Proposed Development of NASA Glenn Research Center's Aeronautical Networks Research Simulator

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Abstract

Accurate knowledge and understanding of data link traffic loads that will have an impact on the underlying communications infrastructure within the National Airspace System (NAS) is of paramount importance for planning, development and fielding of future airborne and ground-based communications systems. Currently, this problem is not well understood, and to make accurate assessment of the impact that data link traffic loads will impose on the NAS requires testing and verification of the characteristics and performance of the Communications, Navigation, and Surveillance (CNS) technologies to be developed and deployed in the future airspace environment. Attempting to better understand this impact, NASA Glenn Research Center (GRC), through its contractor Computer Networks & Software, Inc. (CNS, Inc.), has developed an emulation and test facility known as "the Virtual Aircraft and Controller (VAC)" to study data link interactions and the capacity of the NAS to support Controller Pilot Data Link Communications (CPDLC) traffic. The drawback of the current VAC test bed is that it does not allow the test personnel and researchers to present a real world RF environment to a complex airborne or ground system. Thus, the impact of the varying modulations, antenna equipage, and radio frequency usage upon data link communication cannot be realistically tested and verified.

Fortunately, the United States Air Force and Navy Avionics Test Commands, through its contractor ViaSat, Inc., have developed the Joint Communications Simulator (JCS) to provide communications band test and simulation capability for the RF spectrum through 18 GHz including Communications, Navigation, and Identification and Surveillance functions.

In this paper, we are proposing the development of a new and robust test bed that will leverage on the existing NASA GRC's VAC and the Air Force and Navy Commands' JCS systems capabilities and functionalities. The proposed NASA Glenn Research Center's Aeronautical Networks Research Simulator (ANRS) will combine current Air Traffic Control applications and physical RF stimulation into an integrated system capable of emulating data transmission behaviors including propagation delay, physical protocol delay, transmission failure and channel interference. The ANRS will provide a simulation/stimulation tool and test bed environment that allow the researcher to predict the performance of various aeronautical network protocol standards and their associated waveforms under varying density conditions. The system allows the user to define human-interactive and scripted aircraft and controller models of various standards, such as (but not limited to) Very High Frequency Digital Link (VDL) of various modes. The system also provides a complete RF environment including voice communications, surveillance radars, and airport navigation and landing systems. Additionally, co-site or noise is generated including television stations, cell networks, signal multi-path and reflections, all providing the backdrop for a real-world RF environment. It also allows the user to define associated platforms and emitters and place these according to flight plans.

1. Existing System Capabilities

1.1 VAC Summary

The VAC software set consists of the following major component applications:

- Human Interactive Aircraft (HIA)
- Human Interactive Controller (HIC)
- Autonomous Aircraft (AA)
- Autonomous Controller (AC)
- System Manager

An overview of the VAC System [1] is shown in Figure 1.

The VAC system is composed of software applications (the Applications) that interface with routers using the Aeronautical Telecommunications Network (ATN) network layer protocol, which is Connectionless Network Protocol (CLNP). The routers in turn are connected to aircraft and ground-based data link radios.

The Applications provide a virtual aircraft/controller capability that emulates pilot/controller data link exchanges for as many as 160 aircraft using script-driven events. The Applications generate Context Management (CM) and CPDLC messages that are ATN compliant, the protocol standard that will be implemented by the Federal Aviation Administration (FAA). The CPDLC message set includes all the messages in Aeronautical Data Link Service (ADLS) Baseline I, which is the set of messages to be implemented in the FAA's CPDLC IA program. The Test bed also includes workstations with aircraft and controller graphical user interfaces at which users can generate and respond to CM and CPDLC messages.

The Applications provide script-driven and human-interactive message emulation. End-to-end CPDLC emulation is provided through script-driven, departure-through-arrival scenarios that can support a full range of communications test activities. A System Manager workstation provides configuration control, scenario and script selection, experiment management, and data reduction and analysis capabilities for the Test bed.

An upgrade of the VAC software is currently being performed. The scope of this upgrade project is to add Traffic Information Services - Broadcast (TIS-B) and Automatic Dependent Surveillance - Broadcast (ADS-B) capabilities to GRC's existing Virtual Aircraft and Controller (VAC) large-scale Aeronautical Telecommunications Network (ATN) emulation software set. This upgrade includes a significant enhancement in real world scenario planning by providing a flight-planning tool that is coupled to the messaging scripts.

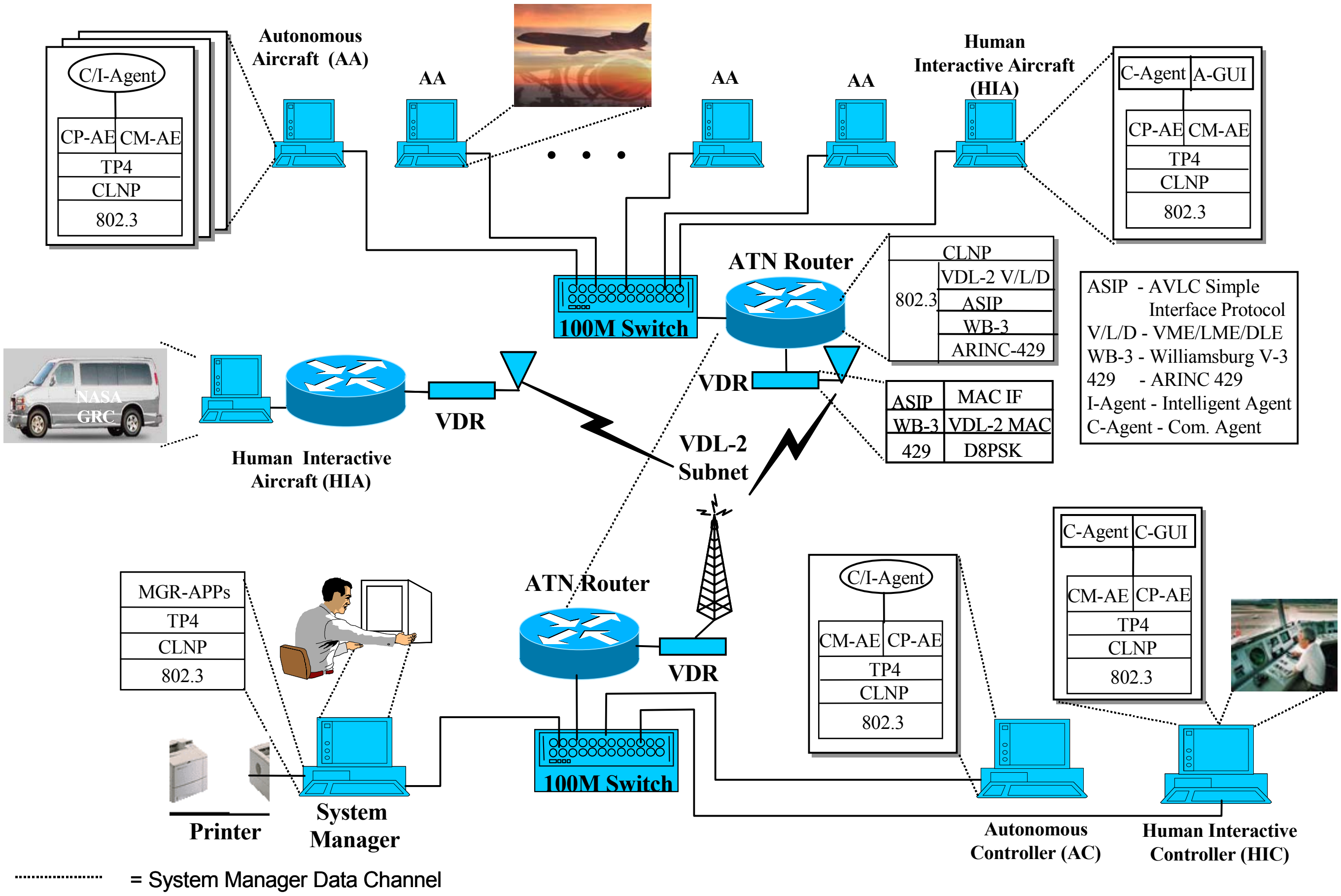


Figure 1. VAC System Overview

1.2 JCS Summary

1.2.1 Test Philosophy for JCS

The development of the Joint Communication Simulator [2] was driven by a desire to test many types of disparate communications systems using common test equipment. Each system being tested would typically operate in a real-world RF environment that varies from that of other systems in many ways including frequencies, bandwidths, modulations, antenna patterns and geographic region, to name a few. Each System Under Test (SUT) would typically be exposed to some signals that were common among the various types of SUTs (e.g. television signals, radio signals, …etc.). Therefore, the JCS was designed to be capable of generating many different types of communication signals simultaneously.

Operationally, an SUT might be exposed to a set of signals of interest that were dynamic in RF characteristics. For example, an SUT might fly into a region around an airport that uses secondary surveillance radars and then find that it was being interrogated, or it might fly within line of sight of a Tactical Air Navigation (TACAN) station and periodically receive Morse code identifying the airport. In either of these cases the amplitude of the pulsed signals would vary with respect to the SUT as the transmitting antenna rotated. As another example, an SUT could receive voice bursts of command, query and status from an air traffic controller. In each of these cases, the RF presented to the SUT would vary, not only because of the signal modulation, but also because of specific system functionality. Therefore, the JCS needed to be capable of emulating the functionality of systems that generated the signals of interest to the SUT.

An SUT could be mobile and could communicate with other systems that were also mobile. This could affect communication between the SUT and other platforms in many ways. The relative motion between platforms could induce Doppler effects on the received signal. Transmit and receive antenna gain characteristics could change as the relative position of the SUT and other platforms changed. Also, the ability to receive a given signal could be affected by the altitude of each platform. In other words, the RF environment the SUT would see could change with the time varying relative geometry between the SUT and the other communicating platforms. Therefore, the JCS was designed to be capable of calculating platform motion for all of the communicating platforms and determining the effects on the RF signals at the SUT and virtual receivers.

Finally, the researcher would want to examine conditions that might be difficult, if not impossible, to produce in the real world. As an example, supposed an SUT's Mark XII Interrogation system is being tested and is not reporting the correct Mode C altitude of a virtual transponding aircraft, based upon the aircraft's true altitude within the scenario. The researcher would want to have the freedom to change simulation conditions and parameters in an effort to determine why this is occurring. Manual control of the virtual transponding aircraft could be affected to change its altitude, repeatedly noting the differences in reported versus actual altitude. (Other altitude-related parameters could also be altered, such as received signal power at the SUT, to remain constant in an effort to change only the virtual aircraft's reply information.) If it were found that the reply information is still processed incorrectly, all emitters could be disabled in the scenario except the reply from the virtual platform. If the SUT then began to correctly track the altitude change in the virtual platform, other emitters could be enabled, one at a time, until the disrupting signal is identified. Many permutations of this illustration are possible, and the ability to change individual parameters of interest is an extremely useful capability allowing researchers to affect scenario parameters and events in real time.

1.2.2 JCS Capabilities and Architecture

The JCS has been developed with a sharp focus on modularity, allowing grouping of hardware as required by researchers. The largest JCS systems built to date provide programmable RF sources for 92 simultaneous signals. Of these, 76 are termed Non-Angle-of-Arrival (Non-AoA) RF while the other 16 signal sources are termed AoA. The Non-AoA RF sources are meant to feed RF antenna inputs of an SUT that are not sensitive to the direction of arrival of the signal. Most antennas are of this type. The AoA signals are meant to feed SUT RF interferometers used for direction finding. The JCS is designed for interferometers of up to 32 elements. The Non-AoA signal frequency coverage is from 0.5 MHz to 18 GHz, and for AoA signals, the frequency coverage is from 20 MHz to 2 GHz. All signal sources are programmable to vary by signal type, bandwidth, signal strength and operating frequency. Using these signal sources, the JCS is capable of simulating scenarios involving numerous platforms, each emitting several different RF CNI signals. The JCS can create effects due to relative motion of the System Under Test with respect to other simulated platforms including path loss, carrier Doppler, antenna directivity variations, and AoA amplitude and phasing.

The JCS signal generators have been designed as field programmable gate array-based arbitrary waveform generators. These signal generators can produce signals of many different modulation types (such as AM, FM, SSB, DSB, QPSK, FSK, OQPSK, QAM, PPM). The most common mode of operation for the signal generators is to receive data because of virtual model communications. Developed signal types include Air Traffic Control (ATC), Identification Friend or Foe (IFF), navigation, and data communication signals. Additionally, the signal generators are capable of receiving external analog and digital data that they can modulate. They can be externally triggered and also can supply an output trigger. These signal generators can produce digital signals of up to 10 mega-symbols per second and pulsed signals with a minimum pulse width of 25 ns.

The architecture of the JCS is modular in form and is built up from a relatively small number of unique modules as illustrated in Figure 2. The JCS architecture consists of the following main components:

- Control Station (CS)
- Control Station Subsystem (CSS)
- Signal Generation Units (SGU)
- Non-AoA RF Data System (NARFDS)
- AoA RF Data System (ARFDS)

The Control Station is a SUN Workstation with two monitors. The CS presents the JCS Graphical User Interface (GUI) to the user. The JCS GUI allows the user to construct as well as control a scenario. This GUI allows the operator to define emitters, define platforms and scenarios, run scenarios, and perform built in test (BIT) and calibration functions. Each Signal Generation Processor (SGP) within the SGU Subsystem is responsible for simulating a subset of the real-world systems being emulated by the JCS. The Non-AoA RF Data Processor (NARFDP) within the NARFDS is responsible for RF attenuation and mixer band control for presentation of the waveform to the SUT. Automatic user-initiated calibration is performed to ensure the RF accuracy including timing, power level and phase of signals presented to the SUT. In addition, the JCS contains BIT features down to the lowest user replaceable module. The calibration and BIT are also accessible via the simulator GUI.

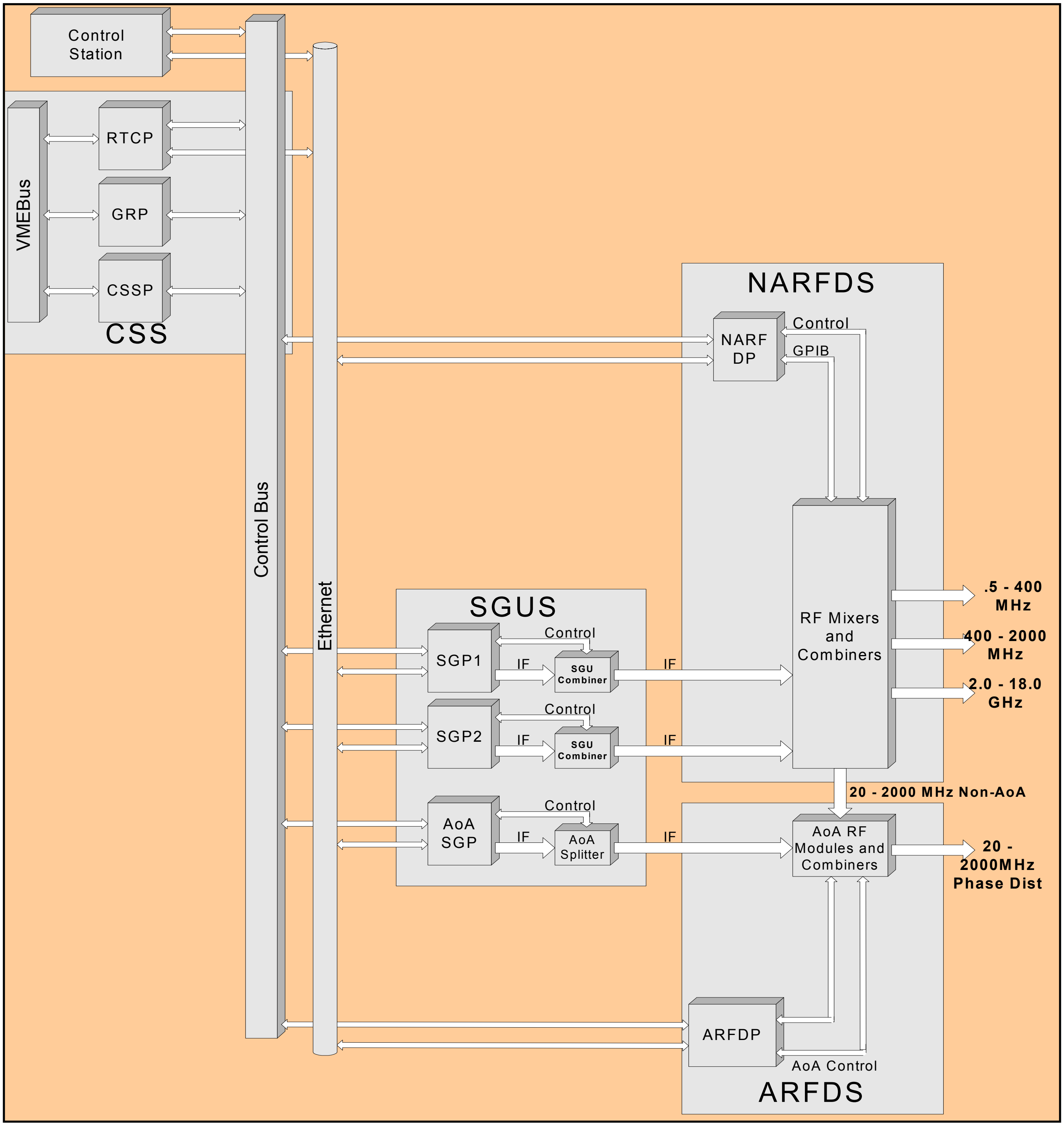


Figure 2. JCS Architecture

1.3 ANRS Proposal Summary

Meeting the objectives of a cost effective Virtual RF Test Bench Environment requires a modular, scalable approach allowing future functions and upgrades to be included with minimal risk and minimal cost impacts. The architectural approach undertaken to meet the ANRS objectives is an outgrowth of architectures previously implemented in VAC, JCS and related programs. The ANRS architecture [3] will build on the key elements from these programs and add updated technology and designs to provide CNS performance through 50 GHz.

In deriving the proposed ANRS architecture, our focus was two-fold. First, we desired to leverage existing JCS assemblies or Hardware Control Items (HWCIs), and subsystem definitions to the greatest extent practical and still provide a modular, flexible ANRS solution. Second, we were extremely concerned about any architectural evolution that would require a re-definition of software states and modes, as we believe a large cost impact is avoided through the preservation of the JCS software functional architecture.

The Staged approach to build the ANRS test bench will utilize development of early test scenarios to ensure that adequate system capability is available at each stage of development. This allows ANRS to operate from a virtual RF environment through hardware-in-the-loop testing. At each development stage of the program additional hardware, software and systems capability will be integrated and demonstrated, providing GRC with a continually more capable testing asset for the life of the program.

The modular, scalable nature of the ANRS architecture allows new waveforms to be added without significant impact to the existing hardware compliment. This will minimize the risk of adding future (currently undefined) waveforms to the ANRS waveform library. This approach will enable the ANRS developer to customize and adapt deliveries to specific NASA budget and schedule constraints without adding additional risk to the development and delivery of the final system configuration.

2. Technical Approach to ANRS

2.1 Theory of Operation

The Aeronautical Network Research Simulator is a tool that allows the researcher to predict the performance of various aeronautical network protocol standards and their associated waveforms under varying density and environmental conditions. A block diagram showing a pushdown view of the critical subfunctions of the ANRS is provided in Figure 3.

The Critical components that comprise the heart of the ANRS are the Controller and Aircraft Model and Simulation Subsystem (CAMSS) and the Controller and Aircraft Physical Simulation Subsystem (CAPSS).

The CAMSS contains subfunctions that allow the researcher to define human-interactive and scripted aircraft models and controller models of various standards, such as VDL Modes 1, 2 or 3. It also allows the researcher to define associated platforms and emitters and place these according to flight plans. Via the System Monitor (SM) in the CAMSS, the researcher creates scripts or flight plans for Autonomous Aircraft (AA) and Autonomous Controllers (AC) and places these in PC workstations. Human Interactive Aircraft (HIA) and Human Interactive Controllers (HIC) are also defined on PC workstations. As the name implies HIA's and HIC's allow researchers to interact with the simulation as pilot or controller respectively

Each AA, AC, HIA and HIC is associated with a corresponding platform/emitter pair and this association is sent to the CAPSS Control Station. These become part of the scenario that is run. The Control Station in the CAPSS is used to initially define emitters with appropriate modulations (e.g. D8PSK). In addition, antenna patterns, effective radiated power (ERP), receive sensitivity and other physical radio parameters can be associated with these emitters. The CAPSS control station is used to create platforms that will contain these emitters in any combination desired. These platforms are given dynamic parameters based upon the type of platform. For example, the platform may be defined as fixed, ground-based, or airborne. These platforms are made available to the SM in the CAMSS so that the researcher can associate each with a particular AA, AC, HIA or HIC. In addition, the Control station is used to define platforms and emitters that are independent of the network defined in the CAMSS. These emitters may be of any type and are used to populate the scenario with signals that would be found in the area of interest. These signals may include television, radio, VHF Omni-Range (VOR), TACAN, Mode S, ATC voice etc. Digital Terrain Elevation Data (DTED) information may also be associated with the area of interest to allow high fidelity terrain and atmospheric propagation effects. These are loaded at the Control Station.

Once a scenario is defined by the user and input into the SM and CS, the scenario is initialized. During the initialization process, the SM actually extracts available platform/emitter information from the CS and uses this information to associate aircraft and controller network models with instantiations of the available platform types. The SM will use flight pattern information for each platform that contains models under its control to place the platforms with initial positions and motion. The SM will then command the Control Station to initialize its scenario. The Control Station will inform the SM when it is finished and this will be echoed to the researcher.

The researcher then runs the scenario by sending a command to the SM. Using the initial flight parameters and waypoints from the Control Station, the Geometry Relationship Processor (GRP) will fly each airborne platform in real time and compute platform to platform relationships such as pointing angles and ranges. The SM can send to the GRP platform flight plan updates via the Run Time Executive Interface (RTEI).

Using the message scripts associated with each AA and AC, a model will request to send a message to a given receiver. This request will be sent to the RTEI in light of the access architecture being used by the signal to transfer the type of message in question. For example, if the RTEI receives a request to send a message that uses VDL Mode 2, then the RTEI will decide whether the message satisfies the Carrier Sense Multiple Access (CSMA) criteria for obtaining the network.

If the message in question does pass this test, the request will be forwarded on, along with the accompanying time of transmission from the SM, to the RF Environment Processor (RFEP). The RFEP will decide, based upon the various RF signals impinging on the input to the intended receiver as well as the modeled receiver's input characteristics and platform relative geometry, whether the message of interest would be successfully received and demodulated. The RFEP will send back to the RTEI the result of the RF analysis in the form of a Yes or No. If an affirmative is sent, meaning that the message was successfully received, then a time delay accompanies the response. This time delay is the composite of RF propagation time from the transmitting platform to the intended receiving platform and receiver processing delay time. The RTEI forwards the results of the analysis of the requested message to the appropriate receiving model. The model uses the time delay accompanying a successful communication to decide when to transmit its reply, if needed. Every message transmitted from any of the AA, AC, HIA, or HIC models will undergo the same processing. These models send their status to the SM for logging and run time statistics generation and display. In addition, the individual subfunctions of the CAPSS store emitter and platform RF connectivity and relationship information for later retrieval by the researcher.

Two other critical subfunctions of the CAPSS, shown in Figure 3, are the Run Time Control Processor (RTCP) and the Signal Generation Processor (SGP). The RTCP is used to synchronize all other CAMSS subfunctions. It also places the CAMSS subfunctions into appropriate states (i.e. run, pause, initialize, etc.) and retrieves all extracted data when commanded by the Control Station. The SGP is the signal generation hardware controller. It controls attenuators, mixers, phase shifters and arbitrary waveform generators based upon simulation results in order to generate RF from the viewpoint of a system under test.

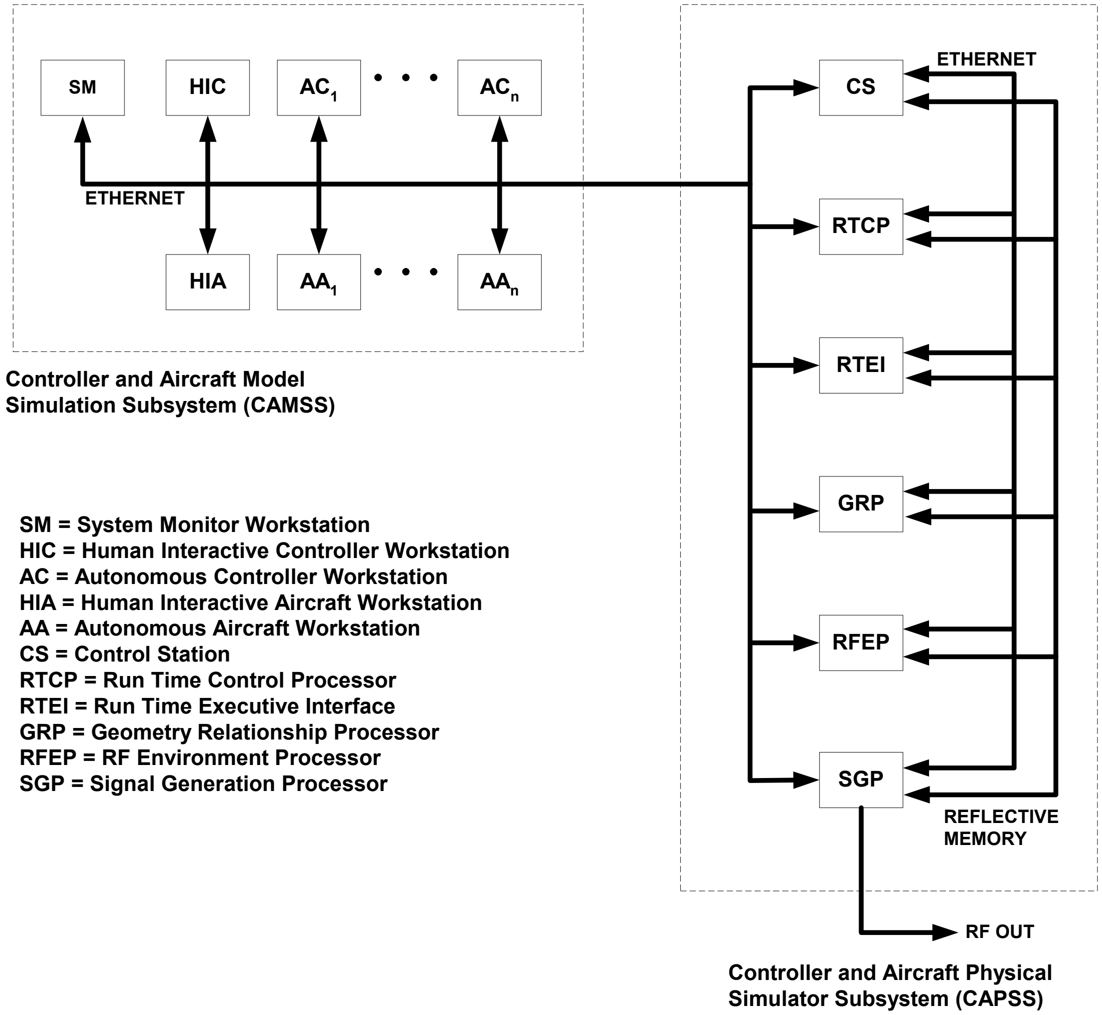


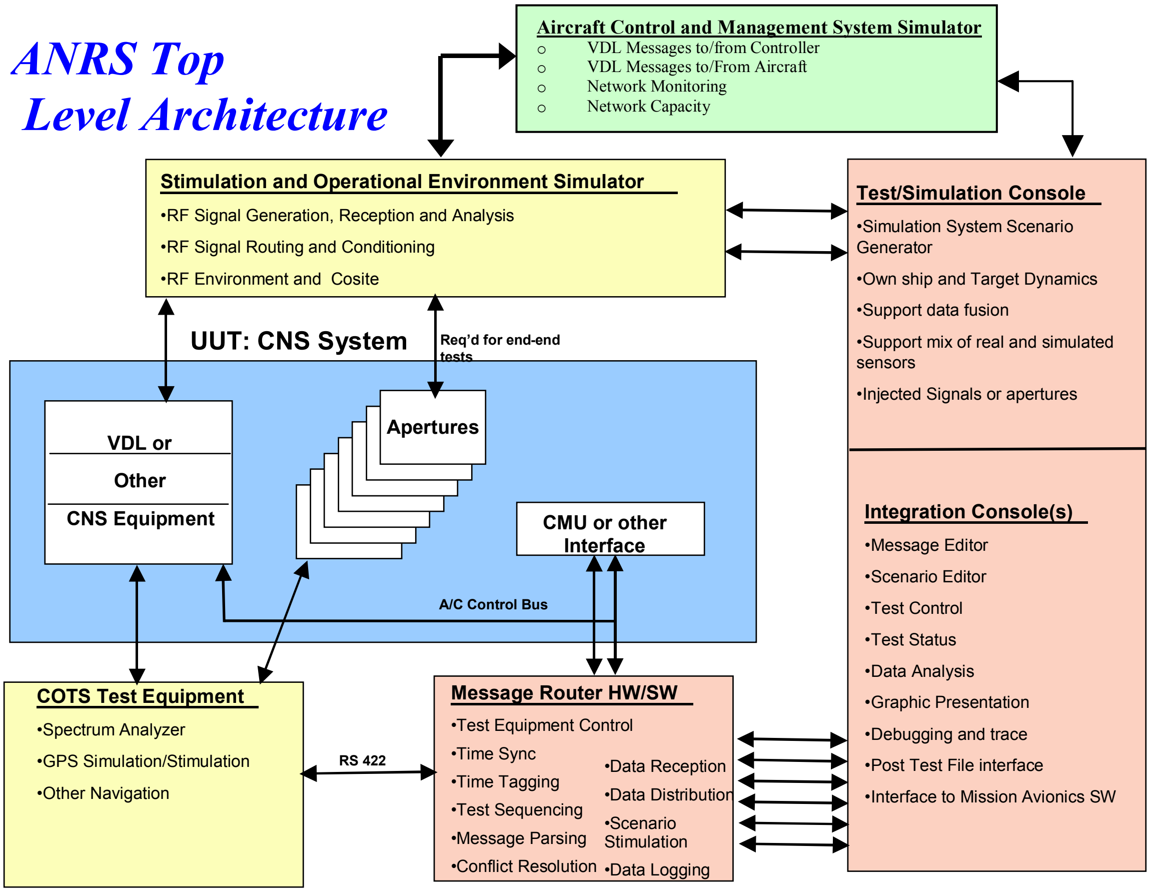
Figure 3. ANRS Top-Level Architecture

2.2 ANRS Architecture Description

The ANRS architecture is a blend of both the VAC and JCS products that have been successfully developed and delivered to NASA GRC and to the U.S. Air Force and Navy Avionics Test Commands, respectively. The VAC product was initially developed as a network capacity simulation tool while the JCS system was initially developed as an RF stimulation and test tool. The development of a suitable architecture to support the described theory of operation of the ANRS test bed application requires key elements including:

- Real time software interface between network management tools and RF assets
- RF Simulation capability
- RF Stimulation of System under Test
- Simplified Scenario generation and post test analysis tools

The Top Level architecture presented in Figure 4 illustrates the ANRS system at a higher level then that shown in Figure 3 in order to better describe the architecture from a user and top-level interface perspective. The proposed Full Operational Capability (FOC) architecture is centered on a System Under Test or SUT. This can be a real CNS hardware system or a virtual system depending on the particular test objectives desired. As discussed, when an experimental or operational avionics system is tested, the ANRS will perform as an RF stimulator. In the case of a virtual system, the ANRS provides virtual RF test capability, creating appropriate timing delays, signal characteristics and performance as



though RF was transmitted and received on a network within a realistic RF environment.

Figure 4: ANRS Top Level Architecture

The Aircraft Control and Management System Simulator provides functionality that is included in today's VAC system and ANRS CAMSS concept. In this subsystem network messages from air traffic control or the pilot are received, generated, acknowledged and monitored. This subsystem will be adaptable to many communications, navigation and surveillance messaging such as VDL, CPDLC, etc. The CAMSS will represent an entire network for air traffic control based on the total number of interactive aircraft predicted for the Los Angeles basin in the year 2020. The CAMSS will be capable of real time interaction or scripted scenarios to run longer test sequences and will operate with a single control interface through an entire network.

The Stimulation and Operational Environment Simulator provides the key RF links to the SUT or a virtual SUT and between other communicating virtual players in a scenario. This subsystem, which includes the CAPSS, contains the capability to generate an RF environment with moving and fixed platforms and dynamic interaction between the SUT and other defined players in the scenario. In a virtual SUT environment, this subsystem will provide the geometric keys to simulate signal timing, fading and signal in space effects without generating an actual RF signal.

The Test /Simulation Console and the Integration Console provide user interface to the ANRS system for the purpose of monitoring tests, monitoring SUT performance, generating Scenarios and test scripts and interactively conducting tests or integration experiments. This subsystem will provide the researcher with all pertinent pre and post testing data and allow manipulation for data reduction and test report generation. Additionally, support of integration activities, software debugging, software trace and scenario editing capabilities all reside in this subsystem.

The Message Router Subsystem provides interface to an SUT avionics interface bus. This subsystem can be modified and adapted to various architectures allowing the monitoring of low-level bus messages and software performance within the SUT. Finally, the test subsystem will provide RF spectrum analysis tools, and various test equipment used to calibrate, test and monitor the RF performance of the RF Stimulation subsystem and/or the SUT.

2.3 ANRS Key Features

The ANRS includes several key features that will allow the researcher to conduct "what if" analysis easily, greatly enhancing the situations that are accessible for study.

First, the ANRS has an inherent capability to present the researcher with a realistic mix of signals. All networks under consideration are used in an environment that is filled with independent RF sources. These sources can be placed in the scenario by the researcher at the locations that correspond to the actual locale, given the correct physical characteristics including frequency, modulation, ERP, antenna patterns and content. In addition, the terrain characteristics of the locale being researched are included in the ANRS via the inclusion of the NIMA Digital Terrain Elevation Database.

Second, the ANRS provides the researcher with full run time control over the experiment being performed. This allows the researcher to perturb the environment to see what happens. The researcher can enable and disable any individual emitter, change the emitter's carrier frequency, ERP or messaging rate. The researcher can manually control individual platforms during run-time, disable or enable them, change their heading, climb rate and velocity in order to study situations that may be, at the very least, unsafe to implement in the real world.

Third, the ANRS is capable of signal simulation and generation for almost any type of modulation imaginable, up to its symbol rate limitation of 10 mega-symbols per second, in combination with any other set of signals. This gives the researcher the ability to study new waveforms as they are being developed, before they are actually implemented in operational hardware, in a realistic environment. In addition, the signal version of the waveform that is implemented in the ANRS could be modified as the developing counterpart waveform evolves through the standardization process. Moreover, feedback from the researcher's study results could be made available to the groups developing the individual waveforms of interest.

Fourth, the ANRS will provide a realistic messaging environment that can be linked to operational scenarios. The use of fight plan driven scenarios that are coupled with CPDLC, FIS, AOC, ADS-B,TIS-B, and other transactions will allow RF testing using the mix of realistic messaging loads that emulate real conditions.

3. Conclusion

The purpose of this paper is to propose the development of a new and robust research tool taking advantage of two successfully developed simulation/stimulation tools. Leveraging heavily from the VAC and JCS strengths, the proposed ANRS system will give the researcher the needed information to make accurate and cost effective decisions relating to emerging aeronautical network protocol standards and their associated waveforms under real world conditions.

4. Acknowledgement

The authors would like to thank the management at NASA Glenn Research Center, Analex Corporation, CNS, Inc. and ViaSat, Inc. for their support and encouragement in pursuing a robust and cost effective research tool to aide in the improvement of the NAS.

5. References

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[3] Project White Paper to NASA GRC for the Aeronautical Networks Research Simulator, October 4, 2003.

6. Biographies

***Thanh C. Nguyen** is an Electrical Engineer for Analex Corporation in Cleveland, Ohio. He has more than 20 years of software engineering and data communications related experience, the past four years dedicated to supporting aeronautical communications research and advanced communications for air traffic management (AC/ATM) modeling and simulation for NASA Glenn Research Center. He has held positions as Senior Software Engineer and Software Project Manager for Wyle Laboratories, Senior Software Engineer for ZIN Technologies, Inc., and Systems Engineer for Sverdrup Technology, Jocobs Engineering Group. He has a BS in Applied Physics from University of California, Riverside, and has completed numerous graduate level courses in Electrical and Software Engineering.*

***Robert J. Kerczewski** has been involved with research and development of satellite communications systems and applications since 1982, for the Analex Corporation and NASA. He holds a BEE degree from Cleveland State University (1982) and MSEE degree from Case Western Reserve University (1987). At NASA, he has managed the High Burst Rate Interference Experiment, Advanced Space Communications Laboratory, Telemammography Using Satellite Communications, and the Advanced Communications for Air Traffic Management (AC/ATM) Project. He is currently the Project Manager for the Advanced CNS Architectures and System Technologies (ACAST) at NASA Glenn Research Center.*

***Chris Wargo** is the President of Computer Networks & Software, Inc. – a firm specializing in the development of aviation CNS systems and defense software systems. He has held positions as Vice President and General Manager for ARINC, Inc., C3I Program Manager and Manager, Strategic Planning and Advanced Programs Development, for RCA Automated Systems and GE, as well as a Systems Engineer for GTE Sylvania, Electronic Systems Group, and for the US Army. He has a BSEE from the University of Wisconsin and an MS, Systems Engineering, from the University of Southern California, and has attended the Defense Systems Management College and the Advanced Management Program at the Harvard Business School.*

***Michael J. Kocin** has over 26 years of engineering and technical management experience. He has expertise in specification, analysis, design, development, integration and testing of large, integrated communication systems including over 14 years experience on Integrated Communications Navigation Identification Avionics (ICNIA) and related programs. He was lead engineer for the F-22 CNI design and integration effort and was overall system engineer responsible for integration, test, and demonstration of multiple waveforms on the terminal during the final I&T phases of the program. Mr. Kocin has direct experience with IFF systems including Mark XII, XV and with existing spread spectrum systems including EPLRS, GPS, Mark XV, Have Quick, HFAJ, VDL, TCAS, IFDL, Mode S and SINCGARS. He has a BSEE from California State University, Long Beach and an MSEE from the University of Southern California.*

***Manuel L. Garcia** has over 20 years of experience performing technical analysis, design, development, simulation, specification, integration and testing of avionics and surveillance hardware. He has over 8 years experience with the Integrated Communications Navigation Identification Avionics (ICNIA) and related programs. Mr. Garcia maintains expertise with digital signal processing hardware design for many military communication, navigation, identification, and electronic combat systems including VHF/UHF Clear Voice, SINGARS, HAVEQUICK, GPS, JTIDS, TACAN and IFF. Mr. Garcia has designed ICNIA preprocessors to detect and demodulate wide bandwidth communication waveforms. He is co-inventor of the Universal Matched Filter (for which there is a patent pending) used in the ICNIA to detect and filter UHF and L-band waveforms. Mr. Garcia maintains a working knowledge of a wide variety of signals and applies this knowledge across ViaSat's simulator programs.*

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Presentation Overview

- CNS Testing Needs
- Current Test Bed System Overviews
  - Virtual Aircraft & Controller (VAC)
  - Joint Communications Simulator (JCS)
- New, Robust and Cost Effective Test Facility
  - ANRS Summary
  - ANRS Architecture
  - Key Features
- Summary
- Questions/Answers

CNS Testing Needs

- Enhancing activities on research & development of CNS technologies that help modernize the NAS
- Studying impact of data link traffic loads on future underlying communications infrastructure within the NAS (currently, NOT well understood)
- Current test bed system is inadequate, no real RF environment and lack of robust features and capabilities
- A need for a new, robust and cost effective test facility to allow:
  - Complex RF signal generation
  - Flexible and large scale testing of numerous CNS/ATM Concepts
  - Modeling CNS communication traffic loads of realistic operational scenarios (flight plan)
  - Performance evaluation of throughput and delay of aeronautical subnetworks under load
  - Supporting repeatable experimental trials
  - Provide an affordable approach to large scale testing
  - Include mobility related RF effects

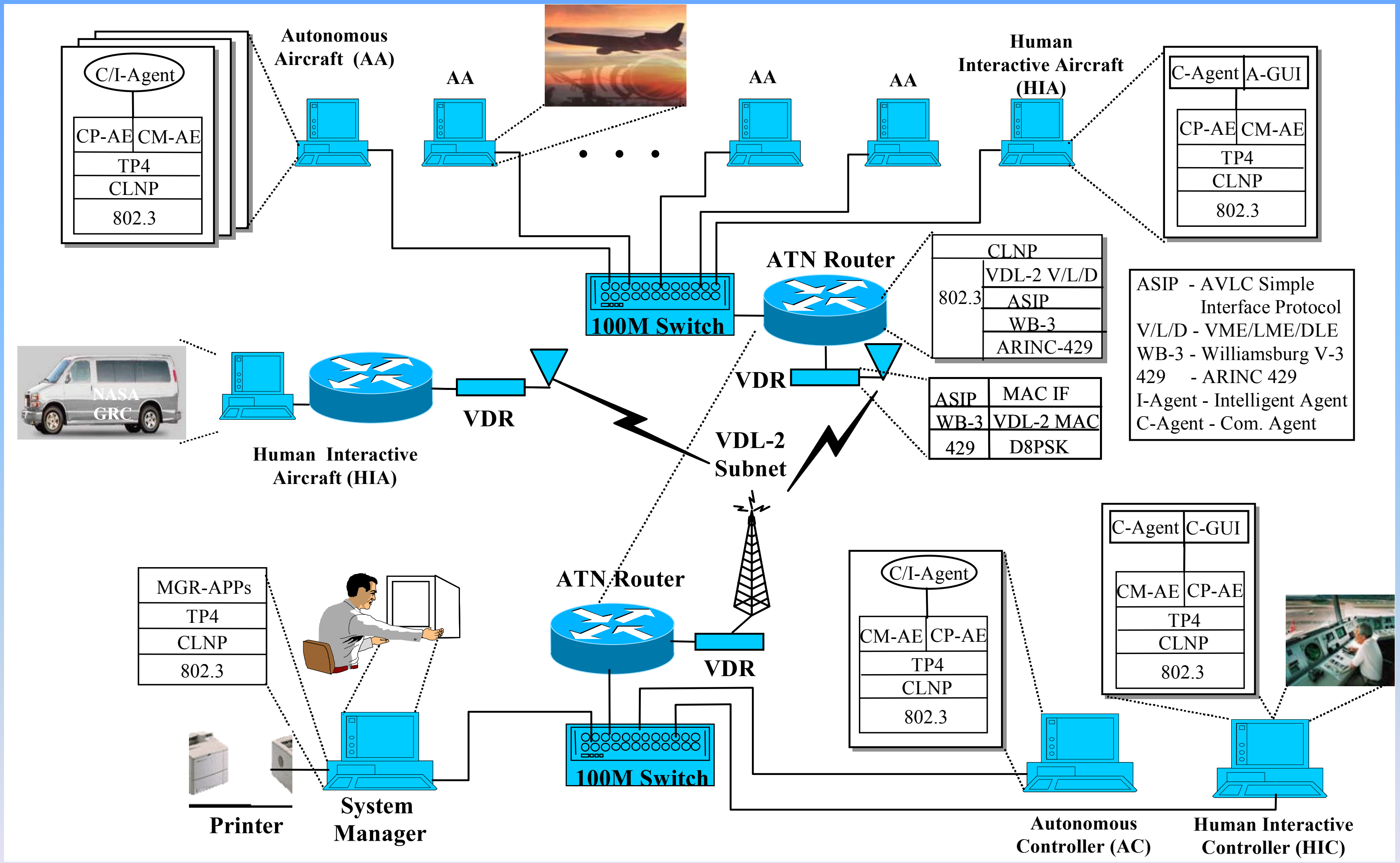
NASA GRC VAC Overview

- NASA GRC VAC consists of major component applications:
  - Human Interactive Aircraft (HIA)
  - Human Interactive Controller (HIC)
  - Autonomous Aircraft (AA)
  - Autonomous Controller (AC)
  - System Manager
- Software applications interface with ATN routers & provide a virtual aircraft/controller capability that emulates pilot/controller data link exchanges for up to 160 aircraft, using script-driven events
- Support Context Management (CM) & CPDLC messages
- VAC Build C (an upgrade) supports TIS-B, ADS-B and realistic flight-plans

Analex Corporation

VAC System Overview

Glenn Research Center



ASIP - AVLC Simple Interface Protocol
V/L/D - VME/LME/DLE
WB-3 - Williamsburg V-3
429 - ARINC 429
I-Agent - Intelligent Agent
C-Agent - Com. Agent

…………………… = System Manager Data Channel

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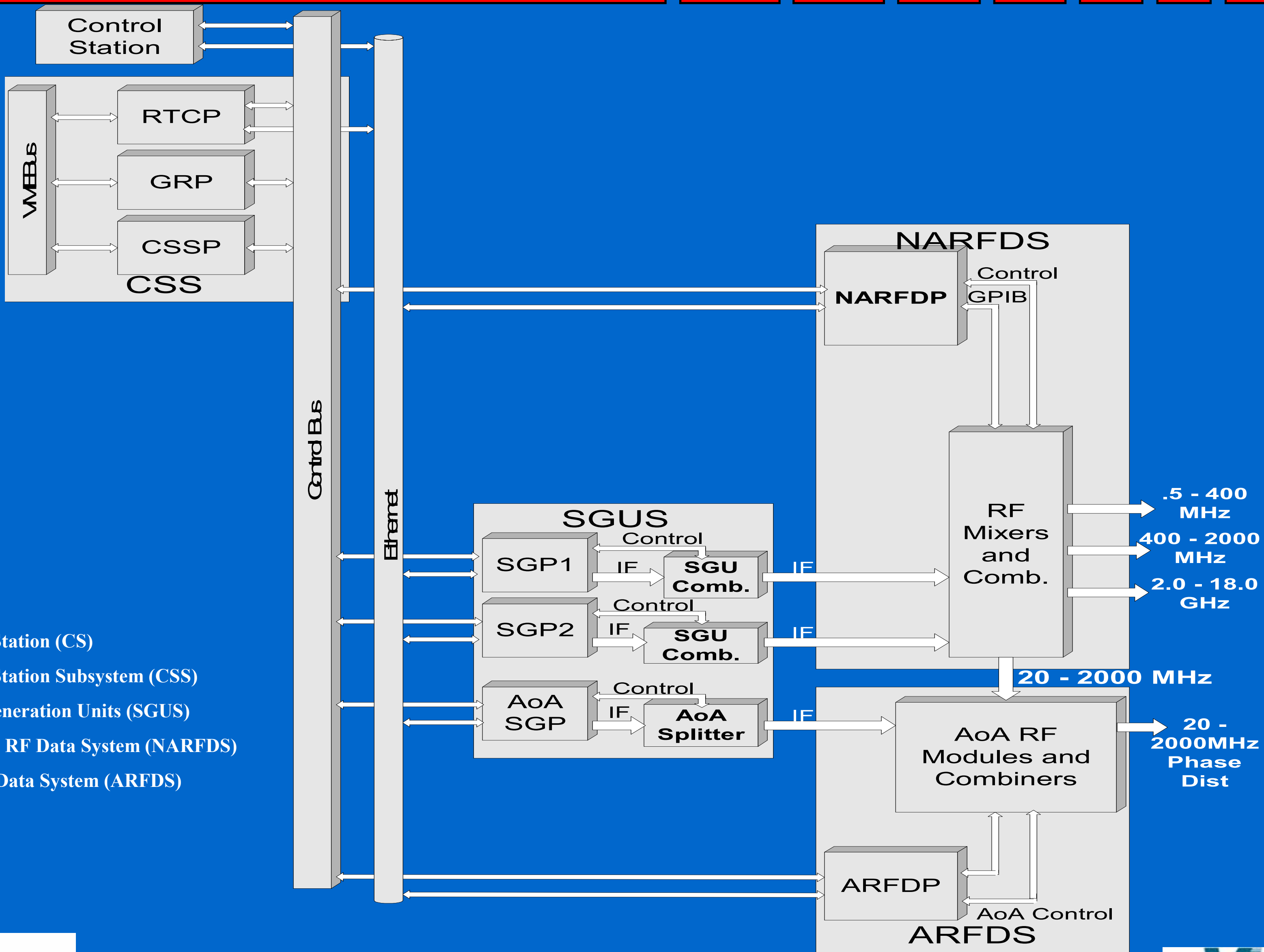
Government Systems

JCS Overview

- JCS was built for the U.S. Air Force & Navy Avionics Test Commands by ViaSat, Inc to provide communications band test & simulation capability for RF spectrum.
- JCS architecture consists of following main components:
  - Control Station
  - Control Station Subsystem
  - Signal Generation Units
  - Non-AoA RF Data System
  - AoA RF Data System

JCS Top Level Architecture



- Control Station (CS)
- Control Station Subsystem (CSS)
- Signal Generation Units (SGUS)
- Non-AoA RF Data System (NARFDS)
- AoA RF Data System (ARFDS)

Joint Communication Simulator

Summary of Proposed ANRS

- **To develop a new, robust and cost effective Virtual RF Test Bench Environment/Facility requires a modular, scalable approach to allow:**
  - **New functions and upgrades to be added at minimum risk and cost**
  - **Leveraging existing architectures, functions and HW/SW capabilities of NASA GRC VAC and U.S. Air Force & Navy Avionics Test Commands JCS Systems**
  - **Minimize redefinition of software states and modes while maintaining flexibility, thus avoiding large cost through preservation of existing JCS software functional architecture**
- **Incremental/staged approach to development and implementation to ensure**
  - **Adequate system capability available at each stage of development**
  - **And, thus allowing ANRS operating from a Virtual RF environment through hardware-in-the-loop testing**
  - **Additional HW, SW and system capability to be integrated & demonstrated at each phase providing researchers with additional capability**
- **Additional waveforms added without significant impact to existing hardware**
  - **Customize future deliveries based on budget and schedule constraints**
- **Model Air Traffic communication traffic loads of realistic operational scenarios (flight plan)**
- **Performance evaluation of throughput and delay of aeronautical sub networks under load**
- **Support repeatable experimental trials**

ANRS Architecture

- **ANRS architecture is a blend of both VAC & JCS**

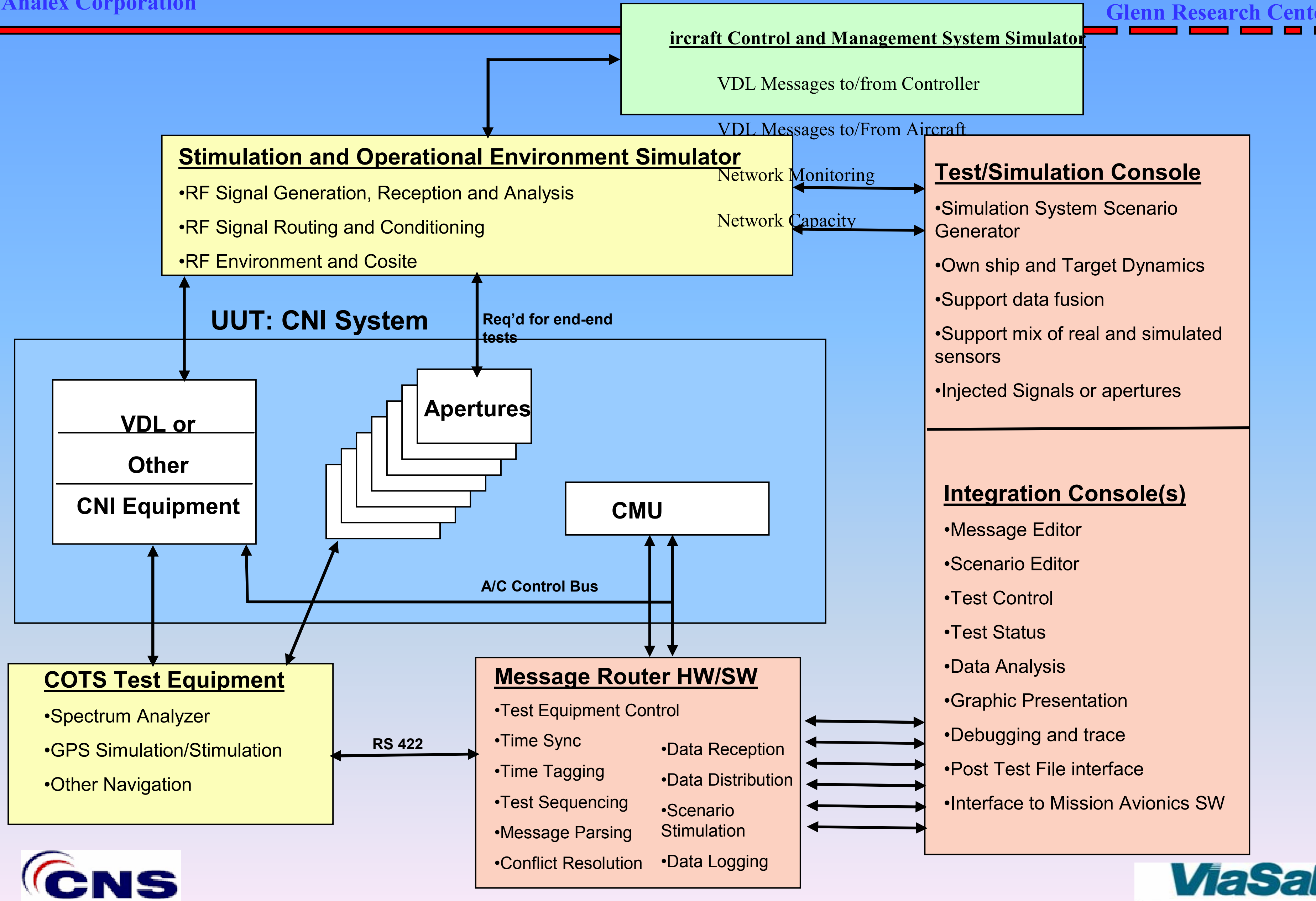
  Note: VAC was developed as a network simulation capacity tool, while JCS as an RF stimulation & test tool

- **Key elements of ANRS architecture:**
  - **Real time software interface between network management tools & RF assets**
  - **RF simulation capability**
  - **RF stimulation of system under test (SUT)**
  - **Simplified scenario generation & post-test analysis tools**

Analex Corporation

ANRS Top Level Architecture

Glenn Research Center



ircraft Control and Management System Simulator

VDL Messages to/from Controller

VDL Messages to/From Aircraft

Network Monitoring

Network Capacity

Stimulation and Operational Environment Simulator

- RF Signal Generation, Reception and Analysis
- RF Signal Routing and Conditioning
- RF Environment and Cosite

UUT: CNI System

Req'd for end-end tests

VDL or

Other

CNI Equipment

Apertures

CMU

A/C Control Bus

Test/Simulation Console

- Simulation System Scenario Generator
- Own ship and Target Dynamics
- Support data fusion
- Support mix of real and simulated sensors
- Injected Signals or apertures

Integration Console(s)

- Message Editor
- Scenario Editor
- Test Control
- Test Status
- Data Analysis
- Graphic Presentation
- Debugging and trace
- Post Test File interface
- Interface to Mission Avionics SW

COTS Test Equipment

- Spectrum Analyzer
- GPS Simulation/Stimulation
- Other Navigation

RS 422

Message Router HW/SW

- Test Equipment Control
- Time Sync
- Time Tagging
- Test Sequencing
- Message Parsing
- Conflict Resolution
- Data Reception
- Data Distribution
- Scenario Stimulation
- Data Logging

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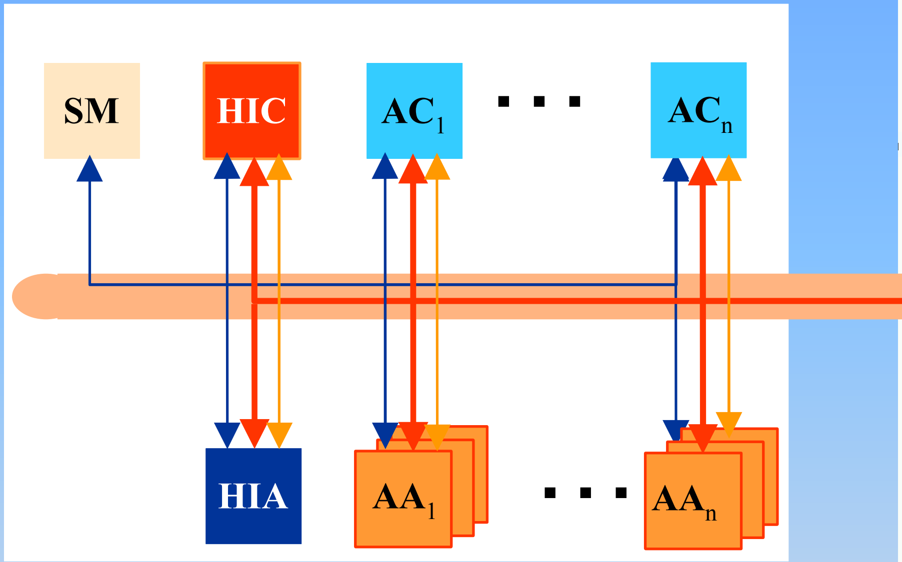
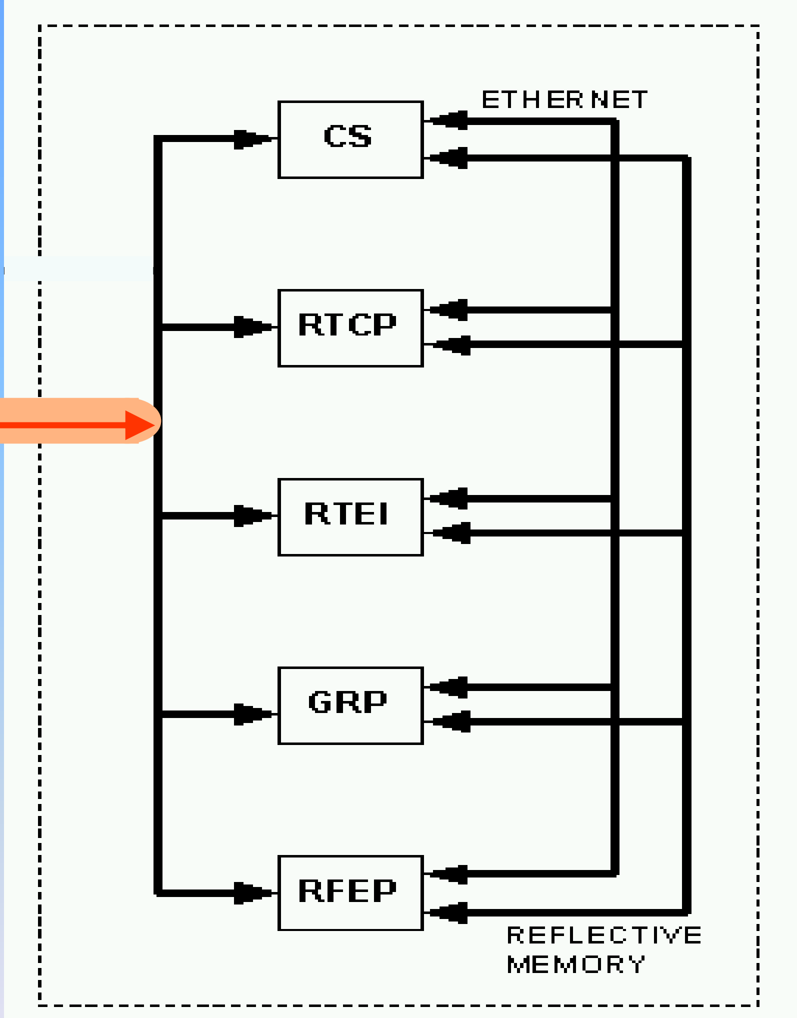
Government Systems

ANRS Logical Architecture

- Control Channel
- Application Communication Channel
- CAMSS and CAPSS Communication Channel



Controller and Aircraft Model Simulation Subsystem (CAMSS)



Controller and Aircraft Physical Simulation Subsystem (CAPSS)

SM = System Monitor Workstation
HIC = Human Interactive Controller Workstation
AC = Autonomous Controller Workstation
HIA = Human Interactive Aircraft Workstation
AA = Autonomous Aircraft Workstation
CS = Control Station
RTCP = Run Time Control Processor
RTEI = Run Time Executive Interface
GRP = Geometry Relationship Processor
RFEP = RF Environment Processor

ANRS Key Features

Desirable key features:

- Realistic Mix of Signals
  - Environment filled with independent RF sources
  - RF sources placed with physical characteristics including frequency, modulation, ERP, antenna patterns and content
  - Terrain characteristics
- Full Run Time Control
  - Operator intervention to instantly change environment
  - Enable or disable any individual emitters carrier frequency, ERP or message rate
  - Manually control movement of platforms including dynamic movement
- Capability to present almost any type of signal simulation
  - Up to 10 mega symbols per second in combination with any other set of signals
  - Creates realistic operational environment prior to operational status
  - Existing Waveform modifications tested prior to final implementation of change

Summary

- Proposed ANRS test facility represents a new, robust and cost effective research tool that can leverage on existing systems
- Implementation of emerging aeronautical network protocol standards and the associated waveforms under complex conditions
- Enhancing R&D activities in CNS technologies

Questions/Answers

Thank You!