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FINAL REPORT

AIR FORCE AVIONICS STANDARDIZATION: AN ASSESSMENT OF SYSTEM/SUBSYSTEM STANDARDIZATION OPPORTUNITIES

March 1978

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Prepared for
AERONAUTICAL SYSTEMS DIVISION (ASD)
DEPUTY FOR DEVELOPMENT PLANNING (XR)
WRIGHT-PATTERSON AFB, OHIO 45433
under Contract F09603-76-A-3231-SC02

ARINC RESEARCH CORPORATION

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FOREWORD

This report summarizes ARINC Research activities under Contract F09603-76-A-3231-SC02. The technical activities covered a wide variety of tasks relating to U.S. Air Force standardization activities, including procurement approaches, technical approaches, and an assessment of the potential for consolidating subsystem requirements at a force-wide level. Conclusions and recommendations are offered in each of these areas of investigation.

The investigation reported in this document was requested by the Aeronautical Systems Division, Deputy for Development Planning (Code ASD/XRE); however, it does not necessarily bear the endorsement of the requesting agency.

ACRONYMS AND ABBREVIATIONS

AAA	Anti-Aircraft Artillery
AFLC	Air Force Logistics Command
AFR	Air Force Reserve
AFSATCOM	Air Force Satellite Communications (System)
AFSC	Air Force Systems Command
ALS (MLS)	Advanced (Microwave) Landing System
ALSS	Advanced Location Strike System
AM	Amplitude Modulation
APB	Avionics Planning Baseline
APG	Avionics Planning Guidance
BIT	Built-In Test
BITE	Built-In Test Equipment
CAS	Close Air Support
CEP	Circular Error Probable
COMM	Communications
CRAF	Civil Reserve Air Fleet
DAIS	Digital Avionics Information System
DF	Direction Finder
DME	Distance Measuring Equipment
EAR	Electronically Agile Radar
ECM	Electronic Counter Measure
ECCM	Electronic Counter-Counter Measure
EW	Electromagnetic Warfare
FAC	Forward Air Control(ler)
FEBA	Forward Edge of the Battle Area
FLR	Forward Looking Radar
FM	Frequency Modulation
FOI	Follow-On Interceptor
GATB	General Avionic Test Bed
GBU	Guided Bomb Unit
GCI	Ground Controlled Intercept
GEANS	Gimbaled Electrostatic Aircraft Navigation System
GOR	General Operational Requirement
GPS	Global Positioning System
GPWS	Ground Proximity Warning System

HF	High Frequency
HQ	Headquarters
ICAO	International Civil Aviation Organization
IFF	Identification Friend or Foe
ILS	Instrument Landing System
INS	Inertial Navigation System
IR	Infrared
IRCM	Infrared Counter Measure
JTIDS	Joint Tactical Information Distribution System
LGB	Laser Guided Bomb
LLLTV	Low Light Level Television
LORAN	Long Range Navigation
LRU	Line Replaceable Unit
MAA	Mission Area Analysis
MATE	Modular Automatic Test Equipment
MENS	Mission Element Needs Statement
MFBARS	Multifrequency Multiband Airborne Radio System
MLS	Microwave Landing System
NAV	Navigation
PENAID	Penetration Aid
PLSS	Position Location Strike System
PMD	Program Management Directive
POM	Program Objective Memorandum
RDT&E	Research, Development, Test and Evaluation
RECCE	Reconnaissance
RHAW	Radar Homing and Warning
ROC	Required Operational Capability
RPV	Remotely Piloted Vehicle
RRG	Requirements Review Group
RWR	Radar Warning Receiver
SAM	Surface-to-Air Missile
SAC	Strategic Air Command
SIGINT	Signal Intelligence
SIF	Selective Identification Feature
SLR	Side Looking Radar
SRU	Shop Replaceable Unit
TAC	Tactical Air Command
TACAN	Tactical Air Navigation
TAF	Tactical Air Forces
TDMA	Time Division Multiple Access
TFR	Terrain Following Radar
TISEO	Target Identification System Electro-Optical
TRACALS	Traffic Control Approach and Landing System

UHF	Ultra High Frequency
UHF-DF	Ultra High Frequency - Direction Finder
USAFE	U.S. Air Forces in Europe
USS	USAF Security Service
VOR	Very High Frequency Omnidirectional Range
W/W	WILD WEASEL
WX	Weather

CONTENTS

CONTENTS (continued)

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-SC02. These activities included systems engineering support in developing procedures for assessing avionics standardization candidates and in conducting associated development planning activities prior to acquisition.

A major portion of our efforts resulted in material that was incorporated into official Air Force planning and management documents; therefore, it would not be appropriate to reproduce that material in this report. An overview of the subject matter and methodologies entailed in those activities are described in this chapter. The remainder of the report centers on an assessment of standardization opportunities at the avionics system and subsystem levels. Lower levels of standardization, e.g., module, piece parts, and software, were not addressed in this effort.

1.2 BACKGROUND

The benefits of standardization to equipment users and producers have long been recognized: increased production efficiencies, lower spares requirements, reduced test equipment requirements, increased competitive base, etc. However, efforts at large-scale standardization within military aviation have been generally frustrated. Since requirements for military avionics vary considerably from mission to mission and change frequently as new threats or scenarios are identified, it is not unusual to find several dozen different equipment models performing the same function in the Air Force alone.

The variety of mission requirements is not the only contributor to equipment proliferation. Communication of requirements between planners in the various organizations responsible for the development of equipments has not been reliable. There are now 151 Air Force type/model/series designations for approximately 10,000 aircraft currently in the inventory or planned for introduction into the inventory over the next 15 years.

Equipment requirements for installation or retrofit into these aircraft are developed within the major operating commands and implemented by organizations within Air Force Systems Command (AFSC) or Air Force Logistics Command (AFLC), depending on the inventory status of the aircraft. The lack of awareness from one planner to another has made it difficult to determine if the requirements for one aircraft are similar to another.

There are notable exceptions, of course, and these standardization successes are described in this report; however, only recently has the Air Force established an organizational framework and communication channels for the express purpose of promoting greater avionics standardization. At the Air Staff level, an avionics division with a charter that cuts across mission areas has been established with the Directorate of Development and Acquisition (AF/RDPV). At the implementation level, the Deputy for Development Planning within the Aeronautical Systems Division has established an avionics planning directorate (ASD/XRE)*. The efforts described in this report were performed in support of the following initiatives taken by these two organizations:

- Development of a technical characteristic for a standard moderate-accuracy INS and a procurement strategy for the system
- Development of technical and managerial information necessary for a standard terminal interface for the Joint Tactical Information Distribution System (JTIDS) aircraft installations and other overall design criteria
- Development of avionics planning information for examining other avionics standardization opportunities

The following specific contractual tasks were defined for ARINC Research by ASD/XRE:

- Task I: Provide Engineering Support in Preparation for Future INS Procurement Activities -- Perform the analyses and trade-off studies to support the Air Force INS Single Agency in the preparation of the RFP and source selection tools for use on the initial standard INS procurement. (This effort was limited to support during the RFP preparation phase only.)
- Task II: Provide Engineering Support in Analyzing New Opportunities for Specification Development -- Investigate and analyze Air Force avionics requirements to determine the patterns, the extent of force applications, and the commonality of force needs. Organize data by class of equipment, quantities, timeframe, application, and other pertinent market survey parameters. Develop criteria for weighing

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*ARINC Research's work began for the predecessor organization, the Directorate for Avionics Standardization, and Systems Architecture within the Deputy for Aeronautical Equipment, Code ASD/AESS. This reorganization occurred in October 1977.

standardization opportunities and ranking opportunities as they are identified.

- Task III: Provide Engineering Support to Develop, Refine, and Update Avionics Planning Baseline Document -- *Perform the analyses* and data collection necessary to develop, refine, and update the Avionics Planning Baseline document. This task includes circulating the document to users, data suppliers, and decision-makers to improve and adjust information for achieving the best potential planning tool in identifying standardization opportunities. Investigate the feasibility of computerizing the data contained in the document.

1.3 TECHNICAL APPROACH

Our approach for accomplishing these three tasks was as follows:

- Task I: Provide Engineering Support for Future Procurement Activities -- Efforts under this task were a continuation of our 1976 engineering activities reported in ARINC Research Publication 1902-01-2-1599, *Air Force Avionics Standardization: An Examination of Implementation Alternatives for an Avionics Form, Fit, and Function Procurement Concept*, (Contract F09603-76-A-3231) dated March 1976. Engineering support continued until March 1977, when the INS Single Agency (ASD/AEA) released the Request for Proposal (RFP) to industry.

  During this time we reviewed procurement and engineering management procedures established by current DoD/USAF regulations to determine consistency with commercial precedents for a form, fit, and function (F^3) acquisition concept. Implementation approaches were documented in the form of a draft Program Management Plan (PMP) submitted to ASD/AEA.

- Task II: Provide Engineering Support in Analyzing New Opportunities for Specification Development -- Efforts under this task may be divided into two areas:

  - JTIDS Standardization Opportunities -- The program sponsor considered that the requirements for this equipment warranted special emphasis in examining standardization opportunities for the JTIDS programs. We reported the findings in the form of a draft Integration Management Plan (IMP) for the ASD Associate Program Office of the JTIDS Joint Program Office; that document focuses on the JTIDS standard interface technical issues.

  - Other Standardization Opportunities -- Because of the emphasis accorded to the F^3 INS and JTIDS programs, our examination of other standardization opportunities was limited to a preliminary screening and selected analysis of other avionics standardization opportunities. Our approach to this subtask consisted of the following:

(a) A review of the literature to determine technical, economic, and operational factors that govern the attractiveness of equipments as standardization candidates

(b) Formulation of qualitative and quantitative criteria for screening candidates on the basis of the considerations determined in (a)

(c) Development of a matrix of USAF avionics arrayed by these criteria; the primary source of data for this array was the Avionics Planning Baseline document, which is discussed in detail in the following Task III description

(d) Examination of performance requirements, interface characteristics, and potential applications of several equipments selected from the array developed in (c)

The findings of these efforts form the main body of this report.

- Task III: Provide Engineering Support to Development, Refine, and Update the Avionics Planning Baseline Document -- The Avionics Planning Baseline document was developed in 1976 by ARINC Research for Headquarters USAF/RDPV and Headquarters ASD/AESS under Contract F09603-76-A-3231. It was circulated to a large number of Air Force commands by Headquarters USAF/RDPV, with the request for comments on improving the presentation format, data content, and data accuracy. On the basis of letter response from the Air Force commands and on experience developed through organizing and summarizing these data, the following improvements were made:

  - Substantive corrections were received from 20 Air Force organizations concerning equipment nomenclature, installation/modification schedules, or funding for plans of the 151 model/series aircraft. These corrections were incorporated into the Avionics Planning Baseline document. In those cases where conflicting corrections were identified, an attempt was made to resolve the conflict by telephone or by visits to the cognizant Air Staff Program Element Monitor (PEM).

  - Updated information was entered from the following periodical publications:

    - The Approved Modification Maintenance Program (AMMP)

    - Aircraft Class V Modification Funding Plan

    - Air Force Fifteen-Year Navigation Plan

    - Required Operational Capability (ROC) Status Report

    - Force Structure Projections

•• A section was added to address plans for Remotely Piloted Vehicles (RPVs) with avionics similar to manned aircraft. The AQM/BGM-34C and COMPASS COPE were the initial nominations.

•• A systematic update procedure was developed. The forwarding letter for the revised document designates the Offices of Primary Responsibility (OPRs) for each class of information. Formatted data sheets were also provided to the Air Force commands. It is believed that these steps will greatly improve the quality and consistency of the information for future updates.

•• Estimates were made of the total number of data fields and the types of numerical operations entailed in the data analysis. This information was provided to Headquarters ASD/AESS for use in specifying a computer-based system for the planning data.

The revised Avionics Planning Baseline (U) document, dated 31 May 1977, was provided to Headquarters USAF/RDRV for review and official distribution. This document, classified SECRET, contains the details of methodology and source materials.

1.4 REPORT ORGANIZATION

The remainder of this report is organized into the following four chapters:

- Chapter Two describes the development of the assessment criteria for standardization activities, including broad inferences that can be drawn from these criteria to enhance the USAF posture in avionics standardization.
- Chapter Three provides an overview of current avionics programs and their interrelationships, including standardization initiatives.
- Chapter Four defines the major additional opportunities for increasing the level of standardization and the criteria ranking.
- Chapter Five summarizes the conclusions and recommendations for general initiatives and specific system/subsystem opportunities.

CHAPTER TWO

DEVELOPMENT OF ASSESSMENT CRITERIA FOR STANDARDIZATION OPPORTUNITY

2.1 BACKGROUND

Standardization studies conducted within the defense community over the past few years have recognized that not all avionics systems make good standardization candidates for a number of reasons -- e.g., technical, operational, and economic. Currently, there are no universally accepted, precise quantitative measures for determining the attractiveness of a particular subsystem for standardization; however, the following four general selection criteria that are widely accepted by the R&D community were applied during the USAF F^3 Standard Inertial Navigation System Program:

- Technological -- the technology must be mature.
- Architectural -- the subsystem must perform identifiable, discrete, and separable functions.
- Applicability -- the system specification must be broadly applicable to Air Force weapon system requirements.
- Economic -- a sufficient market must exist for new systems within the period under consideration.

It is realized that these criteria are not a comprehensive set of considerations in selecting standardization candidates; however, a review of USAF avionics against these factors enforces a disciplined examination, providing useful insight into the issues that must be reconciled. The following sections discuss critical aspects of each of these criteria with respect to standardization and develops the application of quantitative and qualitative measures. A few very broad inferences are drawn regarding the characteristics of high-potential standardization candidates, as well as other issues that should be addressed to increase the level of standardization within the aviation community.

2.2 TECHNOLOGICAL CONSIDERATIONS

The application of developments in avionics technology has proceeded rapidly in recent years, therefore making identification of "mature" technologies extremely difficult to base standardization activities. The improvements in packaging, reliability, and performance made possible by large-scale integration (LSI) and microprocessor technology have been especially significant. The full potential of the related metal-oxide semiconductor (MOS) technologies for charge-coupled devices (CCDs) and focal plane arrays has yet to be assessed. Fiber optics technology promises further space and weight reductions in the digital communications buses between sensors and processors.

The degree of technological maturity required depends on the standardization concept adopted. If the approach is to designate a conventional military specification as a standard, then a very high degree of stability is desirable. This environment has prevailed for voice radio designs for many years, and standardization success has been made by all of the military services for these equipments.

Specifications may also be limited to the equipment interfaces (e.g., mechanical, electrical, environmental), thus permitting considerable flexibility for technical innovation within the equipment. The commercial airlines have employed this form of standardization for many years. The commercial standardization approach has resulted in a family of interface standards, or ARINC Characteristics, as they are referred to in the commercial aviation industry. There are several advanced technology avionics within the family of commercial interface standards. For example, equipment being built for the Air Transport Inertial Navigation System (INS) (ARINC Characteristic 561-11) embodies precision-gimbaled and strap-down inertial measurement units, digital computational circuitry, and other components that are products of recent laboratory accomplishments. However, the system characteristic does not *specify* the use of any particular component -- thus substitution is permitted at any time that the manufacturer believes a better component is available. This type of system characteristic has also been called a form, fit, and function (F^3) specification.

Figure 2-1 represents the fundamental relationship between performance, cost, and state of the art. Typically, military equipment designs crowd the current technology asymptote (requiring large investments), as suggested by the point on the solid curve. This investment has been justified on the rationale that a technically superior weapon will provide military superiority; further, that the investment itself pushes the curve to the right, thus advancing the state of the art.

It is widely acknowledged in the R&D aviation community that the commercial (nonavionics) application, rather than military applications, are the significant force in pushing the state of the art in critical technical developments (such as microprocessors and other MOS technologies), and that this rapid movement forces obsolescence on equipments introduced in the traditional five- to seven-year development cycle (Reference 1)*. Therefore, the selection of the relative location for future military point

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*References are listed in Appendix B.

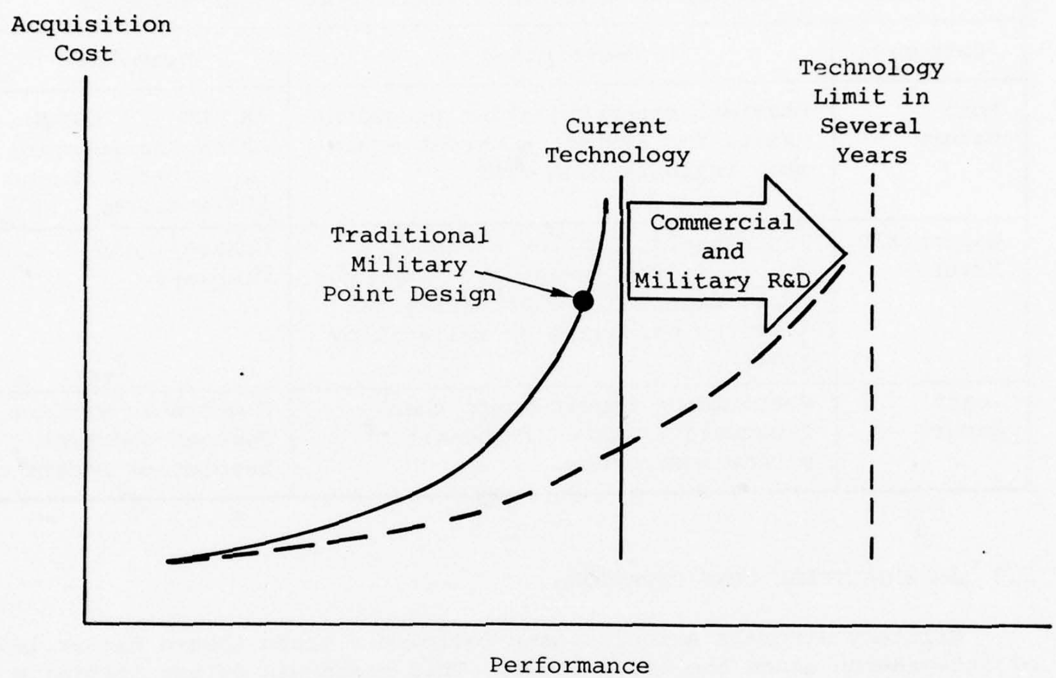

Figure 2-1. DESIGN PHILOSOPHY RELATED TO EXPECTED TECHNOLOGY GROWTH

designs in the cost-performance axis is controversial. A design philosophy that stipulates modest performance requirements but permits growth (through evolutionary software and hardware modifications) as a fallout of other technology improvements appears to be plausible in some equipment. The F^3 interface specification is one approach for providing this flexibility.

One generalization that can be made with respect to technological maturity is that it does *not* characterize mission-specific equipment, such as electronic warfare systems and high resolution radar systems. The dynamics of countermeasures and counter-countermeasures have forced a short-cycle, repetitive requirement for new technological approaches to these systems. The achievement of most of the successful standardization activity in both the military and commercial aviation communities has been for the broad-based communication and navigation equipments. The definition of technological maturity, then, becomes a very illusive entity. It may be characterized as "at least one way to do it" rather than "*the* way to do it". In the candidate screening for standardization potential, ARINC Research attempted to categorize the systems or subsystems into three levels indicative of their maturity, as shown in Table 2-1.

Table 2-1. SCREENING CATEGORIES FOR TECHNOLOGICAL MATURITY		
Category	Description	Examples
Most Mature	Previous standardization precedent exists for system. Current equipment exhibits high MTBF.	AN/ARN-118 TACAN, ARINC Characteristic 578-3, Airborne ILS Receiver
Moderately Mature	Functionally similar equipments exists in the inventory. Improvements expected are primarily related to packaging or reliability growth.	Controls and Displays
Least Mature	Performance requirements change frequently; state-of-the-art pacing equipments.	Electronic Warfare Systems and High Resolution Radars

2.3 ARCHITECTURAL CONSIDERATIONS

Military aircraft avionics have followed a trend toward higher levels of integration since the early 1960s. This trend was driven initially by the desire to refine and improve sensor data by combining related inputs, e.g., doppler with inertial sensors. Earlier reservations toward higher levels of integration were that the number of interfaces required to establish the architecture increased geometrically with the number of subsystems included. In addition, the loss of subsystem integrity increased fault-isolation and maintenance problems.

While fault isolation still remains a problem, the move to all-digital concepts has greatly reduced the interconnectivity design penalties. In addition, the steady increase in the number of components per integrated circuit combined with the production efficiencies permitted by LSI (and potentially VLSI) technology has outpaced analog design concepts in the subsystems' economic attractiveness. The cost of digital integrated circuits has been reduced each year since 1959 by approximately 28 percent per year; production costs for comparable analog circuitry have been reduced but such reductions are less than one-half of this rate (Reference 2.) Thus the transition to all-digital avionics and a digital architectural concept is driven by very powerful economic forces.

Federated multicomputers represent the current state of the art in military-integrated digital avionics systems. The USAF concept, "Digital Avionics Information System (DAIS)", features the MIL-STD-1553A multiplex (MUX) bus with centralized bus control and dual redundant central computers. The DAIS architectural philosophy is software-oriented and partitions software along processing lines (e.g., compute angular velocity, dive angle) rather than functional lines (e.g., navigation, weapon delivery) thus reducing redundancy and attendant high software costs associated with conventional avionic configurations.* The high-speed bus permits the distribution of processing functions and enhances the "graceful" degradation qualities of the system. The DAIS program has given impetus to a number of important military standardization decisions, including MIL-STD-1553A/B, the use of Jovial 73 Higher Order Lanugage, and control/display concepts.

The advent of "computational plenty" provided by advances in microprocessor and platform sensor technology produces an alternative firmware-oriented architectural concept. The distributed inertial sensor technology has been termed Multifunctional Inertial Reference Assembly (MIRA). The combination of MIRA and distributed microprocessors is also a compatible concept with the MIL-STD-1553 MUX bus protocol and provides for a low-cost growth potential in the hardware. The significant effect of the alternative architectural concept is on the design of equipments that are to be both retrofitted on older aircraft and installed as production avionics on new aircraft. If the DAIS-software-federated concept prevails, many of the functions currently performed by individual aircraft sensors could be distributed elsewhere in the architecture. While the distributed concept may be desirable from the viewpoint of software efficiency, it makes sensor standardization difficult during the transitionary phase of current inventory to the newer aircraft. It is difficult to isolate a "separate and discrete function" when the software is partitioned differently among older and newer aircraft. Therefore, for equipments with extensive software, it may be necessary to establish several sets of standards -- one or more for inventory aircraft and one for aircraft currently in the conceptual stage. The use of alternate, firmwave interface front-ends offers an approach to accommodating differences in signaling formats in the transitionary period.

Yet another digital architectural concept has appeared for use in the new transport aircraft avionics designs for delivery to the commercial airlines (Reference 4). This concept features a low-speed digital bus and four information processors -- flight control, flight management, flight warning, and flight augmentation. The digital standard is entitled "Digital Information Transfer Standard (DITS)" and is described in ARINC Characteristic 429. The primary differences between the commercial and military standards are outlined in Appendix A. The important distinction -- and an important consideration for the development of alternative architectural concepts for the military -- is that the output requirements are forced on a few central architectural components rather than the subsidiary sensors. It may well be that some military aircraft architectures will find the economics of such a concept attractive for implementation.

The digital architectural philosophy that ultimately is accepted may be very unforgiving in subsystem design flexibility. The transition from analog to digital should therefore include any other desirable interface

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*There are potential savings in other features of the DAIS implementation concept, not all of which are specifically related to the architectural concept (Reference 3).

changes that would otherwise be deferred in the interest of evolutionary development and backward compatibility. The airlines have elected to make a sharp departure in architectures with the parallel introduction of ARINC Characteristic 600 and ARINC Characteristic 429. The former characteristic permits the use of recent innovations in low-insertion-force connectors and improvements in air-cooling concepts. Similar types of interface changes are currently under consideration by the military services.

Because of the uncertainty in partitioning software concepts and the difficulty in establishing integration approaches for transitionary architectural concepts, the measure of architectural suitability proposed for avionics subsystems encompasses combinations of the software and interconnectivity levels represented in equipment candidates. Table 2-2 presents the categories chosen and representative examples.

Table 2-2. CATEGORIES OF ARCHITECTURAL SUITABILITY

Category	Description	Example
Most Attractive	Low degree of interconnectivity with other avionics subsystems; very low internal software implementations	UHF Radio HF Radio
Moderately Attractive	Low degree of interconnectivity with other avionics subsystems; moderate or higher degrees of software implementations within subsystem	MLS Weather Radar
Least Attractive	High degree of interconnectivity with other avionics subsystems; moderate or higher degrees of software implementation within subsystem	Air Data System Fire Control Radar

2.4 APPLICABILITY

The existing process for retrofit avionics requirements does not lend itself to the identification of large lot standardization opportunities. The need for new avionics systems arises when the changing threat indicates a need for force improvement or when a technological opportunity has been identified for exploitation. These circumstances drive mission-specific solutions and focus attention only on that fraction of the inventory applicable to those missions.

Similarly, during the conceptual design of a military aircraft, tradeoffs are performed to optimize the avionics, propulsion, and airframe components for the expected missions. Aircraft-peculiar avionics requirements may result from such a trade study that do not lend themselves to standardization concepts. For example, the cost-effective approach might be to combine a sophisticated missile avionics system with a relatively inferior airframe/propulsion design. The resulting avionics requirements may well be overspecified for general application.

To a large extent, the degree of applicability for a particular equipment across aircraft types has been determined through an evolutionary implementation process. UHF radios, for example, are installed on every military aircraft, while HF radios are generally installed only on long-range aircraft or those that require communication on command links peculiar to that frequency band. Avionics requirements for planned aircraft usually follow the functional equipment configuration of the aircraft being replaced, with additional capabilities as permitted by the technology base.

The federal budgetary process requires considerable foresight for the introduction of updated avionics systems. New initiatives for the five-year defense plan must be submitted three years in advance. For example, the USAF FY 1980-1984 Planning Objective Memorandum (POM) is reviewed during the winter of 1977 to 1978. The FY 1981-1985 POM will be reviewed the following winter. Requirements identified in the official USAF Required Operational Capability (ROC) or General Operational Capability (GOR) documentation that have been approved and budgeted are therefore "locked in" for as many as eight years. Users are understandably reluctant to change such approved solutions in the interest of standardization alone.

Since it is difficult to interrupt the approved procurement processes, the key to broadening the applicability of avionics systems across multiple aircraft and mission areas appears to be to assure that avionics development initiatives arising in one command are communicated in their early stage to all other potential users. This communication will permit an assessment to be made of the potential for a common solution across commands. Recognition for this communication need gave rise to the Avionics Planning Baseline document, issued twice yearly by HQ USAF/RDPV and HQ ASD/XRE, for wide distribution within the avionics development, logistics, and using communities. Currently, the document is an *ad hoc* planning concept; that is, the burden of recognizing opportunities for consolidation of requirements and individually adjusting schedules, funding plans, and other criteria rests with the document recipient. It is apparent from the adjustments made after only two circulations of this document that the *ad hoc* approach is causing changes that place the Air Force in a more favorable position with respect to standardization; however, the more difficult consolidation cases will likely require the "teeth" of a coordinated Air Staff position. Further, additional data on technical characteristics, reliability, and performance for individual avionics is needed to assess the replacement and the potential for wider applicability of the system or subsystem candidates.

The assessment of multiple-use applicability for the candidates screened in this investigation was based on (1) a review of the ROCs and GORs referenced in the Avionics Planning Baseline document, (2) inferences drawn from historical usage of certain functional capabilities in aircraft types evident in that document, and (3) the examination of technical specifications, when available for selected common systems or subsystems. The three categories used to reflect the relative attractiveness of systems for multiple aircraft use are summarized in Table 2-3. Potential commercial and other joint military applications were assessed by comparison of the existing equipment standards and service usage documentation (References 5 and 6).

Table 2-3. SCREENING CATEGORIES FOR MULTIPLE USAGE APPLICABILITY		
Category	Description	Examples
Most Attractive	Used across multiple mission areas, other military services, and in commercial aircraft.	Radio Altimeter VOR
Moderately Attractive	Used across multiple aircraft types and in other military services.	FLIR Laser Designator
Least Attractive	Used only in aircraft with similar performance characteristics operating in identical threat environment.	Data Link (Wide-Band) ESM

2.5 ECONOMIC CONSIDERATIONS

The final standardization screening criterion considered in this examination is the candidate attractiveness from a market standpoint. Historically, the avionics industry has been interested in developing a product for competitive purposes when the market base reaches several hundred units per year. The larger the requirements -- the more sincere the interest; likewise, the delivery timing is also important. Requirements to be filled many years in the future are a less credible inducement than those for the next few years. However, if a large number of requirements must be filled over a short period of time, then the production base is overextended and in-economies of scale will result. While a "smoothing" of requirements on a force-wide scale is desirable, standardization for achieving large-lot procurements alone is not necessarily the principal, valid economic motivation.

The cost-quantity discounts (frequently referred to as "learning" curves) for military avionics used in estimates prepared by the comptroller's office at the Aeronautical Systems Division (ASD/ACC-X) average a 93 percent slope on a log-linear cumulative progress curve for procurement awards to a single developer.* Larger benefits can be achieved with the price-lowering forces of competition in a sustained multiple-manufacturer market. The economic penalties and benefits that require investigation for developing a comprehensive view of the economic attractiveness should include a market impact survey, as well as estimates of the modification costs and the logistics support costs. A task of this magnitude was not

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*By way of contrast, the "learning" rate for the airframe and engine components employed by that office is 80 percent and 83 percent, respectively. These characteristics of the avionics acquisition process and the other market force implications discussed in this paragraph are reviewed in more detail in ARINC Research Publication 1902-01-2-1599, referred to in Chapter One.

within the scope of this investigation; however, the general trends inferred from current literature suggest that it is the acquisition and modification costs, rather than support costs, that have the greatest potential for cost reduction through standardization. This is attributable to the recent MTBF improvements brought about by solid-state avionics, the reduction in associated support costs made possible by more acceptable Built-In Test Equipment (BITE), and the increasing emphasis on new maintenance concepts (e.g., two-level and RIW). Thus while the equipment demand totals do not represent a complete economic indicator, they are a satisfactory first-order screening criteria.

Table 2-4 presents the categories used in this screening. Demand quantities were developed from the Avionic Planning Baseline document and are based on liberal interpretation of requirements. For example, examination of the equipment in the radio altimeter category revealed many 1960 tube-type sets that surely will be replaced by 1990, if only for the lack of repair parts. Also, the avionics listings for new conceptual aircraft in the document did not include architectural subsystems, such as bus controllers. These requirements can be reasonably inferred since these aircraft will have an all-digital capability.

Table 2-4. SCREENING CATEGORIES FOR ECONOMIC ATTRACTIVENESS

Category	Description	Examples
Most Attractive	Greater than 4,000 USAF installations required before 1990.	Radio Altimeter Controls/ Displays
Moderately Attractive	Between 2,000 to 4,000 USAF installations required before 1990.	Flight Director Computers Bus Controllers
Least Attractive	Less than 2,000 USAF installations required before 1990.	Omega DME

CHAPTER THREE

STATUS OF MAJOR AVIONICS DEVELOPMENTS

3.1 OVERVIEW OF EQUIPMENT DEVELOPMENTS

This section summarizes the major planned or ongoing equipment programs and their orientation in terms of functional requirements. Equipment quantities, installation plans, and funding profiles for these programs are contained in the Avionics Planning Baseline document.

3.1.1 Target-Acquisition Equipments

The PAVE TACK/PAVE SPIKE/PAVE PENNY electro-optical (E-O) sensor programs are the major tactical-target-acquisition programs. PAVE TACK provides a day and night, under-the-weather, high-resolution imaging IR capability for air-to-ground missions. Installations are planned for selected F-111s and F-4s.

The PAVE TACK pod, designated the AN/AVQ-26 E-O Attack and Surveillance Pod, includes the AN/AAQ-9 Infrared Detecting Set and the AN/AVQ-29 Laser Designator and Rangefinder. The AN/AAQ-9 Detecting Set is also used as a part of the RF-4C Quick Strike System and may become a standard high-resolution imaging infrared (I^2R) set for fighter aircraft. The PAVE TACK system provides essentially hemispherical target tracking and permits defensive aircraft maneuvers while a weapon is guided to the target. Because of its high aerodynamic drag and limitation to subsonic speeds, this equipment is considered only an interim solution to the operational requirement of tactical target acquisition. It is oriented more toward reconnaissance, interdiction, and counterair air-to-ground missions. Complementary control and display concepts are under investigation in the single-seat attack and visually coupled systems programs.

PAVE SPIKE provides a capability for enhanced low-light-level target acquisition and precision designation. It is planned for installation on A-10s and a few F-4s for close ground support missions. The PAVE SPIKE pod is designated the AN/AVQ-23. The target designation system contains a 525-line closed-circuit TV, a laser designator/rangefinder, and a gimbaled mirror system controlled by a self-contained IMU, which provides tracking in the forward, lower hemisphere. When installed on the F-4E, the PAVE SPIKE is identified as the AN/ASQ-153 Target Designation System.

PAVE PENNY is a passive laser spot tracker. It is identified as the AN/AAS-35 Laser Search and Tracking System (LSTS). It will be installed on A-7s and A-10s and is being considered for selected F-16s for ground support missions.

The Electronically Agile Radar (EAR) is the only active strategic target-acquisition sensor program. This equipment will provide all-weather identification of large man-made targets and will perform certain navigation tasks. The current design concept is oriented toward providing variants suitable for tactical use.

Other major far-term all-weather target-acquisition programs employ cooperative technical concepts. Emitter time-of-arrival systems and bistatic radar technology form the central programs.

3.1.2 Command, Control, and Communication (C^3)

Digital communication concepts form the central technical approach to tactical C^3 capability deficiencies. JTIDS is planned for installation on nearly all tactical fighters in the force through the 1980s. The automatic broadcast of mission-essential information on a Time Division Multiple Access (TDMA) basis reduces the traffic on voice nets, while ensuring jam resistance and low probability of interception on a theater-wide basis. In addition, the system will provide a local referencing and limited secure-voice capability.

A reliable secure-voice conferencing capability is regarded as a priority operational requirement for air-to-ground and air-to-air missions. The SEEK TASK and HAVE QUICK programs have been instituted as far-term and near-term programs, respectively, to fulfill this requirement.

All strategic missions require over-the-horizon, jam-resistant nets. Traffic levels are not high. The AFSATCOM program partially fulfills this requirement, but the vulnerability of the satellite systems in a global nuclear exchange prevents complete reliability for this approach. Jam-resistant, secure HF systems are needed for prudent redundancy. Equipment size is not as critical for the aircraft employed in strategic missions as it is for tactical fighters. Tactical use of HF occurs principally in missions closely tied to operations with the U.S. Army (close support and reconnaissance).

U.S. Army and NATO interoperability considerations also produce the requirement for VHF-AM/FM transceivers. The Air Force has initiated a program to procure VHF-AM/FM (AN/ARC-186) transceivers for installation and retrofit in most active inventory aircraft.

3.1.3 Positioning/Navigation Equipments

TACAN, LORAN, OMEGA, VOR/ILS, and the Global Positioning System (GPS) are the major current or planned externally referenced systems for general navigation. By 1979 most of the existing TACAN user equipment will be replaced by solid-state avionics (AN/ARN-118). TACAN may be phased out of Air Force operations during the late 1980s or early 1990s with the advent of the NAVSTAR Global Positioning System.

LORAN C/D predictable accuracy performance in providing absolute position will be improved by current efforts for translating information on terrain characteristics (ground conductivity, surface irregularities, and land-water interfaces) into estimates of signal propagation times. However, no major additional avionics procurements for USAF use are planned. VOR will be retained for use in the civil airspace until GPS is declared to be an acceptable alternative. Because VOR user equipments and ILS user equipments are often combined, they may be retained as long as either one of their functions is required.

Air Force interest in OMEGA is limited to user-equipment applications for interim use between the phase out of LORAN A and the introduction of GPS. Specifically, C-130 (the basic and modified mission) aircraft are to be equipped with low-cost OMEGA navigators.

GPS will provide a unified and permanent means for precise navigation anywhere in the world at any time. The need for other general-purpose position-fixing systems will be eliminated. GPS is planned for installation in all USAF aircraft with substantial airframe lifetimes beyond 1985. Receivers for LORAN, TACAN, VOR, high radar altimeters, and possibly some ADF equipment may be removed to provide necessary space.

The use of inertial navigation systems, unlike many other navigation systems, will not be reduced by the introduction of GPS. There is a broad requirement in all missions for a self-contained navigation capability not susceptible to jamming or deception by the enemy. Further, GPS will provide better service (dynamic response, antijam protection, and immunity to signal dropout problems) when integrated with an inertial system than when operating alone. In addition to providing position-determination capabilities, inertial systems serve other functions that are not strictly navigational in the position-determination sense; they also provide, for example, inputs to flight controls, bombing and fire-control systems, and sensors.

Air Force-sponsored, inertial guidance developments include the Standard Precision Navigator based on the Gimbaled Electrostatic Gyro Aircraft Navigator (SPN GEANS) and the Standard Form, Fit, and Function (F^3) Medium Accuracy Navigator.

Development of a Category III landing capability and a reliable collision avoidance system are tied to national and international programs. Funds have been programmed to permit Air Force involvement in the National Microwave Landing System (NMLS) Program. Current Air Force policy is that implementation will not commence until after a standard MLS is accepted as a national and international (ICAO) landing system.

The DoD, in conjunction with the FAA, has been flight-testing the most promising of proposed cooperative CAS systems. The Air Force is investigating complementary noncooperative systems.

3.1.4 Electronic Warfare Equipments

Current survivability enhancement programs emphasize improved threat warning systems. The Radar Warning Receiver (RWR) update includes the installation of the AN/ALR-64 system, which provides for missile launch warning. Further improvements in the RWR include the incorporation of jammer power management under the COMPASS TIE (AN/ALR-69 RWR) program. These RWR systems provide for omnidirectional threat warning from known radio-frequency (RF) controlled weapon systems but do not provide warning in the electro-optical (E-O) and millimeter (mm) wave spectral regions.

Other threat warning improvements include the development of the B-52/F-15 tail warning doppler radars that are capable of detecting high-speed missiles approaching the aircraft. This warning concept could be expanded to include other aspects (rather than only the tail region) and other aircraft platforms.

Several peripheral programs are contributing to the basic technology needed for warning systems. Information presentation and control studies are being conducted at Air Force Avionics Laboratory (AFAL) to provide improved information display concepts to reduce pilot workload. The previously mentioned PAVE PENNY/PAVE TACK/PAVE SPIKE, as well as systems such as COMPASS HAMMER, may result in technological advances that could be adapted to a threat-warning role, such as detection of laser tracking systems.

3.1.5 General Application Trends

For the most part, new avionics requirements are driven by the need to modernize existing equipments for improved reliability, maintainability, and performance. Aircraft avionics suites entering the inventory are generally functional replicas of the aircraft they replace. Thus the force structure planning provides the best insight into the future demand for avionics subsystems.

The composition of the USAF force structure as planned over the next 15 years is shown in Figure 3-1. Little change in the proportion of aircraft types appears in current plans. Aircraft currently in the conceptual stage, such as the Advanced Tactical Fighter (ATF) and the Advanced Tactical Reconnaissance Aircraft (RF-X), constitute less than 20 percent of the total force at the end of this planning period. The basic avionics architecture

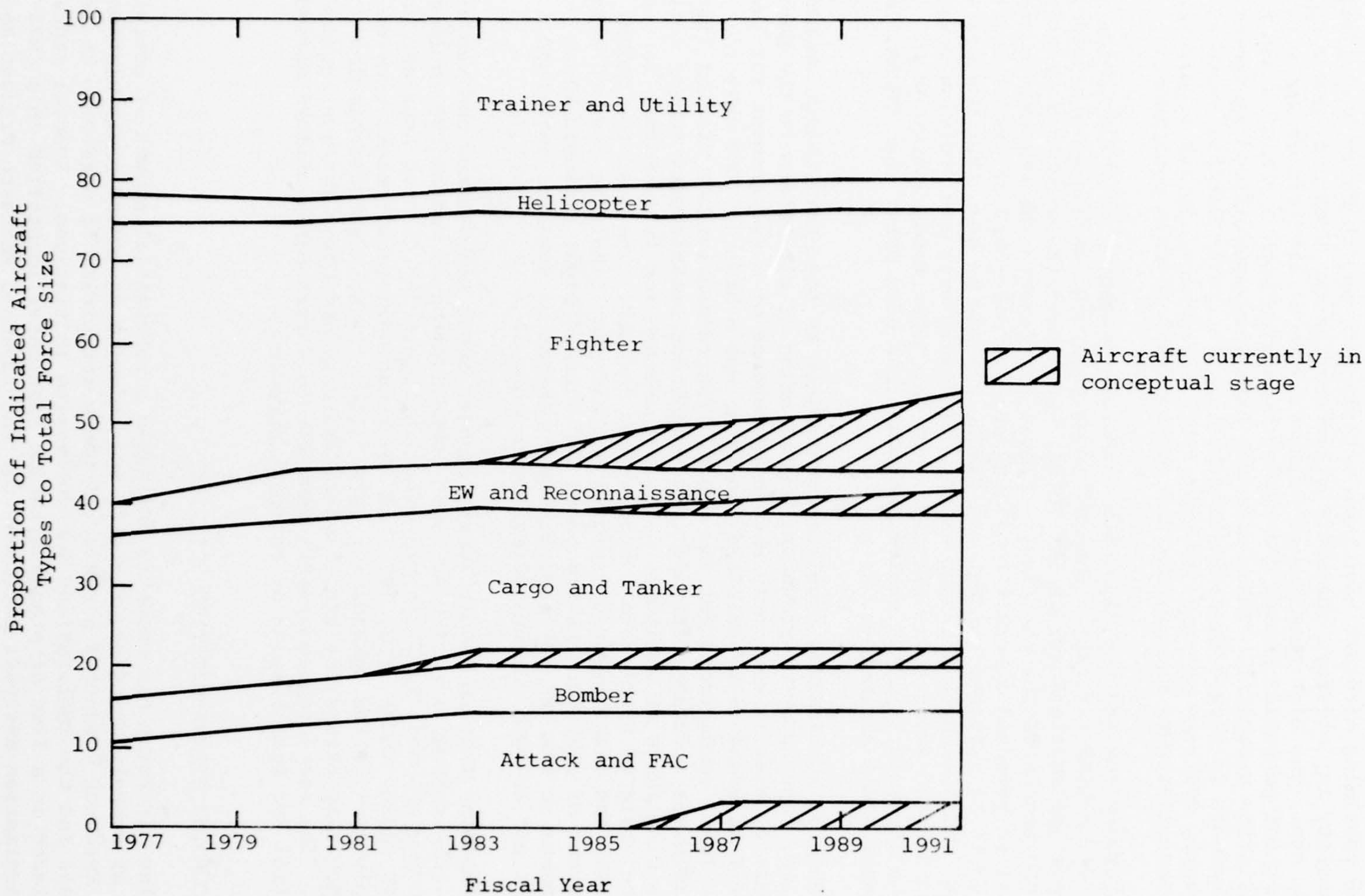

Figure 3-1. PLANNED CHANGES TO FORCE COMPOSITION OF USAF

of the remaining aircraft have been established, and there is very little commonality in interface characteristics such as the data bus, power supplies, etc. The high performance (fighter-attack) aircraft groups provide the highest potential demand for new systems from both a retrofit and new installation viewpoint. These aircraft have very specialized equipment requirements in target acquisition sensors, electronic warfare systems, and weapon delivery systems; however, they share many similar requirements for communications, navigation, and identification (CNI) equipments.

Between now and the mid-1980s, numerous exchanges of CNI avionics are planned for USAF aircraft. Some of these equipment exchanges are used in multiple applications across the force, which have the effect of creating *de facto* standards for the fleet. Figure 3-2 depicts the CNI architecture for twelve selected aircraft totaling just over one-half of the aircraft planned to be retained through the 1980s. It may be seen that UHF and VHF radios, TACAN, and to a lesser extent, IFF equipments are evolving toward standard usage among these aircraft. On the other hand, little or no commonality exists for HF radios, navigational aids other than TACAN, INSs, and radar/radio altimeters.

Several specialized requirements subject to near-term change should be noted. The apparent redundant installation of altimeters in the cargo aircraft classes is currently necessary because of a requirement for low (several thousand feet) autoland functions and a high (10,000 feet to 40,000 feet) requirement for air drops. The reconnaissance mission likewise requires accurate altitude measurement for establishing sensor settings over a wide range of altitudes. The requirement for this extreme in ranges will be obviated by planned installations for GPS. The need for TACAN, VOR, DME, and other related navigational aids may likely be reduced with the advent of GPS. The future needs for line-of-sight communications equipments in the VHF/UHF spectrum is dependent on advances in L-band (JTIDS) and HF-band communications technology.

Assuming that no revolutionary changes occur between now and the mid-1980s, the composition of USAF fleet installations of common CNI equipments (excluding GPS and JTIDS) is presented in Figure 3-3. It is apparent that the UHF radio, TACAN, ILS, IFF, and INS functional requirements provide the multiple application demands for this period. Very low multi-mission applicability exists for DME, high altimeters, and Omega receiver equipments. The remaining equipments demonstrate a reasonably uniform demand potential for installation or retrofit purposes.

3.2 CURRENT STANDARDIZATION ACTIVITY

The Air Force has recently initiated a substantial amount of activity aimed at consolidating requirements and reducing equipment proliferation. ARINC Research conducted a review of these activities to determine their progress and the implications for successive initiatives. Special emphasis was placed on a list of standardization candidates identified in a 1974 standardization analysis performed for the Advanced Research Project Agency (ARPA) (Reference 7).

CNI Equipments	Aircraft											
	C-5	C-130E	C-130H	HC-130HNP	KC-135A/Q	C/NC-141	A-10	F-16	F-15	F-4E/G	RF-4C	FB-111A
Communication												
AN/ARC-164 UHF	X	X	X	X	X	X	X	X	X	X	X	X
AFSATCOM												X
AN/ARC-186 VHF	X	X	X	X			X	X				
AN/ARC-105 HF											X	
AN/ARC-112 HF												X
51S-1B HF				X								
AT-440 HF	X											
618T 1/2 HF		X		X		X						
HF-102 HF			X									
AN/ARC-58 HF					X							
AN/ARC-65 HF					X							
AN/ARC-154 HF							X					
AN/ARC-105 HF											X	
Navigation												
AN/ARN-127 VOR/ILS										X	X	
AN/ARN-14 VOR		X	X									
VOR-101 VOR				X								
806C VOR/LOC	X					X						
51-R6 VOR/LOC					X	X						
AN/ARN-67 ILS		X		X								
800A/C Glideslope	X				X							
51-V4 ILS		X	X		X	X						
AN/ARN-108 ILS							X	X				
AN/ARN-97 TALAR		X	X									
AN/ARA-25 DF				X	X							
AN/ARA-50 DF			X									
ADF-73 DF						X						
DF-203 DF	X											
OA-9797 DF							X	X				
AS-270 DF									X			
AN/UPN-25 Radar Beacon							X	X				
Hoffman TACAN	X											
AN/ARN-118 TACAN		X	X	X	X	X	X	X	X	X	X	X
AN/APN-167 Radar Altimeter											X	
AN/APN-159 Radar Altimeter										X		
AN/APN-155 Radar Altimeter									X			
AN/APN-150 Radar Altimeter		X		X								
AN/APN-133 Radar Altimeter		X	X	X	X							
AN/APN-171 Radar Altimeter		X	X									
AL-101 Radar Altimeter					X							
41003 Radar Altimeter	X											
HG-9025 Radar Altimeter						X						
SCR-718 Radar Altimeter		X			X							
AN/APN-82 Doppler					X							
AN/APN-99 Doppler					X							
AN/APN-147 Doppler		X	X	X								
(Improved) Doppler					X							
C-IV-E INS	X					X						
AN/AJN-16 INS											X	
AN/ASN-56 INS										X		
AN/ASN-63 INS									X			
AN/ASN-109 INS								X				
SKN-2400/3F INS						X	X					
Identification												
AN/APX-101 Transponder						X	X	X				
AN/APX-64 Transponder	X			X	X	X						X
AN/APX-72 Transponder		X	X									
AN/APX-76 Interrogator									X	X	X	
AN/APX-78 Interrogator												X

Figure 3-2. COMPARISON OF SELECTED USAF AIRCRAFT FOR CNI ARCHITECTURES (MID-1980 PROJECTION)

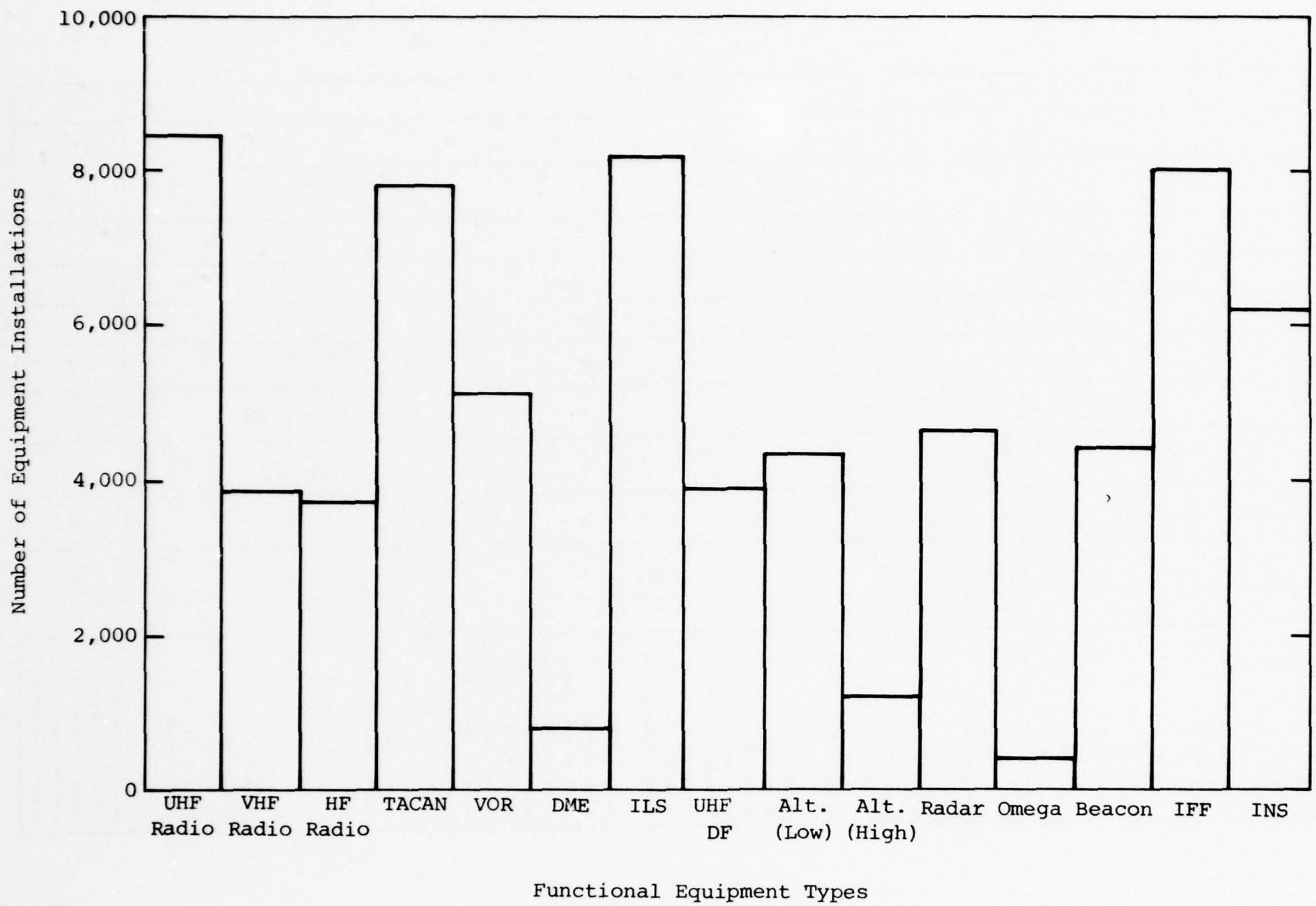

Figure 3-3. GENERAL PURPOSE AVIONICS INSTALLATIONS IN USAF AIRCRAFT (1985)

The ARPA study identified twenty subsystem candidates that appeared attractive for standardization consideration. These candidates were divided into two categories: Category I -- an immediate priority list, which was assessed to have mature technologies with well defined functions; and Category II -- a subsequent priority list, which had wide applicability across the aircraft missions but that required the establishment of a system integration philosophy (e.g., federated or centralized) before substantial progress could be made.

A number of developments have occurred since the formulation of these candidate lists. Table 3-1 lists the candidates suggested in the ARPA effort and the current status indicated by the Avionics Planning Baseline projections. *De facto* standards are being created for most of the Category I candidates through large lot procurements for production installation and retrofit. These are not pure standards from a technical standpoint since each individual procurement must make accommodations for controls, displays, instruments, BITE, and power supplies peculiar to the aircraft type; therefore, the full benefits of standardization have not been achieved. Nevertheless, the existence of equipment with the prescribed performance and a large production base has made the selection of equipments, such as the AN/ARC-164 and the AN/ARN-118, attractive for multiple applications.

Other developments occurring since 1974 further dilute the recommendations of the ARPA effort. The national Microwave Landing System (MLS) has been proposed to replace ILS equipments beginning in the mid-1980s. New solutions for the IFF function have been placed under investigation. "MIRA", the electrostatically suspended, independently referenced technology discussed in Chapter Two, has been proposed to replace most of the gyro-stabilization functions of the sensors. Thus the rationale for major standardization activity for some of these equipments is currently tenuous. Rather, interim standards should be established until the nature of the proposed systems is established. The remaining Category I equipments for which no force-wide acquisition activity was apparent -- Radar Beacon, Radar Altimeters, and UHF-ADF -- remain worthwhile targets for standardization activity.

Figure 3-4 illustrates the proliferation of radar/radio altimeters as a function of time based on the data contained in the Avionics Planning Baseline document. The reduction in a few older equipments, such as the AN/APN-155, reflects the phase-out of the host aircraft. The corresponding increase in "unspecified" equipments demonstrates the lack of specific plans for some retrofit equipment installations and all of the conceptual stage aircraft. Most of the current systems are of older design and will require replacement prior to the end of the period shown in Figure 3-4. Similar profiles exist for the UHF-DF and radar beacon equipments.

Table 3-1. SUMMARY OF USAF ACTIVITY IN SELECTED SUBSYSTEM ACQUISITIONS

1974 Proposed Candidates	Current Status
Category I -- Immediate Priority	
UHF Transceiver	AN/ARC-164 *de facto* standard
VHF Transceiver (FM)	AN/ARC-186 (AM/FM) *de facto* standard
VHF Transceiver (AM)	AN/ARC-186 (AM/FM) *de facto* standard
Radar Beacon	No force-wide acquisition activity
TACAN	AN/ARN-118 *de facto* standard
ILS	AN/ARN-108 and -112 family *de facto* interim standard, future MLS
UHF-ADF	No coordinated ultimate replacement acquisition activity
Radar Altimeter	No coordinated acquisition activity
IFF Transponder IFF Interrogator IFF Reply Evaluator	Mk XII system consisting of AN/APX-101 Transponder and KIT-1A Crypto *de facto* interim standards; some LRUs of the AN/APX-76 Interrogator and KIR-1A Crypto systems are in wide use -- NATO standard under consideration
GYRO Stabilized Heading Reference	No coordinated acquisition activity; MIRA solution proposed
Category II -- Subsequent Priority	
AHRS (Digital)	No force-wide acquisition activity
INS	Standard program awaiting Congressional approval
Doppler	Common strategic program in formulation at ASD
HUD-VSD Symbol Generator	No force-wide acquisition activity
Single Mode Radars	No force-wide acquisition activity
Mission Computer	No force-wide acquisition activity
Flight Director Computer	No force-wide acquisition activity
Digital Air Data System	No force-wide acquisition activity

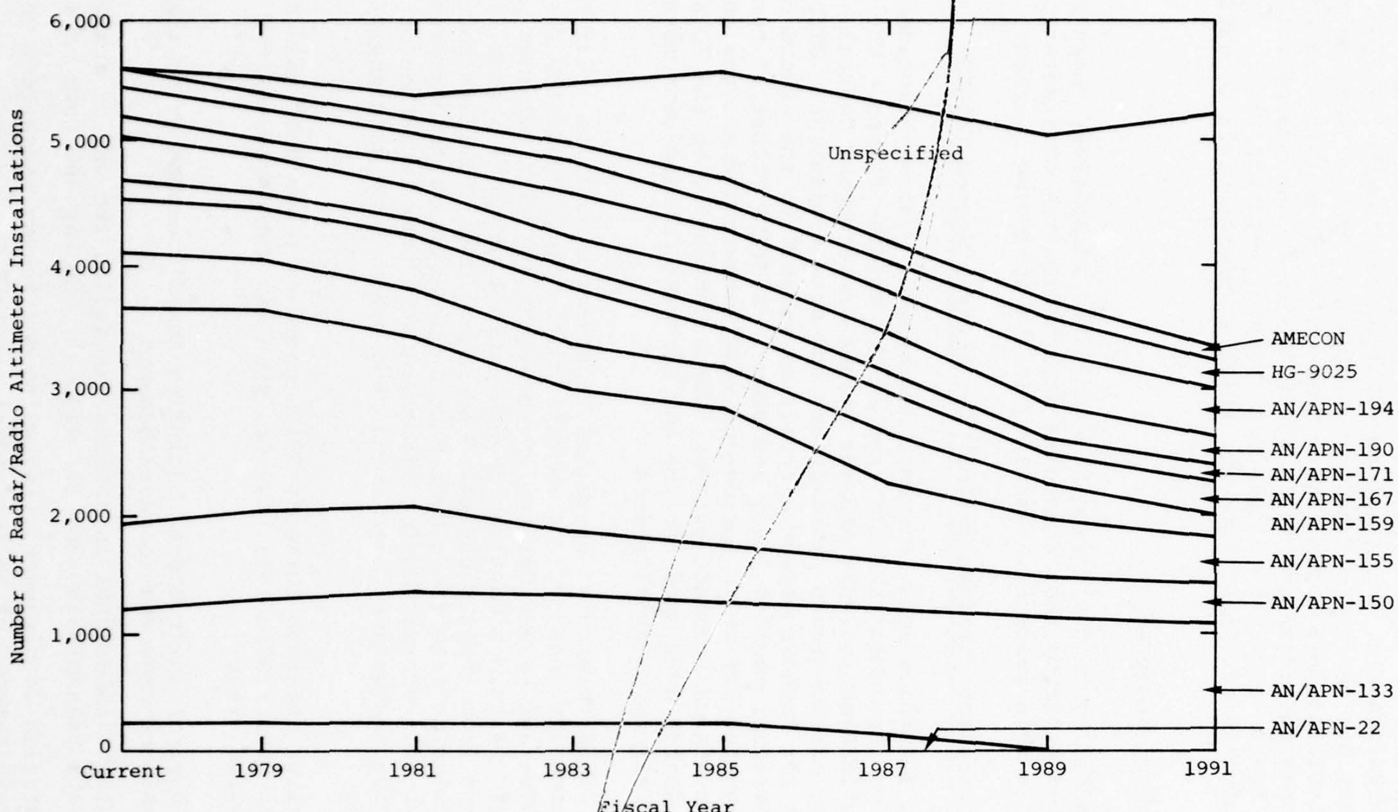

Figure 3-4. ALTIMETER DISTRIBUTION IN USAF AIRCRAFT

The Category II list has had few initiatives. Standardization programs have begun for the doppler and INS (F^3 moderate accuracy and precision-hardened SPN/GEANS). While the integration philosophy referred to in the ARPA effort has yet to be finalized, progress has been made on the bus protocol MIL-STD-1553A/B and software standards. Thus further progress could be made on standardization for those Category II candidates with relatively isolated tasks, e.g., the single mode radars. Weather radars are an example of this equipment type for which standards could be established.

3.3 ADVANCED PROGRAMS

In addition to the foregoing candidates identified, there are a number of advanced programs that emphasize standardization considerations. Opportunities in this group are discussed in the following sections.

3.3.1 Joint Tactical Information Distribution System (JTIDS)

This communications, command, and control system is intended for wide application throughout the U.S. and allied defense forces. The U.S. Air Force application includes AEW/Air Defense Interceptor Control, air-to-air combat and air-to-ground penetration, and attack missions. JTIDS-related equipment for fighter attack aircraft is subject to the severe constraints of size, weight, cooling load, and power. A JTIDS "Class 2" terminal has been designated for which the design requirements address the constraints of fighter-attack aircraft systems, which contrast with the "Class 1" terminal design developed for the AEW/Airborne Command Post mission and large AEW aircraft installations.

The JTIDS terminals, operating together, constitute a jam-resistant, secure communications net (or subnet), with relay capability for extending the net coverage beyond direct line-of-sight and with relative navigation capability. Within a tactical fighter-attack aircraft system, information is gathered from other subsystems and from a crew interface for formatting and transmission into the common net; information is then received from the common net and reformatted for display at the crew interface or for use in the relative navigation calculations and other JTIDS data exploitation processing.

Ideally, the same suite of JTIDS components would be used in all types of fighter-attack aircraft; however, such aircraft types differ widely in the following areas:

- Physical environment, including the dimensions of available space and the crew station arrangements
- Electrical-signal interfaces, including the use of analog or digital data transmission and (if digital) the use and form of a data bus
- Mission requirements, including day-to-day variations in the mission requirements of an individual aircraft

Thus complete standardization of the JTIDS components and functions would be difficult and is not necessarily desirable; therefore, the communication net functions are inherently standardized so that the RF, signal processing, net operating logic, data formatting, coding, and decoding could be accomplished within fully standardized hardware and firmware. This hardware could consist of one or more LRUs described in JTIDS program literature as the "GFE Terminal" and including all of the common data processing functions (such as relative navigation) and presenting a standard interface to other JTIDS components and to the rest of the aircraft avionics subsystems. This would constitute interfaces with a number of subsystems -- each in itself a candidate for standardization. Major subsystems and a preliminary assessment of standardization opportunities are discussed in the following subsections.

JTIDS Antenna System

This system is airframe-dependent and may be shared with other equipments; however, some component standardization appears possible.

JTIDS Mode Control Panel

A standardized (5-3/4 inches wide) console-mounted unit appears possible.

JTIDS Digital Voice

To the extent that planned UHF/VHF secure-voice communications systems can be standardized, this interface should be capable of standardization and embodied within the standard terminal.

JTIDS Data Exploitation Processor/Other Aircraft Subsystems

Because the data exploitation requirements will be aircraft type- and mission-peculiar (as are other aircraft subsystems that need to be interfaced with these subsystems), this interface would be difficult to standardize. One approach is to combine the special processing and interfacing functions into "type peculiar" integration groups.

JTIDS Crew Station Display Generator and Operating Controls

Since the operational requirements and physical arrangement of these subsystems are type- and mission-peculiar, it appears attractive to interface indirectly the controls and displays with the Standardized Terminal via the integration group discussed previously.

TACAN Control Panel

To retain an evolutionary progression through AN/ARN-118 "standardization" into JTIDS integration, the JTIDS terminal would be required to emulate the AN/ARN-118 control panel interface. Thus there is the opportunity to functionally standardize the AN/ARN-118 control panel, subject to the dimensional constraints of the individual fighter-attack aircraft cockpits. Another option is to integrate the TACAN control functions into the JTIDS mode control panel.

IFF Transponder Controls

IFF mode and code controls are not currently being considered for standardization. There is an option for integrating the transponder controls into the JTIDS control panels.

3.3.2 Microwave Landing System

The Microwave Landing System (MLS) is being developed to meet a need for greater flexibility of ground subsystem deployment and flight operational capability than is feasible with the current Instrument Landing System (ILS). Because the objectives are worldwide, civil/military acceptance, and "signals in space" standardization -- the Federal Aviation Agency is responsible for the management of system development in the U.S. and is working with the International Civil Aviation Organization (ICAO), NATO, and other foreign government agencies. The U.S. Army (DARCOM) is responsible for the initial DoD equipment development activity, which is aimed primarily at extending helicopter all-weather operating capabilities into the tactical environment. The Microwave Landing System provides azimuth guidance (to a selected radial), elevation guidance (to a selected glideslope), and range from a DME transponder located near the azimuth transmitter. The airborne segment of the MLS decodes these data directly for display to the pilot and may also provide for the computation of other flight variables that are critical to the landing approach, such as height, sink rate, ground speed, and ground distance to the desired touchdown point. The MLS may also be configured to provide guidance error signals relative to a predetermined complex flight path (e.g., a curved and/or segmented approach, including segmented glideslope angles) and adjusted to control each aircraft's arrival time within precise limits. Joint services approaches for specifying a tactical version of the MLS include the concept of a basic MLS avionics suite that when fully developed would meet all known performance and environmental requirements -- but that would not include any additional functional capabilities. However, an adequate interface for all known functional requirements would be provided so that the basic units can be used as building blocks in more sophisticated, and where necessary, multiple-redundant flight systems. The joint service current approach emphasizes the overriding importance of meeting the goal of worldwide civil and military interoperability between their MLS avionics and all MLS ground installations.

The Advanced Development Program, validating the Joint Tactical Microwave Landing System (JTMLS) concept, implementation, and "militarized" design, is scheduled in the 1978/1979 period. The following critical factors are to be determined: (1) ICAO acceptance of the angle data "signal-in space" format and (2) satisfactory resolution of the channel allocation plan and minimum performance specification for the DME function, which is required as part of the MLS.

3.3.3 NAVSTAR Global Positioning System (GPS)

The NAVSTAR Global Positioning System (GPS) is a multiservice program with the Air Force Space and Missile Systems Organization (SAMSO) providing overall program direction, and is currently in advanced development. Initial production awards will be given to two manufacturers and production will start in 1984. The chosen manufacturer of the final production award will complete deliveries in 1990. Total production will be approximately 24,000 user sets, including 20,000 sets for the Air Force.

GPS is a space-based radio navigation system that provides worldwide, 24-hour, precise, three-dimensional location information to ground and airborne users.

The GPS functional areas include the user system (US) segment, the space system (SS) segment, and the control system (CS) segment. The US segment is composed of assembled hardware and software, referred to as sets. These sets are divided into the following nine functional areas:

- Antenna
- Receiver/Signal Processor
- Data Processor
- Computer Programs
- Control/Display
- Power Supply
- Flexible Modular Interface
- Chassis Components
- Equipment Mounts

The four distinct set configuration concepts for use in the various aircraft types include the following:

- Concept 1: Stand-alone navigator used for GPS hardware exclusively to provide position, velocity, time, and derived navigation parameters, with a minimum of velocity aiding.
- Concept 2: Positioning sensor used for GPS hardware exclusively to provide position, velocity, and time, while exchanging information with the host vehicle subsystems and accepting velocity from the host vehicle subsystems.

- Concept 3: Receiver-sensor that provides input quantities (such as range and range rate) to the host vehicle subsystems and accepts prompt velocity aiding from the host vehicle subsystems.
- Concept 4: Integrated navigation system used for both GPS and host vehicle subsystem inputs for the navigation process. Velocity aiding from the host vehicle subsystems to GPS enhances dynamic tracking and resistance to jamming.

The GPS sets correspond to the following ten categories of host vehicles:

I. Man/Vehicular

II. Helicopter/Army Reconnaissance

III. Unmanned

IV. Fighter/Attack

V. Tactical Transport/Tanker/ASW

VI. Strategic Aircraft

VII. Surface Ships

VIII. Submarine

IX. Trainer/Transport

X. Austere Vehicle

The largest number of USAF sets consist of Type IV (Fighter/Attack) and represent approximately half of the total 10,000 USAF sets. The GPS specification for the Type IV Fighter/Attack set prescribes the following USAF host vehicles -- A-7s, A-10s, F-15s, F-16s, F-111s, AN/ARN-101-equipped F-4Es and RF-4Cs, F-4Gs, and OV-10s. The Type IV set will be designed for integration into the host vehicles. The host vehicle subsystems to be considered in the integration effort are the INS, UMU, Fire Control System, Attitude/Heading Reference System, Air Data System, JTIDS, and TACAN/ILS instrumentation. The integrated navigation system consists of both GPS and host vehicle subsystem hardware; and host vehicle velocity aiding is used for GPS tracking. Jam resistance and accurate GPS operation in high-performance aircraft can only be achieved when GPS is provided with accurate and timely velocity aiding. Any delays in velocity aiding cannot be compensated for during high acceleration conditions; therefore, any delays in translating IMU outputs to a different GPS language cannot be tolerated, and GPS should interface directly with that particular IMU on each type of aircraft. The GPS to IMU interface hardware can be standardized only if all IMU interfaces are the same.

In the interface with the Fire Control System, timeliness of the data is also important, and GPS output should be in the language of that particular Fire Control System to avoid any intermediate translation. Again, the interface can be standardized only if the aircraft data bus is standardized.

3.3.4 SEEK TALK, HAVE QUICK, and Other Conferencing Voice Radio Programs

The SEEK TALK and HAVE QUICK are two related jam-resistant, secure-voice, communications programs. The basic SEEK TALK requirements include jamming immunity, conferencing capability, and full transmission and communications security. The system must be compatible with conventional UHF-AM voice communications operations, including guard-band operation and AN/ARC-164 fall-back capability. The SEEK TALK program is in early advanced development. To provide an early capability, the HAVE QUICK program was begun to demonstrate concept feasibility.

The SEEK TALK jam resistance is provided by pseudonoise (PN) spread-spectrum modulation, frequency hopping, and null-steering antenna arrays. Conferencing capability is achieved by time division multiple access (TDMA) and is pilot-selectable on the basis of network relative range. Security is provided by modified KY-57/58 VINSON hardware.

SEEK TALK implementation will be based on the use of modified AN/ARC-164 hardware and the addition of new technology hardware, including microprocessors, CCD matched filters, LSI shift registers, and state-of-the-art crystal oscillators.

While not designated as a formal joint military program, the voice radio programs of the Army, Navy, and Air Force are subject to close coordinated activity within the office of the Undersecretary of Defense for Research and Engineering -- interservice interoperability being the chief concern. The Army is developing a VHF Single-Channel Ground/Air Radio System (SINCGARS), which will be a frequency-hopping digital system intended for use by all forces communicating with the Army's tactical theater. It is neither interoperable with the UHF SEEK TALK systems nor is it planned to be interoperable in the AN/ARC-186 VHF AM/FM radio or the Navy's AN/ARC-182 UHF-VHF AM/FM radio. A retrofit situation might develop for the latter two military services in the late 1980s with the introduction of SINCGARS. Therefore, early recognition of the retrofit requirements should be established for the developmental systems to permit minimal modification costs. Certain forms of architectural flexibility can be accommodated in the earlier modification programs to minimize the future costs. For example, the Navy has developed a broadband antenna for the AN/ARC-182 that could be used with the other service programs.

3.4 USE OF COMMERCIAL AVIONICS

In the past, the Air Force has procured off-the-shelf avionics that are developed for use in commercial air transports. These equipments were installed in military transports having usage environments similar to commercial profiles. The procurement of the DELCO Carousel IV, built to ARINC Characteristic 561-11 (Air Transport INS) for use in the C-141 and C-5, is a recent example of a *de facto* commercial and military joint standard.

Other similar opportunities for joint usage exist for equipments that do not have exceptional USAF mission requirements. Examples include radar altimeters, weather radars, and navigational aids such as VOR/DME. These equipments have very high, matured reliabilities enabled by the higher flying times provided by commercial flight schedules. Further, the acquisition costs are kept to attractive levels by a competitive market environment. Table 3-2 summarizes ARINC documents of possible interest for military usage.

This is a particularly favorable period for joint USAF/commercial specification development. The commercial airlines are in the process of redrafting most of the ARINC Characteristics to reflect the all-digital environment that will prevail with new air transports, such as the Boeing 7X7/7N7. Most of the changes will be minor with respect to performance; the primary intent is to accommodate the new commercial Digital Information Transfer Standard (DITS) (ARINC Specification 429, Mark 33 DITS) and the new Modular Concept Unit (MCU) packaging specification (ARINC Characteristic 600). However, areas of compromise do exist in the specification of ranges, accuracy, and other technical characteristics. It would be to the joint advantage of both the Air Force and the commercial airlines to attempt such compromises, since each shares about one-half of the total ownership of approximately 4,000 U.S. Air transport inventory aircraft. The mechanism for this endeavor exists; the Air Force has been accorded representation to the Airlines Electronic Engineering Committee (AEEC) through which the ARINC Characteristics are developed.

An additional benefit for developing joint standards in this fashion is the inherent NATO interoperability aspects of commercial standards. The European Airlines Engineering Committee actively participates in AEEC proceedings and generally employs the resulting ARINC Characteristics. From a European viewpoint, the form, fit, and function (F^3) specification approach is economically attractive. European electronic manufacturers have, on an international scale, the opportunity to sell equipments meeting the same characteristic. European airlines can purchase U.S. manufactured airframes with European manufactured electronics, without undergoing a respecification process with the airframe manufacturer. Thus, the technical approach (F^3) could sustain a very healthy competitive environment on an international scale.

Table 3-2. ARINC DOCUMENTS

Number	Subject	Date
Specification 404A	Air Transport Equipment Cases and Racking	15 March 1974
Specification 408A	Air Transport Indicator Cases and Mounting	15 December 1976
Specification 413A	Guidance for Aircraft Electrical Power Utilization and Transient Protection	30 December 1976
Reports 416-10, -11, -12, -13	Abbreviated Test Language for Avionics Systems (ATLAS)	1 May 1975 2 August 1976
Report 419-1	Digital Data System Compendium	1 December 1975
Report 423	Guidance for Design and Use of BITE	29 December 1976
Report 424	Area Navigation System Data Base	16 July 1975
Specification 429	Mark 33 Digital Information Transfer System (DITS)	15 September 1977
Characteristic 547	Airborne VHF Navigation Receiver	22 April 1974
Characteristic 552A	Radio Altimeter	15 March 1972
Characteristic 559A	Mark 2 Airborne HF/SSB	12 February 1976
Characteristic 561-11	Air Transport Inertial Navigation System (INS)	17 January 1975
Characteristic 566A-4	Mark 3 VHF Transceiver	10 June 1975
Characteristic 568-5	Mark 3 Airborne Distance Measuring Equipment	5 February 1976
Characteristic 570	Mark Airborne ADF System	22 March 1971
Characteristic 571-2	Inertial Sensor System (ISS)	15 May 1974
Characteristic 573-7	Aircraft Integrated Data System (AIDS) - Mark 2	2 December 1974
Characteristic 575-3	Mark 3 Subsonic Air Data System (Digital) DADS	15 July 1971
Characteristic 576	Mark 4 Subsonic Air Data System (All Digital Outputs) DADS	10 February 1969
Characteristic 577-1	Audible Warning System	15 March 1975
Characteristic 578-3	Airborne ILS Receiver	24 July 1974
Characteristic 579-1	Airborne VOR Receiver	5 February 1971
Characteristic 580	Mark 1 Omega Navigation System	25 May 1976
Characteristic 582-5	Mark 2 Area Navigation System	11 November 1974
Characteristic 583-1	Mark 13 Area Navigation System	
Characteristic 587-4	Air Transport Time/Frequency Collision Avoidance System	1 December 1973
Characteristic 594-1	Ground Proximity Warning System Supplement 2 Supplement 3	30 January 1976 13 October 1976 2 August 1977
Characteristic 595	Barometric Altitude Rate Computer (BARC)	12 February 1975
Characteristic 596	Mark 2 Airborne Selcal System	20 April 1976
Characteristic 599	Mark 2 Omega Navigation System	28 November 1977
Characteristic 600	Air Transport Avionics Equipment Interfaces	7 December 1977

CHAPTER FOUR

SELECTION OF SYSTEM/SUBSYSTEM CANDIDATES

4.1 SUMMARY OF MAJOR OPPORTUNITIES

A wide variety of equipment suitable for or currently undergoing standardization activity was discussed in Chapter Three. It would be unrealistic to expect the Air Force to pursue standardization for all of these equipments simultaneously; the technical and organizational initiatives required would overwhelm the established channels for consolidating requirements and thus could possibly be counterproductive for the interests of standardization. Some form of prioritization is needed to focus activities on equipments with potential that reflect all aspects of the commonly-accepted standardization criteria -- technological, architectural, applicability, and economic. The following sections present the approach to a prioritization scheme and the findings concerning system/subsystem opportunities.

4.1.1 Ranking Criteria

Each avionics system and subsystem was considered from the viewpoint of the four criteria developed in Chapter Two -- technological, architectural, applicability, and economic. The categories for assigning equipments to each of these criteria is summarized in Table 4-1. The three rankings within each of these categories were assigned a numerical weight of 1, 2, or 3 for the least attractive, moderately attractive, and most attractive, respectively. It should be noted that with the exception of the economic criteria, a subjective determination is required to assign an equipment to a category. Thus the overall attractiveness of a system or subsystem selected is highly sensitive to the division of the categories, as well as the arbitrary weightings assigned. However, more objectivity is achieved by enforcing a disciplined evaluation process, and therefore some insight into the relative attractiveness of standardization opportunities can be gained. The assessments employed in the ranking are the consensus of ARINC Research technical staff assigned to this effort.

Table 4-1. CATEGORIES EMPLOYED FOR RANKING OF SYSTEMS/SUBSYSTEMS

Criteria	Category		
	1. Least Attractive	2. Moderately Attractive	3. Most Attractive
Technological	Performance requirements change frequently; state-of-the-art pacing equipments.	Functionally similar equipments exist in the inventory. Improvements (primarily packaging, reliability, etc.) are expected.	Previous standardization precedent exists. Equipment currently exhibits high MTBF.
Architectural	High degree of interconnectivity with other avionics subsystems; moderate or higher degree of software implementation within subsystem.	Low degree of interconnectivity with other avionics subsystems; moderate or higher degree of software implementation within subsystem.	Low degree of interconnectivity with other avionics subsystems; very low internal software implementation.
Applicability	Used only in aircraft with similar performance characteristics or that operate in identical threat environments.	Used across multiple-aircraft types and in other military services.	Multiple mission and commercial usage.
Economic	Fewer than 2,000 USAF installed requirements indicated before 1990.	Between 2,000 and 4,000 USAF installation requirements indicated before 1990.	Greater than 4,000 USAF installation requirements indicated before 1990.

4.1.2 Ranking Results

Figure 4-1 presents the results of the ranking exercise. Those systems and subsystems for which existing or *de facto* standards have been achieved (such as the AN/ARC-164 and AN/ARN-118) or for substantial standardization activity currently under way (such as in the GPS and JTIDS program) have been omitted from this list. Thus the figure represents major additional standardization opportunities. The ranking is in descending order of the product value of the individual category numerical assignments, and assumes that each criteria is an equally important consideration. Variations on this approach would change the priority order; however, the positions of the highest and lowest candidates would remain relatively unchanged. Additional information for each equipment is discussed in the following subsections.

Radar Altimeter

There are currently about 6,000 radio or radar altimeters in the USAF inventory; of these, about 1,200 have either a high-only capability or a combined high/low capability. The GPS will eliminate the need for the high capability; therefore, the low capability function will be the requirement of interest. An additional requirement of several thousand units could be generated if a decision is made to provide a terrain-following/terrain-avoidance (TF/TA) capability to the F-15, F-16, and A-10 aircraft. Many older tube types still existing in the fleet may need replacement purely from a part-availability standpoint.

VOR, VOR/ILS

The VOR/ILS functions are combined in some retrofit equipments. Those with solid-state ILS or with new-generation MLS would require a separation of functions. In addition, the requirement for VOR may be eliminated by GPS; however, most aircraft equipped for VOR is not scheduled for GPS installation until the end of the 1980s -- thus a substantial continuing requirement still exists.

HF/SSB RADIO

HF radios are the principal beyond-line-of-sight communications capability for all military services and commercial aircraft. Interoperability requirements and the need for additional power and jam resistance dictate the need for new equipments in both the tactical and strategic environments.

UHF/DF and Radar Beacon

These equipments fall into identical evaluation categories and are not considered high cost items; however, they are currently proliferated in the force. A replacement opportunity exists during the extensive communications retrofit activity scheduled between now and the mid-1980s.

Avionics System/Subsystem	Ranking Criteria: Technological	Architectural	Applicability	Economic	Comments
Radar Altimeter (Low)	Most Attractive	Most Attractive	Most Attractive	Most Attractive	Currently, 12 USAF equipment types consist of 6,000 installations.
VOR, VOR/ILS	Most Attractive	Most Attractive	Most Attractive	Most Attractive	
AF/SSB Radio	Most Attractive	Most Attractive	Most Attractive	Moderately Attractive	Currently, 9 USAF equipment types consist of 3,000 installations.
Multipurpose Controls/Displays	Moderately Attractive	Moderately Attractive	Most Attractive	Most Attractive	JTIDS/GPS installations are the driving requirements.
Weather Radar	Most Attractive	Moderately Attractive	Most Attractive	Moderately Attractive	New commercial specifications are under development.
UHF/DF	Most Attractive	Most Attractive	Most Attractive	Least Attractive	
Radar Beacon	Most Attractive	Most Attractive	Most Attractive	Least Attractive	
DME	Most Attractive	Most Attractive	Most Attractive	Least Attractive	
GPWS	Most Attractive	Most Attractive	Moderately Attractive	Moderately Attractive	
Omega Receiver	Most Attractive	Most Attractive	Moderately Attractive	Moderately Attractive	Will ultimately be replaced by GPS.
Bus Controllers/RTUs	Moderately Attractive	Moderately Attractive	Moderately Attractive	Moderately Attractive	Requirements are primarily for aircraft now in conceptual stage.
Air Data Systems	Moderately Attractive	Least Attractive	Moderately Attractive	Most Attractive	
EW Systems	Least Attractive	Least Attractive	Moderately Attractive	Most Attractive	Software flexibility approaches are being investigated.
E-O Systems	Least Attractive	Least Attractive	Moderately Attractive	Most Attractive	Low-drag, low-cost replacements for "PAVE" programs represent the major requirements.
Acquisition Radars	Least Attractive	Least Attractive	Moderately Attractive	Most Attractive	Some modularity standardization concepts are under study.
Flight Director Computer	Moderately Attractive	Least Attractive	Moderately Attractive	Moderately Attractive	
Mission Computer	Least Attractive	Least Attractive	Least Attractive	Moderately Attractive	
Automatic Flight Control System	Least Attractive	Least Attractive	Least Attractive	Moderately Attractive	
Data Link (Wideband)	Least Attractive	Least Attractive	Least Attractive	Least Attractive	
ESM Systems	Least Attractive	Least Attractive	Least Attractive	Least Attractive	

Legend

System/Subsystem Rankings:

Most Attractive (shaded) | Moderately Attractive (hatched) | Least Attractive (blank)

Figure 4-1. RANKING OF MAJOR SYSTEM/SUBSYSTEM STANDARDIZATION OPPORTUNITIES

Multipurpose Controls/Displays

Many new capabilities are being added to military aircraft where cockpit instrumentation space is not available. In addition to GPS and JTIDS, there are new electronic warfare warning receivers, electronic optical sensor systems, and high resolution radar systems -- all with requirements for controls and displays. Standardized multipurpose units will be needed to achieve a tolerable situation from the standpoint of integration difficulty as well as operator workload.

Weather Radar

Requirements exist for replacing these equipments in several USAF cargo/tanker categories. In addition, the commercial airlines are re-specifying their current standard to provide additional discrimination capability (e.g., rain vs. sleet).

DME/GPWS/Omega

The number of new equipments required by the USAF for these categories is not large; however, the effort required to standardize this small population would be almost trivial. An existing military or commercial candidate could be nominated for this purpose.

Bus Controllers and Remote Transmitting Units (RTSs)

These equipments are architecturally dependent; however, for those new aircraft with architectures to be defined or for extensive retrofit applications, such as planned for the F-111H, it would be possible to establish a single standard.

Air Data Systems and Automatic Flight Control Systems

Well-defined requirements now exist; however, the interconnectivity differs widely between aircraft classes -- thus several "standards" may be required.

EW Systems and Acquisition Radars

These are high-cost systems that deserve standardization attention; however, the technology is fluid and the architectural interconnectivity is high. The systems require stabilization inputs from inertial sensors, fire-control system components, and other high software-implemented equipments. Modularity and other approaches short of full-system standardization are being investigated.

Flight Director and Mission Computers

Requirements for these subsystems are airframe-dependent, and the partitioning of these functions in future aircraft is very uncertain.

Wide-Band Data Links and Electronic Support Measures (ESM) Systems

The use of these equipments is confined to ferret or reconnaissance missions. While typically high-acquisition cost items, the numbers procured are generally limited so as not to warrant single-military service standardization consideration (especially in view of the technology dependence); however, the limited procurement lot sizes for single-military service usage suggest that these equipments be examined for joint-service standardization activity.

4.2 TECHNICAL ISSUES IN SELECTED STANDARDIZATION OPPORTUNITIES

The candidates developed in the preceding section require additional examination from all aspects of the screening criteria employed in their identification. For example, a completely rigorous analysis of a candidate's economic attractiveness would include a life-cycle-cost (LCC) evaluation of the potential standard compared with individual equipment approaches. This degree of resolution was beyond the scope of the study as defined by the Air Force sponsor; however, we were able to collect a data base of technical information that provides additional insight into the issues included in the standardization of the higher-priority candidates in Figure 4-1. This technical information is organized into three groups: (1) potential joint standards for USAF and commercial usage, (2) USAF and other military service standardization candidates, and (3) integrated multi-subsystem possibilities.

4.2.1 Potential Joint Standards for USAF and Commercial Usage

Four equipments that appear especially attractive for joint USAF and commercial standardization activity are the weather radar, the radio altimeter, the HF radio, and the VOR. These equipments are widely used in the cargo/tanker classes, have no apparent standardization initiatives under way, and have reasonably stable performance requirements. The following subsections present a brief technical description of the commercial ARINC Characteristics and, if applicable, a representative military counterpart.

Radio Altimeter

ARINC Characteristic 552-A describes the analog interface version of the commercial low-altitude altimeter. Efforts are under way to develop a new specification for meeting the new signal and sizing constraints imposed by ARINC Characteristics 429 and 600, respectively. This specification will not be finalized until approved by the AEEC; however, certain characteristics can be estimated with confidence from a "strawman" specification currently in circulation within the industry.

The commercial altimeter R/T unit will be mounted in a standard NIC/ARINC-600-sized aircraft rack provided with cooling air. The R/T unit will consist of a 3 MCU box, 3.56 inches × 12.52 inches × 7.62 inches (in the airlines' new dimension system, 1 MCU ≈ 1/8 ATR). The power requirement is 115 Vac, single-phase, 400 cycle. The connectors will be low-insertion force per ARINC Characteristic 600. The cooling is specified by forced air. Accuracies from 0 to 500 feet altitude are 1.5 feet or ± 2 percent of the indicated altitude, whichever is greater, of the indicated altitude.

The AN/APN-194, currently installed on the A-7, is representative of a modern military altimeter. It was recently designed as a direct replacement for the AN/APN-14 (hybrid analog/digital system). The AN/APN-194 is hard-mounted, conduction-cooled, and measures externally 3.83 inches × 8.21 inches × 3.125 inches. The indicators are of different dimensions than the commercial specification.

All the TNC and SMA electrical connectors of the AN/APN-194 are installed according to MIL-E-5400. The power supply requires 115 Vac, single phase, 28 Vdc and 5 Vdc. The specified accuracy is 3 feet or 4 percent of the indicated altitude, whichever is greater.

In summary, while the performance characteristics of the commercial "strawman" meet or exceed those stipulated by the military specification, the following primary differences in interface requirements must be accomplished if a joint specification is to be developed:

(a) Provide for either DITS or 1553A signalling format options

(b) Provide for choice of connectors (MIL-E-5400)

(c) Provide for alternate power supplies

(d) Provide the capability to operate reliably with only natural convective air flow through the unit

The earlier (analog) version of the specification may be attractive for retrofit purposes in the older, wide-bodied aircraft.

VHF Omnidirectional Range (VOR)

VOR equipments are used in civil air space. ARINC Characteristic 579-1 describes the commercial specification for analog systems.

Currently, the 51R-6 VOR/localizer is aboard both the KC-135 and C-141 aircraft. It was chosen for the following comparison because it exemplifies a typical military VOR for use in wide-bodied aircraft. The following is a comparison of the 51R-6 and ARINC Characteristic 579-1.

	51R-6	ARINC Characteristic 579-1
Volume	700 in^3	340 in^3
Weight	19 pounds	8 to 14 pounds
Frequency Range	108 to 117.96 MHz	108 to 117.95 MHz
Channel Spacing	100 kHz	50 kHz
Selectivity	22 kHz	17 kHz (-60 dB)
Cooling	Convection	Convection

The two systems appear to be compatible with the exception of the channel spacing. (The 50 MHz spacing has since become the standard for commercial and military operations.) The 51R-6 is approximately twice the size of ARINC Characteristic 579-1; however, the 51R-6 does include the localizer function. Thus the use of the commercial standard equipment is dependent on the provision for the localizer function elsewhere in the avionics architecture.

HF Radios

ARINC Characteristic 559A describes the commercial Mk 2 Airborne HF SSB/AM System. A representative USAF HF radio is the AN/ARC-112, currently installed in the FB-111A. The major similarities and differences between the two are as follows:

	AN/ARC-112	ARINC Characteristic 559A
Size (in inches)	R/T unit 10.0 × 11.7 × 16.0 Mount 6.3 × 12.8 × 18.4 Amp/PS 8.5 × 9.2 × 17.8 Mount 6.5 × 9.9 × 20.2 Control 2.6 × 5.8 × 5.0	R/T unit 3/4 ATR short (6 MCU) (7.5 × 12.52 × 7.62) Control 2.6 × 5.8 × (as required)
Power	115 Vac 3ϕ, 400 Hz	115 Vac, 3ϕ, 400 Hz
Cooling	Varies by aircraft	Type A (ARINC Characteristic 404A)
Connectors	MIL-E-5400	ARINC Characteristic 600 (Low Insertion Force)
Power Out	400 watts (PEP)	200 watts (PEP)
Frequency	2 to 30 MHz	2.8 to 24 MHz
Channel Spacing	1 kHz	1 kHz
Modulation	AM double sideband/SSB full carrier, or SSB U or L suppressed carrier	AM double sideband/SSB full carrier, or SSB U or L suppressed carrier

Although both systems operate in the HF band, the AN/ARC-112 covers a larger frequency range. Current Air Force requirements include the frequencies of 2 to 2.4 MHz and 24 to 30 MHz, in addition to the frequencies stated in ARINC Characteristic 559A. Both systems exhibit channel spacing of 1 kHz, although ARINC Characteristic 559A states that current military HF radios must exhibit the capability of operating at 0.1 kHz spacing. Some new radios do actually provide for 100-Hz channel spacing. Even though the decreased space between channels produces a 280,000 channel capability, the full capability cannot be realized because of limited selectivity. Aircraft in the same vicinity cannot operate on adjacent channels at 100 Hz spacing or even at 1 kHz spacing. Currently, the airlines are proposing the use of 3-kHz channel spacing.

The power output of the AN/ARC-112 is 400 watts PEP. ARINC Characteristic 559A requires only a 200-watt PEP output. There has been some discussion in the commercial airlines community concerning the HF transmitter output. The older solid-state RF amplifier was limited to the lower power output; therefore, the specification was set at 200 watts PEP. Some users now contend that 200 watts is inadequate to provide reliable communication in difficult communication situations, although a new upper limit is still undecided. Current technology can provide the 400-watt capability by solid-state amplifiers and is no longer the limiting factor. With no hardware factor to limit performance, a new ARINC Characteristic may provide for a 400-watt output.

The transmitter/receiver bandwidth for both systems is 2,700 Hz (300 to 3,000 Hz). Future military requirements for an HF radio include a wide-band audio capability. The Air Force is also considering other features such as secure voice, selective call, all call, automatic frequency selection, frequency scanning, and remote automatic system control. The final decision on these will follow a reassessment of current systems by military users.

In summary, military requirements for HF radios are considerably more stringent for commercial aircraft use. However, it may be possible to designate a less stringent military and commercial standard for aircraft operations in "benign" (non-penetrating) environments. The trade-offs between increased capability costs and savings in quantity discounts for larger lot standardization should be performed following a survey of principal USAF user requirements.

Weather Radar

Weather avoidance radar systems are employed on military and commercial transport aircraft. The primary purpose of the weather radar is weather detection, ranging, and analysis. A secondary function is provided on some designs in ground mapping for facilitating navigation. The systems operate either in the X-Band (at 9,345 or 9,375 MHz) or C-Band (at 5,400 MHz). Sensitivity time control (STC) (to normalize reflection amplitudes with range) and iso-echo-contour circuits (to outline intense, beam-filling rainfall) are conventionally employed to facilitate weather analysis.

The Airlines Electronic Engineering Committee (AEEC) is in the process of developing Characteristic 708 for a reliable, low-cost, lightweight, airborne weather radar that takes advantage of recent technical advances. A significant feature of the Characteristic at this stage of development is that it does not ask for backward compatibility to earlier weather radars but anticipates forward compatibility with fully digital avionics interfaces. All digital interfaces are to meet ARINC Characteristic 429 Mark 33 DITS requirements, except the data input to the display will be per draft ARINC Characteristic 453 (high speed data bus). ARINC Characteristic 453, in the preparation process, will state the requirements for a new standard 1 MHz data bus, similar to MIL-STD-1553A. The differences will be in word format only. The Characteristic will specify a 1606-bit, gapless data block, which includes 3 synchronization bits at the beginning and end of each block.

The attitude stabilization control signals will also be in DITS format, which may require an external analog-to-digital converter in some aircraft. System power will be from 115 Vac, 400 Hz, single phase, and the maximum Transmitter-Receiver (T-R) unit shall not exceed 200 watts. The T-R unit will receive forced air cooling from the host platform. Interchangeability shall be in accordance with the New Installation Concept (NIC) ARINC Specification 600. The T-R size should not exceed 8 MCU (equivalent to 1 ATR) and weight should be 20 to 30 pounds. The new weather radar characteristic will probably allow the option for displaying the data on a Multi-Function Display (MFD) system.

The military have used the AN/APN-59 Radar Navigation Set for almost 20 years. In addition to navigation and weather avoidance, the system provides radar beacon operation (interrogation at 9,375 MHz and reception at 9,310 MHz). The AN/APN-59 is used on the C-130s, C/KC-135s, C-141s, and B-52s. Efforts have begun to replace the AN/APN-59 with the AN/APQ-122 Radar Set. This provides dual frequency operation, replacing the AN/APN-59 functions and adding Ka-Band capability for short-range, weather-penetration, and high-resolution navigation, such as required for the Adverse Weather Aerial Delivery System (AWADS).

4.2.2 USAF/Other Military Service Standardization

The equipments discussed previously are additional candidates for a separate USAF or joint military standardization activity. The size, cooling, and performance allowances permitted by transport aircraft types are very liberal; therefore, additional standards may be required to accommodate fighter-attack classes. The technical data for the military systems covered in the previous sections adequately describe these considerations. This discussion incorporates two additional common avionics unique to the military -- the UHF/DF and radar beacon.

The UHF/DF system candidates and radar beacon are used for rendezvous and general navigation purposes in all military services. Approximately 4,000 systems of each are installed in USAF aircraft. The following subsections discuss pertinent technical characteristics of representative systems.

UHF/DF

Two recent equipments that might serve as models for standardization are the OA-8639/ARD system employed in the F-15, and the ARA-50 system to be installed in the EF-111A. The basic amplifier relay units in each case measure approximately 5" × 5" × 7", weigh about 5-1/2 pounds, and the frequency ranges between 225 to 400 MHz. Other characteristics of these equipments include the following:

	AN/ARA-50	OA-8639/ARD
Altitude	Up to 70,000 feet	Up to 70,000 feet
Accuracy	Less than ±5°	Less than 2.5° rms
Overshoot	Less than 10°	Less than 5°
Response Speed	60° per second average	360° per second minimum
Sensitivity	10 dB for 30 percent modulation at 1,000 cps	5 microvolts for 30 percent modulation at 1,000 cps
Power Supplies	Limitation of 23.4 to 28.6 volts	±0.5 dc generated from aircraft at 28 Vdc
Other	--	BIT module generates 45-degree bearing self-test

Radar Beacon

Airborne radar beacons extend the radar range of cooperating aircraft and ground radars to facilitate identification and rendezvous requirements. These transponders reply to single-pulse or double-pulse (depending on the equipment) interrogations at the proper frequency with a single-pulse or double-pulse transmission.

A representative current technology of the X-Band transponder is the AN/UPN-25, installed on the A-10A and F-4E (it is designated the SST-181X on the F-4E). The AN/UPN-25 accepts single-pulse interrogations at 9,375 MHz for pulse widths from 0.25 to 5 μsec. After a 1 μsec transponder delay, it replies with a single or double pulse (depending on the control setting) at 9,310 MHz, providing up to 2,600 pulses per second at a peak power of 400 watts. Mini-code positions are available for the double-pulse reply, ranging the code spacing from 48.8 μs to 146.4 μs. The reply pulse width is 0.3 μsec.

The AN/UPN-25 system consists of the RT-853/UPN-25 Radio Receiver-Transmitter (also referred to as the encoder-transponder), the AS-2038/UPN antenna, and a cockpit control panel. The encoder/transponder measures 3.4" wide × 2.9" high × 4" long and weighs 3.3 pounds.

4.2.3 Integrated Multi-Subsystem Possibilities

Multipurpose Controls/Displays

A number of programs have been initiated to combine control and display functions of several systems into common hardware on a time-shared basis. One example is the Multiple Sensor Display Group (MSDG) on the F-4E, which utilizes the Digital Scan Converter Group (DSCG) for displaying fire-control radar data (AN/APQ-120E), data from on-board sensors (e.g., AN/ASQ-153 PAVE SPIKE), or data from an E-O weapon (e.g., AGM-65 Maverick).

A Modular Digital Scan Converter (MDSC) system has been flight-tested and is being considered as a replacement for earlier analog scan converters, which accept radar and E-O data. The MDSC uses reprogrammable software and works with any radar system. Candidate aircraft are the A-7, RF-4C, F-111D, and F-5. On newer aircraft (such as the F-15A), a multifunction display group (e.g., F-15 VSD) is installed on a forward-fit basis. However, since the display "menu" is limited, some changes will be required when new systems, such as the JTIDS and GPS, are added.

Efforts to standardize multipurpose controls and displays have been under way in the USAF for several years. A controls and display working group has been established at ASD to coordinate this activity.

CNPI

The Communications, Navigation, and Positioning Integration (CNPI) study began in 1977. The four tactical fighter aircraft included in this study are the F-15A, F-16A, Block 48 ARN-101-equipped F-4E, and F-111F. The CNPI goal for small tactical aircraft is to reduce duplication of functions and hardware between JTIDS and GPS and to arrive at an optimum technical and cost integration solution. The initial phase considers technical and cost advantages from an analytic viewpoint. A subsequent phase to develop initial hardware design of the optimum functional integration approach is expected.

MFBARS/ICNI

The Multifunction-Multiband Airborne Radio System (MFBARS) concept is a standardized architecture for communication, navigation, and identification (CNI) at a very high level of integration. Systems operating in the 2 to 2,000 MHz are under consideration. Related activity in the Integrated Communications, Navigation, and Identification (ICNI) Systems is under way at the Naval Air Development Center. These programs seek to identify elements within the architecture that can service more than one function. Opportunities for size and weight reduction, cost reduction, and improved properties of system degradation are under investigation to provide alternatives for aircraft installation and retrofit in the mid- to late 1980s.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

This chapter presents the conclusions, recommendations, and related observations resulting from the conduct of this investigation. The findings are divided into two broad categories -- general standardization considerations and specific system/subsystem opportunities.

5.1 GENERAL STANDARDIZATION CONSIDERATIONS

5.1.1 Technology Transfer

A "mature technology" is a difficult entity to define in the current avionics development environment. While many of the performance aspects (range, accuracy, and other requirements) for common avionics subsystems appear to have stabilized, continuing dramatic improvements in packaging, reliability, and maintainability are resulting from the introduction of LSI and VLSI. The full design impact of the rapidly changing and related technologies of microprocessors and focal point arrays is not understood. Fiber optic implementation and other bus-oriented developments are facilitating the feasibility for a selection of integration and architectural concepts. Most of these developments appear to be driven by commercial, nonavionic applications for other than purely avionic use.

Recommendation

The Air Force should make a projection of critical avionics technologies for determining the potential additional improvements that could be utilized in major subsystem classes. The resulting projection should be formulated into design guidance for equipment developers and manufacturers so that growth potential for standard equipments may be understood and accommodated in the early design phase. Future standards should avoid the specification of technology-specific components, e.g., specific microprocessors and detector arrays.

5.1.2 Transition of Avionics Architecture

The transition from analog to digital avionics is proceeding under very strong economic forces. The price of digital integrated circuits has been declining at a rapid rate since the early 1960s. Analog components, while experiencing some modest cost reductions in linear-integrated circuit technology, do not keep the economic pace for similar functional capabilities. Size, weight, power consumption, and reliability considerations similarly favor digital over analog design concepts.

These benefits, and other attractive architectural innovations, such as low-insertion force connectors, improved cooling concepts and fiber optics communications, are difficult to introduce in an evolutionary manner. The military services will very likely be forced to give up backward compatibility concepts to accommodate the range of analog retrofit applications (e.g., F-111A), digital retrofit applications (e.g., F-15A), and hybrid analog/digital aircraft retrofits (e.g., AN/ARN-101-equipped F-4s). Extensive use of firmware in the avionics subsystems offer a technical alternative to accommodating the variety of digital signal protocols in recently produced aircraft.

Recommendation

The Air Force should provide a choice of analog or digital standards for ongoing modification programs, particularly those modifications that primarily upgrade general reliability and maintainability of equipments. Modification programs that introduce a new capability often affect a number of previously installed avionics. Therefore, options exist for replacing an entire suite of avionics with new digital systems and necessary bus architectural elements or introducing multiple interface units. These cases must be evaluated individually from an economic standpoint that consider total lifetime of the airframe and the payback in savings from future modifications expected to occur during that lifetime. The architectural standard should anticipate the increased usage of firmware within the avionics subsystems.

5.1.3 The Requirements Process

Identifying the future applicability for standard avionics subsystems was the most difficult of the analysis tasks. The military requirements and budgeting process does not lend itself to the timely capitalization of standardization opportunities. Requirements for new or improved avionics normally start in the using commands and are directed at correcting specific mission deficiencies. Some consolidation of requirements can occur during the ROC/GOR validation process at the Air Staff level; however, this can occur only if the similar requirements were submitted nearly simultaneously. It is very difficult to identify avionics requirements for more than one five-year budget period in the future.

Recommendation

A comprehensive vehicle for communicating decisions, intentions, and alternatives for avionics acquisition among the development and logistics communities will permit the reduction of proliferation caused by unilateral initiatives, providing there is a single agency with a charter for periodically screening the data base constituted by this vehicle. The Avionics Planning Baseline document fulfills most of the requirements for this communication vehicle; however, the document requires the "teeth" represented by a coordinated Air Staff position and some supplementary data to assist in the screening of opportunities, specifically including the following:

- Technical descriptions of the avionics subsystems
- Reliability performance data
- Descriptions of the intent of major modification programs for each aircraft, particularly if a change in mission role is indicated
- Alternative modification programs to extend the aircraft usefulness should the deployment of replacement aircraft be delayed

5.1.4 Economic Criteria

The economics of avionics acquisition and support concepts associated with standardization are peculiar within the aerospace industries; since the technology is undergoing change, the Air Force should consider a change in the acquisition policy for the evaluation of avionics costs.

Advocates of standardization often point to production efficiencies of the larger lot sizes; however, the avionics "learning curve" provides the least return to the buyer for large lot production of all the modern aircraft construction components. The price-lowering forces of competitive smaller lot productions appear to offer equally attractive economic benefits. The logistics penalties of piece-parts proliferation resulting from multiple-manufacturer design approaches to a single interface specification are eased by significant MTBF improvements achieved in the newer solid-state equipment. Two-level maintenance concepts and the more extensive use of RIWs can reduce the associated support equipment penalties.

Finally, the time used in evaluating economic return is suspect from a technology viewpoint. Traditional LCC analyses employ 10 to 15 years as estimates for effective system lifetimes. The formidable, tactical-counterwarfare defensive systems, which are now deployed by the Soviet Union, suggest an era of early obsolescence for avionics systems that exploit signals in almost any RF spectrum region.

Recommendation

Avionics standardization activity should focus on interface standards, architectural approaches, and other concepts that tend to reduce acquisition and modification costs, and provide short-term payback to the Air Force.

An investigation of prior avionics modification programs should be performed to determine if a predictable cycle for modifications can be established for avionics classes or for the aircraft by type. This information, together with the associated cost data, should be incorporated in revised policy and evaluation tools for standardization opportunities.

5.2 SPECIFIC SUBSYSTEM OPPORTUNITIES

5.2.1 USAF - Commercial Joint Standards

There is a potential for economic and operational benefits from the use of existing commercial avionics analog standards for common retrofit applications and new-generation commercial digital interface standards for aircraft with compatible mission requirements; however, the requirements of the USAF using commands are frequently not forwarded to the USAF engineering community in time for participation in joint USAF/commercial specification development; thus opportunities for joint standards have been missed. Development and acquisition costs of commercial equipment would normally be lower than those for corresponding military equipments. These opportunities apply primarily to a wide-bodied transport-type aircraft; however, it may be possible to define options that extend the specified environment for more severe operational conditions. To the extent that such standards are employed, they will also serve NATO interoperability objectives.

Recommendations

The USAF should direct more management attention to its current role in the development of commercial standards.

Specific commercial standards that should be immediately investigated for USAF applicability in either their digital or analog interface form include the following:

- Radio Altimeter
- VOR
- HF/SSB Radio
- Weather Radar

DME, GPWS, and the Omega receiver are also potential joint specification endeavors; however, no urgent action is indicated since there are few requirements for these equipments.

5.2.2 USAF - Joint Military Standards

The USAF -- through its participation in joint programs such as JTIDS, GPS, and MLS -- is actively engaged in developing standard equipments that are interoperable with other military services. The terminal and integration group partitioning options for these equipments are still under investigation; therefore, the LRU dimensional characteristics and other interface characteristics necessary for further standardization assessments (e.g., controls and displays) are not available. More immediate standardization opportunities exist for the UHF/VHF voice radios. The Air Force has developed the AN/ARC-164 and the AN/ARC-186 as retrofit or new installation standards for the UHF-AM and VHF-AM/FM radios, respectively. The Navy's AN/ARC-182, operable in either UHF or VHF AM/FM modes, is planned for fleet and air use. Interface methods for these units, with modems for secure voice and jam resistance, are under study (SEEK TALK, HAVE QUICK). In addition, the Army is developing a VHF, Single-Channel Ground/Air Radio System (SINCGARS), which will be a frequency-hopping digital system intended for use in the mid- to late 1980s by all forces communicating with the Army's tactical theater.

Recommendation

It is not necessarily desirable to purchase the same unit for use by all services; however, interoperability between ground, air, and naval units should be assured and the cost of future modifications considered. If (upon the introduction of SINCGARS) interservice and interoperability must be achieved through the installation of a similar transceiver aboard the Navy and USAF aircrafts, then the transceiver should be designated form, fit, and environmentally compatible with the AN/ARC-182 or AN/ARC-186 LRUs to minimize the technical modification difficulty. Other advance considerations, such as the use of the Navy's broadband antenna, should be examined in the USAF integration approach to the interim voice-radio retrofit programs.

5.2.3 Other Avionics System/Subsystem Standardization Opportunities

Future Aircraft Avionics

Opportunities exist in standardization for nearly all types of aircraft avionics currently in the conceptual design phase (e.g., ATF, RF-X). The market demand will be driven primarily by the fighter-attack classes and, with few exceptions, the cumulative total demand will be less than 2,000 units for each subsystem type through 1990. A set of standards could be developed for these aircraft as a generic class; however, under the current USAF management philosophy, the aircraft development SPOs will have little incentive for selection of these standards. The primary criteria for selecting a standard from a SPO viewpoint are cost, maturity of design, and availability within the production schedule. A "paper standard" provides little attractiveness in any of these attributes. In addition, there is little motivation for industry to invest in equipments meeting such standards if the payback is projected far in the future.

Recommendation

Standardization activity for future aircraft systems should be directed at *architectures* rather than specific subsystems. These architectures should be partitioned so that SPO directors may select functional elements (e.g., communications or identification) for inclusion in the aircraft design as dictated by their mission. The Air Force Multi-Function, Multi-Band Airborne Radio System (MFBARS) and the Navy's ICNI program are examples of laboratory initiatives that should be sustained for this purpose.

Retrofit Applications

Fighter-attack class applications drive the retrofit standardization potential, both from a total demand quantity and a performance standpoint. The current extensive modification programs now under way will very likely be repeated at least once before 1990, indicating a total demand of 8,000 to 10,000 common avionics systems (e.g., voice radios, inertial navigators, and identification equipments). Many previous arguments for selecting high-performance aircraft avionics as standards have been obviated by solid-state technology. The design penalties for high acceleration, high-temperature environments, and dense packaging in these aircraft are not as severe as once was the case. Thus the fighter-attack retrofit avionics group emerges as the high-payoff target for standardization. Within this group, the Communications, Navigation, and Identification (CNI) avionics family and their associated controls, displays, and processing equipment are most common across the high-performance aircraft classes and the entire USAF inventory. Over the past few years, the Air Force has instituted significant development and production programs for many common avionics subsystems, having the effect of creating *de facto* standards. Examples of *de facto* standards are the AN/ARC-164 UHF radio, AN/ARC-186 VHF/AM-FM radio, and the AN/ARN-118 TACAN. The SPN/GEANS precision INS and the F^3 moderate-accuracy INS are expected to be standards for wide use; however, program uncertainties exist.

Recommendations

The Air Force should announce its intentions with respect to the *de facto* standards. Consideration should be given for establishing F^3 characteristics for the equipment specifications to permit evolutionary technology improvements and to assure a wider production base for the official standards. It should be noted that both the ARPA and IDA studies referenced in this report produced strong recommendations for F^3 standards as potential solutions to the technology growth, architectural, and economic dilemmas in avionics modernization programs.

In addition, the Air Force should pursue standards for other common avionic equipments that have reasonably stabilized design parameters, specifically including the following:

- Radio Altimeter (high-performance aircraft applications)
- HF Radio (jam resistant, adaptive)
- UHF-ADF
- Radar Beacon

5.3 CONCLUDING OBSERVATIONS

Implementation of the preceding recommendations would constitute only a modest beginning to the potential standardization activities of benefit to the Air Force. However, the Air Force should proceed with deliberate conservatism in its standardization initiatives. There are a great many cultural impediments to standardization, as was demonstrated in the activities aimed at implementing the F^3 INS program. There is a need to establish a record of successes in military avionics standardization.

Standardization of the core architectural elements -- e.g., bus controllers, central computers, controls/displays -- of the aircraft avionics system is an obvious necessity. The Air Force has initiatives in this area with the Digital Avionics Information System (DAIS) program in AFAL (now transitioning to ASD), digital flight control systems in AFFDL, and crew station experimentation currently under way in AMRL, ASD/EN, and ASD/AE. It will be a difficult task for the Air Force to assure harmonious efforts for these activities. Peripheral activities in support equipment standardization, fault-detection/fault-isolation guidelines, and hazard protection (e.g., EMP, TREE) should be coordinated with the preceding initiatives. This coordinated activity will require the examination of organizational charters, interagency relationships, and other policy issues.

Mission avionics such as target acquisition radars, electro-optical sensors, and electronic warfare systems are attractive targets for standardization from an economic standpoint. The acquisition cost of these systems, on a per-system basis, are much higher than general CNI equipments and are now widely employed in both tactical and strategic aircraft. This technology is far from mature; however, mission flexibility provided by the high software implementation suggests a technical approach. These areas present the far-term challenge for standardization in the Air Force.

APPENDIX A

A COMPARISON OF MILITARY AND COMMERCIAL DIGITAL STANDARDS

1. INTRODUCTION

Substantially different avionics integration approaches have evolved in the military and civil aviation communities, resulting in the creation of two digital standards for use in new generation aircraft -- MIL-STD-1553A and Mark 33 Digital Information Transfer Standard (DITS), ARINC Characteristic 429. These standards were not developed in isolation; military and commercial technical specialists involved in each development held frequent communications before their finalization. However, there were fundamental differences in the respective avionics suite composition and equipment acquisition philosophy that dictated separate approaches. The differences between the two standards and the rationale for the selection of each are summarized in this appendix so that the technical issues entailed in joint standardization activities may be brought into focus.

2. GENERAL

The MIL-STD-1553A describes the signal format for a very high speed multiplex (MUX) bus having equal numbers of transmitters and receivers. The Mk 33 DITS describes a ternary bus system that broadcasts labeled-digital parameters similar to the ARINC Characteristic 575 air data system. The broadcast approach is tailored to an architecture where information is distributed to multiple users from a small group of sensors. The MIL-STD-1553A MUX approach is tailored to the situation for a network of distributed control points. This latter approach reduces the number of inputs but requires more sensor outputs for the response. A fundamental commercial specification philosophy has been to minimize black box output requirements -- thus the choice of the broadcast standard was strongly influenced by the airline community's desire to minimize subsystem design requirements.

The following sections present technical specifications and an assessment of some design accommodations that could be facilitated for military use of commercial equipments, or vice versa. An alternate approach -- the use of a DITS/MIL-STD-1553A MUX adapter -- is under development at the Aeronautical Systems Division, AFSC.

3. SYSTEM REQUIREMENTS

A data bus imposes the following five major subsystem requirements for interfacing:

- Bit Rate
- Modulation Type
- Word Format
- Voltage Levels
- Operation Mode

The following sections describe the specific DITS and MIL-STD-1553A requirements.

3.1 Bit Rate

The DITS bit rate is specified at 12 or 100 kilobits per second with a tolerance of ±1 percent. MIL-STD-1553A requires a 1-megabit-per-second rate with a tolerance of only ±0.01 percent. For compatibility of a subsystem with both system standards, it must be equipped with an automatic clock synchronization circuit that has the flexibility of performing in ranges differing by an order of magnitude. This is not a formidable technical challenge, and therefore does not pose a severe penalty for standardization.

3.2 Modulation Type

The airlines have elected to use the return-to-zero (RZ) bipolar modulation. MIL-STD-1553A utilizes Manchester biphase modulation. A subsystem designed to operate with RZ bipolar modulation would require hardware addition to provide the proper interface for each of the modulation methods.

3.3 Word Format

The formats in Figure A-1 present the similarities and differences between the two systems. Bit No. 1 is the first bit of a word fed into the bus serially. The only similarity between the two systems is the requirement for odd parity. Major restructuring of subsystem software or hardware or an interface adapter unit would be required, permitting a subsystem designed for the standard to interface with the other.

3.4 Voltage Levels

Since MIL-STD-1553A utilizes Manchester biphase modulation, there is no steady-state null level (zero volts), and comparison of the systems'

1 2 3 4 5 6 7 8	9 10	11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29	30 31	32
Label	SDI	LSB Data MSB	SSM	P

DITS Data Word

1 2 3 4 5 6 7 8	9 10	11 12 13 14	15 16 17 18	19 20 21 22	23 24 25 26	27 28 29	30 31	32
Label	SDI	BCD Word	BCD Word	BCD Word	BCD Word	BCD Word	SSM	P

DITS System Management Word

1 2 3	4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19	20
Sync	MSB Data LSB	P

MIL-STD-1553A Data Word

1 2 3	4 5 6 7 8	9	10 11 12 13 14	15 16 17 18 19	20
Sync	Address	T/R	Mode	Word Count	P

MIL-STD-1553A Command Word

1 2 3	4 5 6 7 8	9	10 11 12 13 14 15 16 17 18	19	20
Sync	Address	ME	Status Codes	T/F	P

MIL-STD-1553A Status Word

Legend:

SDI - Source/Destination Identifier
T/F - Terminal Flag
P - Parity
SSM - Sign/Status Matrix
T/R - Transmit/Receive
ME - Message Error

Figure A-1. WORD FORMATS FOR COMMERCIAL AND MILITARY DIGITAL STANDARDS requirements becomes difficult. For reference purposes, the following voltage levels are:

	DITS	MIL-STD-1553A
High	+5 to +13	+0.5 to +10
Null	-2.5 to +2.5	N/A
Low	-13 to -5	-10 to -0.5
Maximum	±20 volts peak	±20 volts peak

3.5 Operation Mode

The DIT utilizes a full duplex mode for all remote units having a dedicated "twisted pair" to the system controller. When the system controller selects frequencies or other functions on a remote unit, there exists another dedicated line.

The MIL-STD-1553A utilizes a single "twisted pair" common to all system elements on a time-sharing basis. Discrete lines for the clock, requests, lockouts, acknowledges, flags, and errors are employed when required.

APPENDIX B

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This report summarizes ARINC Research activities under Contract F09603-76-A-3231-SC02. The technical activities covered a wide variety of tasks relating to U.S. Air Force standardization activities, including procurement approaches, technical approaches, and an assessment of the potential for consolidating subsystem requirements at a force-wide level. Conclusions and recommendations are offered in each of these areas of investigation.

The investigation reported in this document was requested by the Aeronautical Systems Division, Deputy for Development Planning (Code ASD/XRE); however,

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