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I am submitting herewith a thesis written by Denis Gerald Tri entitled “Lessons Learned From the Incorporation and Testing of the AN/APG-68 Radar on the United States Naval Test Pilot School Airborne Systems Training and Research Support Aircraft (ASTARS)”. I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Aviation Systems.

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LESSONS LEARNED FROM THE INCORPORATION
AND TESTING OF THE AN/APG-68 RADAR ON THE UNITED STATES NAVAL
TEST PILOT SCHOOL AIRBORNE SYSTEMS TRAINING AND RESEARCH
SUPPORT AIRCRAFT (ASTARS)

A Thesis
Presented for the
Master of Science
Degree
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Denis Gerald Tri
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DEDICATION

This thesis is dedicated to my friends in the Navy and at the Naval Test Pilot School, whose sense of humor, desire to excel at every endeavor, and dedication to professionalism have been of great assistance. I would especially like to thank the ASTARS II team who worked so many hours outside their normal duties to make this training asset a reality for current and future test pilot students.

I would like to mention those associated with the United States Navy degree funding programs who had the foresight to make college education a priority, and in doing, so paved the way for financing this degree.

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ABSTRACT

In August 1994, a Statement of Work (SOW) was issued for the design, installation, and integration of Government Furnished Equipment (GFE) and Commercial Off The Shelf (COTS) technology on a U.S. Naval Test Pilot School (USNTPS) aircraft. The program was known as the Airborne Systems Training and Research Support (ASTARS) Aircraft.

The proposed aircraft would train test pilot students throughout the globe on airborne systems flight test techniques. The concept was initiated from a cancelled A-12 design bed and would be built on a P-3 Orion aircraft. In April 1995, the proposal to build the ASTARS aircraft was accepted, resulting in a contract award to private industry. In its first few years the new ASTARS program experienced terrific success. More than 1,000 individuals from 19 different countries were trained using the ASTARS system. The aircraft was an integral syllabus component for the world's largest test pilot schools.

Although an excellent training tool, the single ASTARS asset could not provide continuous year-round training. Rising flight training demands along with a required 8-month maintenance phase amplified the need for a second ASTARS aircraft. In 2001, the acquisition of a second ASTARS (ASTARS II) commenced. Unfortunately the ASTARS II acquisition schedule slid noticeably. By the planned Initial Operation Capability (IOC) date, the aircraft remained only partially capable and only a few student-training exercises had been conducted. On 14 July 2004, a meeting by USNTPS upper management was called to determine answers to the following questions: How far

along is the ASTARS II program development? What will it take in cost and schedule to complete the development? Is further development supportable? Are there options for use as a partially mission capable aircraft? In general, management was trying to decide whether or not the program should be cancelled.

This thesis discusses the programmatic and technical obstacles experienced in this government-only acquisition program. Based on lessons learned and an analysis of this material, the author made recommendations as to how acquisition programs such as this can be conducted in a more efficient manner with an emphasis on systems analysis and readily available program management strategies.

PREFACE

The analyses, opinions, conclusions and recommendations expressed herein are those of the author and do not represent the official position of the Naval Air Warfare Center, the Naval Air Systems Command, the United States Naval Test Pilot School or the United States Department of the Navy. The author's recommendations should not be considered attributable to any of the aforementioned authorities or for any purpose other than fulfillment of the thesis requirements. Data and conclusions were gathered from ground and flight testing in support of an official Department of Defense Test and Evaluation project. The author played a significant role in the planning, program management, and gathering of both the ground and flight test data. Although the author was the requirements officer for this government project, this project was not conducted for the purpose of the thesis.

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ACRONYMS AND ABBREVIATIONS

ACM	Air Combat Maneuvering
ACQ	Acquisition
AFB	Air Force Base
AFRL	Air Force Research Laboratory
AFTPS	Air Force Test Pilot School
AGL	Above Ground Level
AIS	Aircraft Intermediate Shop
AMARC	Aerospace Maintenance and Regeneration Center
AMLCD	Active Matrix Liquid Crystal Displays
AoA	Analysis of Alternatives
APSP	Advanced Programmable Signal Processor
ASA	Airborne Systems Aircraft
ASTARS	Airborne Systems Training And Research Support Aircraft
ASTTA	Avionics System Test and Training Aircraft
BuNo	Bureau Number
BIT	Built-In Test
CCD	Charge-Coupled Device
CDU	Control Display Unit
CINC	Commander in Chief
CMOS	Complementary Metal-Oxide Semiconductor
COTS	Commercial Off The Shelf
CPU	Central Processing Unit
CRT	Cathode Ray Tube
CVI	Crew Vehicle Interface
DBS	Doppler Beam Sharpening
DBS1	Doppler Beam Sharpening (Coarse 8:1)
DBS2	Doppler Beam Sharpening (Medium 64:1)
DDI	Digital Display Indicator
DoD	Department of Defense
DON	Department of the Navy
DMS	Display Management Switch
DMT	Dual Mode Transmitter
DT	Developmental Testing
EEFCC	Electronic Emulating Flight Control Computer
ECM	Electronic Countermeasures
EMC	Electromagnetic Compatibility
EO	Electro-Optical
ETPS	Empire Test Pilot's School, United Kingdom
EXP	Expand Mode
FCF	Functional Check Flight
FCR	Fire Control Radar

FFP	Firm Fixed Price
FLIR	Forward Looking Infrared
FMS	Foreign Military Sales
FOV	Field of View
FRZ	Freeze mode
FY	Fiscal Year
GFE	Government Furnished Equipment
GM	Ground Map
GMTI	Ground Map Moving Target Indicator
GPS	Global Positioning System
HUD	Head Up Display
HMI	Human Machine Interface
IFAST	Integrated Facility for Avionics Systems Testing
ICD	Interface Control Document
ICS	Intercom System
INS	Inertial Navigation System
I/O	Input / Output
IOC	Initial Operations Capability
IR	Infrared
JOG	Joint Operations Graphic
JNC	Jet Navigation Chart
KIAS	Knots Indicated Airspeed
KPPs	Key performance parameters
LCDR	Lieutenant Commander
LRU	Line Replaceable Unit
MDA	Milestone Decision Authority
MDS	Mission Design and Series
MFD	Multifunction Display
MIL-STD	Military Standard
MIPR	Military Interdepartmental Purchase Request
MLPRF	Modular Low Power Radio Frequency
MLU	Mid-Life Upgrade
MMC	Maintenance Manual Commercial
MNS	Mission Need Statement
MOA	Memorandum Of Agreement
MOTS	Military Off The Shelf
MTBF	Mean Time Between Failure
MRK	Mark Point
NADEP	Naval Air Depot
NATOPS	Naval Air Training and Operating Procedures Standardization
NAVAIR	Naval Air Systems Command
NDI	Non-Developmental Commercial Items
NEAT	Noise Equivalent Delta Temperature
NRE	Non Recurring Engineering
NSATS	Naval Strike Aircraft Test Squadron

NSN	National Stock Number
NTWL	Naval Test Wing Atlantic
OAG	Operation Advisory Group
OAT	Outside Air Temperature
OFP	Operational Flight Program
O&M,N	Operations and Maintenance, Navy
ORD	Operational Requirements Document
OT	Operational Testing
PDM	Planned Depot Maintenance
PEO(T)	Program Executive Officer Tactical Aviation
PM	Program Manager
P/N	Part Number
PRF	Pulse Repetition Frequency
PSP	Programmable Signal Processor
RDT&E	Research Development and Testing
RINU	Ring-laser Inertial Navigation Unit
RO	Requirements Officer
RWS	Range While Search
SCU	Signal Conditioning Unit
SECNAV	Secretary of the Navy
S/N	Serial Number
SOI	Sensor of Interest
SOFT	Safety of Flight Test
SOW	Statement of Work
SPI	Sensor Point of Interest
SSSC	Surface Subsurface Surveillance Coordination
T&E	Test and Evaluation
TACAIR	Tactical Aviation
TAP	Test Article Preparation
TEMP	Test and Evaluation Master Plan
TMS	Target Management Switch
TWS	Track While Scan
TWT	Traveling Wave Tube
USAFTPS	United States Air Force Test Pilot School
USNTPS	United States Naval Test Pilot School
VGA	Video Graphics Array
VOR	VHF (Very High Frequency) Omni-directional Radio-range
VX-20	Air Test and Evaluation Squadron Two Zero
XMTR	Transmitter

NOMENCLATURE

MILITARY AIRCRAFT DESIGNATIONS

An unusual aspect of the aircraft described in this thesis is that it had two atypical military designations. The subject aircraft, Bureau Number (BuNo) 148889 was originally designated a UP-3A. After undergoing ‘series’ modifications to extend service life, the aircraft was re-designated from a UP-3A to an UP-3D. Once complete with the ASTARS II modifications the aircraft designation was changed again, this time from UP-3D to NP-3D.

General designations for military aircraft follow a set of standardized nomenclature in the format: type, model and series. Designations describe various aspects of the aircraft mission and modifications. The first designation is a letter that indicates the aircraft’s primary function and capability. For the NP-3D, that first letter is the ‘P’, which stands for the Maritime Patrol mission defined as: “a long range, all weather, multiengine aircraft operating from land or water bases that is modified for independent antisubmarine warfare, maritime reconnaissance, and mining.”

The next designation given to military aircraft is the model number. The model number identifies major design changes within the basic mission. Model numbers run consecutively from ‘1’ to ‘999’ and appear to the immediate right of the primary function letter, separated by a dash. So the ‘3’ in the NP-3D designation represents the third design in Maritime Patrol.

The series letters ‘A’ and ‘D’ identify the production model of the particular design. The designation for 148889 was changed from ‘A’ to ‘D’ because major

modifications were made to the original aircraft that significantly altered the aerospace vehicle system components and changed the logistics support of the vehicle.

Status prefixes are uncommon among U.S. Navy aircraft because they are used to indicate nonstandard use of an aerospace vehicle such as test, experimental, prototype, etc. If used, the status prefix letter appears to the immediate left of the modified mission symbol or basic mission symbol for the aircraft. The prefix ‘U’ in UP-3A was used to identify a “special utility” mission capability, which the aircraft flew in support of prototype projects and range support before being acquired by United States Naval Test Pilot School (USNTPS). A prefix change from ‘U’ to ‘N’ was made for the completed NP-3D to differentiate the aircraft’s new “permanent special test” mission at the U.S. Naval Test Pilot School. The image in Figure 1 is a three view of the NP-3D.

(Description of Standardized MDS Designation Symbols, 1997)

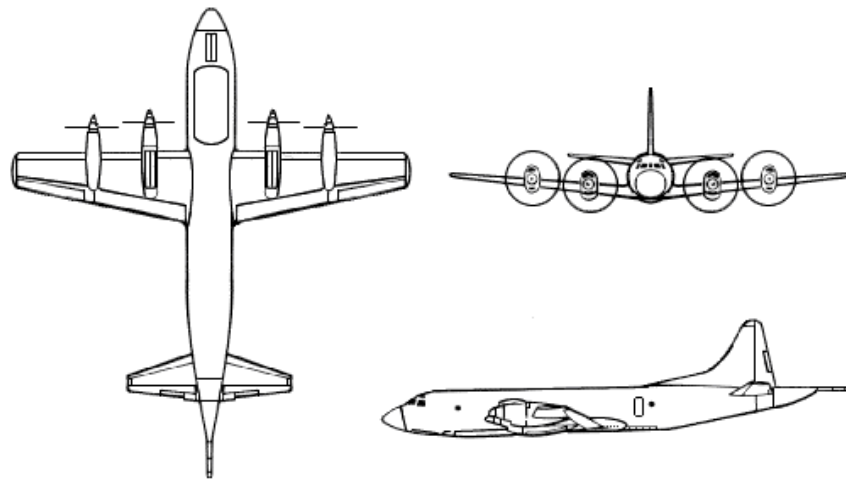


Figure 1
NP-3D 3-Plane View

CHAPTER 1: INTRODUCTION

BACKGROUND

In the early 1990s, the United States Naval Test Pilot School identified the need for a modern, highly integrated, multi-sensor training aircraft. The objective was to use Non-Developmental Military and Commercial Off the Shelf (MOTS/COTS) items to create a modern strike-fighter training aircraft for the instruction of U.S. and foreign test pilots, flight officers, and test engineers in flight test techniques involving radar, Forward Looking Infrared (FLIR), navigation, and Human Machine Interface (HMI). Specific goals included:

- Provide an integrated system typical of current and future tactical aircraft (A-12, F-14, F-15E, F-16, F/A-18, F-22, F-35)
- Provide support systems typically employed in developmental test aircraft
- Allow complete control of entire sensor suite from either of two operator stations
- Allow instructor monitoring of all student actions
- Maximize use of equipment already on aircraft
- Ensure support for future growth

In August, 1994 a Statement of Work (SOW) was issued for the design, installation and integration of Government Furnished Equipment (GFE) on the U.S. Naval Test Pilot School Airborne Systems Aircraft (ASA), on a P-3 Orion aircraft. This was later

renamed ASTARS when the mission was expanded to include technology demonstrations.

The Westinghouse Electronics Systems Group (later Northrop Grumman Electronic Systems and Sensors Division) completed the design in October 1994. The package submitted to USNTPS for review also included a Firm Fixed Price (FFP) proposal to implement the design for \$595,339. In April 1995, the proposal was accepted, resulting in a contract award with work commencing in June 1995, and initial deliveries in September of the same year. The first integration flight was conducted in February 1996. Final GFE sensor installations were completed in June 1996, followed by final system acceptance.

The first major ASTARS modification was completed in 1997 when the original F-16 APG-66 radar was upgraded to an APG-66 Mid-Life Upgrade (MLU) version, configured for foreign military use. The MLU radar provided higher performance and additional operating modes. The fundamental design of the ASTARS system originated from a series of avionics testbed aircraft used by Westinghouse for developmental tests of the F-16, B-1B, YF-23, C-130 and F-22 radars. These testbeds, built on commercial transports and light business aircraft, were designed to allow full in-flight system tests early in an aircraft development cycle. This was to reduce developmental test costs and to allow flexibility in the numbers and types of personnel able to participate in the test programs.

Each test program had the benefit of lessons learned from preceding programs. The result was that each succeeding implementation was more flexible, more modular

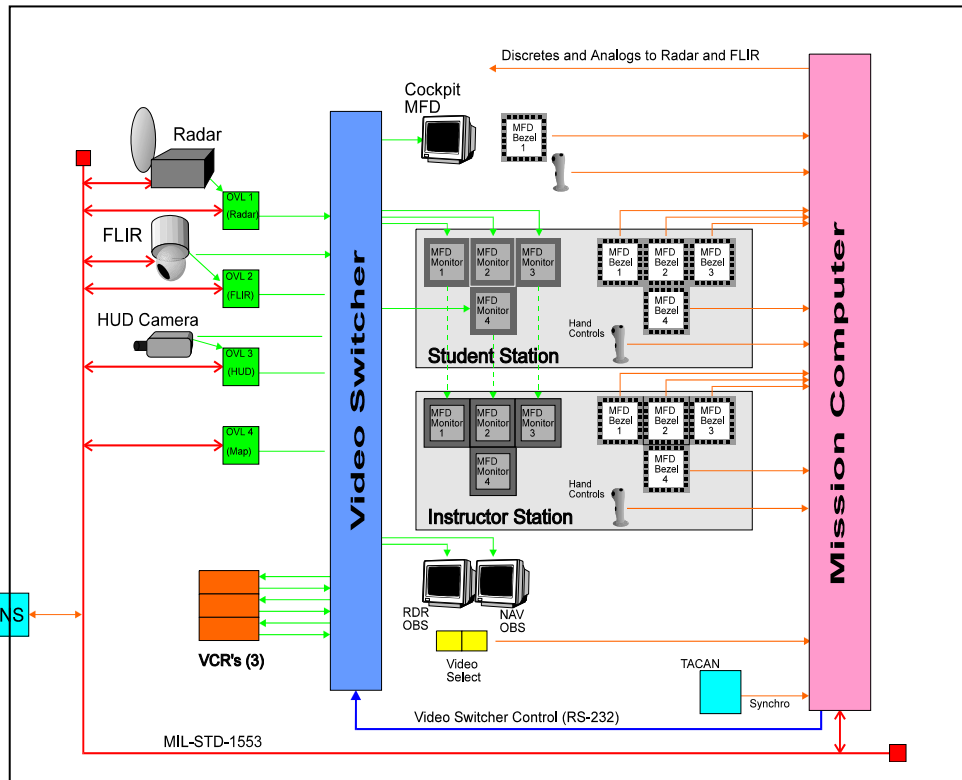


Figure 2
ASTARS System Architecture

and more capable of quickly supporting other programs, requiring fewer and smaller specialized modifications. The finished ASTARS configuration was a generic aircraft, which supported a wide range of radar, electro-optical, and navigation programs. The overall systems architecture is shown in Figure 2.

The ASTARS system was similar to the federated architecture used in next-generation aircraft such as the F-22, Comanche and Joint Strike Fighter. All processing was performed in multiple commercial off-the-shelf PCs. Multifunction Displays (MFDs) were emulated using studio-grade video monitors with added bezel buttons. Sensors included a multi-mode X-band radar (APG-66) and a turret-mounted FLIR (WF-360TL) which included a visual band camera. Navigation was handled by two Inertial

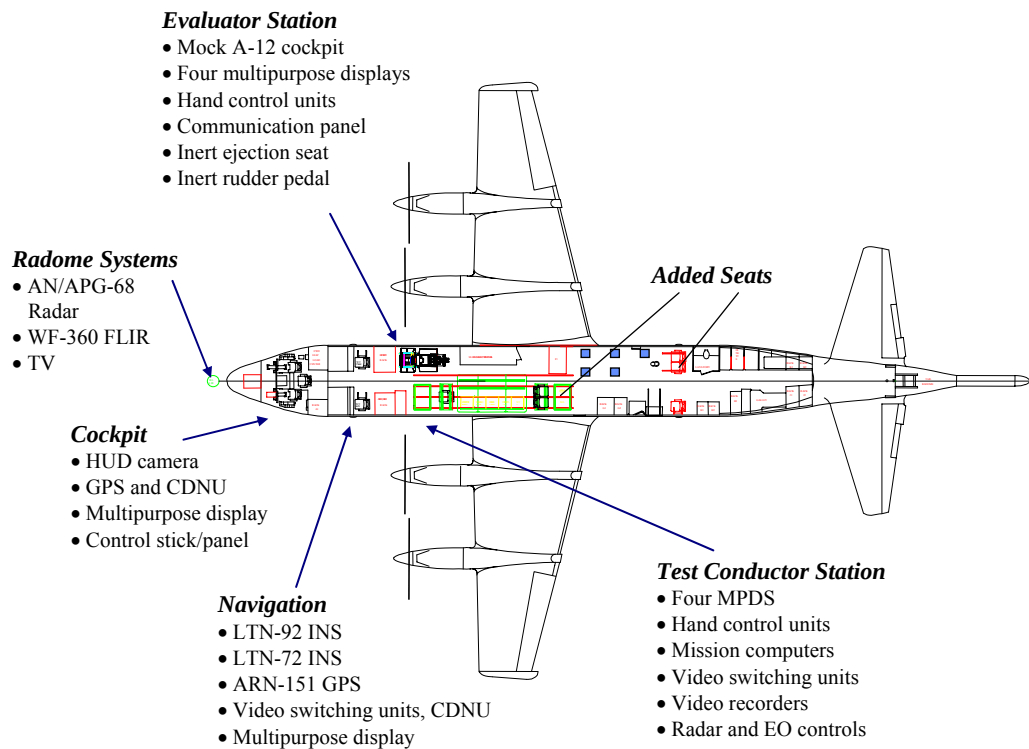


Figure 3
ASTARS Systems Configuration On The NP-3D

Navigation Systems (INS) with integrated Global Positioning System (GPS) data. A Head Up Display (HUD) was simulated using a cockpit-mounted camera with overlaid flight path and sensor symbology. The last of the four graphics generators provided a digital moving map with full continental U.S. coverage. Figure 3 shows the layout of systems in the NP-3D aircraft.

THE NEED FOR AN ADDITIONAL ASTARS AIRCRAFT

The first ASTARS aircraft was a major success and an invaluable asset in training students at the USNTPS, the U.S. Air Force Test Pilot School (AFTPS), Empire Test Pilot's School (ETPS) of the United Kingdom and students in the Test and Evaluation

(T&E) Short Courses. By the end of 2001, 520 students from 15 different countries had been trained on the ASTARS systems. This included students from all branches of the military in the United States, Germany, Spain, Italy, Canada, Israel, Finland, the Netherlands, Norway, Australia, Taiwan, Greece, Singapore, Pakistan, Switzerland, Sweden, France, and Japan (Smith, 2004). In addition, the USNTPS was flooded with requests for airborne systems training from many other countries in Europe, Asia, and South America.

ASTARS I was pressured to fly continuously. Annual USNTPS syllabus requirements were for 89 exercise flights. The T&E Short Courses were growing to 48 exercise flights per year and once the proposed Test and Evaluation University was underway there would be a need for 84 more ASTARS exercise flights. These requirements would be in addition to the already established semi-annual detachments to the AFTPS and ETPS.

No aircraft is available one hundred percent of the time. Routine maintenance events alone restricted support to current levels with no option of handling planned growth. All of the desired flight requirements would not be met. When a more lengthy maintenance phase was required, such as a Planned Depot Maintenance (PDM), the ASTARS aircraft could be unavailable for months, leaving the test pilot schools without a primary systems training platform and forcing the cancellation of syllabus instruction.

An unavoidable 8-month maintenance phase period was scheduled to start in November 2002. If a suitable replacement aircraft could not be fielded, all ASTARS training for the end of 2002 and start of 2003 would be lost. If any additional

maintenance issues surfaced, all of the 2003 systems exercises could be cancelled. The threat of such a long downtime reinforced ideas to embark upon a development program to field a second ASTARS aircraft by spring of 2002.

CHAPTER 2: ACQUISITION PROCESS

CONVENTIONAL DEPARTMENT OF DEFENSE ACQUISITION

In order to understand the acquisition process employed by the ASTARS II team, one must have an understanding of the defense acquisition principles and guidelines. These guidelines are outlined in the Department of Defense (DoD) Acquisition Guidebook and Department of Defense Instruction 5000.2, Operation of the Defense Acquisition System. The process is mandatory for all major defense acquisition programs. A primary goal of any DoD acquisition strategy is to minimize the time and cost of satisfying an identified and validated need, consistent with common sense and sound business practices. The conventional acquisition process is highlighted in Figure 4.

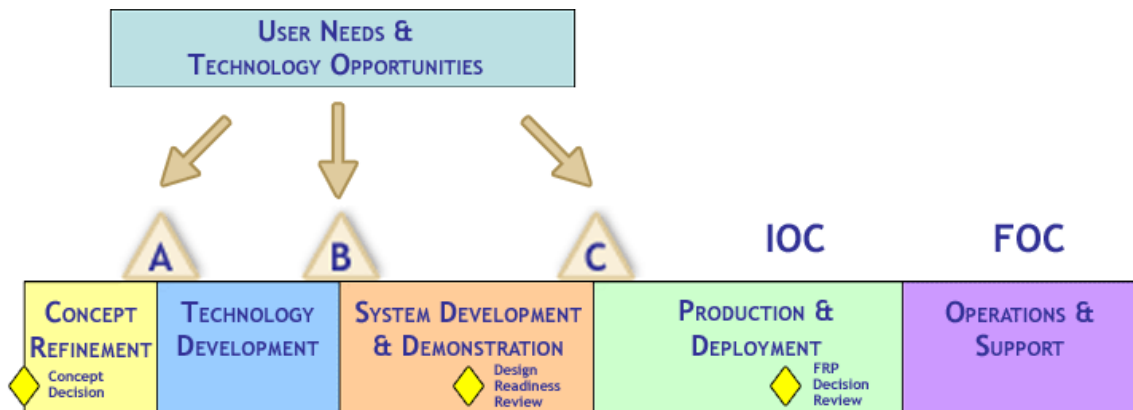


Figure 4
The Department Of Defense Acquisition Process

At the start of any program, the user's need must be defined and understood by the primary stakeholders. In the case of Naval Aviation, the end user expresses the need and, in due course, it is formally documented in a formal Mission Need Statement (MNS), then an Operational Requirements Document (ORD). If approved for acquisition, such needs are given funding, developed and fielded. Nothing is procured without documented needs or requirements. In general, formalized needs are created to identify warfighting deficiencies and/or technological opportunities through mission area assessments of current and projected capabilities.

In order to initiate the process, the end user--the Fleet operators--express their operational needs through the chain of command. Commanders meet annually at Operational Advisory Group (OAG) meetings to create a 'needs priority list'. The priority list is forwarded to the warfare specialty Requirements Officer at the Pentagon and the aircraft type Program Manager at Naval Aviation Systems Command. The Requirements Officer lobbies for funding from pre-existing DoD budgets or from Congressionally appropriated projects. The Program Manager aligns end-user priorities amongst current aircraft acquisition developments.

Once funding is approved, a Program Manager oversees all planning, integrated product team selection, analysis of alternatives, proposal solicitation, design selection, risk assessment, design development, Test and Evaluation Master Plan (TEMP) construction, production of the system, and finally, fielding and supporting the system. All tasks must meet cost, performance, schedule, and environmental constraints.

DoD acquisition programs are required to undergo periodic statutory and regulatory milestone reviews. Key Performance Parameters (KPPs) must be achieved in order for the project to continue to the next phase of development. Funding is often tied to these milestones to prevent cost overruns and further development of systems that are not meeting performance requirements.

Prior to the Initial Operational Capabilities (IOC) point, the program will undergo both Developmental Test (DT) and Operational Test (OT). These phases evaluate the new system at various stages of maturity to ensure that the Fleet gets an operationally effective product. The two test organizations report their findings at various stages of the program to a Milestone Decision Authority (a high ranking military officer or civil servant), who decides to move the program to its next phase and eventually makes the decision to field it. The performance of the system tested in both DT and OT is spelled out in the TEMP. The TEMP utilizes the ORD and other documents to define the quantitative measures that must be met for the system to perform in the employment environment and satisfy mission suitability requirements. With a constructed TEMP and properly executed test program, the program should conclusively meet the needs of the end user.

Altogether, the DoD concept-to-IOC acquisition process usually takes three to five years. In addition, the production and testing of the prototype system could take another one to two years. This drives the time spent developing the system through the acquisition process to as many as seven years.

DEFINING THE NEED

The current ASTARS system met all the user needs with one exception - availability. The end user's desire was not for greater, newer, or different performance capabilities. The need was simply for additional asset time to teach the current test pilot school exercises and meet forthcoming requirements. With the highly structured and inflexible P-3 Fleet maintenance schedule, no option existed to expand availability of ASTARS I. Moreover, in addition to the test pilot schools, the Navy was preparing to stand up a Test and Evaluation University that could use the aircraft for 250 hours per year (O'Connor, 2004).

An ad hoc ASTARS II team was called together to investigate the acquisition of a second aircraft. The mission of the aircraft would be identical to ASTARS I. The assembled team consisted of the ASTARS I aircraft monitor, the USNTPS Senior Systems Instructor, engineering support personnel, software developers, project officers in charge of subsystem acquisition, and a former employee from the company responsible for the completion of ASTARS I.

PROGRAM INITIATION

ASTARS II ACQUISITION PROCESS

Like any typical DoD acquisition program, once the need was identified, the ASTARS II product team attempted to determine what restrictions existed on plans they selected to acquire a second ASTARS aircraft. With such well-defined performance prerequisites, the team moved to determining an acquisition strategy. Navy acquisition

doctrine provided several options in the type, structure, and formality of an acquisition program. In accordance with Secretary of the Navy (SECNAV) Instruction 5000.2B, administrators could bypass many of the normal steps required to produce a system and employ an Abbreviated Acquisition Program. Program size restrictions were the first strategy determinant. ASTARS I was produced with a modification cost of \$595,339 plus the costs of taking ownership of a P-3 aircraft. SECNAV and DoD governing documents required a formal acquisition plan under the following guidelines:

1. Development programs with a total cost of all contracts estimated at \$5 million or more in Research, Development, Test and Evaluation (RDT&E) funds.
2. Production, service acquisitions, or contractor services that provide assistance to a program office or functional organization in supporting systems or programs, whose total cost of all contracts is estimated at \$30 million or more for all years of the program; or \$15 million or more for any one fiscal year.
3. Foreign Military Sales (FMS) requirements, when dollar thresholds above are met by either FMS alone or by combined U.S. Government and FMS requirements.

The instructions further stated that an “Acquisition Plan is not required for military construction, NDI, spare and repair parts; component overhaul, maintenance, or repair at the depot, intermediate, or organizational levels.”

The team believed ASTARS II could be constructed with COTS/MOTS items alone. They planned to use depot level construction for the student and instructor stations as well as structural modifications for mission system components and additional crew

capacity. All spare parts would come from military and non-developmental commercial sources.

Since The ASTARS II development was within DoD and SECNAV guidelines for small program and abbreviated acquisition, the team pursued in-house government construction. As none of the standard acquisition documents and reporting milestones were required, the ASTARS team would be responsible for satisfying only two groups: the test pilot school end users, who required performance equal to or greater than the first aircraft, and USNTPS upper management, who would periodically review cost and schedule developments ensuring expenditures were within the school's annual operating budget.

FUNDING

With the pressing need for a second ASTARS aircraft and the perceived small cost of producing the system, funding was promptly approved from the annual USNTPS operating budget. However, no exact dollar amount was agreed upon nor was any funding schedule formulated. The cost would be absorbed by the annual budget during each subsequent funding quarter.

The team had to investigate the exact source of USNTPS funding. A large portion of the annual budget was defined as Operations and Maintenance, Navy (O&M,N) money. O&M,N limitations, restrictions and use were all governed by U.S. Title Code 31, 1517 and 1301(a), which stated that "O&M,N is allocated to the service

for the purchase of all resources consumed in operating and maintaining the Navy.”

Specific items included:

- Civilian labor, including contractual labor
- Rental payments on leases for equipment and facilities
- Food, clothing, petroleum, oil and lubricant items
- Expendable supplies and materials
- Maintenance, repair, overhaul and rework of investment items including real property maintenance facilities
- Assemblies, spares and repair parts which were not designated for centralized individual item management by an inventory control point or central supply system that cost less than \$100K
- All other equipment items not in the preceding categories that had a unit value limit of \$100K or less and which were not designed for centralized individual item management (O&M,N Participant Guide, 2002)

As long as the ASTARS II acquisition process was within the above guidelines and was being used in accordance with the command’s mission and purpose, funding could be drawn from the available O&M,N apportionment. It was up to USNTPS to determine quarterly and annually if it could afford program continuance.

ALTERNATIVES AND AIRCRAFT SELECTION

Although the first ASTARS system was created using a P-3 Orion aircraft, the team recognized that there could be other aircraft options for the installation of the same or similar systems in order to train test pilots. An Analysis of Alternatives (AoA) was conducted by one of the team members who had more than 20 years of military and commercial flight test experience. The AoA was then presented to the team for

assessment. The comparison weighted factors such as: acquisition cost and risk, utility, syllabus support, operating costs, training requirements and supportability (Roderick AoA, 2001). Business analysis rating scales confirmed that the P-3 was the best option. It was specifically concluded from the AoA that a P-3A aircraft would make the most suitable solution from a performance, cost, schedule and risk perspective.

The team explored acquisition of a P-3A. Discussions with the P-3 Program Office from Naval Air Systems Command (NAVAIR) were conducted to identify an aircraft that would suit the USNTPS requirements. The ideal aircraft would be one that no longer suited Naval Aviation needs but would still possess sufficient service life for USNTPS purposes. One area that held the greatest potential for a suitable airframe was at the long-term military aircraft preservation at Davis-Monthan.

The ASTARS II team sent a three-member delegation to Davis-Monthan to try and identify a candidate aircraft. Preservation personnel identified the best candidate of all those in storage - BuNo 151394 (AMARC Trip Report, 2001). The aircraft was not a P-3A as expected; it was a P-3B that had been with a group of reserve squadron retirements. Of all retired aircraft, it had the most service life remaining, was in the best maintenance condition and had many of the needed safe-for-flight modifications already incorporated. These factors made it the most cost-effective solution with respect to aircraft overhaul for subsequent ASTARS II modifications.

A few months after the search for an airframe started, another even more cost-effective solution presented itself. The newcomer was BuNo 148889, which belonged to a local command. It was an older P-3A, designated as a UP-3A, which was already

performing project work at the Naval Air Station in Patuxent River. Unlike the first aircraft considered, 148889 was already in a flyable condition, which would eliminate the million dollar plus return-to-flight overhaul costs that would be required for Aerospace Maintenance and Regeneration Center (AMARC) aircraft. Aircraft 148889 was also not Fleet representative because it had never been equipped with acoustic or Surface Subsurface Surveillance Coordination (SSSC) mission systems. This unusual lack of mission equipment meant that it would, in all likelihood, never be reclaimed for Fleet use. It had also been equipped with a unique power distribution system for research and development projects that would simplify ASTARS modifications.

Aircraft 148889 did require a \$1 million maintenance phase. That phase in combination with a shrinking number of test projects at VX-20, resulted in this older P-3 airframe being scheduled for retirement unless a sponsor was found to assume all maintenance and operational costs (Roderick, 2004). Considering that the first ASTARS II candidate would cost approximately \$1.6 million to refurbish and make air worthy, not to mention the risks associated with a long downtime and a non-flyable airframe, this new option presented many advantages. The team moved forward to take ownership of the aircraft. The acquisition made plans for a simultaneous maintenance/modification phase.

MODIFICATION

The only entity capable of performing the upcoming aircraft maintenance was a Naval Air Depot (NADEP). Discussions with regional depots indicated that they could simultaneously work the phase maintenance and ASTARS II structural modifications as

the team had hoped. After agreeing on the final SOW with NADEP Jacksonville, FL, and just before flying the airplane to Florida to commence work, it surfaced that NADEP Jacksonville's schedule would be longer than the team wanted due to a backlog of work. A suitable facility in Greenville, NC was identified with more suitable availability than that of Jacksonville. The aircraft was flown to Greenville and indoctrinated for PDM with concurrent ASTARS modifications.

RADAR ACQUISITION

The FLIR and radar still had to be obtained by USNTPS. The FLIR was relatively simple to acquire because USNTPS had several available in supply that were supporting ASTARS I. However, finding another APG-66 proved to be more difficult. With aircraft 148889 already undergoing maintenance and modifications, the team explored every available option for a replacement radar system.

The ASTARS II team first tried APG-66 radar channels within the U.S. Air Force. None were available. With the given schedule constraints, the team contacted test pilot school counterparts at AFTPS. AFTPS was unable to locate an APG-66 radar, but continued with a broader search for any suitable radar.

In January of 2002, AFTPS located an APG-68 radar system that was in a storage facility at their base. Although the team would have preferred the APG-66, the APG-68 was the USAF replacement for the APG-66, and it offered some potential advantages for Mean Time Between Failure (MTBF) and parts support. Commonality with ASTARS I would be lost while at the same time increasing acquisition risks, but with no other means

of locating an APG-66 and the offer of a free radar, the team elected to pursue the APG-68. Compensation for the radar would be a promise from USNTPS to support AFTPS with biannual ASTARS systems flights by sending a detachment to AFTPS for one to two weeks bi-annually. (Nickles, 2002)

Changing radar systems from an APG-66 to an APG-68 late in the modification schedule introduced several issues. The team conducted informal email discussions over several weeks in order to identify risks. Although obtaining a \$1.2 million radar system in exchange for two weeks of systems training per year seemed appealing, the ASTARS II team was cautious. All team members had experience in military acquisition and recognized that unknown problems were always lurking. No one had ever attempted to put an APG-68 radar system on a P-3, and that fact alone warned of possible hurdles. As one team member stated in the first round of discussions, “To my knowledge, no one has an engineering package to hang an APG-68 on a P-3. As I recall, the 68 is heavier and requires more power. A cheap radar could cost us a ton of time and have high Non Recurring Engineering (NRE) costs.” (Elliott, 2002) Various questions surrounded the APG-68.

During the email discussions two major issues surfaced. First, the APG-68 power requirements were much higher than the APG-66. However, the power supply system on 148889 was sufficient to handle the new radar. The second issue was that the APG-68 radar antenna weighed 63 pounds more than that of the APG-66. A quick mounting bracket structural analysis showed that anything less than 100 lbs difference in weight would be insignificant.

Unknowns remained, but a reasonable explanation was found for every question raised, and the problems brought forward were judged to be solvable. The team surmised that the APG-68 radar was worth the risk and should be pursued for ASTARS II. It was this risk analysis that finalized the acquisition study and resulted in abandonment of the APG-66 in favor of the APG-68 system. Below are representative APG-68 installation, modification and employment risk assessment issues and a summary of the risks mitigated:

Question: “What condition is the equipment in?”

Response: “Our Integrated Facility for Avionics Systems Testing (IFAST) folks have been running a survey and checking out of this radar equipment. According to them, the APG-68 antenna, Dual Mode Transmitter (DMT), Modular Low Power Radio Frequency (MLPRF), and Programmable Signal Processor (PSP) all work fine with Block 30 and Block 40.”

Risk interpretation: Radar components are in a fully functioning condition. The Line Replaceable Units (LRUs) will not require repair or replacement, which will minimize and return-to service costs.”

Question: “Are there limitations to operation with current APG-68 supply system parts? What block is the radar?”

Response: “IFAST tells me that the DMT, MLPRF, and APG-68 antenna should be able to run with all USAF Blocks with the proper avionics configuration. However, with the PSP it has now, this radar can only run Block 30, Signal Conditioning Unit (SCU) 4, and Block 40 (T1 - T6). In addition, if it were to run

on SCU 4.1, the Electronic Emulating Flight Control Computer (EEFCC) needed for the avionics system, or the Block 40T7 PSP, needs to be upgraded with more memory. Furthermore, if these units were to run with a more advanced USAF Operational Flight Program (OFP) (such as Block 50 and MMC) the PSP would need to be upgraded to Advanced Programmable Signal Processor (APSP) with additional hardware (such as a MMC).

They also said the DMT, MLPRF, and Antenna could be run with an Foreign Military Sales (FMS) OFP. However, the MLPRF would need to have the appropriate A-13 FMS controller/Central Processing Unit (CPU) board. He said that nowadays there aren't many FMS programs that run with a PSP. Therefore, a specific APSP and avionics configuration would be required.”

Risk interpretation: The system is compatible with the current USAF APG-68 component supply chain so parts support should not be an issue. Configuration management will remain a risk; future LRU replacement and repair may cause incompatibilities that will not allow the system to function.

Question: “What software load does it have? USAF or FMS? If a USAF load, would there be any releasability issues?”

Response: “The IFAST engineers tell me the OFP ID load on the PSP is 6310. This is an USAF development Block 30, used before 1993. We are checking to see if we can obtain a non-country specific FMS-like baseline load that we can use in our Electronic Countermeasures (ECM) lab with foreign students. If it works out, we may also be able to load this into this APG-68 radar set. This should eliminate any country proprietary and releasability issues.”

Risk interpretation: A large percent of the USNTPS, AFTPS, ETPS and T&E Short Course (future T&E University) students are Foreign Nationals, which

limits the type of information that can be displayed. United States Air Force Test Pilot School (USAFTPS) may be able to assist with the releasability issues, but the risk will have to be further mitigated by the ASTARS II software designers with the support of team security researchers.

Question: “What is the history of the radar? Was it a test article? Was it warehoused in the past 10 years? Any known previous usage?”

Response: “I’m told that the Air Force Research Laboratory (AFRL) at Wright Patterson Air Force Base (AFB) took a brand spanking new radar and put it into storage 10 years ago. This is the set we now have in our possession. When we acquired it, we took it over to our IFAST to have them check out the LRUs. We wanted to make sure it wasn’t a piece of junk or that it hadn’t ‘gone bad’ while sitting in storage. They said that all of the LRUs physically look fine. They found no damage and all National Stock Number (NSNs), Part Number (P/Ns), and Serial Numbers (S/Ns) matched up with the invoice. The three DMT, MLPRF, and PSP LRUs were checked out on the IFAST Radar Station with their existing APG-68 antenna. The engineers reported that all three LRUs functioned properly.”

Risk interpretation: The radar appeared to be in good condition. All LRUs were in a functioning condition, which indicated no replacement or repairs would be required.

Question: “What is the support vehicle/posture (software, parts, etc)? Will/could we be included in a USAF support contract?”

Response: “Yes, we have a logistics trail you could use. To be honest, it might slow down a little with an extra step (us) in the middle. Is it possible for you to use the same logistics trail you already have for your APG-66? Or, I understand the Navy had F-16's. Maybe you could fold into their support trail? Naturally, our management says we won't pay for you to use this radar. So, if you need a box, you'll have to pay for it. However, we can provide the support vehicle where you'd send in the box and Military Interdepartmental Purchase Request (MIPR) us the money for the fix (sic). Therefore, either way you want to go, the long answer is ‘yes’, we can provide you with a support vehicle, if you have no other means.”

Risk interpretation: If a support vehicle trail cannot be created directly from the USNTPS supply system, AFTPS is willing to act as a go-between to tie into the Air Force supply system. Additional investigation into former USN F-16s indicated that the aircraft are no longer in use and are in preservation at Davis-Monthan. The preserved aircraft also had their radars removed, so no spare parts exist anywhere in the Navy. The logistics support system for the APG-66 will not be an option because that partnership of APG-66 users does not have APG-68 users. There is no commonality between APG-66 and APG-68 LRUs so none of the support items for the ASTARS I radar system will be of any use. USNTPS will be on their own to replace APG-68 parts, nonetheless, the risks associated with this process are low because the means to get LRUs exists and the MTBF on the APG-68 is better than the APG-66.

Question: “Are all LRUs included with the radar, including rack? Will any spare parts be included (ideally another ship set)?”

Response: “IFAST says it's all there. The following are the six LRUs that would be provided:

1. APG-68 Antenna, S/N 10481
2. DMT, S/N 11114
3. Modular Low Power Radio Frequency (MLPRF), S/N 10750
4. Programmable Signal Processor (PSP), S/N 10969
5. A Rack assembly that holds 3 LRUs, S/N 10010 (PSP, DMT, and MLPRF)
6. Digital Computer, S/N 0203

No we don't have any spares in this package. Also, we don't have access to a second ship set. However, to have both an APG-66 and 68 loaded onto your two systems aircraft should be beneficial. You'd be able to provide your students with two different looks at a similar system.”

Risk interpretation: All parts and subcomponents to the APG-68 appear to be included. During the acquisition and modification process, replacement for any failed or defective items will result in ASTARS II modification delays equal to the time required to obtain a replacement subcomponent, which may affect Initial Operations Capability (IOC).

Question: “Is this radar ‘free’ or are there any costs we will have to pick up with the radar?”

Response: “Well, it's not exactly ‘free’. Now, you won't have to ship us a bag of money, but there are a few considerations we'd like:

- Scheduling priority for our Avionics System Test and Training Aircraft (ASTTA) support when we need it.
- Since we'd be "loaning" you a \$1.2-million radar, we'd like a long-term rate break for our ASTTA support. Now, the USAF legal office

says we can't put these "barter" deals into Memorandum Of Agreements (MOA). So, we'd like a gentleman's agreement that we'd be taken care of.

- Priority for use of the new P-3 with the APG-68 radar installed.”

Risk interpretation: No risk mitigation. Cost of accepting the radar from AFTPS will be higher priority support for AFTPS training over other commitments. With two fully mission capable ASTARS aircraft no issues should arise. During times when only one aircraft is available, USNTPS syllabus events will have to move later in the schedule.

Question: “When will the radar be available and what is the mechanism (and time period) for transfer to us?”

Response: “The radar is essentially checked out (not as an integrated system) and ready to go out the door today. We'd use a DD Form 1149, in connection with a MOA to loan the radar to you. This should be enough to get you rolling. Let me know if there is anything else you need.” (Nickels, 2002)

Risk interpretation: Modification schedule risks were reduced since the system would be available right away.

CHAPTER 3: THE ASTARS II SYSTEM

Aircraft modification and maintenance (PDM) phase started in January of 2002 at the Greenville, NC Aviation Depot facility. Modification was conducted in two stages. The first stage completed all necessary ASTARS modifications with the exception of the evaluator station mock “cockpit” and structural support that would allow for more ditching stations (20 g impact design limit). The mock cockpit was built by NAVAIR Test Article Preparation (TAP) facilities located at Naval Air Station Patuxent River, MD.

Aircraft structural modifications included the Test Conductor Station, fabrication of a computer cabinet, floor upgrades, construction of an aft lavatory and a galley upgrade similar to the P-3C aircraft design. Avionics upgrades included the APG-68 radar, GPS, FLIR, Ring-laser Inertial Navigation Unit (RINU), ARC-210 radios, Intercom System (ICS), 60 Hz converters, interior lighting, transformer rectifier, and a new power distribution panel. Upon completion of all structural modifications, the aircraft had an aircrew and student capacity increase from 8 to 23. This included three in the cockpit, one at the Evaluator Station, two at the Test Conductor Station and the remaining dispensed among the aft observer stations, galley seats and 12 airline style seats. The first phase took eight months to complete. The aircraft was flown back to Patuxent River, MD at the end of 2002. The aircraft was indoctrinated into the Patuxent River TAP facilities for construction of the evaluator’s station and additional structural modifications for increased crew capacity. By April of 2003, the aircraft was ready for ground testing.

DESCRIPTION OF TEST AIRCRAFT

BASIC AIRCRAFT

NP-3D, BuNo 148889, was a Fleet representative P-3A basic airframe, but not Fleet representative from the installed mission systems viewpoint. It was a special purpose P-3, which was formerly used by Naval Air Developmental Test Center and VX-20. P-3 acoustic and Surface Subsurface Surveillance Coordination (SSSC) missions systems were not installed. It had a unique electrical power distribution system to support project equipment, and a strengthened floor to accommodate rack and plate-mounted project equipment.

The NP-3D aircraft, built by Lockheed Martin Aeronautical Systems Company, was an all-weather military, four-engine, low-wing, turboprop aircraft designed for maritime patrol, anti-submarine warfare, anti-surface warfare and fleet support. The multi-mission aircraft had a gross takeoff weight of 135,000 lbs and was powered by four T56-A-14 turboprop engines. The aircraft was airframe limited to 300 KIAS and had a maximum operating altitude of 35,000 ft. The standard flight crew consisted of two pilots, one flight engineer, two naval flight officers and one in-flight technician. The avionics system coordinated navigation information and accepted sensor data inputs for tactical display and storage. A detailed description of the NP-3D aircraft can be found in the Naval Air Training and operating Procedures Standardization (NATOPS) manuals for P-3C aircraft, NAVAIR 01-75PAC-1, NAVAIR 01-75PAC-1-1, the ASTARS Operator's Manual Revision 3 and the Pilot's Manual for the AN/APG-68 Fire Control Radar as

Table 1
NP-3D ASTARS Envelope

Parameter	NATOPS Limit		NAVAIR Flight Clearance	
	Minimum	Maximum	Minimum	Maximum
Airspeed (KIAS)	--	405	--	300
Altitude (ft MSL)	--	35,000	--	--
Load Factor (g)	1.0	2.0	1.0	2.0
FLIR Turret Extended	--	300	--	--
FLIR Turret Extend/retract	--	300	--	--

installed in the USNTPS ASTARS Aircraft. The aircraft operating envelope is shown in Table 1.

COCKPIT

Full ASTARS II system display and navigation capabilities were provided in the cockpit (Figure 3). One limitation in the cockpit was that there was only one MFD to display the systems and flight profile information. A single hand controller and multifunction keypad were installed at the copilot's seat to control navigation outputs and the MFD display.

FORWARD OBSERVERS

Two observer stations were installed in the crew stations just behind the cockpit. The left station had a color MFD identical to the student and instructor stations. This MFD was also used as a spare for the other eight mock-up MFDs in the aircraft. The right forward observer's station displayed system video on an existing monochrome

video display. These observer stations had 16-position thumbwheel switches, allowing selection of all possible sensor video sources.

AFT OBSERVATION

Video lines were provided for two aft observer displays. The aft observers had no video selection controls and were dependent on the other operators to select their desired sensor.

DESCRIPTION OF THE SYSTEMS

CONTROLS AND DISPLAYS

The crew stations utilized commercial Avalex Active Matrix Liquid Crystal Displays (AMLCD), appropriately shielded and mounted for implosion protection and configured with pushbuttons as MFDs). Multifunction hand controllers provided sensor control and operator interface. System control and video conversion was processed by five commercially available ruggedized computers in a rack-mounted chassis. The instructor/test conductor station was mounted on a standard 19-inch rack. It included four MFDs and two hand controllers, and was designed as the controlling source for system power and video recording. The student/evaluator station was a replica of the proposed A-12 cockpit, using four MFDs and two hand controllers, as shown in Figure 5. Either station could control any sensor through the hand controllers and pushbuttons and route the video to any of the displays at that station. Radar, FLIR, moving map, and HUD camera video was available. In addition, there was a display repeater at the NAV

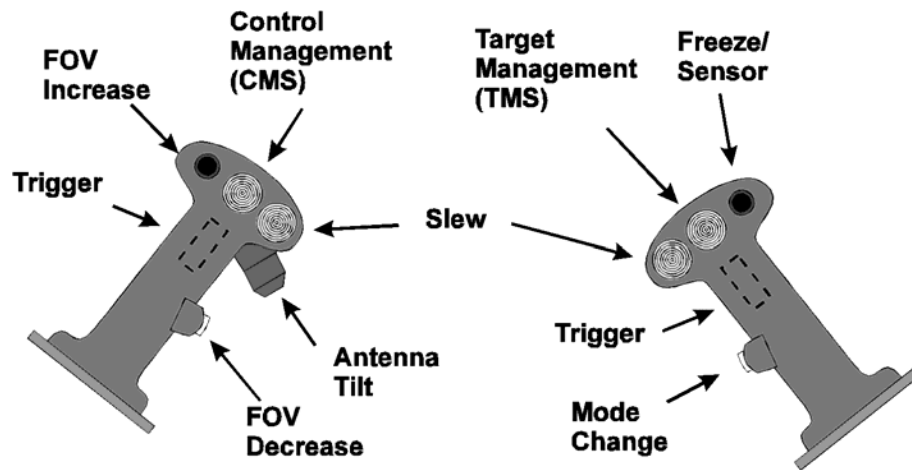


Figure 5
ASTARS Hand Controllers

station and the pilot station to view, but not control systems. Interlocks were provided to prevent radar radiation on deck and to shut down the radar in the event of overheating.

WF-360TL FORWARD LOOKING INFRARED SENSOR

The WF-360TL sensor head contained a FLIR sensor, daylight TV camera, and a laser range finder. The sensors were housed in an environmentally self-contained, stabilized gimbal that was ruggedized for aircraft use. Full 360-degree azimuth coverage was provided. The FLIR operated in the 8-12 μ meter range utilizing mechanically scanned, cryogenically-cooled 480x4 linear array mercury-cadmium-telluride detectors. FLIR specifications were as follows: cooldown time of 5 to 8 minutes, Noise Equivalent Delta Temperature (NE Δ T) of 0.11 deg C, a narrow field of view 2.7 deg x 3.6 deg, and a wide field of view 11.1 deg x 14.8 deg with 360 deg azimuth coverage from +30 deg to –

85 deg in elevation. The WF-360TL FLIR consisted of five LRUs as shown in Table 2. A depiction of the WF-360 is shown in Figure 6.

In addition to the primary Infrared (IR) detector, the WF-360TL offered added capabilities provided by a co-aligned optical camera and laser range finder. The optical camera was a monochrome 768 x 488 pixel Charge-Coupled Device (CCD) camera mounted in the same turret and provided the option of obtaining higher resolution images when sufficient light was available. The video camera was not low-light level capable and was unusable for unlighted targets in shadows or after dusk. The WF-360TL used a solid-state, single-burst laser to provide active ranging to targets. The laser was considered eye-safe, but required specific operator actions to arm and fire. The contractor furnished laser range finder characteristics are shown in Table 3. The WF-360TL FLIR could be set to the pointing and tracking modes depicted in Table 4. The ASTARS mission computer managed five WF-360TL FLIR hand controllers, mapping them to the displays. The following FLIR functions were available from the hand controllers:

1. Zoom in / out
2. Slew to line of sight
3. Toggle track modes or make sensor of interest
4. Recenter to boresight
5. Slave to sensor of interest
6. Slave to waypoint
7. Toggles from FLIR to TV
8. Toggle from black hot to white hot

Table 2
WF-360TL Forward Looking Infrared Components

LRU	Size (inches)	Weight (lbs)
Gimbaled Turret	16 x 22	145
Turret Drive	8 x 8.5 x 21	33
Avionics Electronics	12 x 8.8 x 21	42
Image Interface	9 x 6.5 x 11	16
Control Panel	9 x 5.8 x 7	7

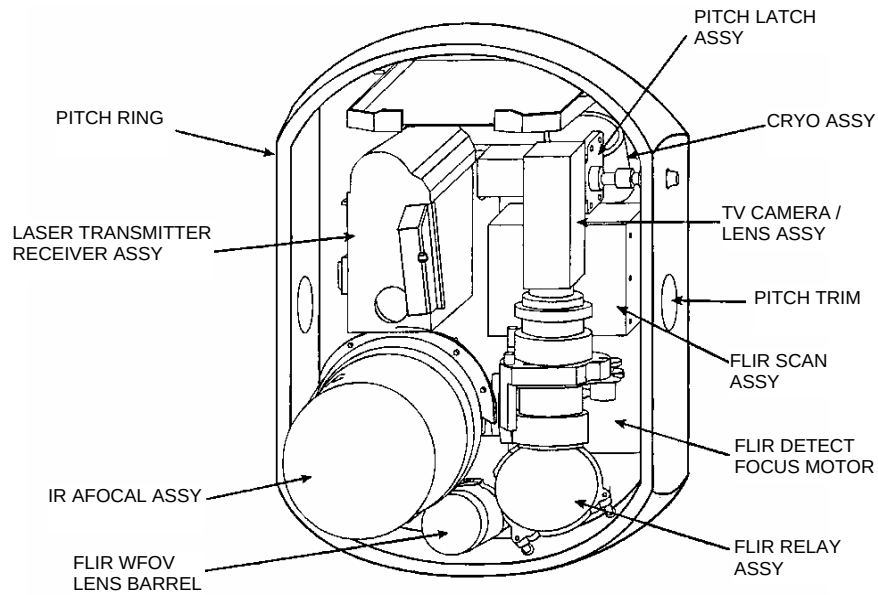


Figure 6
WF-360TL Forward Looking Infrared System
(Source: ASTARS Operating Manual)

Table 3
Laser Range Finder Characteristics

Parameter	Specification
Pulse energy	16 millijoules
Beam divergence	1.0 milliradians
Range	50 - 9,995 meters
Resolution	5 meters

Table 4
WF-360TL Pointing And Tracking Modes

Tracking Mode	Description
CAGED	The FLIR line of sight was fixed at zero azimuth and a small depression angle
GROUND TRACK	The FLIR remained at a fixed location on the surface of the earth
AREA TRACK	The FLIR attempted to keep the entire scene stable in the display
POINT TRACK	The point track mode was optimized to track small, well defined targets which were distinct from the background scene
SLAVE	The FLIR was slaved to the Sensor Point of Interest (SPI) or to the current navigation reference point

AN/APG-68 RADAR

The AN/APG-68 was a coherent, digital, multimode radar derived from the AN/APG-66 and introduced into service in the Lockheed F-16 with Block 30/40 aircraft and used in subsequent blocks. The radar featured an electrically driven antenna, a MLPRF unit that featured plug-in modules and an air-cooled DMT that permitted the radar to operate using low, medium and high-pulse repetition frequencies (PRFs). This hardware capability and flexibility allowed the radar to be optimized easily for any air-to-air or air-to-ground search, track or mapping scenario. Since programmatic comparisons

and risks that existed when replacing the APG-66 with an APG-68 are a primary focus of this paper, a short description of both radars follows.

AN/APG-66 RADAR

The APG-66 was a medium power, single-channel, low and medium PRF multimode radar that employed a mechanically scanned, planar-array antenna. The fully coherent system included a traveling wave tube (TWT) transmitter to generate approximately 21.5 kW peak power. Pulse-Doppler techniques were employed in air-to-air modes. Four operator selectable channels were available with frequency agility employed within each channel. The specifications for the APG-66 radar are shown in Table 5.

The AN/APG-68 incorporated a total of 25 air-to-air and air-to-surface modes of operation. Air-to-air modes were designed to detect, track and engage targets at all aspects and altitudes, even in the presence of ground clutter. Air-to-surface modes were designed to provide mapping, target detection, location, tracking and navigation capability. The radar employed low PRF for air-to-surface use and medium and high PRF modes for longer-range air intercept. The specifications for the APG-68 radar are shown in Table 6. The AN/APG-68 radar is depicted in Figure A-1. The AN/APG, as installed in the NP-3D aircraft, is shown in Figure A-2.

Table 5
AN/APG-66 Radar Specifications

Parameter	Specification
Peak Transmit power	21.5 kW
Beam width	3.2 deg azimuth, 4.8 deg elevation
Maximum scan rate	62 deg/s
Noise figure	3.9 dB
Frequency	8-12.5 GHz
PRF, Air Search	7.7 - 14.9 kHz
Volume	0.13 m ³
Weight	149 kg
Search range	160 nmi (air-to-air), 80 nmi (air-to-ground)
Power	5,200 VA
Transmitter	Gridded, multiple peak power traveling wave tube
Antenna	Planar array, 740 × 480 mm
Range scales	10, 20, 40, 80, 160 nmi
Azimuth scan	±10 deg, ±25 deg, ±30 deg, ±60 deg
Elevation coverage	1, 2, 3 or 4 bar
Number of units	4 LRUs, all in the nose of the aircraft
Reliability	264/390 h MTBF
Cooling	9.9 kg/min at 27 deg C

Table 6
AN/APG-68 Radar Specifications

Parameter	Specification
Peak Transmit power	17.5 kW at low duty (0.03 max) 1.75 kW at high duty (0.45 max)
Beam width	3.25 deg azimuth, 4.55 deg elevation
Maximum scan rate	65 deg/s for RWS (horizontal scan) 84.6 deg/s for ACM 10x40 (vertical scan)
Noise figure	3.25 dB
Frequency	9.695-9.905 GHz (Radar Modes) 9.375 GHz (BCN transmit)
PRF	0.077 - 310 kHz
Volume	0.13 m ³
Weight	172 kg
Search range	160 nmi (air-to air), 80 nmi (air-to-ground)
Power	5,600 VA
Transmitter	Gridded, multiple peak power traveling wave tube
Antenna	Planar array, 740 × 480 mm
Range scales	10, 20, 40, 80, 160 nmi
Azimuth scan	±10 deg, ±25 deg, ±30 deg, ±60 deg
Elevation coverage	1, 2, 3 or 4 bar
Number of units	5 LRUs, all in the nose of the aircraft

INERTIAL NAVIGATION SYSTEM

LTN-72 INS

The LTN-72 Inertial Navigation System (INS), made by Litton Industries, was a two degree of freedom, gyro-stabilized, analytical inertial navigation system. It consisted of four LRUs: (1) a mode selector unit, located on the Pilot-side instrument panel, which provided for power application and mode selection; (2) a Control Display Unit (CDU), located at the Navigator station, which provided display of navigation data and selection of navigation functions; (3) a battery unit which provided approximately 15 minutes of back-up DC power; and (4) an Inertial Navigation Unit which provided a stable platform for the four accelerometer system and incorporated a power supply and navigation computer to compute navigation information.

LTN-92 INS

The LTN-92 INS, also manufactured by Litton Industries, was a strap-down INS incorporating ring-laser gyro stabilization. It was also comprised of four LRUs: (1) a mode selector unit, located on the Pilot-side instrument panel which provided for power application and mode selection; (2) a CDU, located at the Navigator station, which provided display of navigation data and selection of navigation functions; (3) a battery unit which provided approximately 30 minutes of back-up DC power; and (4) an Inertial Navigation Unit which incorporated the RLG package and navigation computer. The LTN-92 was aided by the ARN-151 GPS at a rate of once per second to increase the accuracy and reliability of the system.

ARN-151(V)2 GPS

The ARN-151(V)2 GPS consisted of an AS-3822/URN fixed reception pattern antenna and an R-2332/AR 5-channel receiver processor unit. The system required a minimum of four satellite signals to develop accurate fixing information. The receiver processor was integrated with the mission computer through a MIL-STD-1553B data bus. The GPS system did not require any external inputs for initialization or operation and provided storage of 20,000 waypoints and a 200 waypoint local identifier database.

MOVING MAP

The moving map was a COTS system from Horizons Technology that provided continuously updated pixel-based maps to the operator. The map coverage ranged from a Joint Operations Graphic (JOG) (1:250,000 scale) map through a Jet Navigation Chart (JNC) (1:2,000,000 scale) map. The LTN-92 INS provided either an ARN-151 GPS aided or an unaided navigation solution to update ownship position on the moving map. The moving map acted as the navigation reference point source for the system; all other sensors could display or be slaved to the moving map's navigation reference point. The map display scale could be selected to 5, 10, 20, 40, 80, 160, 500, and 1000 nmi scales. A waypoint library contained all Very High Frequency Omni-directional Radio-ranges (VORs) in the continental U.S. (approximately 1300) and up to 99 user-defined waypoints. The waypoints were loaded via a waypoint file on the map computer hard drive or in the removable disk drive. The map also stored up to 99 mark points, which could be created in flight. The moving map is shown in Figure 7.

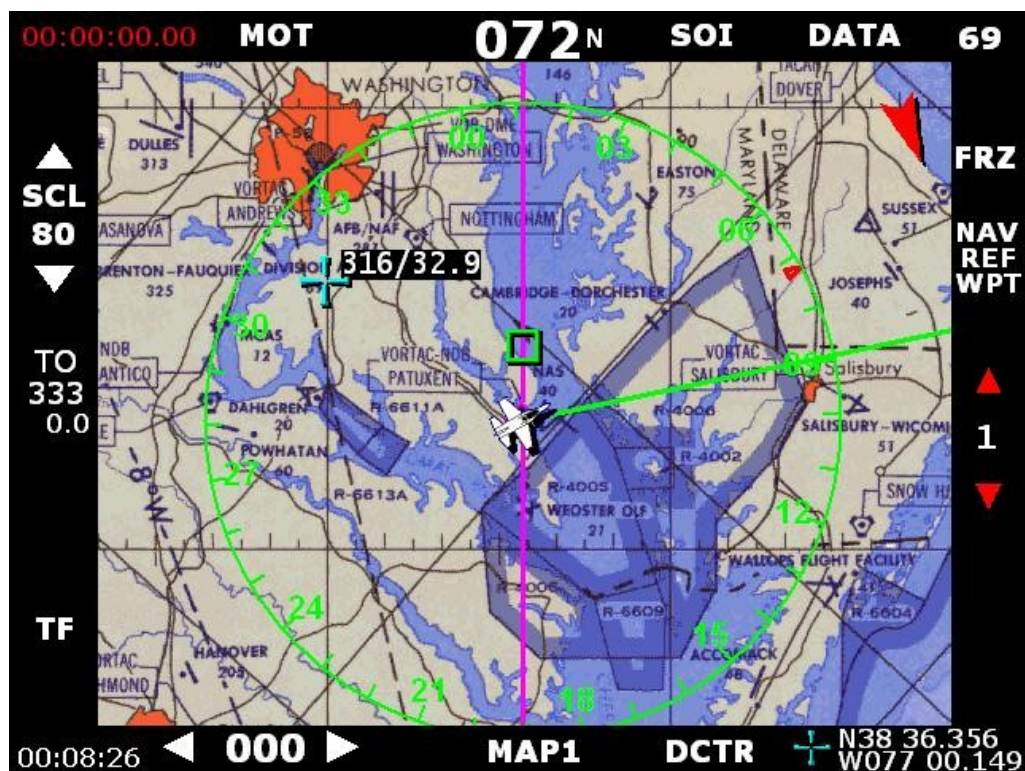


Figure 7
ASTARS Moving Map

HEAD UP DISPLAY

The simulated HUD used on the ASTARS was designed with graphics overlaid on real-time images from a cockpit-mounted video camera. An off-the-shelf multi-media card combined the camera input and Video Graphics Array (VGA) graphics generated by a dedicated IBM PC class computer. The composite image was then viewed on a Cathode Ray Tube (CRT), providing a visual scene identical to that generated by a HUD camera looking through an actual HUD combiner glass, but lacking the peripheral cues and collimated (focused at infinity) aspects of a real HUD. All symbology was displayed using bright green lines to closely emulate the green CRTs used in high-brightness

HUDs. The camera lens was selected to give a field of view similar to current tactical HUDs (approximately 22° x 30°). The ASTARS HUD is shown in Figure 8.

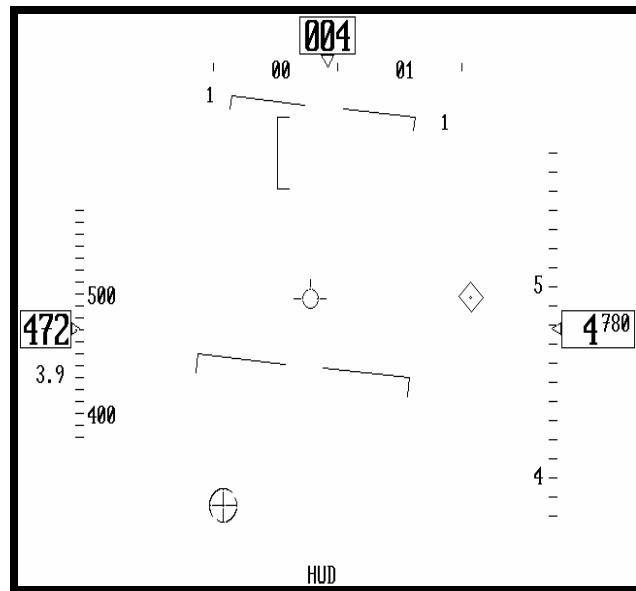


Figure 8
ASTARS System HUD

CHAPTER 4: TEST, EVALUATION AND CORRECTIONS

HARDWARE AND SOFTWARE FAILURES

Initial ground testing started April 20 2003. The purpose was threefold: conduct an Electromagnetic Compatibility Safety of Flight Test (EMC SOFT) prior to the aircraft's Functional Check Flight (FCF), perform the first power-on checks of the AN/APG-68 radar and perform a complete system checkout of the ASTARS II to compare performance/functionality with the ASTARS I configuration.

An EMC SOFT was completed with the radar powered down. An additional EMC SOFT would be required once the radar was in fully functioning condition. Representative hardware and software test results are listed in Tables 7 and 8. Solutions to the failures and anomalies discovered are also included in the sample results. Overall, non-radar related hardware and software problems were being fixed at a rapid rate, which encouraged the team belief that 148889 could be fully mission capable in a very short time.

RADAR-SPECIFIC TEST RESULTS

The radar failed to power up or respond to inputs from both the instructor station and the student station during ground test events. It was determined that radar cabling was configured incorrectly. This was verified with temporary jumper cables that were used to provide radar video. Although the radar display functioned and power-up sequence was completed, the radar still did not complete Built in Test (BIT) or operate in any settings.

Table 7
Hardware Failures

Hardware Failure	Resolution
Found one of the four new sticks had no elevation slew output	Made repairs to the stick. All sticks now have proper response from all slews, knobs and switching.
Video selection switch at the NAV station did not operate properly.	Found a pin in one connector in the wrong location and found an error in mission computer software. Fixed both, video select switch now works properly.
Found an error in the bezel cable diagram.	This could have been handled with a significant software change or by making a change to the bezel cables. Decision was made to change cables, which was then completed prior to next integration session.
Found slew controls on two of the four new sticks to be slightly misaligned, resulting in cross coupling between azimuth and elevation slew inputs.	Adjusted orientation of the slew elements.
The 20-button panel in the cockpit does not operate properly with the mission computer.	Cause was wiring misalignment between the panel and the cockpit digital Input / Output (I/O) unit. Required only rearranging pins in the connector to the control panel.
No video from the radar.	The video line from the radar was improperly connected to the radar processor. The proper connector used an unusual reverse-gender BNC connector. Temporary jumper cables were used to continue testing until the connector on the video line was changed to the proper type required for first flight.

Source: (Eide Daily, 2003) (Whelan Daily, 2003)

Table 8
Software Failures

Software Failure	Resolution
Sensor azimuth and elevation slew inputs were opposite to intended design convention.	Used a stick from 443 to confirm that the problem was with software and not the new sticks. Corrected software.
MRK button on MAP was inoperative. Works from Target Management Switch (TMS).	Pin numbering on the high-density connectors on the digital I/O units was not clearly identified in any of the manufacturer's documentation. Made a minor change to mission computer software to adapt to the actual wiring configuration.
Found that radar MFD software disabled video output when no radar 1553 bus traffic was found.	Changed radar MFD software to control overlay generator properly.
Video switching on the FLIR MFD did not operate properly.	Problem was caused by a minor coding error, which was corrected.
Map Computer drive boot order was floppy, then hard disk. This resulted in waypoint floppies not being available for new system waypoint input.	Complementary Metal-Oxide Semiconductor (CMOS) boot drive order was modified to read the hard disk first.
All MFD functionality present, however controls were very sensitive resulting in frequent overshoots. May be a result of bezel key "bounce" or too high a sampling rate.	Changed the bezel button repeat delay to eliminate unintended multiple inputs.
Map smearing during freeze (FRZ) operations with slews outside of the original map area.	Found the source of map smearing when slewing. Changed software to prevent smearing. The only correction for this was to change the range scale up/down.

Source: (Eide Daily, 2003) (Whelan Daily, 2003)

RADAR OVERHEAT

The following ground evaluation period resulted in radar overheat and subsequent shut down after just a few minutes of operation. LRU temperatures were qualitatively assessed by the test crew. The PSP was extremely hot while all other LRUs were only slightly warm. The radar system cooling fan appeared to be operating properly. They hypothesized that the problem was probably airflow balancing. A suggestion for improving airflow included removing the PSP and changing the size of the outlet orifices in the cooling plenum.

The team also believed the PSP external overheat sensor was not close enough to the PSP to properly indicate component overheat temperatures. This may have resulted in the system shutting down before indications of overheat. It was suggested that the overheat sensor be repositioned so that it would be nearly in contact with the PSP. The ASTARS test team found that the overheat sensor was cool to the touch even though the PSP had already shutdown due to overheating.

After failure to launch on Test Flight #1 and complete any radar test events, technicians and the software designer met for a weekend session to solve as many problems as possible. The team investigated airflow and component functioning and believed airflow rates were the cause of the overheat indications. Several cooling fan and ducting combinations were attempted using fans and ducts already in place in attempts to increase cooling to the PSP. The radar system still failed to function.

RADAR PSP CONFIGURATION

Attempts to run the radar past BIT were, in part, caused by overheating, but another major hindrance to solving configuration and wiring problems was a lack of Interface Control Documents (ICD). Without knowing if the hardware issues were to blame for the radar not functioning past start-up, it was difficult to ascertain if other issues were contributing to the problems as well. Previously identified troubles with locally manufactured cabling and inadvertent power phase reversals prompted further configuration study.

This study showed that the PSP was running a pre-1993 Operational Flight Program (OFP) while the other LRUs operated with a newer hardware and software configuration. According to AN/APG-68 experts, the individual radar units were incompatible and would not work together with the current OFP mix. Further complicating the problem was the fact that none of the APG-68 designers or users had ICDs for the older configuration. The only way to be certain that the PSP was working as designed was to get a thorough bench test. Unfortunately, the ASTARS II team had no means of testing the PSP functionality or any radar LRUs. Northrop-Grumman radar systems in Baltimore had some test options, but not to the level required for a full box check. A quick logistics check showed that ordering a newer compatible PSP from the supply system would cost the program \$327,395.59.

Background records showed that all radar LRUs were inspected and bench checked individually before being shipped from the Air Force, but a fully-integrated

radar system check had never been conducted before attempting to do so on the P-3 aircraft.

In June an ICD arrived. The ASTARS team was able to get the radar further along in the start-up process and could display more fault pages. Nonetheless an APG-68 had never been installed on a P-3 aircraft and the only real way to determine the status of the radar would be to send the PSP to an APG-68 repair facility. The team made contact with the world's foremost APG-68 experts at the IFAST Hill AFB, UT who handled all USAF APG-68 repairs. IFAST agreed to assist with the troubleshooting. The PSP was sent to Utah to be tested, arriving mid-July.

Bench and lab testing showed that the PSP would not complete a built-in test. The fault codes, shown in Table 9, indicated that the PSP was inoperative. Attempts to reload the PSP with SCU5.1 & Block 40 software did not work. The Aircraft Intermediate Shop (AIS) tried to run the PSP on their test station to check out subcomponent functionality so that possible defective modules could be isolated which would minimize repair costs. However, every effort was rejected by the PSP.

Finally, the PSP went through several lab test methods, but did not respond. That further indicated that the PSP was defective. Additionally, the PSP did not have sufficient memory to hold the latest SCU5 or Block 40. This particular PSP needed to be replaced from the supply system. The part number needed was the more modern PSP version, part number 783R240G01 S/N 20237 or later.

The results of extensive IFAST testing meant two things. First, the PSP was inoperable. Second, even if it were operable, the OFP was definitely incompatible with

Table 9
Radar BIT Indications

Failure Code	Description
FCR 004	Antenna digibus wraparound test failed
FCR 005	System waveguide pressure failed
FCR 007	Azimuth and elevation motor
FCR 008	Antenna ARC- computer count
FCR 020	MLPRF digibus wraparound test
FCR 021	Receiver protector fail
FCR 024	Reference oscillator lock bit
FCR 084	DMT digibus wraparound test
FCR 085	Low voltage power supply fault
FCR 088	Hi voltage power supply fault
FCR 089	Transmitter OK on
FCR 095	Hi voltage wraparound test
FCR 214	PSP digibus external wraparound test

the rest of the ASTARS II APG-68 components. The system would not work without a new PSP compatible with the other system components.

The PSP was shipped back to USNTPS as the team investigated PSP upgrade. As it turned out, the military parts system no longer supported the older PSP, and the supply system would not allow replacement or upgrading the old PSP. The team was again faced with the prospect of purchasing a new PSP. Additional attempts to submit the PSP to the DoD supply system for repair and a software upgrade failed. A break for the team occurred when DoD supply personnel agreed to take the old PSP in and replace it without charge at the request of the IFAST team.

Three months later the new PSP arrived. It was installed in September of 2003, a full seven months after the aircraft was supposed to IOC.

RADAR SYSTEM CONFIGURATION

Despite installation of a fully functioning PSP, the radar still did not function properly. With continuing hardware, software and configuration problems, the team decided to get the entire APG-68 overhauled by IFAST. The team agreed that a full system check was crucial to alleviate the tedious and time consuming serial troubleshooting that had delayed fielding ASTARS II. The team could not clearly assess whether radar problems, component issues, cooling or modification wiring faults were the root cause of the inoperable radar.

RADAR SYSTEM TEST SCHEDULE

Although the team began planning a trip to Hill AFB in October of 2003, departure was delayed until March 2004 due to maintenance issues and the holidays. Once at Hill, the IFAST personnel were able to load up the LRUs on the ground test station, use new IFAST parts as required, and verify performance as a set with IFAST avionics.

RADAR SYSTEM TEST RESULTS

Upon arrival in Utah, the team removed all APG-68 equipment from the racks and sent them in for tests. The first two discrepancies discovered were a bad MLPRF and a bad antenna.

On the second day, the team installed good equipment, but still had a problem with the antenna locking up and the system not completing the start up BIT. All avenues were exhausted in attempts to get the antenna functioning.

On day three, the new antenna was removed and sent back for testing to determine its condition. During this time, the team explored rack wiring harness issues. The IFAST team helped install a new wiring harness. With the new wiring harness and confirmed good antenna, the system worked for the first time. The ASTARS II team was extremely relieved to finally have the radar working.

In terms of faulty components, four of the five main LRUs from the “free” radar initially received were bad. The team had seen two bad PSPs (the initial unit plus the first one from supply), two bad radar antennas (the initial unit plus the first one from supply), a bad MLPRF and an inoperable rack harness.

The rest of the time at IFAST was used to analyze software and cooling issues on the system. The system was subsequently secured for the return trip to Patuxent River. The defective antenna and MLPRF were left with IFAST for repair. IFAST was extremely supportive and loaned the ASTARS II team the functioning harness until payment could be arranged.

The team felt there was a light at the end of the tunnel. Now that the radar was working, only one major issue remained, a solution to the cooling problem.

RADAR COOLING

IFAST gave the team the actual cooling air requirements based on flow and temperature. For a cooling air supply of 27 deg C, the flow rate should have been 21.9 lbs/min. Since the aircraft normal operating conditions were in hot weather during training exercises, plans were formulated to test the worst-case conditions. The team’s

next step was to test the current fan and determine what cooling temperatures and flow rate would be required to keep the radar from reaching thermal shutdown temperatures in hot weather, which was defined as a MIL-STD-210B hot day (103 deg F) environment.

COOLING TESTS

The purpose of the ground test was to determine the proper mass airflow cooling requirement necessary to operate the AN/APG-68 Radar Set both on the ground and in-flight without experiencing overheating conditions and system shutdown.

DESCRIPTION OF TEST EQUIPMENT

The cooling fan that was installed (EG&G Rotron, Part No. 035392) provided ambient cooling airflow drawn from the radome to the cooling air manifold that supplied air to the individual units of the radar set. The fan was rated to provide at least 314 ft³/min at a mass airflow rate of 21.9 lbs/min. Another fan was used to exhaust ambient air within the radome to the nose wheel well, where it was exhausted overboard.

METHOD OF TEST

The scope of the AN/APG-68 Radar Set cooling system ground test was to utilize the NP-3D in an operational environment. Specific goals for this test included: (1) determining the correct size of cooling fan for proper mass airflow; (2) determining airflow value at the radar manifold cooling inlet; and (3) verifying the capability to maintain radar system exhaust temperatures at or below 70 deg C (158 deg F) with the

required 21.9 lbs/min mass airflow, which equated to 314 ft³/min at 27.2 deg C (80.9 deg F) ambient temperature. A 60 deg C exhaust temperature was selected to provide a margin of error to the 70 deg C maximum allowable exhaust temperature of the PSP. The PSP was thermally protected to shutdown at 70 deg C. The tests were conducted within the limits of the P-3 NATOPS with the exception that the radome was open throughout the test. The radar was not transmitted on the ground for personnel safety reasons. A ground air conditioning cart was used to provide the required mass airflow to the radar. The data was recorded on a Fieldworks portable computer through an InstruNet Model 100B Analog-Digital Input/Output interface. Data was downloaded onto an MS/Excel Spreadsheet for analysis.

Two ground tests were conducted, one on June 3 and one on June 7, 2004. During the June 3rd test, the air conditioning cart was used to provide ambient (non-refrigerated) air to the radar. The second ground test conducted on June 7th utilized the air conditioning cart in both ambient and refrigerated modes. Approximately 11 hours of ground testing was conducted. The aircraft was temporarily modified for this test and returned to its pre-test configuration immediately thereafter.

The radar's inlet cooling fan was removed and a locally manufactured mass airflow test section was interconnected to the inlet cooling duct and a ground air conditioning cart. A schematic showing this setup is presented in Figure 9.

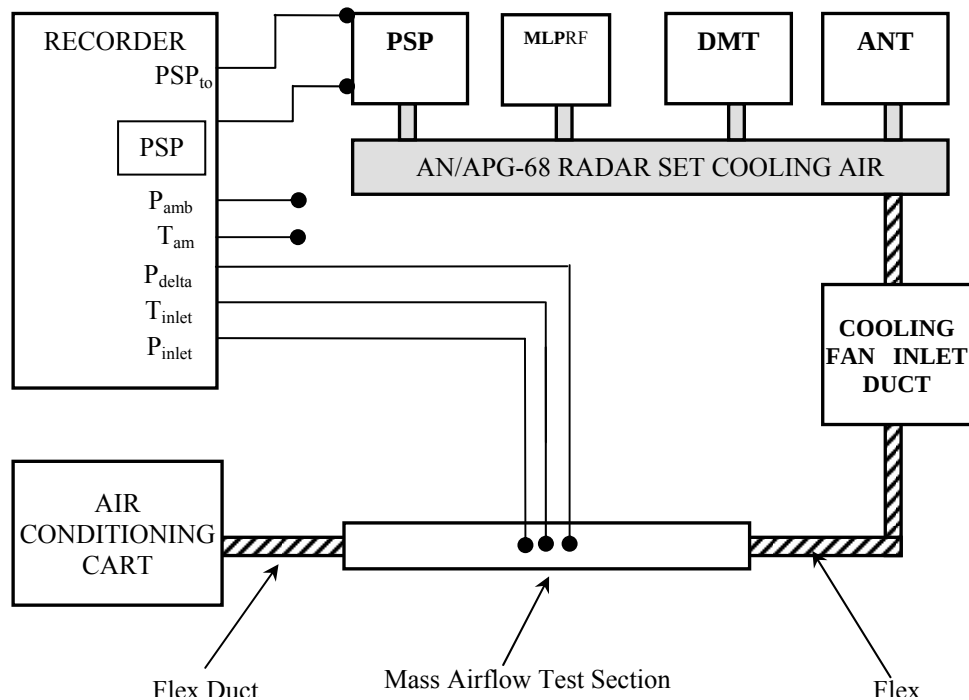


Figure 9
AN/APG-68 ASTARS II Cooling Test Setup

COOLING TEST RESULTS

The data clearly showed that the AN/APG-68 radar set required conditioned air to operate satisfactorily in a MIL-STD-210B, hot day (103 deg F) environment without thermal shutdown due to excessive exhaust temperatures at the individual LRUs, particularly the PSP.

Results (Figure A-2) showed that the AN/APG-68 radar set as installed in USNTPS NP-3D aircraft, could not be operated on the ground for any significant length of time due to thermal shutdown. The fan configuration for the system was not sized adequately to provide enough airflow.

RECOMMENDED FIX

The economical solution was to maintain the current configuration but substitute a larger capacity fan for the current cooling fan. Also, installation of a cooling duct from the nose wheel well inlet orifice to the fan would be required to draw only outside air to the radar set. For ground operations, an air conditioning cart would have to be used on hot days (OAT >80 deg F) to supply refrigerated air to the wheel well. This refrigerated air would then be drawn through the nose wheel well bulkhead orifice by the cooling fan to be delivered to the radar.

COOLING SOLUTION

The team researched different vendors for COTS cooling fans that would meet the requirements for rated performance, size, weight and cost. While the search effort continuing, a structural analysis of the mounting location was accomplished, along with an analysis of the electrical power required. All mounting hardware could be fabricated in-house and installed locally.

Flight and ground testing of the new cooling fan would be required. Baseline thermal data of the present configuration as well as thermal data obtained from the new configuration would be recorded and analyzed to confirm the AN/APG-68 Radar Set received adequate cooling for all flight and ground operations of the aircraft.

The cooling fan that met the requirements of the ground cooling test was the Hamilton Sundstrand Fan 4101238E shown in Figure A-4. As a precautionary measure, the team ordered two fans in order to have a spare readily available. Total cost for the

fans was \$17,440. The fans were ordered in July of 2004 with expected delivery date of October 25, 2004. Actual delivery date was November 8, 2004.

CHAPTER 5: DISCUSSION OF PROGRAM MANAGEMENT METRICS

PERFORMANCE

The ASTARS II aircraft met all the performance capabilities of ASTARS I with two exceptions. First, to protect the PSP from overheating, the AN/APG-68 radar would be restricted from operating and transmitting on deck during hot weather conditions. This limitation would only affect one exercise - the Airborne Systems Radar Evaluation, which incorporates a ground test event using actual air-to-air targets flying over the Chesapeake Bay to collect radar performance data. The second limitation would be a requirement to operate the radar with the FLIR turret extended to increase airflow around the radar in-flight. Since the FLIR turret has to be retracted in visible moisture, the radar would have to be off during the same conditions. This limitation would result in no means to provide air traffic deconfliction in bad weather. ASTARS II would have to rely solely on air traffic control agencies in Instrument Meteorological Conditions.

COST

AIRCRAFT COSTS

The largest costs for the aircraft were in four areas: structurally modifying the aircraft for the ASTARS mission systems, completing the required acceptance maintenance phase, purchasing mission system avionics, and structurally modifying the aircraft for additional ditching stations. Total costs were approximately \$2,170,000 for the aircraft modifications, which was \$130,000 less than initial AoA estimates. Despite

the program going well beyond the desired schedule timeline, the creation of ASTARS II came close to meeting budget-estimated goals.

RADAR SYSTEM COSTS

The actual parts costs for the “free” radar were significant. Had the team not been able to get the old PSP replaced without charge, the total costs for repairing and replacing parts alone would have been \$418,586, sending the overall budget beyond the desired cap. Since the PSP was replaced without charge, the parts ended up costing \$91,200. Nevertheless countless man-hours were spent in discussion of the problems, troubleshooting the radar system, traveling to get parts tested, investigating radar issues and making software adjustments. A list of the LRU replacement costs is shown in Table 10.

Table 10
ASTARS II Radar System Replacement Costs

Part	Part Identification	Costs	Significance
Waveguide	5985-01-157-8193	\$9940	Part not included in original delivery.
PSP Initial	1270-01-231-9800WF	\$327,395	Massive schedule delay. High cost jeopardized ASTARS II program. Final cost was not incurred due to supply system workaround.
PSP from supply	783R240G01	No cost	Schedule delay
Antenna Repair	1270-01-212-2950WF	\$17,746	Would not allow the radar system to work
MLPRF Initial	1270-01-233-0011WF	\$7581	Radar inoperative
MLPRF From supply	1270-01-233-0011WF	\$38,493	Radar inoperative, schedule delay
Cooling fan (2)	Hamilton Sundstrand Fan 4101238E	\$17,440	Necessary to meet cooling requirements

SCHEDULE

The most significant program issue was the schedule delay. The impacts to the U.S. Naval Test Pilot School, Empire Test Pilot School, U.S. Air Force Test Pilot School, and T&E Short Courses were significant. ASTARS I was in a long downtime maintenance phase just as ASTARS II was supposed to IOC. Further exacerbating the problem, the ASTARS I six-month maintenance phase extended by two months. After ASTARS I completed the phase, it returned to USNTPS, where it subsequently went down for various maintenance items, keeping it in a non-flying status for the majority of four months. This resulted in the following:

- USNTPS did not have an ASTARS aircraft for an entire year.
- Air Force Test Pilot School training detachments were cancelled.
- The Empire Test Pilot School detachment was cancelled.
- No USNTPS Short Course flights were conducted in an ASTARS aircraft.
- One entire USNTPS class did not have an ASTARS platform to train on and overall class systems training was significantly degraded. Back-up exercises were flown in more expensive F/A-18B aircraft.
- USNTPS training in HMI, radar and integrated system test techniques were sacrificed.
- Substitute aircraft had to be found (S-3B, EA-6B, F-16, MH-60K) that cost more and did not offer the same advantages to test pilot instruction that the flying laboratory ASTARS environment offered.

In November of 2004, ASTARS II was approaching a fully mission capable status. All remaining radar issues were well understood and the various radar corrections and cooling system modifications supported confidence in completing the ASTARS II

acquisition program. However, the aircraft had now reached a point in its maintenance schedule that required its return to PDM. By November 22, the aircraft would find itself in a non-flying status for another six to eight months. It would also be located a great distance away from the needed engineering and fabrication support organizations. With the new radar cooling fan install and functional tests remaining, the aircraft would be unable to support any syllabus items before PDM. Adding this delay to the overall schedule slide, the aircraft has been unable to support various Test Pilot School schedules for a total of two years.

CHAPTER 6: CONCLUSIONS

PROGRAM MANAGEMENT

From the start of the ASTARS II Program no clear designation was made as to who would hold the position of PM. The acquisition team was run in a democratic fashion. Meetings were called as needed by any member. Assignments were given to whomever seemed most qualified for the task or to whomever was generally available at the time. Progress was reported back to the entire group instead of a single PM. Resource intensive program decisions were made by polling all members for objections.

Key drawbacks occurred with this type of organizational structure. First, there was no final decision authority when a consensus could not be reached, resulting in individuals continuing their work without firm direction. A consensus, or lack of significant objection, resulted in unofficial approval to continue with the course of action in question. Another disadvantage was that no ASTARS II team member was afforded the opportunity to take over the program and set aside his or her regular work duties to manage what was often a full-time job. Individual members did not always know who would be the signoff authority on clearances, sublevel signoffs, budget expenditures or schedule changes. Approval for work units went to whoever seemed most appropriate. Decisions were made on an individual basis as to how a task should be done, who should be informed and what higher authority would be sought out when needed. Work was done when time permitted with priority based on each team member's personal demands.

In all likelihood, the democratic structure succeeded as well as it did because the team was able to fall back on their collective acquisition experience.

ACQUISITION STRATEGY DESIGN

An acquisition strategy was never formalized. Not having a defined acquisition plan resulted in two major disadvantages. First, because the schedule was not formalized, the team worked to unrealistic deadlines that were too generous. It was assumed that the impact of any schedule slides for ASTARS II, in terms of restricting its availability for test pilot school training, could be lessened by getting a waiver to the ASTARS I maintenance phase schedule. In reality, no waivers for P-3 maintenance phases would be granted for either ASTARS aircraft. The second drawback was that an acquisition strategy would have been an excellent way to educate new managers and new program office personnel on program intent, objectives, considered alternatives, how and why strategic decisions were made, and the current status of the program. New members had to learn about the program on-the-job, resulting in a vague understanding of the ASTARS II acquisition plan and time lost learning about the program through routine exposure.

TEAM ROLE DEFINITIONS

Team members described the team structure as ad hoc. As it was with the undefined PM position, the lack of team structure and role assignment led to confusion, vague duties and no clear understanding of the approval process.

An additional limitation introduced by the absence of team role definitions was that when immediate tasks outside the program required a team member's attention, the

ASTARS II program had to wait for those higher priority tasks to be completed before the member could return to work on ASTARS II.

TECHNICAL RISK IDENTIFICATION

In the majority of instances risks were quickly identified and dealt with, but a clean sheet engineering analysis of the APG-68 radar was never prepared. The systems engineering process was informally conducted via email. A dedicated and complete analysis of the radar's requirements such as electrical, structural, supportability, reliability and cooling budgets was not conducted. Specifically, the team failed to identify a cooling requirement that was double that of the APG-66.

The first step in conducting engineering risk analysis would have been to obtain all Interface Control Documents for the APG-68. This would have allowed for a full examination of the wiring, data transfer and software interfaces. Since the ICDs were not obtained upfront, systems integration and software designers had to go with a best guess on interface controls with a reliance on the APG-66 knowledge. Since the radar interfaces were not the same, time was lost correcting integration incompatibilities that resulted from the APG-66 and APG-68 differences.

Looking past the cooling requirements was also a result of groupthink acceptance. The common perception was that this generation of radar operated without extensive cooling because the manufacturer had built numerous "air-cooled" vice liquid or ECS cooled radars. The APG-68 system was, in fact, designed at the very extreme of what could be considered air-cooled. Ambient airflow rates and pressure required to keep the

PSP from overheating were significant. The blind acceptance of the manufacturer's reputation for making air-cooled radars and a failure to design sufficient cooling support resulted in more schedule delays.

ACQUISITION PROCESS ITERATION

The Defense Acquisition Guidebook states that strategy modifications during program execution should be iterated if:

1. The strategy is not succeeding;
2. Requirements and/or environmental factors have changed or new ones have been introduced; or
3. New risks have been identified.

The ASTARS II team had an ad hoc strategy that was not succeeding as new risks were identified, yet the iterative review process was not applied. Modifications to the acquisition process in a structured and disciplined manner offered assurance that the acquisition strategy could be adjusted in an explicit, logical, connected and coherent manner. Schedule slides and costs incurred from the unstructured acquisition process could have been eliminated with a program review and restructuring.

OPTIONS AND MARKET RESEARCH

Although an APG-66 radar could not be found at the start of the ASTARS II program, it may have been possible to find one later. As soon as the APG-68 was proposed, no additional time was spent in trying to locate another APG-66. If finding an

APG-66 had remained a priority and one had been found, all of the radar system issues particular to the ASTARS II program could have been avoided.

COMPETITION

Commercial competition was not considered. Lack of a formal program budget resulted in not having the option to solicit commercial bids because the team did not have a pool of funds that could be committed to pay contractors. Instead, work was paid for incrementally and budgets were reviewed quarterly during the program's execution. The team never solicited private industry to determine if they could develop an acceptable product within reasonable cost, schedule and performance constraints.

ACQUISITION MILESTONES, REVIEWS, AND DOCUMENTATION

Formal acquisition milestones and reviews were not established and no official documentation was maintained. Without the milestones and reviews, the normal methods of refining the program and making periodic adjustments did not occur, resulting in an inefficient task completion process that did not improve over the duration of the program.

Without normal risk tracking and documentation, the standard way of identifying risks, formulating mitigation plans and conducting periodic reviews did not occur. The team had no formal process to identify when a mitigation path had reached the breaking point and a new course would be needed. Example problems that took place due to the lack of documentation included the failure to track and review flight clearances, which delayed clearance approval, and a requirement to justify aircraft 148889 ownership when

the Fleet was looking for training aircraft. Had documentation been formally maintained, the countless man-hours required to prepare justification documents for keeping the aircraft in USNTPS possession would have been avoided.

CHAPTER 7: RECOMMENDATIONS

CLEARLY IDENTIFY PROGRAM NEEDS

The Program Manager should work closely with the user to validate the need and make certain it is well understood by the program stakeholders. As part of identifying the program needs, the PM should ensure that market research and analysis is conducted to determine the availability and suitability of existing commercial and non-developmental items prior to starting developmental acquisition.

APPOINT A PROGRAM MANAGER

All acquisition programs need a formally recognized manager. Programs require a lead to channel information to higher authority inside and outside of the program's reporting chain. Outside organizations and the chain of command also want a single contact that represents the acquisition team for all aspects of development communication. Furthermore, the integrated program team will benefit from having a single point of contact for approval and decision-making responsibilities.

The Program Manager is responsible for insuring that an acquisition strategy is developed and updated. Without a PM, no one is accountable for writing the acquisition strategy. The Program Manager has the overall responsibility for meeting user-defined Key Performance Parameters while staying accountable for contracting, funding, cost, test and evaluation, software, logistics support, production, technology and risk management.

Finally, the assigned Program Manager has to be given sufficient resources to stay abreast of the program developments and risks. Time is a resource. The manager cannot have so many collateral duties that he or she is unable to monitor all aspects of the program real-time or is unavailable when time critical decisions have to be made.

FORMALLY DEFINE THE ACQUISITION STRATEGY

The PM should select and develop the acquisition strategy and keep it current by updating it whenever the system acquisition approach requires further definition, correction or modification. As a minimum, the strategy should be updated for each program milestone review. Since change is common in DoD acquisition - specifically in terms of threat assessment, business processes, product advances and funding stability - a continuing review of acquisition strategy must be the normal practice as a change management tool and risk mitigator.

The acquisition strategy is the formal record of all strategic choices and changes made in response to an evolving threat, technology, business process and other environmental factors. As such, it is best to formally document the strategy, to educate new program managers and new program office personnel regarding program intent, objectives, considered alternatives, how and why strategic decisions were made and monitor the current status of program. It should be the baseline for evaluating program effectiveness as well as for determining any requirements for changes to the existing strategy. As the Acquisition Strategy Guidebook states, the acquisition strategy serves as:

- A checklist to ensure that all important issues and alternatives are considered
- A decision aid in prioritizing and integrating functional requirements, evaluating and selecting alternatives, identifying decision points and providing a coordinated approach
- A basis for preparing program plans and activities
- Documentation of the ground rules of assumptions on which the program was based
- The vehicle for building and achieving consensus
- The formal record of all strategic changes made in response to evolving threat, technology and environmental factors.

A sound acquisition strategy could have eliminated the majority of the ASTARS II programmatic woes. If the strategy is properly system engineered, the PM can utilize it to defend the program, build support and stay abreast of change.

START WITH A CLEAN SHEET ENGINEERING REVIEW

Risk management publications like the DoD 4245.7-M provide clear guidance on assessing the risk of technology. Guides such as this should be used to make a clean sheet analysis of risks. From an aviation systems management perspective, these guides provide a framework for conducting a fresh top-to-bottom review.

In the case of ASTARS II, the guide's "Critical Risk Attribute Matrix" would have the team define all physical, performance, cost, and process attributes. Under the "performance/physical" category alone, the evaluator is reminded to review power, weight, survivability, size, heat dissipation, interface commonality, bandwidth, reliability,

maintainability, receiver range, transmitter range, human-machine interface, etc.

Brainstorming and group discussions should not be left out, but the various analysis tools that are readily available should be employed.

FINISH THE PROGRAM

The ASTARS II program is close to being complete. A fully mission capable aircraft should be available in a short time with a relatively minor effort and relatively small costs. There is great confidence among those familiar with ASTARS II that the issues remaining have sensible and feasible solutions. Radar functional issues that remain will be resolved. Only minor modifications will be required for the remaining non-radar related anomalies.

The cooling air problem has been thoroughly studied. A logical solution is ready for implementation and testing. The cost of completing the radar cooling fixes and the time involved in doing so will also be small. Getting the radar working as designed will merely require installing and testing the new fan configuration in the operational flight environment. Data reduction and reporting will add to the final costs, but these costs will be inconsequential. The team in place can get the job done. With their understanding of the system, they are the best solution to getting the aircraft operational as quickly as possible.

The additional ASTARS aircraft will significantly enhance test pilot training capabilities. Thousands of students from across the globe will benefit from this additional asset. ASTARS II should be fielded at the earliest opportunity.

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REFERENCES

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APPENDIX A

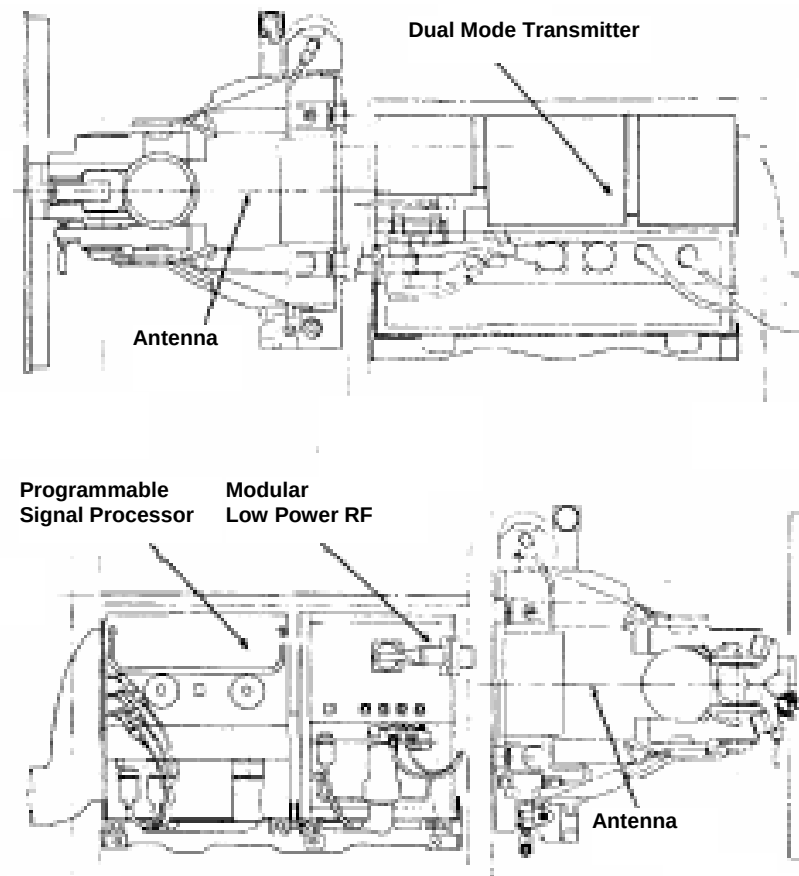


Figure A-1
AN/APG-68 Radar Configuration
(Source: AN/APG-68 User's Guide)

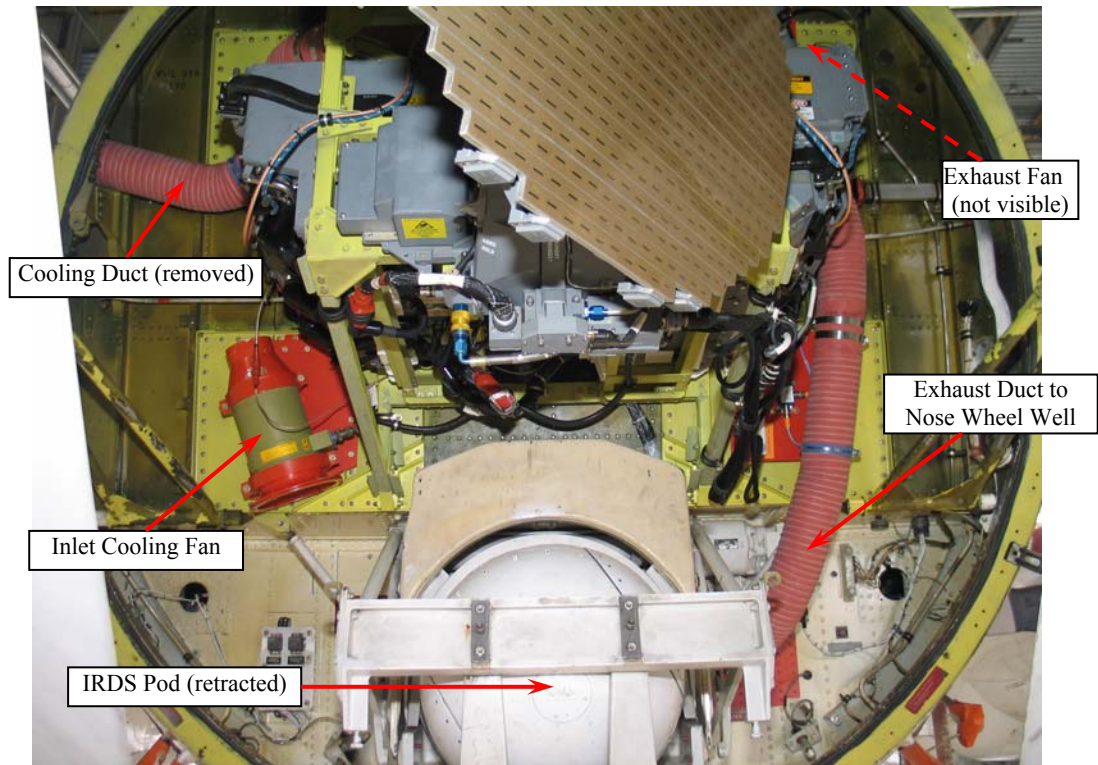


Figure A-2
AN/APG-68 Installation

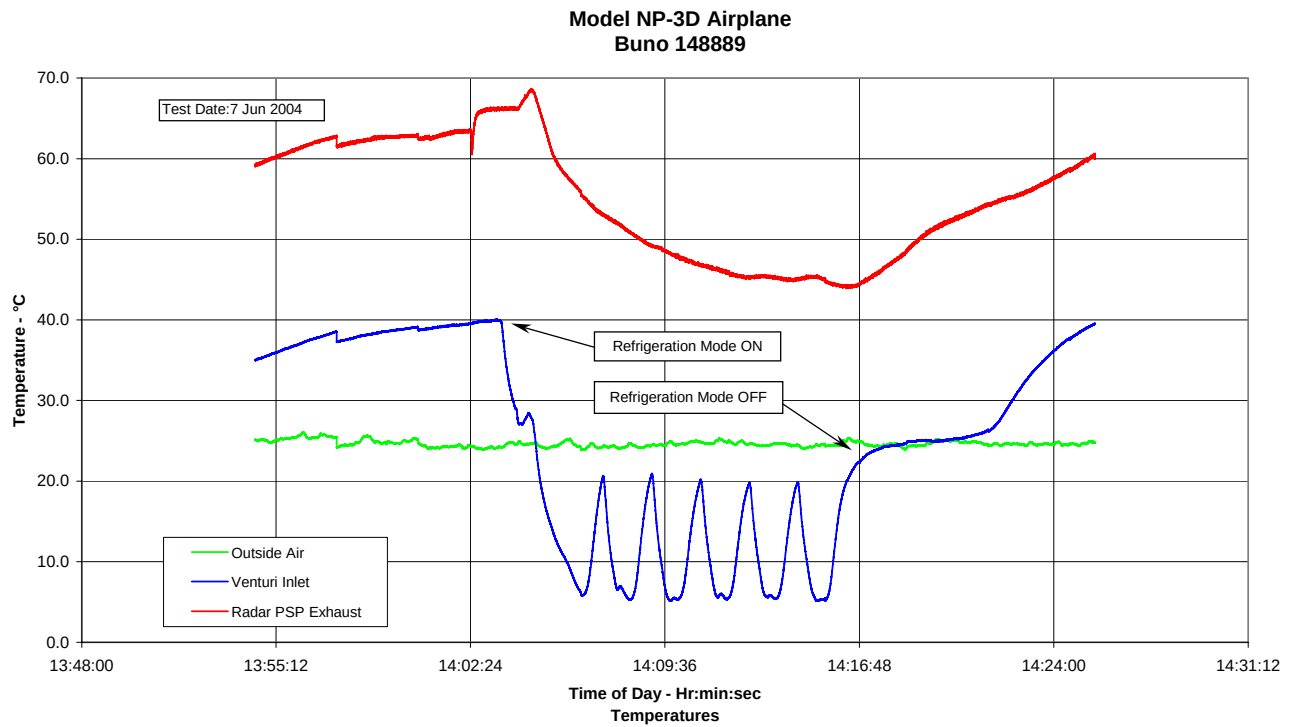


Figure A-3
AN/APG-68 Ground Cooling Test Results



Figure A-4
Hamilton Sundstrand Fan 4101238E

Vita

Lieutenant Commander Denis G. Tri is a native of St. Paul, MN and graduated from Iowa State University with a Bachelor of Science degree in Mechanical Engineering. He entered the Naval Service in 1991 and reported to Naval Flight Officer Training in Pensacola, FL.

LCDR Tri was selected to fly F-14 aircraft and reported to VF-124 in Miramar, CA for advanced training in the Tomcat. In 1994, after graduating first in his class, he reported to the VF-111 *Sundowners* on deployment in the Yellow Sea, in support of Korean Contingency Operations. Upon disestablishment of VF-111, LCDR Tri reported to the VF-211 *Fighting Checkmates* and made two more deployments in support of Operations Southern Watch and the Taiwan/China Missile Crisis. Prior to his third deployment, LCDR Tri was selected to attend the USMC Weapons and Tactics Instructor course at MAWTS-1, Yuma, AZ. His first tour was highlighted by early designation as a Mission Commander and being the first in the F-14 fleet to complete the Strike Fighter Weapons and Tactics program.

Ashore, LCDR Tri was selected to the United States Naval Test Pilot School as part of Class 114, where he graduated with Distinction in 1999. LCDR Tri reported to Air Test and Evaluation Squadron 23, Patuxent River, MD as the project officer for numerous F-14 and F/A-18E/F programs including F-14 DFCS envelope expansion, the first Joint Tactical Combat Training System flight and the first F-14 refueling from the F/A-18E/F Super Hornet. LCDR Tri was also selected for the immediate response test team in charge of getting the F/A-18 Advanced Tactical Airborne Reconnaissance System to the Kosovo conflict.

In 2001, LCDR Tri reported to the Carrier Air Wing Two staff and completed a fourth operational deployment in support of Operation Southern Watch and counter terrorism operations. Selected to the Acquisition Community in 2002, he reported to the United States Naval Test Pilot School as a Flight Instructor, responsible for training fleet aviators, naval flight officers, and engineers, as well as Army, Air Force and international students. In April 2004, he became the Airborne Systems Curriculum Department Head, in charge of all airborne systems test and evaluation training for USNTPS. In November of 2004 he was selected as Aide to the Commander of Naval Air Systems Command.

LCDR Tri has accumulated over 1,800 flight hours in 36 different aircraft and has logged over 350 carrier landings. His decorations include the Strike/Flight Air Medal, Navy Commendation Medal, Navy Achievement Medal, and various other awards. LCDR Tri resides in Solomons, MD.