipment such that it is peculiar to that application. If this is allowed to happen, there will be condeptually little difference between the "standard" variants and the families of equipments that now normally evolve from the successful introduction of a new equipment. Thus proliferation would occur at both the piece-part and LRU levels.

Configuration control of the product baseline should be transferred to the manufacturer while the equipment is under warranty. The attractiveness of the future potential market and the economic penalties incurred for returns of equipment under warranty will provide incentive for the manufacturer to improve the product, whether or not the manufacturer is currently in production for that unit. The degree to which this incentive is successful depends on the size of the market and the "teeth" in the warranty, and neither of these factors has been established. Nevertheless, enough flexibility must be provided for the manufacturer to work within those incentives.

The recommended configuration control policy consists of the following key aspects:

(1) Definition of the product baseline during the qualification process

(2) Definition of testability coincident with the proposal for production award

(3) Definition of functional baseline by the interface specification

(4) Tailoring of configuration control procedures by the manufacturer with Government approval (control by serial number a firm requirement)

(5) Use of MIL-STD-480 formatted proposals for changes affecting functional baseline, including testability

(6) Establishment of contractual obligation to bring each manufacturer's equipments to latest approved configuration or provide modification kits prior to expiration of warranty (time phasing dependent on procurement scenario)

5.5 SUPPORT CONCEPTS

An initial warranty or similar form of contractor support incentive is recommended for the INU and mount so that full advantage can be taken of the concept's potential. Such incentive is required because there must be some form of economic controls to take the place of those configuration controls which have been relaxed. The terms and conditions of this warranty should be reviewed by Government and industry in the same spirit in which the INS characteristic was developed. Ambiguity in the language resulting in an undefined risk to the manufacturer will result in unnecessary and probably unacceptable costs to the Government. A recommended "strawman" RIW is presented in Appendix A.

It is possible that with multiple INS suppliers for a single aircraft type, repair parts would proliferate upon transition to organic maintenance. If only one aircraft application is implemented, this situation is unattractive logistically relative to "business as usual" (one aircraft type, one INS manufacturer). However, a number of aircraft applications are envisioned. In a "business as usual" acquisition philosophy, there would normally be a peculiar INS for each aircraft type, with attendant parts proliferation at the force level. The F^3 competitive strategy can reduce LRU proliferation at the force level by controlling the interfaces across aircraft types. A single manufacturer's equipment may be compatible (with minor software of I/O changes) with a number of aircraft types. Thus the aggregate number of parts required to support the Command (say, Tactical Air Command) may be smaller. In any case, piece-parts proliferation should be no worse than under previous acquisition policies. The benefits to be achieved under this pessimistic assumption would then accrue only from sustained competition and maturity of the design.

5.6 NEW OPPORTUNITIES IN AVIONICS STANDARDIZATION

A preliminary review of the data accumulated for the Avionics Planning Baseline document reveals other avionics requirements with a market attraction comparable to or greater than that of the INS over the next 15 years. The data need refinement through an iterative review process among users before detailed recommendations can be drawn; however, it is felt that a useful analytic tool for avionics development planning has been set in motion.

We recommend that development of the Avionics Planning Baseline be continued and that a revision process be instituted on a three- to six-month cycle.

5.7 GENERAL OBSERVATION

One of the difficult aspects of the analysis of the implementation approach for the F^3 INS was the lack of applicable quantitative data on the impact of the technical and business innovations entailed in this program. The experimental nature of this program was recognized by DoD planners at the inception of the concept, and it should be kept in mind that the nature of the program has not changed. The benefits to be realized from the successful implementation of the F^3 INS in one or more aircraft are to be measured at a force-wide rather than aircraft-program level. This is outside the scope of conventional life-cycle-cost analysis and perhaps cannot be accounted for in the traditional manner of DoD budgeting. The first tangible evidence of the program's success will come at the time when bids are solicited for the production contracts. Conclusive evidence will not be available until several years' experience in the operational environment is obtained. In view of the uncertainty entailed in this sequence of activities, ARINC Research believes that the incremental implementation approach, which has been described in this document, is practical and appropriate and that the potential benefits, however difficult to quantify, justify the development-program initiatives that have been undertaken.

APPENDIX A

MODEL RELIABILITY IMPROVEMENT WARRANTY (RIW)

PART I - INTRODUCTION

1.1 The purpose of this introduction is to provide the contractor with an overview of the specific contractual requirements contained in Parts II through VII. The purpose of an RIW is to induce the contractor to design reliability and maintainability (R&M) into the equipment. Furthermore, the RIW extends the contractor's responsibility for a period of time beyond delivery of the equipment and provides an opportunity to improve R&M further, at no additional cost to the Government above the negotiated fixed price.

1.2 A product baseline shall be defined prior to delivery of the first production unit on the basis of a complete physical configuration audit of a unit nominated by the contractor. The contractor is permitted to improve reliability, maintainability, producibility, and performance through changes to this product baseline, provided such changes do not affect form, fit, function, testability or safety-of-flight of the Inertial Navigation System (INS). The contractor shall maintain records by equipment serial number of all changes to the product baseline. These records shall be subject to Government audit at any time.

1.3 Under the RIW defined herein, the contractor will be required to correct or replace, at no additional cost to the Government, any equipment which fails during the warranty period.

This warranty is for a five-year period commencing with the Government's acceptance of the first complete production INS. The projected use rate for the system is ____ operating hours* per equipment month. Provisions are contained herein to adjust the contract price if the use rate varies significantly from the projection.

1.4 The Government will be responsible for managing the spare Line Replaceable Unit (LRU) inventory. The Government, based on use/predicted reliability/pipeline, will purchase and place in inventory at various locations and the contractor's facility a quantity of spare LRUs which is consistent with the schedule for new installs. When a LRU demand exists in the field, the contractor will be notified and he will promptly provide a replacement.

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*To be furnished by the Government on the basis of aircraft mission characteristics.

The contractor's obligations as described herein, however, are not contingent upon the quantity of spares unilaterally positioned at any location by the Government.

1.5 The contractor will be required to provide consignment spares at specified intervals if his actual measured LRU Mean-Time-Between-Failure (MTBF) is less than the agreed-upon MTBF or if the contractor turnaround time is greater than agreed upon at each specified interval.

1.6 The contractor will be required, at no additional cost to the Government, to bring all delivered units up to the latest approved configuration by the end of the warranty period or provide modification kits within the time specified. A more detailed description of contractor requirements is provided in the following sections.

PART II - STATEMENT OF CONTRACTOR WARRANTY

2.1 Notwithstanding Government inspection and acceptance of supplies and services furnished under this contract, or any provision of this contract concerning the conclusiveness thereof, the contractor warrants that all INS Line Replaceable Units (LRUs) furnished under this contract shall be free from defects in design, material, and workmanship, and shall operate in their intended environment in accordance with the specification governing this contract, for a warranty period set forth. The INS consists of the INU and the Mount.

2.2 Any LRU furnished under this contract which fails to meet this warranty shall be returned to contractor's designated repair facility at Government expense. This LRU shall be either corrected or replaced, at the contractor's sole option and expense, so as to operate in accordance with said specification. The LRU as corrected or replaced shall be accepted in accordance with CDRL Item ____ by the Government and shipped to satisfy a demand or placed in bonded storage.

2.3 The contractor shall not be obligated to repair or replace, at no cost to the Government, any LRU under the provisions of this warranty for any of the following reasons:

(a) Nonconformance, loss, or damage by reason of (1) non-INS-induced fire or explosion; (2) submersion; (3) acts of God, such as flood, hurricane, tornado, lightning, and earthquake; (4) aircraft crash; or (5) combat action. In addition, the contractor shall not be obligated under these warranty provisions for (1) repair of damage caused by unauthorized maintenance by Government personnel authorized maintenance is defined in Part VII, paragraph 7.4); (2) repair of external physical damage caused by accidental or willful mistreatment by Government personnel and authorized agents of the Government; or (3) repair of internal physical damage which, in the determination of the Government, has been caused by accompanying external physical damage due to mistreatment by Government personnel.

(b) The conditions specified above, except acts of God, apply only to loss or damage occurring on locations other than those owned and controlled by the contractor, or occurring while the INS is not under the contractor's possession or custody.

2.4 In no event shall the contractor be liable for special consequential or incidental damages.

PART III - CONTRACTOR OBLIGATIONS

3.1 The contractor shall maintain records by serial number of each LRU under warranty. These records shall be made available to the Government periodically and for review during the warranty period (Reference Part VI).

3.2 The contractor shall provide and install seals for the warranted INU. The design of the seals should be such that inadvertent seal-breaking is minimized; however, a broken seal does not necessarily void the warranty on that item. The Administrative Contracting Officer (ACO) is the adjudicating authority with respect to the applicability of the warranty to a unit with a broken seal. The contractor shall place on each unit, in addition to the identification plate, a display which will provide, as a minimum, information that the unit is under warranty, the warranty expiration date, failure data requirements and shipping instructions. The contractor shall place a decal on each LRU for field personnel to record the date of installation on an aircraft and the date of removal from the aircraft. The proposed format and application method shall be submitted in accordance with CDRL item ____. The contractor shall also place warranty information in any Technical Orders covering the INS.

3.3 The contractor is encouraged to improve R&M through engineering changes at no additional cost, providing such changes do not affect form, fit, function, testability, or safety-of-flight. Changes to the functional baseline shall be documented as formal Class I Engineering Change Proposals (ECPs) in accordance with MIL-STD-480. The Government waives disapproval authority on all no-cost engineering changes not affecting flight safety, form, fit, function, or testability. Disapproval of any ECP shall in no way relieve the contractor of his obligations pursuant to this contract. The costs of changing any technical data or Government-owned support equipment (SE) and SE software and any other data or supplies procured under this contract necessitated by incorporation of these engineering changes or ECPs shall be borne by the contractor.

3.4 Both the Government and the contractor assume that any unit returned to the contractor's repair facility is covered by the warranty and is repairable. If the contractor considers that correction is not covered by this warranty provision for one of the reasons in Part II, paragraph 2.3, the contractor shall submit the circumstances to the ACO, along with a not-to-exceed cost estimate and proposed time for the repair. If the ACO determines that correction is not within the terms of this warranty, he may direct the contractor to repair the equipment so identified.

Equipment so repaired shall continue to be warranted for the remaining warranty period at no change in contract price. If the ACO determines that the damaged equipment is not covered within the terms of the warranty and is not correctable, the equipment shall be disposed of as directed by the ACO. Equipment disposed of, in accordance with this provision, or equipment declared lost, may be replaced by the Government with new equipment pursuant to the clause entitled "Option for Increased Quantities". Equipment so replaced shall continue to be warranted until the end of the warranty period at no additional warranty charge.

3.5 The contractor shall be responsible for obtaining spare parts for use in repair and/or modification. These parts remain the property of the contractor until incorporated into a line replaceable unit, at which time title for these parts passes to the Government. All spare parts shall be in accordance with approved drawings and specifications. All parts removed during repair and/or modification become the property of the contractor.

3.6 The Government shall reserve the right to perform inspection at the contractor's repair facility to verify failures and corrective actions. All units returned for repair and/or modification shall pass an approved repair verification test (DCRL Item _*_) prior to return to the Government.

3.7 Units returned under this warranty for which the failure cannot be verified and which pass the repair verification test as defined in Contract Data Requirement List Item _*_ shall be covered by this RIW provided that the number of no-defect-found cases in a six-month period does not exceed an amount given by the following formula:

No-defect-found limit = Total number of all items returned for repair during the six-month period times 0.3

The contractor will be reimbursed at a fixed rate of _**_ per return for no-defect-found cases during the period in excess of the defined limit. These no-defect units shall be accepted by the Government and shipped to satisfy a demand or be placed in bonded storage. The ACO shall promptly determine whether any of the exclusions in Section 2.3 apply to a returned LRU upon receipt of the contractor's claim accompanied by clear and convincing evidence.

3.8 Within an average of ____ calendar days (see Table 1) after receipt by the contractor of a returned warranted unit, covered and accepted under this warranty, the contractor shall repair or replace, and install approved modifications as necessary and store the item in the secure storage area. The repair facilities/bonded storage area shall be located so as to minimize pipeline time. The location(s) of such facilities will be subject to the

*Same as specified in Paragraph 2.2.
**Contractor-defined value.

Table 1. RIW TURNAROUND TIMES	
LRU/Warranted Consignment Unit	Turnaround Time (Calendar Days)
1. INU 2. Mount	

approval of the Government. The turnaround time requirement shall apply to all items returned, except those to which one or more of the exclusions listed in Part II, paragraph 2.3, apply.

3.9 Calculation of average turnaround time shall be made over six-month periods. The first such period shall start six months prior to the initial anniversary date of the warranty period, and subsequent six-month periods shall follow consecutively until warranty expiration. If the average turnaround time in a six-month period is greater than ____ days (see Table 1), as computed from warranty data records, the contractor will be required to lend the Government consignment spares in accordance with the following formulas:

$$N = K(T_m - T_r) - L_p$$

where

N = number of LRU spares to be furnished (N rounded to next highest integer)

T_m = measured average turnaround time in days, the average number of days each type of LRU is in the shop from the day it arrives at the contractor's facility until it is placed in bonded storage as a serviceable item. However, those LRUs that are in the contractor's repair facility for more than 180 days will be considered to have a 180-day turnaround time for each measurement period until they are turned around. At that time the total days of the combined 180-day periods will be subtracted from the actual turnaround time to provide the *final turnaround* time for the measurement period in which the LRU was placed in bonded storage as serviceable.

T_r = turnaround time requirement (____ days) (see Table 1)

L_p = spares currently consigned to the Government for failure to meet the turnaround time requirement. Consignment spares must comply with all specifications applicable to production units, plus any payment(s) made (in terms of percentage of unit price) for those consignment units not provided.

K = *the product of* $\overline{N}$, the average number of operating items, and O_a the average operating time per day divided by the item MTBF program-growth goal, G_p. The values of O_a and G_p are supplied by the Government.

$$\bar{N} = \frac{1}{6} (QPEI) \sum_{j=1}^{6} N_j$$

where

N_j = number of aircraft that contain an installed LRU of a given type on the last day of the j^{th} month of the measurement period, and

QPEI = quantity per end item (one, unless dual installation)

A positive value of N represents the liability of the contractor for consignment spares under the repair turnaround time commitment provisions of this RIW. The contractor shall provide such consignment spares to the Government within ____ days (see Table 2) from receipt of notification if the contractor is currently producing such units, or within ____ days (see Table 2) if the contractor is not currently in production. For each consignment unit not supplied within the appropriate period, the contractor will pay the Government at the rate of $_*_ /day for each day late. In no event, however, shall this payment associated with any specific repair turnaround measurement period for any LRU be more than 50 percent of the most recent price for such a unit. The "most recent price" is defined as the most recent price for a production unit as it has been revised to reflect any previously negotiated equitable adjustment thereto. In the event liquidated damages are paid, L_p shall be increased by 0.5 times the number of consignment items required. If N in the above equation is negative, the Government shall return, within 60 days, any consignment spares in its inventory up to an amount equal to the absolute value of N. In no case shall the number returned be greater than the quantity originally consigned by the contractor. The Government shall purchase at the most recent price any consignment spares not returned within the required 60-day period. The

Table 2. DELIVERY SCHEDULE FOR CONSIGNMENT UNIT

LRU/Warranted Consignment Unit	In-Production* (Calendar Days)	Out-of-Production** (Calendar Days)
1. INU		
2. Mount		

*Not to exceed x days.
**Not to exceed xx days.

---

*Suggested value is one percent of most recent production price of LRU. All days to be measured in calendar days.

units returned shall be operable and shall be either units provided by the contractor or equivalent units provided under the production contract. The Government shall not refund any dollar ($) payments that were made by the contractor in lieu of contractor providing consignment units.

3.10 Shipments of failed units to the contractor's repair facility shall be at Government expense. Shipments of repaired units from the contractor repair facility shall also be at Government expense.

3.11 Optional MTBF Guarantee. If the Government decides to exercise this option, the following provisions shall apply in addition to those of the basic RIW, as stated above.

The contractor shall guarantee that the INU delivered under this production contract shall achieve a MTBF equal to or greater than the MTBF stated in Table 3 for each measurement period.

Table 3. MTBF GUARANTEE

Calendar Period from Initial Production Unit Acceptance	INU MTBF
13-24 months	____ hours
25-36 months	____ hours
37-48 months	____ hours (300 min.)
49-60 months	____ hours (300 min.)

(a) For this MTBF commitment, the INU MTBF is defined as the total operating hours for all units in the Government inventory during a specified period divided by the total number of relevant verified failures during the same specified period. A failure is defined as any INU returned to the contractor that has been removed from an aircraft because it does not perform in accordance with contract specifications (Prime Item Development Specification for INS) as determined by the Government. The only allowable exceptions are noted in Part II, paragraph 2.3, and unverified failure returns. The Government shall follow Organizational Maintenance Technical Order procedures (reference CDRL Item ____). Inoperative Elapsed Time Indicators (ETIs) or illuminating lamps shall not be counted as failures for the purpose of calculating the MTBF; however, the contractor is responsible for repair of those items at no additional cost to the Government. Removals solely to accommodate any Government-approved ECP shall not constitute a failure for MTBF calculations.

(b) For each INU the contractor shall make semi-annual measurements of the MTBF achieved over the previous six-month period. These measurements will be based on the performance of all units delivered and warranted under the production contract. The first such measurement will be made 18 months after the acceptance of the first production unit. Paragraph (c), below, provides the basis upon which such measurements will be made. The contractor's obligation with respect to each INU MTBF guarantee shall terminate when two consecutive measurements yield MTBF values that equal or exceed the guaranteed MTBF values for the 37- through 48-month period, but in no event shall the contractor's obligation terminate earlier than 30 months nor be continued beyond 60 months from the date of initial production unit acceptance unless mutually agreed to otherwise. Notwithstanding the termination of the MTBF guarantee, the RIW shall continue with the applicable provisions of the above paragraphs.

(c) Achieved MTBF is defined as follows:

MTBF = TOH/F

MTBF = Achieved MTBF of the LRU

TOH = Total operating hours of the item population over the defined measurement period

F = Number of relevant verified failures of the LRU occurring during the defined measurement period

In the event that a measured INU MTBF for any measurement period is less than the guaranteed INU MTBF value corresponding to that period, the contractor shall furnish to the Government, at no additional cost to the Government, the following:

(1) Engineering analysis to determined causes of non-conforming MTBF

(2) Corrective engineering design changes

(3) Modification of the INUs, spare INUs, and/or spare parts as required, at contractor's expense

(4) "Pipeline" unit spares as needed by the Government on a consignment (no-charge loan) basis, but no greater than the quantity computed by the following formula:

$$n = (A \times S) - S_p$$

where

n = maximum number of consignment spare INUs (rounded to next higher whole number)

S_p = quantity of INUs previously lent to and retained on a loan basis by the Government

A = calculated number defined as follows:

$A = \frac{G}{M} - 1$ (if greater than 1.0, A shall be redefined to be equal to 1.0)

G = guaranteed MTBF value for the INU for the measurement period

M = measured INU MTBF

S = a "target" spares level based on the percentage of the average number of installed units over the six-month measurement:

$$S = \overline{N}\left(\frac{P_d + T_r}{G_p}\right)O_a + 1.65\ \overline{N}\sqrt{\left(\frac{P_d + T_r}{G_p}\right)O_a}$$

where P_d represents the number of pipeline days to and from the contractor's facility and T_r is the required contractor turnaround time as specified in Table 1. O_a, $\overline{N}$, and G_p are as defined in paragraph 3.9.

(d) The objective of consignment units is to support the pipeline flow pending improvement of the MTBF. The PCO will determine the actual number of consignment spares to be provided by the contractor in the event the LRU MTBF commitment value is not achieved. In no event shall the actual number exceed that computed by the formula in Part III, paragraph 3.11.

(e) In the event consignment units are to be supplied by the contractor to the Government, the contractor shall ship such units to the Government as soon as reasonably possible, but not later than __*__ days after the Government notifies the contractor of the number of consignment units required if the contractor is currently producing such units, or no later than __*__ days after such notification if the contractor is not currently in production. For each consignment unit not supplied under this provision within the appropriate time, the contractor will make payment to the Government at the rate of $____ /day (defined in paragraph 3.9) for each day late. In no event, however, shall this payment associated with any specific MTBF measurement period for the unit be more than 50 percent of the most recent price for such a unit. In addition, S_p shall be increased by the amount of payment (in terms of percent of unit contract price) for each unit for which payments were made.

(f) In the event INUs have been consigned to the Government and n, as calculated in Paragraph (d) hereof, is negative, all or a portion of such consigned INUs will be returned to the contractor according to the following formula:

$$\text{Number of consigned INUs to be returned} = S_c - \left(\frac{G}{M} - 1\right) \times S$$

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*See Table 2.

where S_C = number of INUs currently on consignment; G, M, S are as defined in Paragraph (d). In no event shall the number of consignment INUs to be returned exceed S_C.

(g) The Government will return the number of consigned INUs determined in Paragraph (f) as soon as possible, but no later than 60 days after an MTBF measurement indicates that such return is required. The INUs returned shall be operable and shall be either the actual INUs provided by the contractor or equivalent INUs provided under the production contract or associated separate spares contract. In the event that such INUs are not shipped to the contractor within 60 days, the Government shall purchase said INUs.

3.12 Consignment units which are in the Government inventory shall be subjected to all provisions of the contract and the reliability improvement warranty at no increase in contract price. The warranty expiration date for such units shall coincide with the warranty expiration date specified in the warranty herein. All consignment units required at the end of the warranty period, as determined in Part III, paragraphs 3.9 and 3.11, shall become the property of the Government at no additional cost to the Government. Within 30 days after the expiration of the warranty period, the contractor shall notify the PCO, in writing, of any consignment units due. The maximum comulative value that may be assessed against the contractor under the guaranteed MTBF commitment shall be as defined in paragraph 3.11(c), above. For the final measurement period MTBF calculation, the contractor shall deliver all consignment units due in accordance with Table 2 or, with the concurrence of the PCO, pay the Government 100 percent of the most recent production price of any consignment units due.

3.13 When a demand is generated in the field, the Item Manager shall promptly notify the contractor by electrically-transmitted message, giving shipping instructions for LRUs to satisfy the demand. Upon receipt of such notification, the contractor shall package and ship a replacement Government-owned LRU from the bonded storage area, or contractor-consigned LRU, to the designated Government facility. To the extent possible, a first-in/first-out basis shall be used in selecting LRUs for shipments from the storage area. Such shipment will be made within one working day from the time of receipt of notification. Only Saturdays, Sundays, and Federal holidays shall be considered nonworking days. The one-day period shall begin at the time of the start of the contractor's normal workday on the day following notification. The contractor shall use a Government Bill of Lading (GBL) accompanied by a DD Form 1149 for transfer of Government property accountability. Preservation, packing, and packaging and marking at the contractor's facility shall be in accordance with Section G of the contract and shall be at the contractor's expense.

3.14 During years 4 and 5 of the warranty, the contractor shall bring each LRU up to the latest approved configuration as the unit is returned for repair. The contractor may, at his option, implement such changes at any time the LRU is returned for repair, or the changes may be implemented by the contractor immediately on Air Force sites, provided they are on a non-interference basis. It is intended that at the end of the warranty period all INUs shall be in the latest R&M configuration. Those items in the inventory not in the latest R&M configuration shall be modified by the Air Force using kits and T.O.s supplied by the contractor under these reliability improvement warranty provisions. The kits and T.O.s referred to above shall be supplied by the contractor within ____ days following the end of the warranty period as a part of these reliability improvement warranty provisions and at no change in the price fixed for such warranty. The contractor shall perform R&M modifications that are not kitable for those items in the inventory not in the latest R&M configuration during the period of __*__ days following the end of the warranty period as a part of these warranty provisions and at no change in the price fixed for the warranty. Modifications to those items not completed during this __*__-day period become the responsibility of the Air Force, provided that said items were not delivered to the contractor for modification prior to 15 days before the end of the __*__-day period.

PART IV - GOVERNMENT OBLIGATIONS

4.1 The projected total operating hours for each 12-month period for all inertial navigation sets are as follows:

1-12 months after start of warranty	__**__	hours
13-24 months after start of warranty	__**__	hours
25-36 months after start of warranty	__**__	hours
37-48 months after start of warranty	__**__	hours
49-60 months after start of warranty	__**__	hours

In the event that additional units are purchased pursuant to the clause entitled "Option for Increased Quantity", the projected operating hours shall be adjusted by __**__ hours per month per unit beginning on the first day of the month following the delivery of the additional units.

4.2 The Government shall:

(a) Test all units in accordance with applicable Technical Orders prior to return to the contractor (CDRL Item ____).

(b) Provide shipping instructions to final destinations.

(c) Provide normal upkeep and periodic maintenance.

(d) Provide, on a monthly basis, the dates on which aircraft are initially equipped with standard INS. These dates are to be used in the calculation of total operating time.

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*Contractor-defined value.
**To be furnished by the Government based on lot size considerations.

4.3 To the extent possible, the Government shall furnish the installation and removal dates of all repaired units and furnish failure data and test readings with the failed units on AFTO 350.

PART V - CONTRACT SCHEDULE AND PRICE

5.1 For all warranted LRUs, the initial warranty period shall start upon final Government acceptance of the first production INS for delivery and shall extend for a period of 60 months, or until a total of ____ aircraft flying hours on production aircraft are accumulated, whichever occurs first. Development and preproduction equipment and equipment installed in development aircraft are not covered under the terms of this warranty. In the event that accumulated flying hours are _*_ hours or less at the expiration of the 60-month time limit specified above, the RIW costs will be adjusted downward at the rate of _**_ percent of the RIW price per hour under ____ hours. In no event will this downward adjustment exceed _**_ percent of the RIW price.

5.2 This warranty provides for a firm-fixed-price obligation by the contractor. The price for this warranty shall provide for the costs of all materials, parts, labor, etc., required for repair and/or modification of units.

5.3 Annually, on the anniversary date of the warranty, the contractor shall calculate the ratio of the total operating hours (TOH) to the total projected operating hours for the previous one-year period. If this ratio is less than .95, a downward adjustment in (warranty) price shall be made for all operating hours less than .95 times the projected operating hours. If the ratio is greater than 1.05, an upward adjustment in warranty price shall be made for all operating hours exceeding 1.05 times the projected operating hours. The cost per operating-hour adjustment factor shall be $_**_ for the RIW. The operating hours shall be calculated by using the elapsed time indicator readings, installation dates, and removal dates on all LRUs returned, if this information is available. The following calculations of operating time shall be made:

Total operating hours (TOH) - average operating hours per day (AOT) times total unit-days installed where a unit-day is defined as one aircraft equipped with an INS for one day.

$$\text{Average operating hours per day (AOT)} = \frac{EOH}{TID}$$

where

EOH = total elapsed operating hours of all LRUs returned during the measuring period

TID = total installed days of all LRUs during the measurement period

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*To be furnished by the Government.
**To be defined by the contractor.

Operating hours since the last return during a previous period shall be included. Operating time while at the contractor's facility shall be excluded. Returned units on which the ETI is inoperative or which have missing dates of installation or removal shall be excluded from the calculation of the average operating hours per day. The PCO will review the contractor's calculation and supporting data of total operating hours. PCO concurrence is required for any price adjustment. Failures to agree shall be treated in accordance with the Disputes clause.

5.4 The contractor agrees that if the total aircraft flying hours reaches _*_ prior to 60 months of warranty coverage, the Government may, at its sole option, elect to extend the warranty period to 60 months with an upward hourly adjustment in warranty price in accordance with the operating-hour adjustment factors in paragraph 5.3, above, and the operating hours in excess of _*_ that may be accumulated by the end of the 60th month in accordance with the total operating-hour calculation given in paragraph 5.3, above.

PART VI - DATA REQUIREMENTS

The contractor shall develop and maintain a data accumulation, processing, analysis, and reporting system capable of providing the data items necessary for implementing any of the provisions of this warranty, and capable of providing to the Government data and information on the reliability of the warranted LRU. All data required herein shall be made available to the Government at the contractor's plant upon request during the warranty period and for one year thereafter.

6.1 The contractor shall issue a warranty data report in accordance with CDRL Item ____, which shall contain, as a minimum:

(a) A record, by serial number, of initial delivery of each unit

(b) A record, by serial number, of each set returned for repair including ETI readings, dates of installation, dates of removal, dates of receipt, dates repaired, dates shipped, or dates of disposition

(c) A cumulative summary of the direct man-hours, parts and materials for each type LRU used in repair of failed units for each reporting period

(d) Modification status of all units by serial number

(e) An analysis of failures experienced including modes, trends, or patterns of failure and recommended/accomplished or projected corrective actions

(f) A record, by serial number, of LRUs returned in which no failure was verified and base from which received

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*To be furnished by the Government based on lot size considerations.

(g) The measured mean time between failures for each type LRU

(h) The average time, in days, it takes the contractor to ship each LRU once a demand is placed on the contractor by the Item Manager

The reporting formats and records to be used for this report will be submitted to the Government for approval prior to the commencement of the initial measurement period.

6.2 A warranty effectiveness report shall be issued annually. This report shall be submitted by letter and shall contain the contractor's experience, analysis, and conclusions regarding the effectiveness of the warranty. Particular attention shall be given to significant actions the contractor took, and the reasons therefore, especially those he would not have taken on a contract without a warranty. The report shall also contain recommendations regarding warranty clause provisions which may be of mutual benefit to the Government and industry in future procurements.

PART VII - MISCELLANEOUS

7.1 The contractor shall be permitted to retain any LRUs he replaces, or materials he removes from ones repaired, pursuant to his obligations under this reliability improvement warranty. Disposition of LRUs not covered by this warranty shall be pursuant to directions issued by the ACO.

7.2 The Government shall not provide new (i.e., additional) facilities, tooling, or equipment of any type for contractor performance under this warranty.

7.3 To the benefit of both the contractor and the Government, the contractor shall provide, for Government approval, a list of adjustments that may be made by authorized technicians or parts that may be replaced by authorized technicians, at either organizational or intermediate maintenance levels, which adjustment or part replacement will in no way affect the validity of warranty, destroy the warranty seal, or constitute unauthorized maintenance. Any malfunction requiring such adjustment or parts replacement will, however, constitute unauthorized maintenance. Any malfunction requiring such adjustment or parts replacement will, however, constitute a failure for purposes of the MTBF guarantee calculation.

ATTACHMENT

RATIONALE FOR RIW

1. Contractor is *required* to maintain configuration control. This is done to assure that if USAF wants to transition to organic maintenance, appropriate records will be available. Contractor *may* not need to keep such records in performing the RIW. If he is not required to, it could be very costly to recover such data at the time of transition.

2. Contractor is required to bring INUs up to latest configuration as they are repaired. This is considered advisable for the following reasons:

   - The contractor is better equipped to install the ECPs than would be the Air Force intermediate-level maintenance facilities.
   - Experience has shown that the military management of ECPs is not always efficient.
   - The contractor will be more inclined to initiate a "proven" change rather than use Air Force assets as "guinea pigs" to test ECPs, if each return must be brought up to the latest R&M configuration.

3. The contractor is relieved of having to report to USAF any ECs he installs, (except he is required to get approval for ECPs affecting form, fit, function, testability, or safety-of-flight). This grants greater design change latitude and encourages innovation in "fixing" a problem.

4. A RIW period of 60 months was selected for the following reasons:

   - Contractors are reluctant to offer fixed prices for times exceeding good economic visibility. RIW periods longer than 60 months become more unreasonable from that viewpoint.
   - Periods much shorter than 60 months will not allow time for data feedback to assess the need for installation and evaluation of engineering changes (ECs).

5. The Government may, at its option, extend the RIW to the full 60-month period with a predetermined price adjustment. This is desirable because the Government may not have planned for transition at an earlier date

forced by a more intensive flying-hour schedule, and would therefore be in an unfavorable negotiating position for interim contractor support. A lower limit should be chosen as a reasonable threshold value, below which the contractor should return monies for services not needed. The value of 5/6 of the expected flight hours is recommended. It is not analytically derived. The value is considered reasonable and is the same value used for the F-16 RIW. Contractors are allowed to bid the payback rate and the limit of payback.

6. Contractors are allowed to bid their turnaround time, final R&M configuration update limit, and consignment spares delivery time for in-production and out-of-production status. This is to permit maximum accommodation to individual manufacturers' production methods, thus avoiding costs which might be incurred if an arbitrary value is specified by the Government.

7. Contractors have a liability limit in processing "no defect found" LRUs. The contractor will be reimbursed at a fixed-bid dollar amount for processing all "no defect found" LRUs in excess of 0.3 times the total number of INUs returned to him for repair during a six-month measurement period. By having to process the first 30 percent of "no defect found" LRUs, the contractor has an incentive to provide accurate BITE. At the same time, the contractor is protected from the advent of questionable necessity to "clean up" all of a squadron's LRUs during a period of extended stand down. The value of 30 percent was selected following an examination of data pertaining to equipment similar to the F-16 INS.

8. For the MTBFG option, contractor specifies his own value of MTBF for years 2 through 5. Years 4 and 5 have a minimum requirement of 300 hours. This value is consistent with the F-16 INS MTBFG and provides a high degree of operational reliability (.005 probability of in-flight failure for a 1.5-hour mission time). A higher value may be selected for aircraft with longer missions and a more benign operating environment such as tanker and cargo.

9. The MTBF value defined above should be employed in the equations in the RIW and MTBFG option wherever the program growth goal (G_p) term is used. This will circumvent "gaming" of the warranty with very high MTBF values by the manufacturer so as to mathematically reduce the target spares level. A G_p value of 24 × 365 × 10 = 87,600 hours is suggested for the mount if this LRU is placed under warranty. Since the mount is essentially permanently affixed (and boresighted) to each aircraft, the operating period of this LRU may be considered to be continuous upon acceptance of the unit. Failures should be a rare occurrence; however, it is possible that flaws in the material could cause decomposition.

10. If a mixed operating environment (INUs swapped between different aircraft types) is encountered, a weighted average of operating periods should be employed in the equations, based on the relative proportions of each aircraft type.

11. The intent of the clause in Part VII regarding the list of authorized maintenance actions is to provide some warranty flexibility for repairs other than manufacturer-performed. This will make the warranty more attractive for using commands with bases at remote ends of the pipeline to the manufacturer's repair sites. In the case of the F-16 application, it is possible that some of these actions could be performed by the European coproducer. The extent to which this concept can be applied depends on the design approach by each manufacturer.

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AIR FORCE AVIONICS STANDARDIZATION: AN EXAMINATION OF IMPLEMENT--ETC(U)

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APPENDIX B

SUMMARY OF THE FINAL DRAFT OF THE SEPTEMBER 1976 SPECIFICATION

Part I of this appendix is a summary of "Final Draft, Characteristic for a Moderate Accuracy Inertial Navigation System (INS), September 1976." Part II is a comparison of the F^3 specification with the commercial INS specification.

Part I - Specification Summary

This form-fit-function (F^3) specification, developed in five open forum meetings, constrains the physical, electrical, and environmental interfaces, and states the functional performance requirements without prescribing any specific technology or particular design implementation. The right-hand pages of the specification state the requirements, while the left-hand pages provide a commentary on the rationale for the requirements.

The body of the specification gives the general requirements for all future, standard USAF medium-accuracy inertial systems, while the specific General Dynamics requirements for the F-16 INS are given in Addendum A. In the following summary of the specification, the paragraph number corresponds with the paragraph numbering used in the specification.

1.0 SCOPE

This paragraph states that the F^3 specification must allow LRU interchangeability between multiple contractors over a broad range of aircraft. The intent is to define a basic INS configuration usable on many different aircraft by minor modification, limited to the following:

(1) Modification of software

(2) Substitution of internal modules

(3) Passive, mechanical adapter

The commentary accompanying this paragraph discusses the objectives of the Air Force standardization program.

2.0 APPLICABLE DOCUMENTS

This paragraph includes the commonly referenced Government documents plus two General Dynamics specifications imposed for the F-16 INS. The purpose of the applicable documents is given in Table B-1.

3.0 REQUIREMENTS

3.1 Item Description

The INS will comprise three LRUs: Inertial Navigation Unit (INU), Control Display Unit (CDU), and INU Mount for the Standard USAF INS. The commentary states that a battery is required for the F-16 application, where INS utilization of the aircraft battery is not permitted. The commentary also discusses the difficulty of defining a universal CDU.

3.1.1 Item Diagram

This paragraph references Figure 1 of the specification, which illustrates the three LRUs.

3.1.2 Interface Definition

This paragraph references Appendixes I and II and the applicable addenda called out in the statement of work. Digital data transmissions will meet MIL-STD-1553A. The commentary points out that there will be vehicle applications (KC-135, F-4, etc.) that are not compatible with MIL-STD-1553A.

3.1.2.1 Bus Control

The INU will have the dual roles of a MIL-STD-1553A remote terminal and a back-up bus controller. The commentary points out that the bus controller function provides autonomous INS subsystem operation during testing.

Subparagraphs under the bus control heading state the requirements for a dual redundant data bus, externally programmable INU bus address, INU self-test results display in the terminal flag bit, and compliance with MIL-STD-1553A mode command options. The commentary states that the choice of mode command options will be made by the specific addenda for the particular aircraft.

3.2 Characteristics

3.2.1 Performance

The INS is required to supply position, velocity, heading, and attitude after alignment in any three alignment modes: Gyro Compassing (GC), Stored Heading, and Best Available True Heading (BATH).

Table B-1. PURPOSE OF SPECIFYING DOCUMENTS IN FINAL DRAFT CHARACTERISTIC FOR A MODERATE ACCURACY INERTIAL NAVIGATION SYSTEM (INS) (BASIC SPECIFICATION, SEPTEMBER 1976)

Page	Paragraph	Document	Paragraph Title	Purpose
7	3,1.2	MIL-STD-1553	Interface Definition	Defines interface between INS and vehicle avionics
7	3.1.2.1	MIL-STD-1553	Bus Control	
11	3.1.2.1.3	MIL-STD-1553	Status Word Bit Assignment	
11	3.1.2.1.4	MIL-STD-1553	Mode Commands	
15	3.2.1.1	FAR 121-89, Appendix G	Position Accuracy	Specifies accuracy for flight times greater than 1 hour
27	3.2.2.3	MIL-STD-704	Electrical Power	Defines aircraft power sources
29	3.2.2.3.d.6	MIL-STD-461	EMI Filtering	Defines EMI filtering on dc bus for conductive emission
41	3.2.5	MIL-E-5400	Environmental Conditions	Defines environmental conditions the INS will encounter
41	3.2.5.1	MIL-E-5400	Temperature	
41	3.2.5.2	MIL-E-5400	Altitude	
41	3.2.5.3	MIL-E-5400	Vibration	
43	3.2.5.4	MIL-STD-108 and MIL-STD-454	Rain	
43	3.2.5.5	MIL-STD-810	Solar Radiation	
43	3.2.5.6	MIL-STD-810	Acoustical Noise	
43	3.2.5.8	MIL-T-5624	Fluids	
43	3.2.5.8	MIL-H-5606	Fluids	
45	3.2.5.8	MIL-L-7808	Fluids	
45	3.3	MIL-E-5400	Design and Construction	Defines the INS design and construction to meet specified environmental conditions
45	3.3.1	MIL-STD-454	Connectors	
45	3.3.1	MIL-C-38999	Connectors	
45	3.3.1	MIL-C-83723	Connectors	
45	3.3.1	MIL-C-83733	Connectors	
49	3.3.4	AFSC DH1-4	EMI	Defines the INS design and construction to meet specified environmental conditions
49	3.3.4	MIL-STD-461	EMI	
49	3.3.4.1	MIL-B-5087	Bonding	
49	3.3.4.1	MS 25083-2	Bonding	
49	3.3.5	MIL-E-5400	Nameplates and Product Marking	
49	3.3.5	MIL-STD-130	Nameplates and Product Marking	
49	3.3.6	MIL-STD-454	Workmanship	
49	3.3.7	MIL-STD-454	Safety	
49	3.3.7	AFSC DH1-6	Safety	
49	3.3.7	MIL-STD-882	Safety	
49	3.3.8	MIL-STD-1472	Human Engineering	
53	3.3.9	MS 17322	Elapsed-Time Meter	
53	3.3.9	MIL-M17793	Elapsed-Time Meter	
53	3.3.10	MIL-E-5400	Parts, Materials, and Processes	
53	3.3.11	MIL-E-5400	Finishes and Colors	
53	3.3.12	MIL-STD-1472	Handles and Grasp Areas	
62	4.2 Commentary	MIL-Q-9858	Test Classification	Specifies quality program requirements in "Commentary" only
63	4.1.4	MIL-STD-810	Test Apparatus Accuracy	Defines test equipment requirements
67	4.2.4.2	MIL-STD-810	Environmental Tests	Defines environmental tests to be performed to measure performance under environmental conditions specified in paragraph 3.2.5
67	4.2.4.2.1	MIL-STD-810	Temperature and Altitude	
67	4.2.3.2.2	MIL-STD-810	Humidity Test	
67	4.2.4.2.3	MIL-STD-810	Random Vibration	
69	4.2.4.2.5	MIL-STD-810	Rain	
69	4.2.4.2.6	MIL-STD-810	Sand and Dust	
69	4.2.4.2.7	MIL-STD-810	Fungus	
69	4.2.4.2.8	MIL-STD-810	Salt Fog	
69	4.2.4.2.9	MIL-STD-810	Solar Radiation	
69	4.2.4.2.10	MIL-STD-810	Explosive Atmosphere	
73	4.2.4.2.12	MIL-STD-810	Sinusoidal Vibration	
73	4.2.4.2.13	MIL-STD-810	Acoustical Noise	
73	4.2.4.2.14	MIL-STD-810	Shock	
73	4.2.4.2.15	MIL-STD-810	Gunfire Vibration	
73	4.2.4.2.16	OSHA STD 1910.93	Toxicity	
73	4.2.4.2.17	OSHA STD 1910.95	Acoustic Noise	
73	4.2.3.2	MIL-STD-461	EMI	
73	4.2.4.3	MIL-STD-462	EMI	
77	4.2.4.4	MIL-STD-810	Electrical Power Test	
77	4.2.4.4.1d	MIL-STD-704	Ac Transients	
77	4.2.3.3.2b	MIL-STD-704	Dc Transients	
87	4.2.6.1.2	MIL-STD-781	Temperature Cycling	Defines thermal survey for production verification test
101	4.2.7.2	MIL-STD-471	Equipment Repair Time	Defines repair time for maintainability/BIT demonstration

3.2.1.1 Position Accuracy

The military accuracy requirement is stated as 0.8 nm/hr 50-percent circular error for flights up to one hour and imposes the FAA requirement, FAR 121-89, which must be met for the civil environment. The civil requirement is basically 2 nm/hr circular error on 95 percent of the flights. The commentary states that the Rayleigh distribution is to be used for conversions and 0.8 nm/hr 50-percent circular error converts to 1.7 nm/hr on a 95-percent basis.

3.2.1.2 Velocity Accuracy

The X and Y horizontal velocity errors will not exceed 2.5 fps rms per axis, and the vertical velocity error will not exceed 2 fps up to two hours after gyro compass alignment. The commentary establishes the coordinate system and defines the basis for measurements.

3.2.1.3 Reaction Times

The alignment-time requirements above 0°F are 9 minutes for gyro compass alignment and 2.5 minutes for stored heading alignment for full accuracy performance. This paragraph also imposes Table I of the specification for other conditions of temperature.

3.2.1.4 Attitude Accuracy

Table I is imposed; it requires 0.25° accuracy in roll, pitch, and true heading.

3.2.1.5 Latitude Range/Vehicle Motion During Alignment

The INS will meet the specification requirements between 78°N and 78°S latitude, with normal wind buffeting and normal ground maintenance activities. The commentary describes typical aircraft motion during alignment.

3.2.1.6 Performance Certification

CIGTF verification under Appendix IV of the specification is required.

3.2.1.7 INS Functions

The INS functions are:

a. Accept manually inserted latitude-longitude and UTM

b. Display a quantitative indication of alignment progress

c. Perform autonomous self-calibration

d. Store magnetic variation used in magnetic heading

e. Provide a self-test of INU operation

f. Provide roll and pitch

g. Provide true heading

h. Provide three orthogonal acceleration measurements

i. Provide three orthogonal velocity measurements that are corrected for coriolis and local g

j. Display latitude-longitude and alphanumeric UTM

k. Provide an airborne position update capability

l. Provide steering outputs of course deviation, range, time to go, ground track, and steering error for 10 stored destinations

m. Serve as a back-up bus controller

n. Serve as a back-up attitude reference

o. Store align status in nonvolatile memory

p. Output mode status

q. Store a history of navigation performance

3.2.1.8 Selectable Modes

Except for turn-on and ATT, the following INS modes will be selectable via the data bus:

a. Off mode

b. Gyro compass alignment, followed by a NAV RDY indication

c. Stored heading alignment, followed by a NAV RDY indication

d. Best available true heading alignment, followed by a NAV RDY indication

e. NAV mode. The INS will accept external corrections of velocity, position, and gyro bias/tilt/drift. It will provide a "baro altitude valid" indication. The commentary states that external corrections will be processed and filtered before being supplied to the INS.

f. Position fix modes
   1. "AUXILIARY" from outside sources
   2. "OVERFLY" from the CDU

g. Calibrate gyro bias drift in 90 minutes

h. Back-up attitude (ATT) mode, entered when NAV is selected prior to alignment completion

i. "TEST" mode for fault detection and isolation, with 95-percent confidence in fault detection and a 2-percent false-alarm rate

j. "GRID MODE", selected by the operator and enunciated by the INS, during which grid heading replaces true heading, as in polar navigation.

3.2.1.9 Data Output

This paragraph imposes Appendix II of the specification, which lists the output signals.

3.2.2 Physical Characteristics

3.2.2.1 Size

This paragraph imposes Appendix II. The commentary states that the CDU form factor will be supplied later.

3.2.2.2 Electrical Interface

Addendum A defines specific interfaces.

3.2.2.3 Electrical Power

The INS will derive prime power from a 115-volt, three-phase, 400-Hz source per MIL-STD-704B. Back-up power will be +28 Vdc from an external dc bus, which is normally supported by the aircraft battery. The power consumption limits are given in Table II of the specification for ac and dc. The ac starting limits are 340 VA Phase C prime power, 770 VA Phase A heater power, and 710 VA Phase B heater power. The dc running power limit (back-up operation) is 240 watts maximum.

3.2.3 Reliability

The specification does not have an MTBF requirement. The commentary states that the Air Force wants reliable equipment and contractors that provide reliable equipment to obtain future business.

3.2.4 Maintainability

3.2.4.1 Design

Maintainability will be a prime consideration in equipment and installation design, and modular packaging will be used. The calibration interval will be greater than 60 days.

3.2.4.2 Repair

Median equipment repair time will not exceed 30 minutes at the organizational level (LRU replacement) and 1 hour at the intermediate shop level (SRU replacement).

3.2.4.3 Built-In-Test (BIT) Function

BIT will provide self-test functions for fault detection during normal operation and operator-initiated diagnostics.

3.2.4.3.1 Failure-Detection Function

The failure-detection function will be an automatic go/no-go test during normal operation having a 95-percent effectiveness and a 2-percent false-alarm rate, will not require external test equipment, and will provide a failure indication on the CDU or on a remote panel as the installation warrants.

3.2.4.3.2 Failure-Location Function

The organizational-level failure-location function will provide a non-volatile indication on each failure LRU. This function can be operator-assisted.

The intermediate-level failure-location function will provide a non-volatile indication of each failed SRU on the affected LRU.

3.2.4.3.3 Failure-Location Performance

Organizational-level fault location will be 95-percent effective when it is automatic and 98-percent effective when it is operator-assisted.

For the intermediate shop level, in 90 percent of the cases the fault will be isolated to the correct SRU; in 95 percent of the cases the fault will be isolated to the correct SRU and no more than one other SRU; and in all cases the fault will be isolated to the correct SRU and no more than two other SRUs.

3.2.5 Environmental Conditions

MIL-E-5400R applies, except for the following changes:

1. Temperature. Class 2X, except that the operating temperature is -40°C at the low end. Rate of temperature change is 1.7°C per second.
2. Altitude. From -1,500 to +80.350 feet; pressure variation of 0.6 psia per second.
3. Vibration. Operation while subject to random vibration per Figure 7A (0.04 G^2/Hz from 300 to 1,000 Hz, overall level 7.4 G rms). Also, operating sinusoidal vibration per Curve IIIb, MIL-E-5400R, up to 500 Hz.
4. Rain. Operation in dripping water and rain at 45°.
5. Solar Radiation. CDU operation when subjected to solar radiation per MIL-STD-810C, Method 505.1, Procedure II.
6. Acoustical Noise. INS operation when subjected to noise per MIL-STD-810C, Method 515.2, Procedure I, Category A.
7. Flight Environment. Operating azimuth and pitch acceleration of ±6 rad/sec^2, roll acceleration of ±17.5 rad/sec, azimuth rate of ±3 rad/sec, pitch rate of ±1 rad/sec, roll rate of ±7 rad/sec, velocity of ±2,500 fps in all axes, and unlimited latitude.

8. Fluids. Contact with water, JP-4 and JP-5 fuels, hydraulic fluid, lubricating oil, and common coolants at temperatures up to 135°C.

3.2.6 Transportability

Shipment by standard, commercial carriers.

3.3 Design and Construction

3.3.1 Connectors

Connectors will conform to Requirement 10 of MIL-STD-454E. High-density circular connectors per MIL-C-3899F, Series 1. Low-density circular connectors per MIL-C-83723C, Series 3. Rack and panel connectors per MIL-C-83733A.

3.3.2 Design Loads

Operating load factors of 1.5g side-to-side, 3g up, 3g forward and aft, and 12g down.

Limit load factors of 2g side-to-side, 6g up, and 4g forward and aft load acting in combination with a down load of 13g. There will be no permanent set resulting from the limit load factors.

After application of ultimate load factors of 1.2 times the limit load factors, there will be no failure of the structural supporting elements, but permanent set is permitted.

3.3.3 Thermal Design

The INS will be forced-air-cooled, using a heat exchanger to avoid cooling-air entry into the internal parts. BIT will include provisions for over-temperature shut-off. The INU mount will shut off cooling air when the INU is removed. The commentary suggests that a detailed thermal analysis of the INU be performed early in the design phase.

3.3.3.1 Cooling-Air Conditions

a. Supply air temperature

   (1) Minimum, from -51°C (30 minutes) to -18°C

   (2) Maximum, from +49°C (30 minutes) to +38°C

   (3) Normal rate of change, 1.7°C per second. Start-up rate of change 5.5°C per second

b. Each pound of cooling air may contain up to 55 grains of free water condensate and 210 grains total water content.

c. Each pound of cooling air may contain up to 0.1 gram of dust of 50 microns particle size.

3.3.3.2 Cooling-Air Flow

The flow rate is per Figure 4 of the specification, which gives maximum and minimum flow rates as a function of temperature over normal and abnormal limits. For the normal range at -18°C the flow rate is in the range 0.6 to 1.6 lbs/min, and at +38°C the flow rate is in the range 2.3 to 2.8 lbs/min. The commentary states that the minimum flow rate in the normal range is based on maintaining an exit air temperature of +54°C.

3.3.4 Electromagnetic Interference (EMI)

This paragraph references MIL-STD-461A, Notice 3. Bonding clamps will meet MIL-B-5087B; bonding straps will meet MS 25083-2. The commentary states that the open forum consensus was to use bonding straps.

3.3.5 Nameplates and Product Marking

Part and assembly marking will meet MIL-E-5400R, paragraph 3.1.16. Unit nameplates will meet MIL-STD-130D.

3.3.6 Workmanship

MIL-STD-454E, Requirement 9.

3.3.7 Safety

MIL-STD-454E, Requirements 1 and 3. AFSC DH 1-6. MIL-STD-882, paragraphs 5.4 and 5.6.

3.3.8 Human Engineering

This paragraph references MIL-STD-1472A. The touch temperature will not exceed 125°F for hand-actuated devices and control knobs, and 145°F for displays, control panels, and lighted pushbutton switches.

3.3.9 Elapsed-Time Meter

The INU will have a 9999-hour digital elapsed-time meter.

3.3.10 Parts, Materials, and Processes

Parts, materials, and processes will be subject to USAF approval and will meet MIL-E-5400R, paragraph 3.1.

3.3.11 Finishes and Colors

Paragraph 3.1.8.1 of MIL-E-5400R.

3.3.12 Handles and Grasp Areas

Paragraph 5.9.11.4 of MIL-STD-1472A.

4.0 QUALITY ASSURANCE PROVISIONS

The commentary states that this section includes all tests that the Government may find it necessary to invoke. However, a specific contract may impose only specific tests among all the tests described.

4.1 General

This paragraph states that the verification method for compliance with the design requirements is by inspection, analysis, demonstration, or tests, or any combination of these. Table IV lists the specific verification for each design requirement.

4.1.1 Responsibility for Tests

Tests and inspections will be performed at the facilities specified in the contract statement of work, except that all performance testing (reference paragraph 4.2.2) will be at CIGTF.

4.1.2 Test Samples

Test samples will be specified in the contract statement of work.

4.1.3 Standard Conditions

Normal room ambient.

4.1.4 Test Apparatus Accuracy

MIL-STD-810C, paragraph 3.1.3.

4.1.5 Failure Criteria

Noncompliance with the specification requirements, if repeatable, constitutes a failure.

4.1.6 Test-Sample Refurbishment

Test samples will be refurbished prior to delivery in accordance with the contract.

4.2 Test Classification

Inspection and testing of the INS is classified as follows:

a. Examination of Product, paragraph 4.2.1

b. Performance Test, paragraph 4.2.2

c. Acceptance Test, paragraph 4.2.3

d. Qualification Test, paragraph 4.2.4

e. Combined Environment Test, paragraph 4.2.5

f. Product Verification Test, paragraph 4.2.6

g. Maintainability Demonstration, paragraph 4.2.7

The commentary imposes a MIL-Q-9858A quality program.

4.2.1 Examination of Product

Visual and mechanical inspection.

4.2.2 Performance Test

CIGTF tests per Appendix IV.

4.2.3 Acceptance Test

The test procedure will be prepared by the contractor and submitted for Government approval.

4.2.4 Qualification Tests

4.2.4.1 Pre-Qualification Acceptance Test

A complete acceptance test will be performed prior to the start of each major test in this qualification test series.

4.2.4.2 Environmental Tests

The tests will cover temperature and altitude, humidity, random vibration, cooling air, rain, sand and dust, fungus, salt fog, solar radiation, explosive atmosphere, linear acceleration, sinusoidal vibration, acoustical noise, shock, gunfire vibration, toxicity, and personnel protection from acoustic noise.

4.2.4.3 Electromagnetic Interference (EMI) Test

MIL-STD-461A, Notice 3.

4.2.4.4 Electrical Power Test

Ac power tests include voltage, power factor, frequency, transients, and primary power loss. Dc power tests on the CDU include voltage and transients. Ac and dc power consumption is checked.

4.2.4.5 Post-Qualification Functional Test

An acceptance test will be performed at the conclusion of the qualification test.

4.2.5 <u>Combined Environment Test (CET)</u>

Three types of environments are simulated: arctic, desert, and tropic. The test consists of 15 cycles, during which the altitude, temperature, relative humidity, and vibration will be varied.

4.2.6 <u>Production Verification Test (PVT)</u>

This test is run on each deliverable unit and is of the "burn-in" type. The environments include random vibration and temperature cycling. An acceptance test is run at the conclusion.

4.2.7 <u>Maintainability/BIT Demonstration</u>

The test requirements are prefaced by a thorough explanation of the philosophy and goals of the maintainability demonstration.

The test covers equipment repair time, failure-detection capability, and failure-location capability.

5.0 PREPARATION FOR DELIVERY

Preparation for delivery will be specified in the contract.

6.0 NOTES

Contract awards will be based on life-cycle-cost considerations.

APPENDIX I: INU INPUT SIGNAL INTERFACES

Appendix I is a three-page table listing the digital data and discrete input functions and defining the measurement units, range, positive direction, refresh rate, and transmission rate.

APPENDIX II: INU OUTPUT SIGNAL INTERFACES

Appendix II covers INU digital data and discrete output functions in the same format as Appendix I.

APPENDIX III: INU OUTLINE AND MOUNTING DRAWINGS

Appendix III includes drawings of the INU Mount (side, top, front, and rear views) and INU (side, front, rear and bottom views) and includes connector and cooling air interface data.

APPENDIX IV: PERFORMANCE TEST (LABORATORY AND AIRCRAFT)

Appendix IV describes the CIGTF performance tests.

ADDENDUM A, F-16 REQUIREMENTS

This addendum includes those General Dynamics requirements for the F-16 INS which differ from the body of the specification covering the standard USAF INS.

Part II - Comparison of F^3 Specification with Commercial INS Specification

Although both the commercial airlines and the military use inertial navigation systems in their fleets of aircraft, their special requirements necessitate differences in the applicable specifications. These differences (and similarities) are briefly summarized in Table B-2 for the "Commercial Air Transport Inertial Navigation System", ARINC Characteristic No. 561-11, and the final draft of the "Military Characteristic for a Moderate Accuracy Inertial Navigation System", dated September 1976.

Table B-2. COMPARISON OF ARINC 561-11 AND USAF F^3 STANDARD INS SPECIFICATION

ARINC 561-11	USAF F^3
Comparison of Philosophy	
1. Form-Fit-Function Specification	Same
2. Foster competition	Same
3. Standardize OPS procedure	Same
4. Allow customer options (e.g., subsonic vs. SST)	Same (e.g., F-16 vs. AMST)
5. Interchangeable systems	Interchangeable LRUs
A. Interchangeable battery	Same
Comparison of Requirements	
1. World-wide self-contained NAV	Same
2. System units	
A. NAV Unit: 1 ATR long, tall; 19.5" × 10.6" × 9.4"	INU: near 3/4 ATR; 15.2" × 7.6" × 6.7"
B. Control/Display Unit	CDU, including mode selector (Note: CDU is partially specified)
C. ARINC 404 mount specified	INU mount, including F-16 battery
D. Battery Unit, remote	Aircraft battery recommended
E. Mode Selector	Included in CDU
3. System performance: accuracy must meet FAA Requirements	Same, plus military requirements of 0.8 nm/hr circular error for first hour
4. Environment: FAA environment STD	MIL-E-5400R, Class 2X modified
A. Temperature: -15°C to +71°C Cooling Air: +30°C	-54°C to +95°C +27°C
B. Altitude: -1,000' to +60,000'	-1,500' to +80,350'
C. Ground-speed scaling to 2,000 knots	Velocity ±2,500 fps (1,500 knots)
D. Vertical acceleration: ±2g	±12g
E. Commercial airline environment	Severe military environment
5. NAV Unit faces to the rear	INU faces to the right
A. 180° change, external pins select	Same
6. Power: MIL-STD-704-1959	MIL-STD-704B (wider limits)
A. Single-phase ac, 5 amp breaker	Single-phase ac, 340 VA
B. Separate ac heater, 10 amp breaker	Separate ac heater, 1480 VA
7. Reliability: no MTBF specified, "market-place" pressure for reliability	Same, but may be called out by procuring agency
8. Interface: analog and digital	Digital only (plus HSI for F-16)*
B. Data bus: ARINC 419	MIL-STD-1553A data bus
9. Integrity monitoring	Built-in test
B. No quantitative requirements	95-percent failure detection; 2-percent false failure
10. No tests specified	Quality assurance: references MIL-Q-9858 in "Commentary" for guidance Performance: extensive list; selection left to procuring agency
11. *FAA EMI Requirements*	MIL-STD-461 (tighter requirements)

*Permits change of modules and/or [illegible] adapters to accommodate analog interfaces.

APPENDIX C

REFERENCES

1. Gates, H.P., et al, *Electronics-X: A Study of Military Electronics with Particular Reference to Cost and Reliability*, prepared by the Institute for Defense Analysis for ARPA, January 1974.

2. Genet, R.M., and Meitzler, "Avionics Proliferation, A Life Cycle Cost Perspective", *Proceedings of the Quarterly Meeting,* LCC Task Group of the Joint Services Data Exchange for Inertial Systems, July 1975.

3. *Economic Feasibility of Standardized Avionics,* Logistics Management Institute, Washington, D.C., May 1974.

4. Graham, L.J., and Retterer, B.L., *Airline Procurement Techniques,* Technical Perspective Number 26, ARINC Research Corporation, July 1976.

5. *Assessment of Historical Cost Data Regarding the Effects of Competition on DoD/Military Procurement Costs,* ARINC Research Publication 6411-1555, June 1976.