Aeronautical Network Research Simulator (ANRS)

ICNS Conference

May 2005

ANRS Overview

- Implementation of a cost effective Virtual RF Test Bench Environment utilizing a modular, scalable approach
  - Minimizes cost and risk
  - Outgrowth of architectures previously implemented in Virtual aircraft Capability (VAC) and Joint Communication Simulator (JCS)
  - Minimize redefinition of software states and modes while maintaining flexibility
- Staged approach to development and implementation
  - Virtual RF environment through Hardware-in-the-loop
  - Additional HW, SW and capability designed, demonstrated at each phase providing GRC with additional capability
- Additional waveforms added without significant impact to 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

Integrated CNS Laboratory Concept

On-Site User

Off-Site User

N-ACT Laboratory Management and Control
- System Administrator
- System Manager
- Experiment Support Software
- Test and Metrics Software
- Electronic Development Library
- Access Control and Security Management

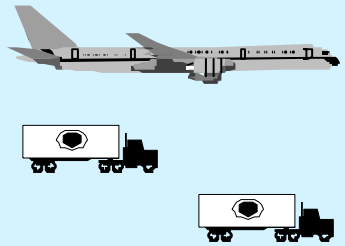
Modeling & Simulation Facility
- Communications Models
- Navigation Models
- Surveillance Models
- Integrated CNS Models

Interfaces
- ATN
- NADIN PSN
- WWW
- VSCS
- Telco
- Others

Laboratory Testbed
- Aircraft Comm Systems
- Ground Comm Systems
- Scripted Applications
- "Man-in-the-Loop" App'ls
- Multi-System Test

Information Exchange

Mobile Testbeds



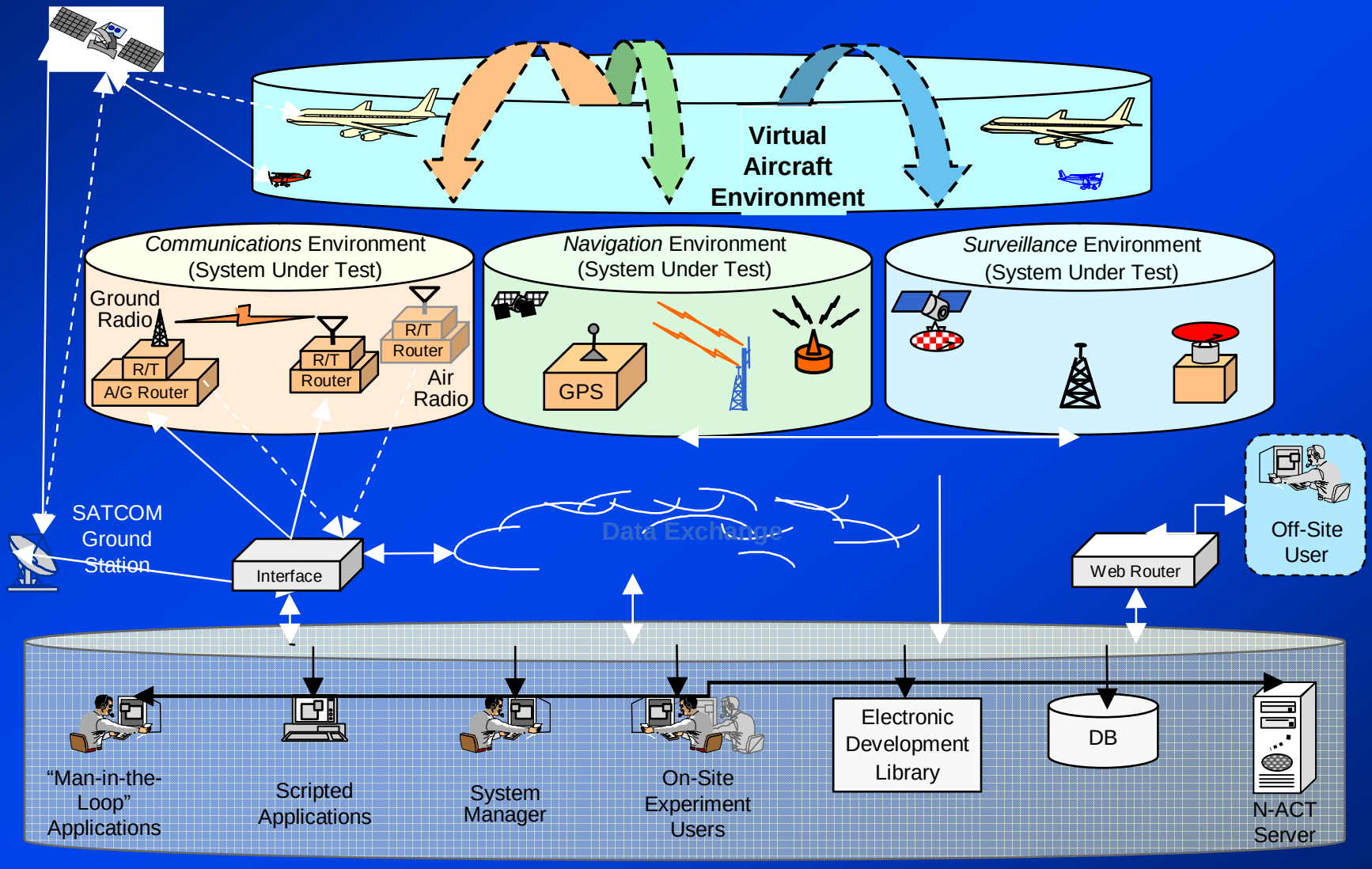
Communications
- Air/Air
- Air/Ground
- Ground/Ground
- Data Link
- SATCOM
- Multi-Spectrum
- Voice

VDL

Navigation
- Space Centric
- Aircraft Centric
- Ground Centric

Surveillance
- Radar/SIF
- Multilateration
- Space Based
- Aircraft Centric
- Other Ground Centric

N-ACT Laboratory Test bed Concept



Air Traffic Environment

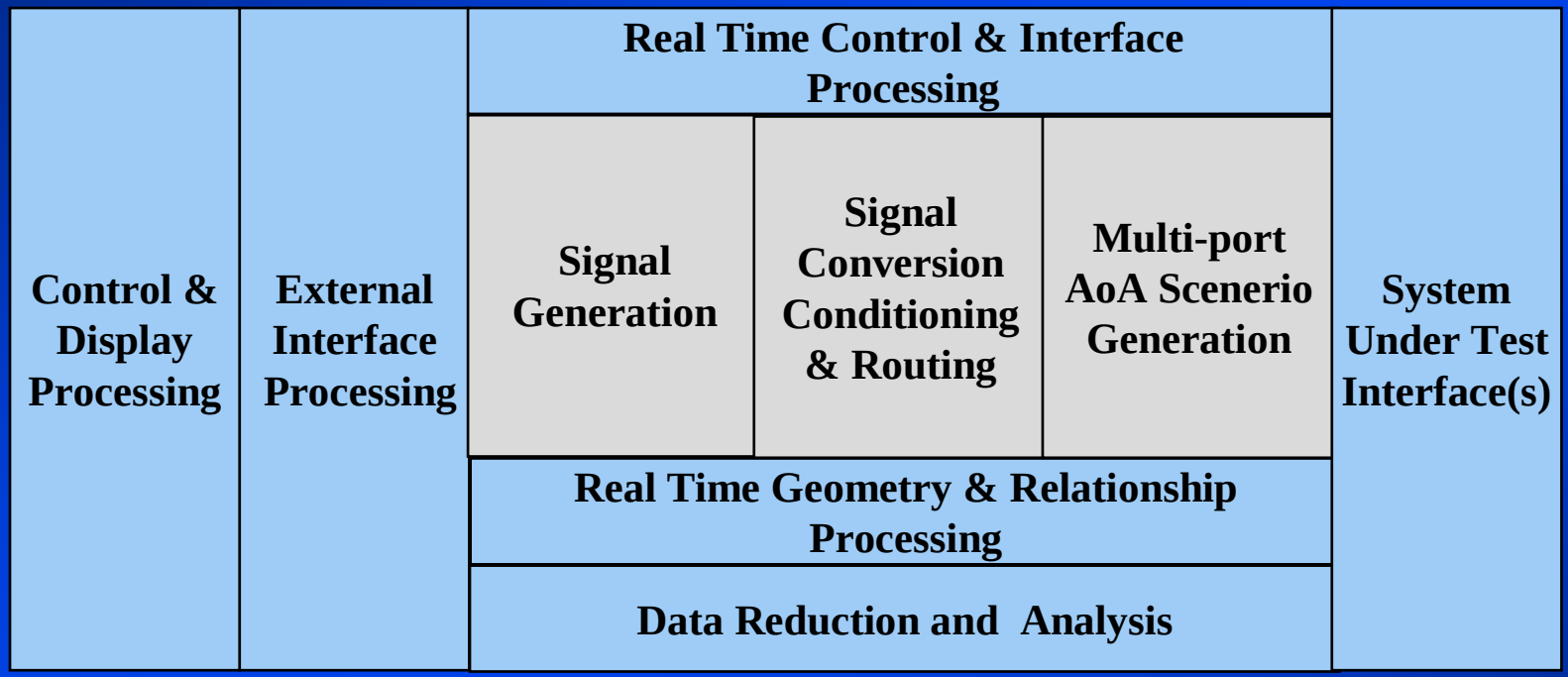
Air Traffic LA Basin

- **Based on FAA Data derived from current website materials**
  - **Aircraft density for the year 2015 is predicted to be 1,110,684**
    - This represents a 2% growth over 2014
    - This factor was applied through the year 2020 for a total of 1,228,741
    - The number was converted to an average of about 200 aircraft per hour

The year 2020 will see an average of 200 aircraft per hour

Or 1,228,741 total flights in the basin

Top Level Architecture



Modular, Scalable Architecture

ANRS Key Features

- Realistic Mix of Signals
  - Environment filled with independent RF sources
  - Sources placed with physical resources 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
  - Controlled 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 signal set
  - Creates realistic operational environment prior to operational status
  - Existing Waveform modifications tested prior to final implementation of changes

RF Virtual Environment

Signal Emphasis

- IFF, NAV, ATC, Communications
  - High Fidelity Timing/Interaction Model (All inclusive)
  - Supports external modulation sources
  - Medium Fidelity Resolution (50 ns - coarse)
- Data links
  - High Fidelity Modulation (programmable BIT Clock)
  - High Fidelity Integrated Air Defense System simulation
- Radars
  - Simple/Slow Rotating Antennas or Fixed
  - Low PRF, Simple PRI (no jitter)
  - Currently no multimode or complex scan capability planned
- Attenuation and phase control per channel
  - Hi Fidelity AoA (.25dB/1º), Med. Fidelity Non-AoA (1dB)

ANRS RF Environment

- **RF Signal Generation**
  - **500 kHz to 18 GHz Non-AoA**
  - **20 MHz to 2 GHz AoA**
  - **Programmable Signal Sources (HFPPM)**
    - » Generate analog, digital & multiple modulations
    - » Modulation BW from CW to 20 MHz
    - » Analog examples: AM, FM, SSB, DSB Quadrature AM, Noise
    - » Digital examples: BPSK, p/4-DQPSK, FSK, BASK, 128 QAM, D8PSK
  - **AoA can support interferometers of up to 32 ports with relative phase and amplitude**
  - **-20 dBm maximum output power**

Signal Manipulation

- **Geometry and Relationship Modeling Accurately Simulates Effects of Platform Dynamics**
  - **Propagation Delay, Path Loss, Doppler, Antenna Directivity/polarization**
  - **Angle Of Arrival (AoA) Phase and Amplitude Conditioning**
  - **Coherent Simulation of Wideband and Narrowband Emitters**
- **Signal Manipulation**
  - **Off Center Frequency**
  - **Modulation errors**
  - **Changes to noise characteristics**
- **Jamming**
  - **Self Jamming and co-site issues**
  - **Adjacent channel interferers**
  - **Broadband and harmonic interferers**
- **Signal Characteristics altered to Test units to failure**

Signal Coherency

- **Behavioral Model Coherency**
  - **Behavioral Models mimic corresponding real-world functionality**
    - » E.g. control tower, Radar, Commercial Aircraft
  - **Generated Events Operationally Oriented and Independent of link signal used.**
  - **Events are virtual, but may be used to drive real emitters**
    - » E.g. VDL, Mode-S, UAT…
    - » Voice Scripts
- **Network Layer Simulation (Multi-ship or Multi-node Operations)**
  - **Signal Models generate network data link signal timing**
    - » Dependent on Signal Type used
      - TDMA, CSMA, Burst …
  - **Network loading effects are simulated for virtual players**
    - » Dependent on signal type used
    - » Interference of similar signals due to loading/proximity simulated
  - **Emitters present the generated dense RF environment to a real radio**
    - » Test radio against operational signals in the presence of noise and physical effects
      - E.g. interfering signals, shadowing due to platform geometry, Terrain effects …

Concept of Operations

ANRS Simulation Capabilities

- **Air Traffic Management State machine based behavioral modeling can drive communication and Scenario Progression**
- **Preprogrammed scenarios allow scripted tests of up to 12 hours in length**
  - **Repeatable Scripting**
- **Operator (or Pilot) in the loop for interactive testing**
  - **Real time intervention and changes in scenario of Unit under test**
  - **Real time intervention of other virtual players**

ANRS Operational Objectives

- ANRS Functional Integration
- ANRS Signal Stimulation and noise environment
  - Up to 2000 emitters, 400 moving
  - Range, pointing angles and closure rate calculated between all virtual platforms and SUT, used to calculate effects such as doppler.
  - Transmit/receive antenna patterns, beyond line of sight status and link equation used to calculate signal power at the SUT for all emitters.
- Man in the loop scenario generation (Hardware in the Loop support)
  - Realistic flight environment with Pilot interfaces
- Automated control of functional tests
- Automated data collection of test results
  - Test repeatability for verification or Acceptance Test of Systems
- System level integration debug capabilities
- Hardware in the Loop/Functional simulations/functional SW-HW integration all accomplished with common interface and control structures
- Support End to End testing of Systems and Apertures

Control Station Functionality

- **All Tests & Simulation Centrally Managed**
  - **Recording and Management Element**
    - » Collection, analysis and Data Management system
  - **User Control Element**
    - » Primary User Interface and Test Management
    - » Graphical interface
    - » Analysis and control interface for tests
  - **SUT Monitoring/Injection Element**
    - » Interface to UUT for data monitoring, synchronization and data injection
    - » Includes CMU interface and UUT Bus Monitoring/Injection
  - **Scenario and Information Element**
    - » Simulation Environment Interface
    - » Off-line Scenario Generator

ANRS Integration Capabilities

- System-level monitoring and control
- Message Injection and Monitoring
- Automated Test Procedure Execution and control
  - Message injection/monitor
  - Test equipment control
  - Data analysis and display
- Manual message injection and monitoring control
- Extensive message and test sequence editing capability
- Test Equipment controlled remotely
  - All user interfaces are controlled through System Command and Control executive
- Extensive BIT and internal calibration support

ANRS Qualification Testing Capabilities

- Allows Test to Break Scenario's
  - Altered Signal Characteristics
  - Significant Dense RF Environments
- Automated Execution and control
  - Repeatable for Individual signals as well as multi signal testing
  - Data capture of key performance elements
    - » Data captured to allow key lower level specification elements to be tested or manipulated to determine system performance
- Preprogrammed Scenario mode for test repeatability
- Interactive Virtual Flight Mode

Benefit to NASA and FAA

- **ANRS represents a new and robust research tool building advantage on previously developed simulation/stimulation tools**
- **Implementation of emerging aeronautical network protocol standards and the associated waveforms under real world conditions**
- **New Avionics and upgrades to current programs can be "stress" tested in a virtual flight environment to significantly reduce deployment risks**
- **Explore new ideas and concepts using both simulation capability as well as RF environment capability**
- **Directly benefits current set of NASA subprojects providing a development, integration and qualification and test environment:**
  - **FAA/Eurocontrol FCS**
  - **Spectrum Research**
  - **Terminal Air to Ground Communications**
  - **Surface Integrated CNS Networks**
  - **Multifunction Multimode Digital Avionics**
  - **VHF Systems optimization**
  - **CNS Technologies**
  - **Transitional CNS Architectures**
  - **Global Air to Ground Networks**
  - **Oceanic/Remote Communications and Surveillance**
  - **Space Based Surveillance**