INTEGRATED ELECTROMAGNETIC SYSTEM SIMULATOR (IESS)
LOGISTICS SUPPORT UTILITY ANALYSIS (LSUA):

"A STUDY INTO NEW TEST FACILITIES AND SUPPORT TECHNOLOGIES
FOR INTEGRATED COMMUNICATION, NAVIGATION, IDENTIFICATION"

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Abstract

With the impending entry of integrated avionics systems into the Air Force inventory, a need exists for a new approach to the implementation of Integrated Support Complexes (ISCs). The Integrated Electromagnetic System Simulator (IESS) is being developed for test, evaluation, and future development of the Integrated Communication, Navigation, Identification (CNI) system (ICNIA) Advanced Development Models (ADMs). Since ICNIA is the first generation integrated Communication, Navigation, Identification (CNI) system and IESS will be instrumental in the introduction of this device into the Air Force, it is logical to assume that IESS could serve as a baseline for an ICNIA ISC. With this in mind, the contractor to conduct a preliminary study, concurrent with the development of IESS, to assess the feasibility of IESS as a baseline for ICNIA Automatic Test Equipment and eventually an ISC. This paper presents some of the findings that are applicable to new generation ISCs for integrated systems.

Background: The Need for Integrated Test Systems

The future of avionics involves the proliferation of increasingly integrated systems. One of the first demonstrations of this integration is provided by the ICNIA program. The ICNIA design integrates a representative set of CNI waveforms/functions in the 2MHz to 2GHz frequency range. Figure 1 lists the many CNI functions currently integrated within the ICNIA ADM design. Integration is accomplished within ICNIA using a combination of modular, software intensive, algorithmic implementation of CNI functions and a common, modular hardware design. The inherent design characteristics of ICNIA will enhance logistics performance through improved availability, supportability and affordability (Figure 2). However, integration is not without potential supportability problems. Recently, there has been increased concern from the logistics community about the eventual supportability and testability of ICNIA. Although ICNIA is projected to have a vastly improved Built-in

FIGURE 1 ICNIA FUNCTIONAL CAPABILITIES

FIGURE 2 ICNIA LOGISTICS ENHANCEMENTS

test (BIT) capability and increased mission reliability over existing discrete CNI systems leading to the elimination of intermediate level maintenance, problems may arise when a faulty line replaceable module (LRM) reaches the depot. Current depot support capability is inadequate for truly integrated systems. Just as ICNIA is an

integrated CNI system, automatic test equipment/facilities will need to be integrated to thoroughly test the simultaneous, multifunction capability of ICNIA. This need introduces the idea behind the IESS program.

Since the inception of IESS, it has been a goal to use IESS as a baseline logistics support center for ICNIA throughout its service life; however budget limitations have prevented the government from aggressively pursuing this goal. This has brought about the need for a redefinition of the IESS goal. IESS is now seen as a "stepping stone" for future ICNIA support capabilities. In particular, the IESS program is investigating how the current IESS design can be modified to address the following:

- The use of IESS as a baseline for developing ICNIA depot-level Automatic Test Equipment (ATE) that is Modular Automated Test Equipment (MATE) compatible.
- The use of IESS as a baseline for an ICNIA ISC.

The development of integrated support equipment is critical at this point in time given that integrated systems could begin appearing in the early 1990's in advanced platforms such as the Air Force's Advanced Tactical Fighter (ATF), the Navy's Advanced Tactical Aircraft (ATA), and the Army's Advanced Tactical Helicopter (ATH).

IESS Overview

Started in 1984, the current laboratory IESS is a real-time dynamic hot bench for ICNIA. It is designed to transmit and receive every signal being implemented in ICNIA. With the additional capability to monitor, store, and retrieve parameters concerning ICNIA's performance, IESS provides a complete laboratory test stand for ICNIA. IESS is composed of the following five basic subsystems (Figure 3):

- Host Processor Subsystem (HPS)
- Signal Synthesis Subsystem (SSS)
- Signal Distribution Subsystem (SDS)
- RF Test Equipment Subsystem (RFTES)
- Unit Under Test (UUT)

The HPS contains computing facilities to perform scenario definition and execution, post run analysis, and software/system support. The SSS contains equipment to transmit/receive the RF signals required to simulate a real-time environment for ICNIA. Included in the SSS are a Global Positioning System (GPS) simulator developed by Magnavox, various off-the-shelf test equipment, and an embedded ICNIA terminal (Integrated Signal Support Unit). The embedded ICNIA terminal will transmit/receive complex spread spectrum signals that are expensive to produce with off-the-self test equipment. Alternative approaches to this embedded ICNIA have been proposed for future developments of IESS but will not be discussed in detail as part of this paper. More detail on alternative design approaches is provided in references (4) and (5) of the bibliography. The

SDS directs and conditions RF signals to and from the UUT, the SSS, and the RFTES. It contains various couplers, attenuators, and phase shifters. The SDS also has five RF ports available for injecting external signals into the test. These ports might be used, for instance, to introduce some sort of smart jamming into the testing. The RFTES monitors and stores the RF signals for later analysis. Contained in this subsection are an HP computer, printer, plotter, spectrum analyzer, bit error rate tester, and a precision measuring receiver. Finally, the UUT is the unit under test. It can be connected to the rest of the system by RF cables, a 1553B data bus, and an IEEE 488 data bus.

FIGURE 3 IESS BLOCK DIAGRAM

IESS Applications

Applications for the current laboratory IESS include the following:

- Testing of an ICNIA ADM
- Support testing of the Advanced GPS Receiver Technology (AGRT) Terminal
- Support testing of an Army Parachute Offset Navigation System (PONS) receiver
- Support research and development (R&D) into advanced communications systems by either government or contractor personnel
- Demonstration tool for baseline Integration Support Complex (ISC) for integrated CNI systems

At this point in time, ICNIA ADM testing is the primary objective of IESS. This testing is expected to begin in 1990. IESS's designed-in flexibility will permit testing of current discrete systems in addition to integrated systems such as ICNIA. The AGRT and PONS receivers are examples of such discrete systems. The GPS simulator installed in IESS provides the capability to produce very realistic scenarios with which to test the AGRT and PONS. In addition, IESS's expandable and adaptable architecture will offer the government and private industry the opportunity to develop and test future CNI systems. ICNIA software development

tools are hosted on IESS. Therefore, R&D personnel will have the capability to reprogram the embedded ICNIA to develop new CNI systems. The final planned application for the current laboratory IESS is as a baseline ISC for integrated CNI systems. While many capabilities will have to be added to IESS to "evolve" it into an ISC to support production integrated CNI systems, the additions follow the true nature of IESS (i.e., expandable and flexible). For now, IESS provides the foundation of core equipment that will be used by laboratory personnel to conduct research on ICNIA.

The addition of integrated CNI into the inventory will generate a need for equipment that will support the testing of LRMs in a real-time multifunction environment. This equipment will need to test stand-alone LRMs as well as those operating in the presence of other "influencing" LRMs. In a highly integrated system with embedded computers, a malfunction may only be detectable while the LRM is operating in a real-time environment in conjunction with the rest of the system. The development of IESS attacks the problem of real-time system level testing. The IESS Logistics Support Utility Analysis (LSUA) study has developed a baseline ISC for integrated CNI systems. The findings of this study are summarized into the following areas:

- ICNIA Support Requirements and Maintenance Concept
- Baseline IESS Capabilities
- Design of an ICNIA ISC
- Near and Far Term Enhancements to IESS to Support Integrated CNI

ICNIA Support Requirements And Maintenance Concept

In order to develop a support facility or concept, the IESS LSUA investigated ICNIA support requirements. ICNIA was selected because of the need to support this system in the near future. Also, many of the technologies used in ICNIA will be incorporated into a fully integrated avionics system (PAVE PILLAR concept).

The basic ICNIA hardware design contains a set of LRMs which can be configured to match specific functional platform requirements (JTIDS, TACAN, GPS, etc.). Fault detection and reconfiguration are provided to maintain priority of pilot requested functions. Time sharing of modules permits graceful degradation; hence increased mission reliability. ICNIA also includes a common module approach that accommodates both new and retrofit applications. Very High Speed Integrated Circuit (VHSIC), surface acoustic wave devices, RF Large Scale Integration (LSI) devices, and charge coupled devices are some of the key technologies used in the LRMs.

The ICNIA maintenance concept is in basic accordance with the Modular Avionics Systems Architecture (MASA) Maintenance Concept (two-level maintenance). Figure 4 illustrates the ICNIA maintenance concept (testability approach). Organizational level (O-level) maintenance primarily involves interrogating LRMs for status

using ICNIA BIT, determining the faulty LRM (ideally, no O-level equipment should be used), removing and replacing the faulty LRM, and shipping it to the depot. Technicians at the depot will also use ICNIA's BIT capabilities to help isolate/confirm faults. Once ICNIA LRM diagnostics are exhausted, depot technicians, using very sophisticated equipment, will conduct more intensive testing to isolate the fault to a particular component. Test equipment must be capable of producing VHSIC speed digital signals as well as both wide band and narrow band RF signals to effectively test ICNIA LRMs. Existing test equipment is inadequate to accomplish this task.

FIGURE 4 ICNIA MAINTENANCE CONCEPT (TESTABILITY APPROACH)

Engineering support for embedded computer systems such as ICNIA will also be needed at the depot. This support consists of problem investigations, software/firmware changes, hardware modifications, system test and integration, and hardware maintenance support. A preliminary list of capabilities needed for this engineering support is as follows:

- Analysis and design capabilities
- Software code generation capability
- Software testbed capability
- Integration testbed capability
- Data reduction and analysis capability
- Integrated engineering data management capability

One of the most crucial capabilities requiring further development is the role of software support. Much work is needed to make this a more viable part of the ISC. The "bottom-line" is that engineers should not have to know several different software languages to work with one device.

Baseline IESS Capabilities

The current laboratory IESS is composed of the five subsystems discussed previously: HPS, SSS, SDS, RF TES, and UUT. The following is a brief discussion of the current laboratory IESS's capabilities to meet the needs of a depot level test facility.

IESS's modular design allows easy expansion of both digital and RF capabilities. Figure 3 shows that RF generators are controlled by off-the-shelf single board computers called device controllers. These device controllers are device peculiar interfaces between the main computing facilities (VAX 11/780) and each signal generator. The addition of more RF generation/reception equipment simply requires that the device be added onto one of the existing device controllers or that another device controller be purchased. The capabilities of the additional piece of equipment is then programmed into the VAX and the expansion is complete. This expansion eliminates the need to redesign the entire facility; thus the term expandability is used in reference to IESS.

IESS provides the capability to conduct complex dynamic testing of the UUT. Such testing is accomplished using either a flight scenario or discrete test sequence. A flight scenario is programmed by the operator using menus to specify such information as latitude, longitude, velocity, RF signal or radio on and off times, etc. With this method, the operator can specify a complete flight scenario to test all the parameters of the device in question. This mode might be used to pretest the device before flight testing or to try to recreate anomalies noticed during a flight. A discrete test sequence can also be set up as a powerful method of testing the UUT. This mode enables the operator to perform detailed tests in a more controlled and intuitive manner. Again, a menu is used to specify the RF signal, on/off times, attenuation, interference, data to be gathered, etc. The major difference between these two modes is the absence of flight data in the discrete test mode and the inability to specify a specific function or parameter of an RF device in the flight scenario mode.

IESS is not currently suitable for use at a depot mainly because it lacks the capability to conduct rapid testing to isolate faulty components. IESS is, however, expandable to accommodate many of the requirements for an ICNIA ISC. IESS can provide initial support capability for integrated CNI and also function as a testbed to develop additional capabilities that may be required in support of an ICNIA ISC.

Design of an ICNIA ISC

Figure 5 shows the basic configuration of an ICNIA ISC. The ISC is composed of three support areas:

- Hardware Support Area (HSA)
- Software Support Area (SSA)
- Integration Support Area (ISA)

These basic support areas are connected by a local area network (LAN) which supports the sharing of information between the basic support areas and a central data base. The central data base is a key part of the ISC. This data base contains information relating to maintenance history. Technicians and engineers can use this information to help isolate faults and recommend

engineering design changes to reduce the probability of recurring faults.

Each of the three basic support areas must be expandable and flexible to accommodate changing ICNIA requirements and the eventual need for a PAVE PILLAR-like ISC that enables testing of an entire integrated avionics suite. As previously discussed, IESS has been designed and developed with this in mind; thereby promoting expandability and flexibility in an ICNIA ISC. Hardware Support Area (HSA)

FIGURE 5 ICNIA INTEGRATED SUPPORT COMPLEX

The HSA (Figure 5a) contains Automatic Test Equipment (ATE) and is the primary test area for faulty LRMs. Defective LRMs are delivered to the depot and undergo functional testing in either RF or digital functional testers. Functional testers will use all the resources of the LRM BIT to help isolate faults, including any onboard information that might be obtained from a projected Inter-active Maintenance System (IMS) used at the flightline. The RF Functional Tester must be capable of making power measurements, Voltage Standing Wave Ratio (VSWR) measurements, frequency measurements, etc. The Digital Functional Tester must be capable of high speed VHSIC testing, clock synchronization and timing testing, bus testing, etc. Functional testers are high volume; hence they must be quick and able to isolate a large majority of the faults. Dynamic testers are used to isolate more persistent faults. Dynamic testers subject the LRM to real-time inputs; thus more accurately simulating the actual system environment. The hardware support area may include the use of an environmental chamber to enhance this simulation. Most faults will be isolated within the HSA; however persistent or recurrent problems will require the use of a more true system simulation provided in the Integration Support Area (ISA).

Integration Support Area (ISA)

The ISA (Figure 5b) is the biggest and most expensive part of the ISC. Exhaustive system

level testing will be performed on LRMs. The main activities that will be performed are:

- vulnerability testing
- final advanced avionics integration testing
- new waveform concept demonstration

The ISA will provide the most complex support environment of the three basic areas. It is configured as a full avionics suite for the aircraft being studied. More specifically, it includes instrumentation, a cockpit, and in the case of ICNIA, a complete ICNIA system. The aim is to simulate, as close as possible, the actual conditions that a LRM is subjected to at the time of failure.

Due to the inherent complexity of the ISA, it will be the most expensive area to develop and support. Time required to set up and run a test scenario and perform exhaustive fault detection and fault isolation will become a factor in determining the use of this area. Equipment required for this area is expected to be relatively expensive in comparison to that of the other support areas. Highly skilled technicians will also be needed to man the ISA. These considerations will need to be addressed as the design of an ICNIA ISC becomes more definitized.

Although expensive and somewhat "bulky", the ISA is essential for certain aspects of ICNIA support. For example, the next support area for discussion, the Software Support Area (SSA), will require an ISA to verify software changes in a full system configuration. Retrofits (including new waveform requirements) will require an ISA to validate performance. In addition, the ISA could identify hardware (as well as software) design changes required to enhance performance or correct some deficiency within the ICNIA system. As such, the ISA will be a very important part of an ICNIA ISC.

Software Support Area (SSA)

The SSA (Figure 5c) contains signal and data processors for the devices being programmed. A complete Ada programming support environment is expected as well as support environments for other languages used in the various devices to be programmed. This part of the ISC must make maximum use of available computer aided design tools. In both the SSA and the ISA, engineers must have the ability to conduct testing at any level in the system. The different levels might be the whole system, an individual LRM, or a component on an LRM. Primarily, the SSA would be used to develop, modify, or correct software. It is well recognized that Air Logistics Centers (ALCs) are continually working on software and that this work is expected to grow exponentially in the foreseeable future.

Near and Far Term Enhancements to IESS

Enhancements to the current laboratory IESS, including new Automatic Test Equipment (ATE) technology development, have been identified to

develop a future support capability for ICNIA. These enhancements are listed below:

- E1: Digital LRM Testers
- E2: RF LRM Testers
- E3: Test Software Generation Capability for Dynamic Testers
- E4: Ada Programming Support Environment
- E5: Environmental Stress Test Equipment
- E6: Additional Monitoring Instrumentation
- E7: Digital and Signal Processor Test Stands
- E8: Automatic Failure/Malfunction Simulation Capability
- E9: Real-Time Scenario Modification and Control
- E10: Flexible Signal Synthesis

Figure 6 shows how the enhancements are time-phased to ultimately evolve IESS into an ICNIA ISC. Most of the enhancements will have a near term phase which will take place in the AFWAL Avionics Laboratory on the current IESS or as separate technology programs. This is to develop interim IESS capabilities and for proof-of-concept technology prototyping which can be used in the IESS and other near term programs to ease the technology transition to the far term phase. Most of the enhancements will also have a far term phase. In this phase, enhancements are further developed for production and eventual use in ICNIA depot ATE, AFLC depot IESS, ICNIA ISC, or other integrated avionics support facilities.

FIGURE 6 ICNIA ISC ROADMAP

Finally, the IESS LSUA suggests a plan for implementation of these enhancements. The plan takes into consideration current state-of-the-art capabilities, cost of the enhancement, and time required to implement the enhancement. The enhancement plan develops/implements all the technology required to design an ICNIA ISC.

Conclusion

Various aspects of how IESS can be evolved into an ICNIA ISC have been summarized. Details as to exactly how to develop such a facility are a

matter of future research. It should be pointed out that data provided from the IESS LSUA is not limited to an ICNIA application. Modularity is the key. If designed with expandability and flexibility in mind, as the current laboratory IESS promotes, an ICNIA ISC could be expanded to encompass all aspects of a truly integrated avionics system. An ISC should not have to be redesigned every time a new weapons system is developed. This should be of immediate concern to AFLC given that integrated avionics technology such as PAVE PILLAR is being used in essentially all future DoD weapon systems platforms (ATF, ATA, etc.). If a depot concept for integrated avionics can be developed, it could dramatically reduce the proliferation of varying ISC concepts for these future weapon systems platforms. Design of future integrated avionics systems should be done with an ISC concept, similar to that described in this paper, in mind to ensure compatibility and "smooth" transition from development to fielded systems.

Future research should address the cost effectiveness of many of the ideas for an ICNIA ISC presented in the IESS LSUA. The IESS LSUA provides some data concerning the cost associated with the development of an ICNIA ISC; however it does not provide data on the cost of maintaining, supporting, and manning such a facility.

The elaborateness of an ICNIA ISC will depend upon the performance of ICNIA's BIT and the reliability of the system as a whole. Upcoming demonstrations of ICNIA ADMs along with the developing IESS should provide valuable insight into potential problem areas concerning ICNIA BIT and reliability and how this may effect requirements for an ICNIA ISC.

The IESS LSUA has not answered all questions concerning future ISCs. In fact, it probably asks more questions than it answers. Even so, the IESS LSUA is a step in the right direction and should prompt more research and development in support of future integrated avionics systems.

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