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USE OF COMMERCIAL 'OFF-THE-SHELF' EQUIPMENT IN MILITARY AIRCRAFT

DEFENSE SYSTEMS MANAGEMENT SCHOOL
FORT BELVOIR, VIRGINIA

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INDIVIDUAL STUDY PROGRAM

USE OF COMMERCIAL "OFF-THE-SHELF"
EQUIPMENT IN MILITARY AIRCRAFT

Study Project Report
PMC 76-1

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DEFENSE SYSTEMS MANAGEMENT SCHOOL

STUDY TITLE:

USE OF COMMERCIAL "OFF-THE-SHELF" EQUIPMENT IN MILITARY AIRCRAFT, AN EVALUATION

STUDY PROJECT GOALS:

To identify and evaluate the documents controlling the performance, environmental testing and reliability testing of commercial avionics equipment, and to compare these procedures with conventional military practice.

To analyze and highlight those factors which impact the decision of an acquisition program manager who is considering the use of commercial equipment in military aircraft.

STUDY REPORT ABSTRACT:

The purpose of the study project was to provide a better understanding of the factors influencing decisions to use commercial avionics equipment in military aircraft.

Background information was obtained through interviews with Federal Aviation Agency (FAA) officials and USAF engineers. Applicable FAA, military and industry regulations, specifications and documents were reviewed.

The primary conclusions of the evaluation were:

1. The FAA approval documents and the supporting specifications are not intended for nor are they suitable for use as procurement specifications.

2. Airframe manufacturers and commercial airlines purchase avionics equipment to airframe company specifications, the equipment manufacturers specifications or industry association specifications. These specifications may be suitable for military procurements but a careful review must be made to ensure that the performance and environmental testing specified is adequate for the intended military use.

3. Reliability testing is not normally required by the FAA on commercial avionics equipment.

4. When an item of equipment is used in both commercial and military aircraft, the reported mean time between failure (MTBF) in military aircraft is normally less than half the MTBF reported in commercial service.

KEY WORDS: Commercial Avionics
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USE OF COMMERCIAL "OFF-THE-SHELF"
EQUIPMENT IN MILITARY AIRCRAFT, AN EVALUATION

Study Project Report

Individual Study Program

Defense Systems Management School

Program Management Course

Class 76-1

by

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May 1975

Study Project Advisor
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This study project report represents the views and conclusions of the author and does not ncessarily reflect the official opinion of the Defense Systems Management School or the Department of Defense.

EXECUTIVE SUMMARY

The purpose of this study project was to provide a better understanding of the factors influencing any decisions to use commercial "off-the-shelf" avionics equipment in military aircraft. The specific goals of the project were: to identify and evaluate the documents controlling the performance, environmental testing and the reliability testing of commercial avionics equipment and to compare these procedures with conventional military practice (Section II through Section V) and to analyze and highlight those factors which impact the decision of an acquisition program manager who is considering the use of commercial equipment in military aircraft.

Background information was obtained through interviews with Federal Aviation Agency (FAA) officials and government engineers. Applicable FAA, military and industry regulations, specifications and documents were reviewed. The data from these interviews and the document reviews were analyzed and conclusions drawn.

The primary conclusions of the evaluations were:

1. The FAA approval documents and the supporting specifications are not intended for nor are they suitable for use as procurement specifications.

2. Airframe manufacturers and commercial airlines purchase avionics equipment to airframe company specifications, the equipment manufacturers specifications or industry association specifications. These specifications may be suitable for military procurements, but a careful review must be made to ensure that the performance and environmental testing specified is adequate for the intended military use.

3. Reliability testing is not normally required by the FAA on commercial avionics equipment.

4. When an item of equipment is used in both commercial and military aircraft, the reported mean time between failure (MTBF) in military aircraft is normally less than half the MTBF reported in commercial service.

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SECTION I

Introduction

Purpose of the Study Project

Program managers involved in the acquisition of aircraft periodically must decide if an "off-the-shelf" item of commercial equipment is acceptable for the program or whether an item qualified to military specifications and standards should be procured. The purpose of this study project is to evaluate the commercial equipment qualification and certification procedures, compare these procedures with conventional military practice and to analyze and highlight those factors which impact the decision of the program manager.

Specific Goals of the Project

The specific goals of the project were:

1. To identify and evaluate the documents used to control the performance requirements for the design of commercial "off-the-shelf" avionics equipment.

2. To evaluate the adequacy of the environmental testing required by the Federal Aviation Agency (FAA) on commercial avionics equipment to see if equipment so tested can be expected to perform satisfactorily when installed in military aircraft.

3. To evaluate the reliability testing required by the FAA on commercial avionics equipment to determine if the tests performed are adequate to forecast the reliability of the equipment in military aircraft use.

4. To compare the reliability of an inertial navigation system as reported in commercial aviation service with that achieved with the same equipment in military service.

5. To provide specific recommendations on factors that program managers should consider when deciding whether to use commercial "off-the-shelf" equipment.

Scope of the Project

This study project is directed toward the impact of performance standards and reliability and environmental tests on the selection of commercial "off-the-shelf" avionics equipment. The study specifically considers two typical items, an inertial navigation system and an altimeter. The controlling test documents are evaluated and in the case of the navigation system, comparative reliability performance in military and commercial service are compared.

Limitations of the Report

The study considered only commercial avionic equipment. Selection criteria from other types of commercial equipment (e.g., generators, hydraulic pumps, tires) was not considered. Even for the avionics equipment within the scope of this report, there are factors influencing the choice of equipment that are not considered. Among the additional factors that were not evaluated are cost, delivery schedules, maintainability, equipment and component standardization, and configuration management.

Organization of the Report

The various types of performance requirement documents and qualification methods are discussed in Section II. Sections III and IV review and compare current environmental and reliability test qualification methods. Section V compares commercial and military reliability experience. Section VI analyses the impact of these factors on decisions of the program manager. Section VII contains conclusions based on the study.

SECTION II

Commercial Avionics Equipment Qualification Methods

A primary factor in the selection of commercially used avionics equipment for military use is the understanding of how this equipment has been accepted for use by the FAA and what are the limits on such use. A brief description of the primary methods of certification will highlight some of the conditions surrounding the certification. The four methods commonly used are:

1. Technical Standard Order Authorizations
2. Aircraft Type Certificate
3. Supplemental Type Certificate
4. Any other means approved by the Administrator

Technical Standard Order Authorization (TSO's)

The general procedures governing TSO approval are contained in the Code of Federal Regulations Title 14, (Aeronautics and Space) Part 37 Technical Standard Order Authorizations (14 CFR 37). This directive is commonly called Federal Aviation Regulation 37 (FAR 37). The crucial portion of Part 37 from a program manager's viewpoint is that it contains "minimum performance and quality control standards for specified materials, parts, or appliances....used on civil aircraft." (Part 37.1 (a)(2)). The key operative words are minimum performance standards. These are interpreted to mean those performance conditions that permit safe performance of the aircraft. This does not mean that the performance is optimized for any particular aircraft installation, just that installation of the equipment will not result in unsafe operations.

A manufacturer desiring to receive TSO approval on an item must:

1. Conduct necessary tests;

2. Submit technical data required by the applicable performance standards of 14 CFR 37;

3. Submit a description of his quality control system;

4. Maintain a current and complete technical file on the article;

5. Mark the article with specified information.

The applicable performance standards mentioned are standards specified in 14 CFR 37 for a particular item of equipment, e.g., rate of climb-TSO-C9c, life preservers-TSO-C13c, fuel flowmeters-TSO-C44a.

The performance standards mentioned in individual TSO's are in some cases contained in their entirety in 14 CFR 37, but are more commonly contained in documents referenced by 14 CFR 37 with the additions or deletions deemed appropriate by the FAA.

References include a few military specifications and many aeronautical standards prepared by industry groups with government participation. The three most common groups preparing avionics equipment performance standards are the Society of Automotive Engineers (SAE), Radio Technical Commission for Aeronautics (RTCA), and Aeronautical Radio Incorporated (ARINC).

The standards reflect the desire of the FAA to require items that will produce an acceptable level of safety for all aircraft without unnecessarily increasing the cost of light private aircraft. The typical standard specifies materials, detailed design requirements, environmental conditions and test conditions. While the standards are adequate to ensure safety, they do not always reflect current design practices. For example, the SAE has published Aeronautical Standards that are used as TSO references in Part 37, but in some cases the SAE committee has decided that the FAA requirements are inadequate as a design guide, and has published a Recommended Aeronautical Practice document with more stringent criteria.

Update of the TSO's is a continuing process complicated by the broad range of aircraft types involved, numerous manufacturer and user associations with strong preferences and vested interests, and an approval procedure requiring substantial time for comment and protest after the publication of a proposed rule change.

Some of the TSO references are very dated (e.g., Turnbuckles-TSO-C21a is a 26 year old document). Many of the instrument related TSO's are based on Aeronautical Standards dated in 1959. On the other hand, the FAA has created TSO's for new types of equipment in a very limited time as evidenced by the rapid reaction to provide standards for the Ground Proximity Warning system.

One important fact is that few items with TSO approval met just the minimum standards set forth in the TSO. Most instruments with TSO approval have performance characteristics that exceed the standards by a substantial amount. For some equipment, major aircraft manufacturers develop specifications that are as detailed as government specifications. In addition to requiring compliance with the company specification, the aircraft manufacturer will require the instrument manufacturer to obtain TSO approval from the FAA. Obviously not all items approved under the same

TSO are equivalent. There can be substantial differences in performance among instruments meeting a given TSO.

In addition, the TSO does not control the size or the interface characteristics. The primary reason for this is that the TSO has never been intended as a procurement document.

The airline industry benefits from the standarization of equipment. Aeronautical Radio Inc. (ARINC) is primarily funded by the commercial airlines. ARINC has published a number of standards detailing performance requirements for avionics equipment. These documents also specify electrical and mechanical interface requirements and test requirements. If the equipment is of a class covered by a TSO, the ARINC document incorporates the TSO requirements. ARINC documents have provisions for additional equipment capability where appropriate. ARINC documents have been used by both the government and industry as procurement specifications.

A quick comparison on two altimeters, one built to the minimum requirements of TSO-C-10b, and the other conforming to the requirements of Mil-A-83212 Altimeter (AAU-27/A) specification, will illustrate some of the differences. The basic accuracy of the two instruments (altitude vs. pressure) is reasonably comparable at room temperature with the TSO instrument being 10 to 15 feet more accurate below 8,000 feet altitude, and the AAU-27 more accurate by up to 90 feet at higher altitudes. Many tests are similar for both instruments, but the following tests are called out for the AAU-27/A and are not required for the TSO instruments.

1. Maintainability Test
2. Reliability Test

3. Longevity
4. Operational Stability
5. Lighting
6. Over-voltage Protection
7. Undervoltage Protection
8. Warmup Time
9. Dielectric Strength
10. Backlash
11. Acceleration
12. Shock
13. Shelf Life
14. Response (lag)

In addition, the display characteristics, viewing angle, dimensions and the mechanical and electrical interface are defined for the AAU-27 but not for the TSO instrument. These last items reflect the fact the AAU-27 specification is a procurement document while the TSO reference is not intended for that purpose. The differences in environmental tests are covered in Section III.

When a major airframe manufacturer (Boeing, McDonnell Douglas, Lockheed, etc) buys a TSO altimeter, the procurement specification exceeds the TSO minimum requirements and has tests parelleling most if not all of the military specification requirements.

Aircraft Type Certificate

The second method of item certification is as a part of the entire aircraft. During the development of the aircraft and its related equipment, the FAA monitors the design and technical verification of the entire aircraft including the avionics items. The primary goal is to assure that the item installed meets minimum performance standards under the conditions that it will be used in the new aircraft. While the instrument does not have to be TSO'd, the FAA must be convinced by the data produced that a safety level at least equivalent to that provided by a TSO instrument will result.

After the aircraft has satisfactorily passed all applicable ground and flight tests, a Type Certificate is granted for the aircraft. The Type Certificate contains an approved parts list giving the make, model and dash number of the approved equipment. Items receiving approval under the Type Certificate are approved only for use on that particular aircraft type. In this case, the airframe manufacturer rather than the equipment manufacturer is responsible for ensuring that all produced items meet the performance standards that applied during the certification process.

Supplemental Type Certificate

The procedure followed before a Supplemental Type Certificate is granted parallels very closely the procedure for the Type Certificate. Supplemental Type Certificates are granted following a major aircraft modification by either the original manufacturer or another company. Any items changed are listed on the Supplemental Type Certificate.

For both the Type Certificate or Supplemental Type Certificate, alternate items may be placed on the Authorized Equipment List upon submission of sufficient evidence to convince the FAA that satisfactory safety standards have been maintained. Many of these alternate items are approved based on similarity to the approved equipment.

SECTION III

Environmental Tests

The environmental testing philosophy for the military specified equipment and for commercial equipment approved by the FAA is quite similar. The methods of application may, however, impact on the suitability of a given item for a specific application. Military specified tests are listed MIL-STD-810C, Environmental Test Methods. The civilian equivalent is Radio Technical Commission for Aeronautics (RTCA) Document No. 160, Environmental Conditions and Test Procedures For Airborne Electronic/Electrical Equipment and Instruments. DO-160 or its predecessors DO-138 and DO-104, are referenced in FAA documents when it is necessary to provide detailed instructions on how a given test is to be coordinated.

No item is subjected to all tests listed in DO-160. During the preparation of DO-160, careful attention was paid to permit matching of the severity of the tests with the intended use of the items. In DO-138, aircraft have been divided into three classes: Class X, aircraft with a maximum ceiling of 20,000 feet; Class Y, which includes most passenger and cargo aircraft having ceilings of 50,000 feet; and Class Z, which includes all supersonic aircraft. Thirteen categories have been established for equipment based on variations of the pressure, temperature that the equipment is expected to encounter in service. The proximity of the equipment to the engine, and the use of pressurized and non-pressurized compartments and the temperature controlled avionics compartments add to the variations. MIL-STD-810C is not as easily tailored to such variations. Many TSO's reference DO-138, which is not as inclusive as the newer DO-160.

A key feature of MIL-STD-810C and DO-160 is that they are both "How to test" guides and do not give pass-or-fail criteria. Section 1 of DO-160 states: "The selection of the appropriate environmental conditions and test procedures is the responsibility of those who write the performance standards for the individual airborne electronic/electrical equipment and instruments." Section 1 also contains the following Note: "In each of the test procedures contained herein, the following phase will be encountered one or more times: 'DETERMINE COMPLIANCE WITH APPLICABLE EQUIPMENT PERFORMANCE STANDARDS'."

Obviously, when two manufacturers state that they have built a given type of avionics equipment that has "passed" the high temperature test of DO-160, a comparison between the instruments cannot be made unless the pass-fail criteria established by each manufacturer for the high temperature is known. One manufacturer might accept a much greater reduction in accuracy at high temperature and still "pass" the test.

Returning to the example used in Section II, comparing TSO-C10b requirements for an altimeter with those of MIL-A-83212 for the AAU-27/A altimeter, we can compare the required environmental testing. First, the TSO altimeter has to operate through a temperature range of -30°C to 50°C, while the AAU-27 must operate through a range of -54°C to +71°C. A significant difference here is that the AAU-27 is tested at both high and low temperatures, and while the TSO altimeter is expected to operate at temperatures above room temperature, it is not tested to prove this capability. Other tests which the AAU-27 must pass, which the FAA does not require for the TSO instrument are: salt spray, fungus, sand and dust, shock acceleration and radio noise.

SECTION IV

Reliability Testing

Though over ninety types of equipment fall into categories covered by TSO's, only the TSO for the Ground Proximity Warning System, published in 1975, has a reliability requirement expressed in mean time between failures (8000 hours). For all other TSO's no reliability number is established. The lack of formal reliability testing does not mean that the FAA is not concerned with the reliability of commercial equipment, nor does it mean that commercial equipment is inherently unreliable. On the contrary, commercial equipment is considered by many observers to be more reliable than military equipment. The environmental tests required by the TSO's provide a degree of reliability testing. Many field failures are a result of environmental stresses. The required environmental testing can expose many of these design weaknesses and result in redesign. In addition, if a large number of failures occur during flight operations, the FAA may decide to review the quality control procedures used by the manufacturer. The primary factor that results in high reliability is the competitive environment under which this aviation industry operates. A manufacturer who consistently produces an item with high failures rates and high repair costs will not survive in the open market. Unfortunately, the economics of the market place takes time to take effect, and a marginal manufacturer can place unreliable equipment on the market.

The commercial avionics industry does not have an equivalent reliability document to MIL-STD-781B Reliability Tests: Exponential Distribution. The FAA's recent experience with the reliability requirements imposed on the ground proximity warning system parallels the DOD's experience on many items: reliability demonstrated in the test lab is not always duplicated during flight operations.

SECTION V

Field Reliability Experience

While the FAA does not require laboratory reliability demonstrations, the FAA, commercial airlines and general aviation are all interested in highly reliable avionic equipment from both a cost and safety viewpoint. For the commercial airlines, the primary method used to acquire reliable equipment is to make the manufacturer contractually responsible for the in-service reliability of the equipment. This is done through a variety of full and partial guarantees or warranties. One increasingly common practice is the use of reliability improvement warranties (RIW). All of these practices have a common trait, financial punishment of a contractor whose equipment is unreliable.

Records of reliability performance are not required by the FAA, but each major airline develops historical data from avionics equipment. These records are closely monitored by the manufacturers. While there is no official consolidated airline reliability listing, MTBF performance values and modification suggestions are commonly shared by the airlines. There is no such data base for general aviation avionics.

Detailed analysis of reliability differences between military and commercial avionics may be found in several reports. One enlightening and current report is the Report of the USAF Scientific Advisory Board Guidance and Control Panel "Review of Aircraft Inertial Systems" dated March 1975. Another useful report is The User-Technologist-Industrial Approach to Electronic Equipment Specifications and Procurement (Electronic X) prepared by ARINC Research Corporation for the Institute of

Defense Analyses in July 1973. Both reports point out the fact that operational MTBF as reported by the military should not be directly compared with commercial MTBF. The Scientific Advisory Board's report states "...there are many factors in low USAF reliability -- some under AF control, others due to fundamental differences in operations."

Commercial MTBF values are usually based on verified failures. Preventative maintenance actions, removals to gain access to other equipment and reported failures that are not later verified, are not counted when calculating the MTBF. The Air Force MTBF values are normally obtained as outputs from reports required by AFM 66-1. AFM 66-1 is the basis of the Air Force Logistic Management System, and is not intended as a method to develop accurate MTBF value. As a result, all maintenance actions normally are counted as failures of the equipment. Hence removals to facilitate other maintenance, unverified failures and preventative maintenance all help lower the calculated MTBF. In some cases failures have been charged against a single item of equipment at the flight line, field shop and depot for a single failure.

For inertial navigation systems, the FAA requires that 95% of the flights have errors of less than 2 nautical miles along track, and 2 nm cross track per hour. This is equivalent to a circular error probable CEP of 2.8 nm per hour. For the F-15, the USAF specified a 3 nm/hr system. McDonald Douglas required a 2 nm/hr system from the subvendor who actually delivered a system with an average error of 0.7 nm/hr. USAF pilots have become accustomed with the excellent performance of the system and will normally "write-up" the system if the error is over 2 nm/hr even though the performance is well within the initially required performance. These "soft" failures decrease the reported MTBF. Other features tending to reduce the military MTBF are increased avionic bay temperatures, gun fire vibration, and a higher ratio of equipment turn-ons per 1000 flight hours. Airline avionics equipment may be operated 3000 to 6000 hours per year while most military aircraft fly 600 hours or less per year. As a result, ageing of equipment during periods of non-operation is a more significant factor for military equipment.

As a specific example of differences between MTBF in military and commercial use, the Carrousel IV reliability may be used. This inertial navigation set is widely used by commercial airlines and has use in several special military programs.

During the July to Dec 1975 period, the Carrousel IV accumulated 2,173,122 hours of operation. Verified relevant failures were:

Control Display Unit	279
Mode Selector Unit	3
Battery	21
Inertial Measuring Unit	1100

Based on these values, the commercial service MTBF was 1549 hours.

The Carrousel IV is used by the military on the EC-135J, E-4A, E-3A, C-9B, HH-53 and installed for transoceanic missions on a pallet in KC-135 and EC-135 aircraft. The KC-135 and EC-135 Palletized Inertial Navigation System (PINS) has accumulated the greatest number of operational hours. The PINS accumulated total hours from 4 March 74 to 29 February 76 were 10,200. There were 21 verified relevant failures, with a resulting MTBF of 486 hours. If AFM 66-1 data had been used, the additional unverified failures would have reduced the MTBF by a factor of two. MTBF of the

Carrousel IV in other military installations varies from a low of about 150 hours to the 486 hours reported on the PINS program.

The ARINC Electronics X report contains similar rates for HF, VHF and ILS equipment. The reliability of a particular item of equipment during commercial service is two to three times the reliability of the same item in military use.

SECTION VI

Impact of these Factors on the Program Manager's Decision

There have been several recent cases where the military services have found it desirable to procure fully equipped commercial aircraft. There have been numerous cases where commercial avionics equipment has been selected for installation in a military peculiar aircraft at the time of initial production or during modification. Instructions in the Request for Proposal (RFP), for some of these cases, have required that the avionics and instrument equipment be qualified in accordance with the applicable TSO.

A review of the method used by the FAA to grant TSO approval of the performance requirements of a given item must lead the program manager to the conclusion that a simple requirement that a TSO approved item be furnished is woefully inadequate. Equipment conforming to this requirement could have a performance capability far exceeding that desired or the performance could be below that required for the intended use. For example, an attitude indicator meeting the requirements of TSO-C4c could be a vacuum driven indicator with a useable pitch range of plus or minus 30 degrees of the type frequently used in small private aircraft, or it could be a DC-10 attitude indicator incorporating ILS data, angle of attack information and a radar altitude presentation. Both instruments could meet TSO-C4c, yet the difference in price would be approximately 100 to 1. The proper selection would depend upon the intended use. Certainly there is no objection to the use of a TSO item, but a selection should be made after a review of the particular item specification.

In those cases where the only specifications available are those furnished by the item manufacturers, the selection of an appropriate specification for inclusion in the Request for Proposal (RFR) or in the contract is difficult. There may be several acceptable items available on the commercial market, but no single specification that may be referenced that would permit the procurement of all the acceptable items. As a result, the program manager may find the selection of the specification unintentionally places the procurement in a sole source situation.

The selection of a commercial item for a particular military use should be made only after a careful comparison of the performance requirements of the item with total system needs. Just because a particular performance parameter listed in the specification does not meet the mission requirements, does not mean that the item will not function satisfactorily. The capability of the equipment may exceed the specification requirement. Testing may show the equipment capability exceeds the specification. Most manufacturers would be willing to conduct a few tests to demonstrate additional capability if such tests increase the possibility of sale.

In a similar manner, the environmental testing required by the TSO should be compared with those tests felt necessary for the specific application being considered. In those cases where the TSO required environmental tests are not sufficiently comprehensive, additional test results may be available for the manufacturer. If additional environmental testing is still considered necessary, program funds could be used to pay for additional testing or the tests could be conducted "in-house" at a government facility.

Just because equipment has been subjected to and passed all the desired environmental tests does not automatically qualify an item from an environmental standpoint. An essential second step is the evaluation of the pass-fail criteria for the particular test. The degree of performance deterioration caused by an adverse environment may be considered acceptable by the manufacturer, but might not be acceptable for the intended application. The most common area where commercially available equipment will fail to meet military environmental standards is in the electromagnetic interference (EMI) area.

After all available test information is reviewed, it may occur that the commercial equipment still fails to meet the performance or environmental standards in some regions. At this point, the program manager must decide to:

1. Permit deviations to the original requirements;

2. Develop an item of equipment specifically for his program;

3. Utilize available military inventory equipment if adequate equipment is available;

4. Modify the existing commercial equipment so that it meets the program requirements.

If the choice is modify the existing commercial equipment, the initial intent of buying commercial "off-the-shelf" equipment is quickly lost. Any significant modification will cause the equipment to lose TSO or type certificate approval and a new series of performance and environmental tests must be performed. Depending on the type of modification, the equipment may no longer be suitable for normal commercial use and a military peculiar item results.

A program manager must make decisions on acceptable levels of reliability of commercial equipment frequently with a minimum of information. The situation may occur at the time of original full scale development or when a vendor proposes commercially available equipment as a replacement for avionics equipment already installed that has high support costs because of low reliability. The vendor in the last case may quote a high reliability number which, if achieved in military service, would make the replacement of the existing low reliability equipment with commercial equipment cost effective. The decision before the program manager is a difficult one. Such decisions are normally based on the expected long term cost to the government. Most of the costs can be predicted with a reasonable degree of accuracy with the exception of the repair costs which are inversely proportional to the in-service MTBF of the equipment.

As stated in Section IV, reliability tests to demonstrate a laboratory MTBF for avionics equipment are not required by the FAA with the sole exception of the Ground Proximity Warning System. In addition, the FAA does not track the reliability of avionics equipment presently in service. The commercial airlines and the equipment manufacturers do generate MTBF figures for major items of equipment in airline service. Only very imprecise information is available on avionics equipment installed in the light aircraft general aviation fleet.

Judgement is required by the Program Managers and his supporting engineering staff in the use of the available MTBF figures because of the difference in preventative maintenance concepts, reporting procedures, failure verification methods and repair concepts discussed in Section VI. In addition the effect the environmental differences of the commercial and military installations must be considered.

While in some cases it is possible to forecast that the commercial equipment will exhibit a much higher MTBF than the military equipment, in general, however, the manufacturers who produce military equipment are the same manufacturers who produce for the commercial aviation market. For similar equipment with the same level of complexity it is unlikely that a dramatic difference in inherent reliability exists. Most of the differance in reliability would seem to be accounted for by the environment, reporting procedures, and maintenance factors mentioned earlier. The example of differences in MTBF of the Carrousel IV inertial navigation set in commercial service vs military use (1459 vs 486 hrs) shows that military service MTBF does not always parallel commercial experience.

SECTION VII

Conclusions

The same degree of care must be taken when selecting commercial avionics equipment for a military use as must be taken when selecting an item of qualified government furnished equipment for a new application.

The key points influencing the selection and use of "off-the-shelf" commercial equipment are:

1. The FAA approval documents (TSO's) are not intended for nor are they suitable for use as procurement specifications.

2. To obtain FAA approval, an item of avionics equipment need meet only minimum performance standards, hence the item may not have the necessary capability to permit utilization of all the intended performance of the weapon system.

3. Airframe manufacturers and commercial airlines purchase avionics equipment to airframe company specification, manufacturers specification or association specification (e.g., ARINC, RTCA). These specifications may be suitable for military procurements, but a careful review must be made to ensure that the performance specified is adequate for the intended military use.

4. The fact the performance specification doesn't detail some necessary performance characteristics or the performance values listed are too restrictive doesn't mean the equipment must be rejected. The equipment may have capabilities exceeding the specification.

5. The program manager should consider funding performance testing to determine if the equipment has capabilities exceeding the performance specification if the additional capability is required for the intended use.

6. RTCA Document DO-160, Environmental Conditions and Test Procedures for Airborne Electronic/Electrical Equipment and Instruments specifies a broad range of environmental test conditions and is generally equivalent to MIL-STD-810C, Environmental Test Methods. Both documents are "How-to-Test" guides and do not contain accept or reject criteria.

7. The equipment specifications must be reviewed to determine if the required environmental tests are adequate to assure adequate capability in the expected operational environment. In addition, the performance tolerances of the instrument during environmental tests must be reviewed to determine the extent of performance degradation and to determine if this degraded operation is acceptable for the intended use.

8. The program manager should consider funding additional environmental tests if necessary to establish the suitability of the equipment for the military environment in which it is to operate.

9. The FAA does not require a laboratory reliability test demonstration, nor does the FAA track service reliability of avionics equipment.

10. The MTBF of equipment in commercial airline service, as reported by manufacturers and industry associations, has been collected using failure criteria different than the military services. In addition the operational environment, preventative maintenance concepts and flight line and depot repair procedures effect the reliability of the equipment.

11. Generally, commercial equipment used in military aircraft exhibits a significantly lower MTBF in military service when compared to the MTBF in commercial airline service.

BIBLIOGRAPHY

REPORTS

1. Report of the USAF Scientific Advisory Board Guidance & Control Panel, Review of Aircraft Inertial Systems, March 1975.

2. ARINC Research Corporation, The User-Technologist-Industrial Approach to Electronic Equipment Specification and Procurement, July 1973.

DIRECTIVES, SPECIFICATIONS, STANDARDS

3. Code of Federal Regulations Title 14, Aeronautics and Space, Part 37, 1 Jan 75.

4. Military Specification, MIL A-83212, Altimeter, Pressure AAU-27/A, 1 Dec 70.

5. Military Standard, MIL-STD-781B, Reliability Tests: Exponential Distribution.

6. Military Standard, MIL-STD-810C, Environmental Test Methods, 10 March 1975.

7. Radio Technical Commission for Aeronautics, Document No. 160, Environmental Conditions and Test Procedures for Airborne Electronic/Electrical Equipment and Instruments, Jan 30, 1975.

8. Society of Automotive Engineers, Aeronautical Standard, AS 392C, Altimeter, Pressure Actuated Sensitive Type, 1 Feb 59.

INTERVIEWS

9. Andres, James R., Interview at Aeronautical Systems Division on 16 April 1976.
   Mr. Andres is an instrument Specialist in the Deputy for Engineering.

10. Logus, Paul J., Interview at Aeronautical Systems Division on 16 April 1976.
    Mr. Logus is Chief of the Navigation Branch in the Deputy for Engineering.

11. Marshall, Philip R., Interviews at Aeronautical Systems Division on 20 March and 16 April 1976.
    Mr. Marshall is Chief of the Instruments Branch in the Deputy for Engineering.

12. Owens, Robert A., Interview at FAA Headquarters on 2 April 1976.
    Mr. Owens is a senior engineer of the Systems Branch of the Flight Standards Division.

13. Ryan, Thomas, Interview at FAA Headquarters on 2 April 1976.
Mr. Ryan is a senior engineer of the Systems Branch of the Flight Standards Division.