Computer Networks & Software, Inc.

*Identifying and Addressing Emerging Global Air Transport Issues and Risks*

# *Improving the Future Air Transport Systems by Using Next Generation Innovative Modeling and Simulation Tools and Technologies*

**Prepared**
**For**
**ICNS 2006**

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***A Computer Networks & Software, Inc. Management Perspective***


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# Our Company

- **Founded in Springfield, Virginia in 1987**
- **65 Technical and Management Professionals with ~32 DOD Top Secret clearances**
- **Two core lines of business for government and commercial customers – *technical professional services* and turnkey system *solutions***
- **Mission:**
  - Develop Innovative Wireless and Information Exchange Solutions for mission critical applications in areas of communications, surveillance, simulation and modeling, IPv6 transition, Net-centric architecture, and Web services
  - Provide Professional Technical Services for staffing the engineering and managing of communications network and IT systems
- **Our core competencies:**
  - Engineering and Technical Services
  - Software Development
  - Advanced Systems Simulation and Modeling
  - Systems Integration
  - Professional Services
- **CNS is small business and is a wholly owned subsidiary of SDAC,Inc**

## We Have Provided Advanced Technical Design and Engineering Services to NASA for Key Programs

- **CNS started in 1999 to work with key NASA communications staff for the National Airspace Systems ("NAS") and Small Aircraft Transportation Systems ("SATS") project**
  - Conducted more than 40 task orders in CNS Systems studies , simulation facilities development , and new technology studies related to the air transport industry
  - Received NASA's Turning Goals into Reality (TGIR) award in 2003 for contribution serving as member of Airborne Internet Definition team for the SATS program
- **CNS has assisted NASA GRC all aspects of Communications, Navigation and Surveillance technologies for the air transport community:**
  - Large scale system modeling, simulation and test systems
  - Systems engineering and design of new data link systems
  - Operational requirement analysis

# Assessing the Air Transport Sector : Modeling and Simulation Today

**The critical need is ensuring that security implications, solutions and “what-if” analyzes are fully assessed in developing next generation solutions to meet air transport sector challenge**

# NASA GRC had a history of building CNS Modeling & Simulation Systems

- Aerosapient System
- Virtual Aircraft and Controller Communications and Surveillance Test System (VAC)
- Aeronautical Network Research System (ARNS)
- Future Aeronautical Subnetwork Traffic Evaluator (FASTE-CNS)
- Advanced Concept Evaluation System with CNS Models

- Performance Simulation and testing of CNS systems
- Based upon operationally driven messaging
- Realistic flight scenarios

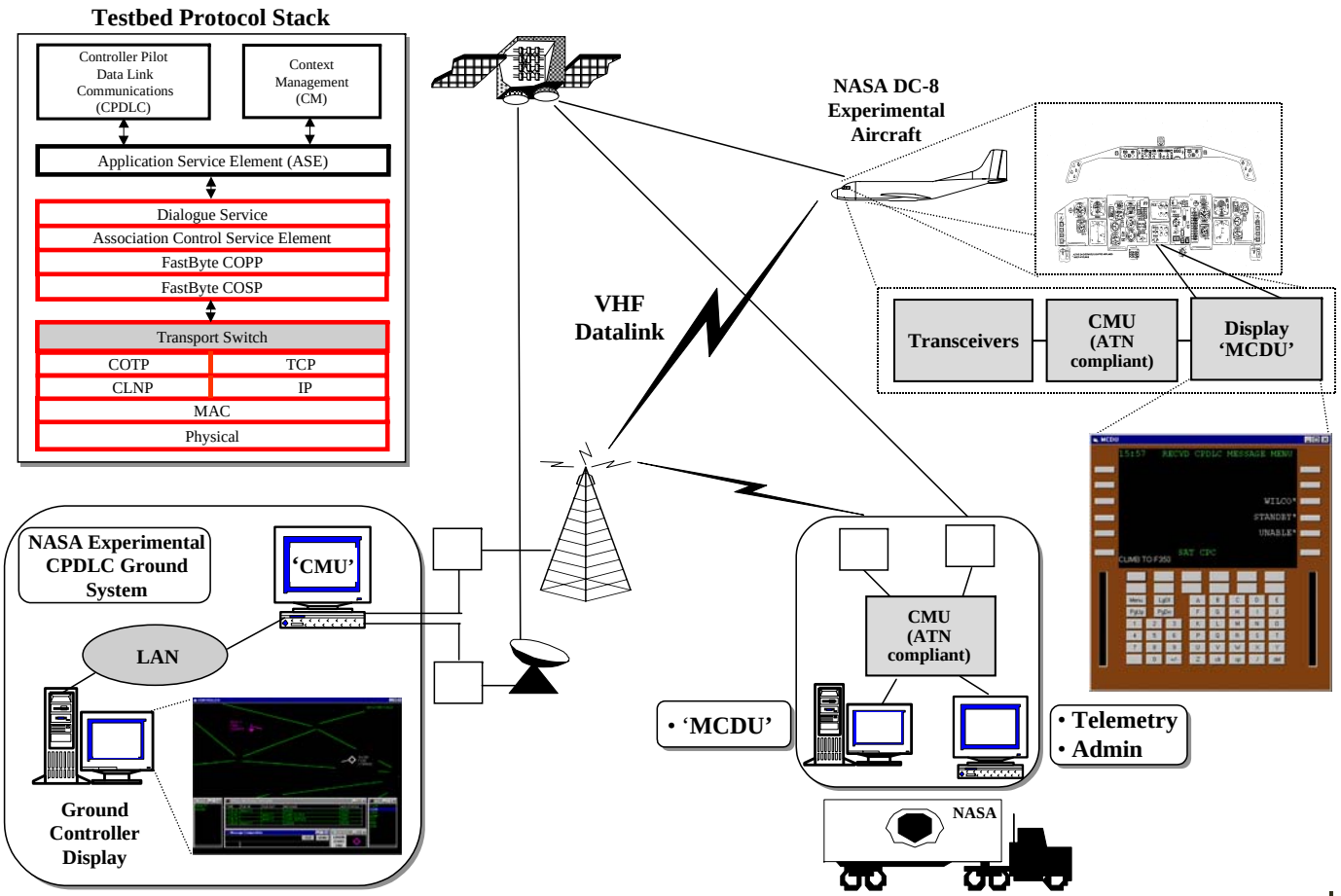
# Aerosapient Project

- **Problem: NASA wanted a fully compliant ATN CPDLC messaging system as part of a Ku Band satellite-based aircraft communications demonstration, but wanted it over Internet Protocol Suite**
- **Solution: We build the software for the a pilot (aircraft end system) and the controller (ground-side end system) that were ATN compliant per the ICAO Manual 9705**
  - Controller to Pilot Data Link Messages
  - Context Management
  - Human in the loop: Controller and MCDU GUIs
  - Transport Level Address translation

# NASA GRC ATN System Testbed

## ATN Build A

- Developed over 120,000 LOC of ATN Compliant Software
- Part of Aerosapient Flight Tests
- C++ and JAVA
- MCDU and Enroute Controller HMIs

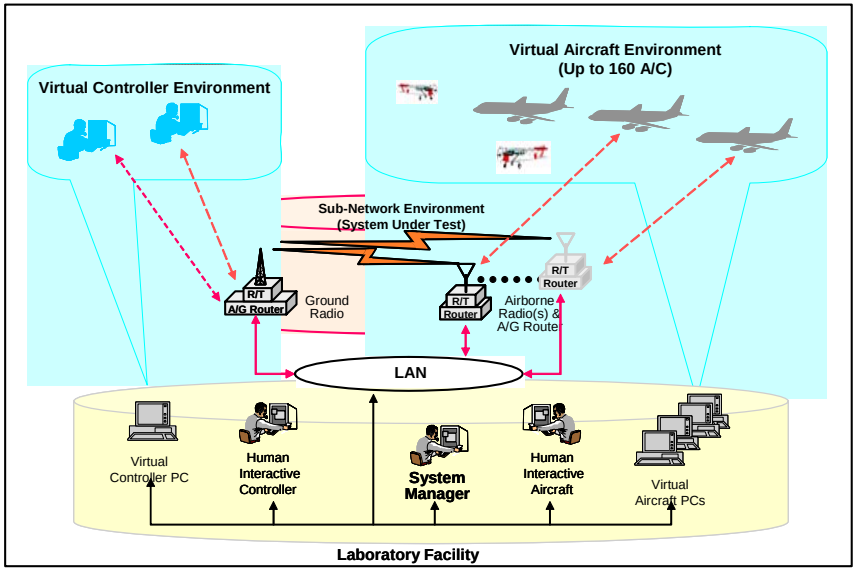


# Issue: Industry Selection of Data Link

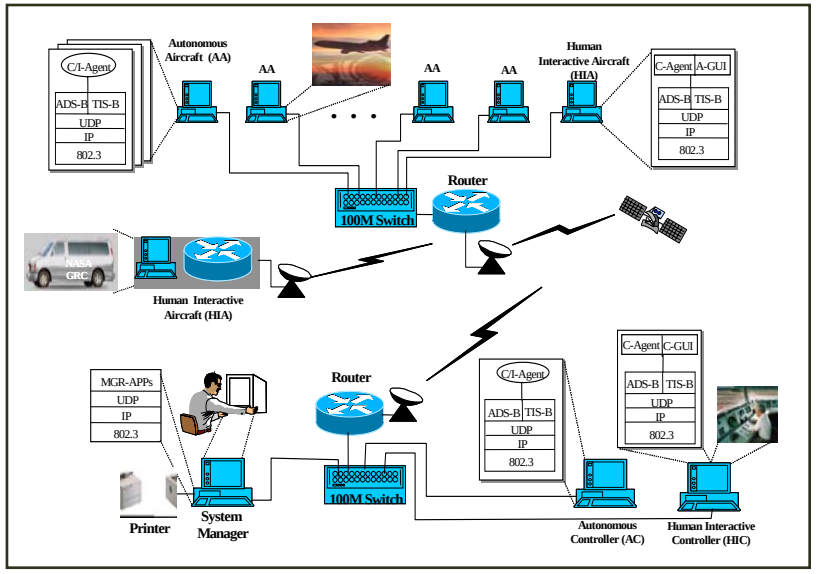
- **Problem:**
  - Aviation community has several solutions for the providing air to ground data link
    - How to perform a selection of the best wireless approach
    - Many vested interests (objectivity lost)
    - Systems tested with only a few aircraft
  - NASA wanted a develop test facility having the tools to perform an objective assessment of various data link approaches
    - Use of real world scenario and messages for a large number of aircraft
    - Would provide a the equivalent of virtual load for flight tests and mobile van tests using real avionics
    - System would be user-driven for set-up, flight plan scenario configurations, collect performance parameters and would be able to run without constant experimenter full-time presence
- **Solution:**
  - We build the Virtual Aircraft and Controller (VAC) Communications Evaluation System
    - Emulation software using an agent-based, distributed processing architecture for 160 aircraft that send  receive ATN CPDLC messages to RF subsystem
    - Emulation software using an agent-based controller behavior using CPDLC messages
    - System management, test data collection and reporting

# CNS Project : Virtual Aircraft & Controller Test Facility

***Aviation Data Link Testing Tool:*** **Supports the realistic message traffic testing of multiple subnetworks (e.g., VDL M2, VDL M3, SATCOM, etc.)**




Functional Diagram




Architecture Diagram

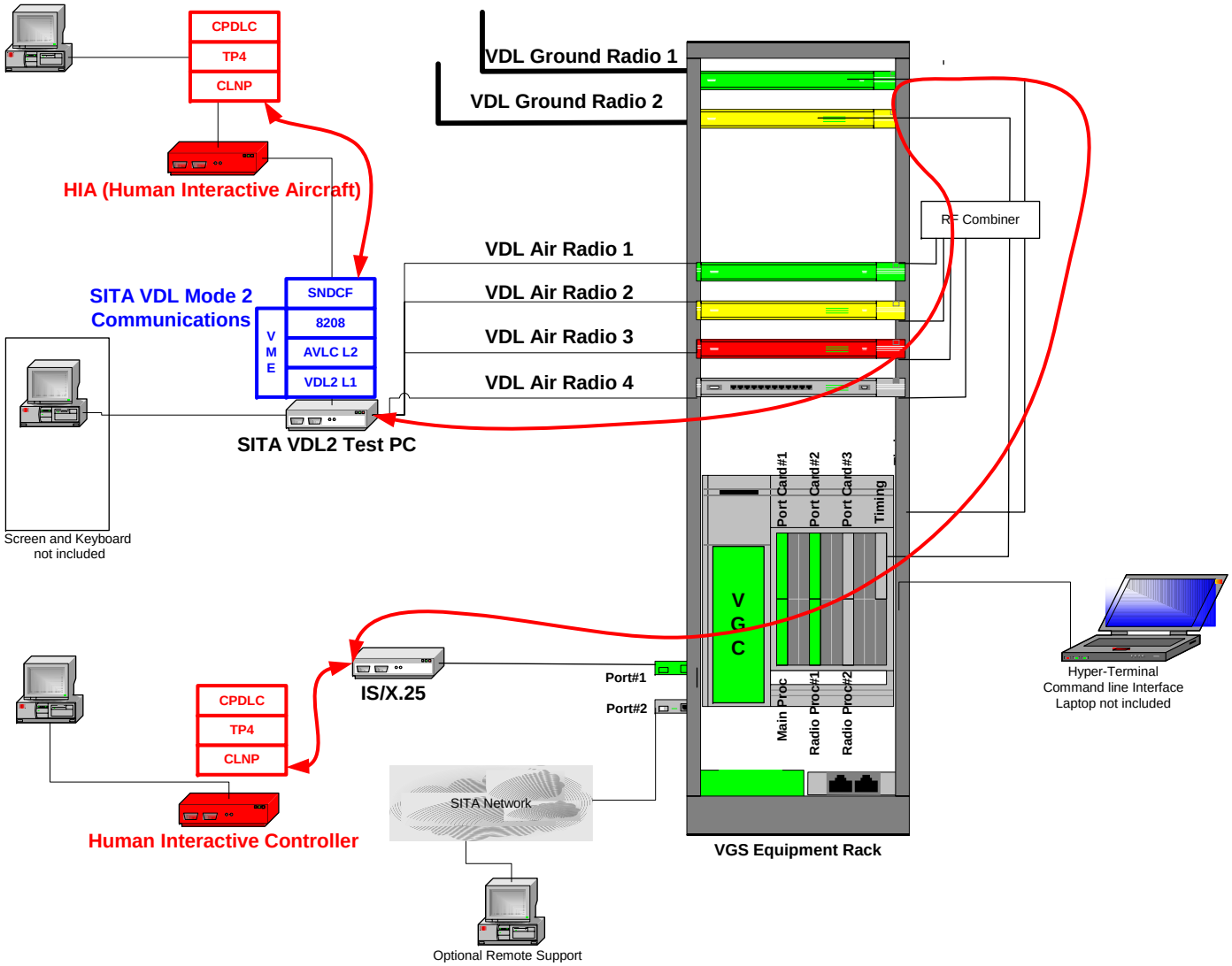
- **Distributed data link communications emulator:**
  **Emulates 160 separate (autonomous) aircraft with "free-play" responses**
  - **Provides multiple controller entities**
  - **Test runs are based upon flight plan driven scenarios**
  - **Includes human in the loop pilot and controller capability**
- **TP4/CNLP ISO and TCP/UDP-IP Protocols**

- **Messaging:**
  **ATN 9705 CPDLC and Context Management**
  **RTCA ADS and TIS**
- **System manager:**
  **Flight plan scenario builder**
  **Generation of TIS-B messaging**
  **Single point of control and test6 data collection**
  **Reporting Capabilities**

# VHF Data Link Test System

- **Problem**
  - Procurement of the radio and communications management unit for test facilities is costly ($200K+ for each aircraft being emulated)
  - NASA wanted 160 plus aircraft test environment
- **Solution:**
  - We with SITA as a Subcontractor developed a means to still use vendor lower cost radios but reduce the cost of the CMU functions to $2000
  - Provide ground stations and aircraft test configurations for the NASA GRC test facility
  - Drive up to eight radios from one PC

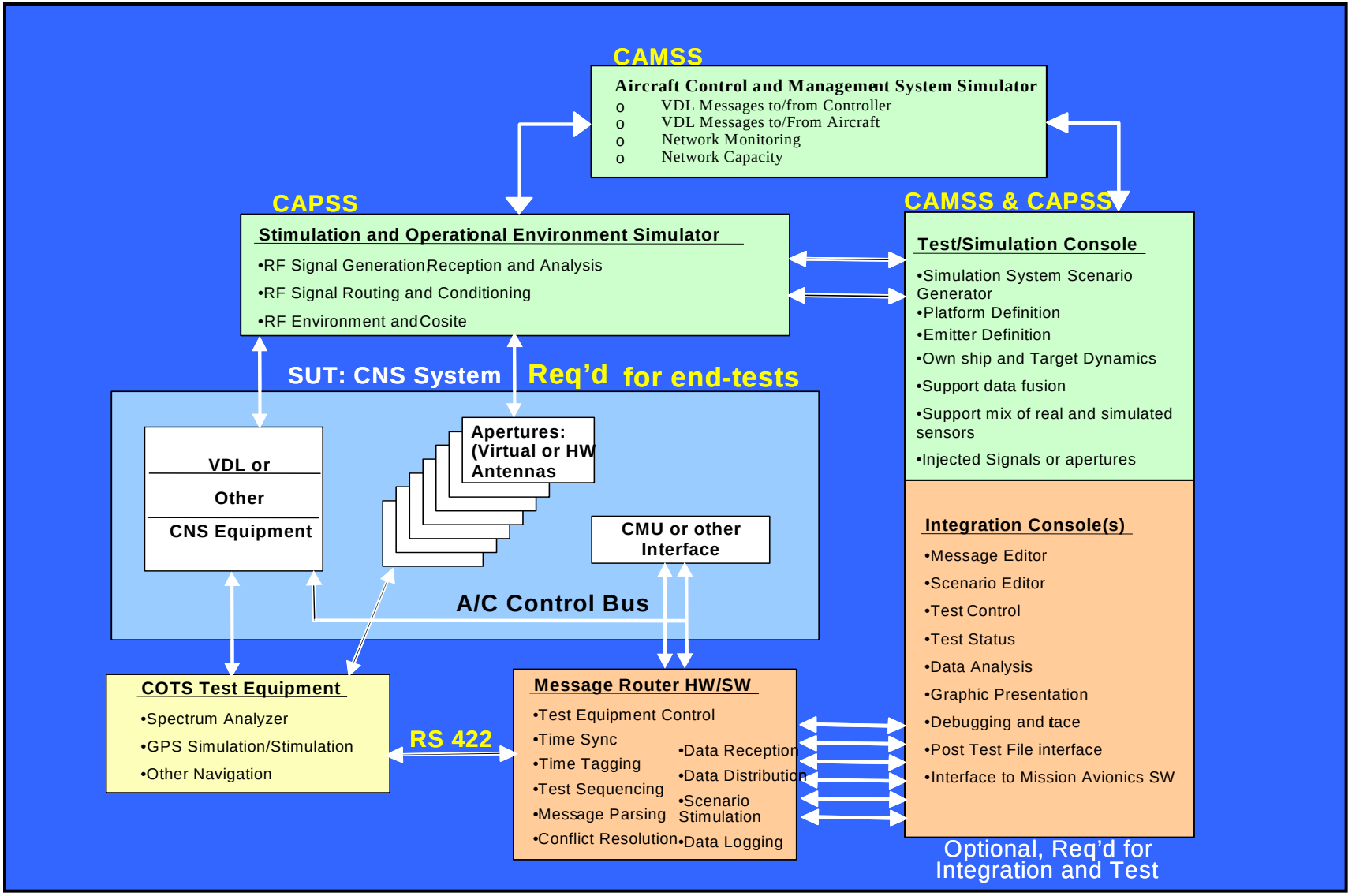
# Hardware Set-up VAC/VTC/VGS



# Issue: Full modeling for the Next Generation Aeronautical Network Simulation

- **Problem:**
  - How to evaluate data link performance using a real mobile platform environment
    - Multiple emitters per platform simulation within a real world RF environment using  that use real waveforms for CNS signals
    - 1000-2000 moving platforms with differing antenna and an interference environment
    - Transaction/message exchange timing and coding that follows differing operational scenarios
  - Acceptance of the new airspace concepts (NGATS) by all stakeholders will require large scale simulators to give that “fly before buy” feel and confidence before investing.
- **Solution:**
  - NASA GRC was proceeding to combine the CNS VAC simulator and the DoD Joint Communications Simulator developed by ViaSat Government Systems Division to develop the Aeronautical Network Research System (ANRS)

# ANRS Architecture



# Why the ANRS is Needed?

- **Future System Concepts of the Next Generation Air traffic Management require a new set of tools**
  - 4D Trajectory based
  - Distributed Objects using Net Centric architecture
  - Controller Monitoring
- **System simulation to show new system performance and support the business case development**
  - CNS technical performance in wide area simulation

# ANRS Supports Future Investment Decisions

- **New technology insertion requires clear understanding of the achieved business value for all stakeholders associated with the NAS**
- **The community needs a cost effective means to show testing and demonstrations to all stakeholders**
- **Requires a massive "Fly before buy" through modeling and simulation before investment will be made**
  - Must show the operational value
- **NASA Investment:**
  - Virtual Airspace Modeling & Simulation System (VAMS)
    - Airspace Concept Evaluation System (ACES) with CNS Models
  - ACAST Project goal to develop national resource for CNS testing
    - Virtual Aircraft and Controller (VAC) Communications Test System
- **DoD Investment**
  - USAF Joint Communications Simulator (JCS)

# Completed Study Work Products

- **Technical Assessment**
  - Each Sub-project reviewed and test needs mapped to logical architecture requirements and system test components
- **TDF Requirements Specifications**
  - System level functional and performance requirements organized according to the logical architecture
- **Facilities/Organizations Site Survey Reports**
- **CNS Facilities Assessment**
  - Study of about 80 CNS models, tools, and testbeds across 13 different government and university organizations
  - Identified existing core set of tools from the NASA Ames VAMS Project, NASA GRC Virtual Aircraft and Controller test system and the USAF Joint Communications Simulator
- **TDF Design Description**
  - Provides the logical system facility design
- **ANRS Concept of Operations and System Specification**
  - Integrates the GRC VAC and USAF JCS and traces requirements to ACAST TDF requirements
  - The ANRS performs 60% of the ACAST TDF requirements
- **ANRS Initial Operating Capability Plan**
  - Establishes the first functionality for ANRS

***Reports compromise approximately 1000+ pages***

# Top ANRS Capabilities

- Emulation of end-to-end system effects using real world NAS scenario and CNS equipage.
- Flexible to support testing of numerous CNS/ATM Concepts using multiple wireless channels (sub networks)
- Allows multiple emitters interacting on one platform
- Include the RF effects of mobile emitters. Incorporates the "physics of wireless" including signal propagation, antenna patterns, aircraft shadowing, terrain effects in dynamic (mobile) environment
- Incremental build of capability towards GRC CNS TDF
- Provides an affordable approach to large scale testing
- Able to generate CNS communication traffic loads of realistic, operational scenarios (flight plan driven)
- Performance evaluation of throughput, delay and other channel effects of aeronautical subnetworks
- Performance evaluation of selected N&S systems under load
- Support mobile van or aircraft testing (UUT) includes man in the loop
- Support repeatable experimental trials
- Provides an infrastructure for command and control and analysis

# Issue: Develop System Level Requirements

- **Problem**
  - Determining the air – ground communications transaction sizing and performance requirements under different future airspace concepts
  - This is a crucial step in the to determination of  the communications architecture and the selection of links to use
  - Different communities (services) set the transaction for the same concept baseline in different manners
- **Solution**
  - NASA approved a project to develop a web-based collaboration tool to size transaction and frequency use.
    - Project stared in 2003 to evolutionary develop the Future Aeronautical Subnetwork Traffic Evaluator (FASTE)
  - FASTE was then enhanced to include performance models for key data link types

# Modeling Using FASTE-CNS Tool

Industry

Government

IE / Netscape

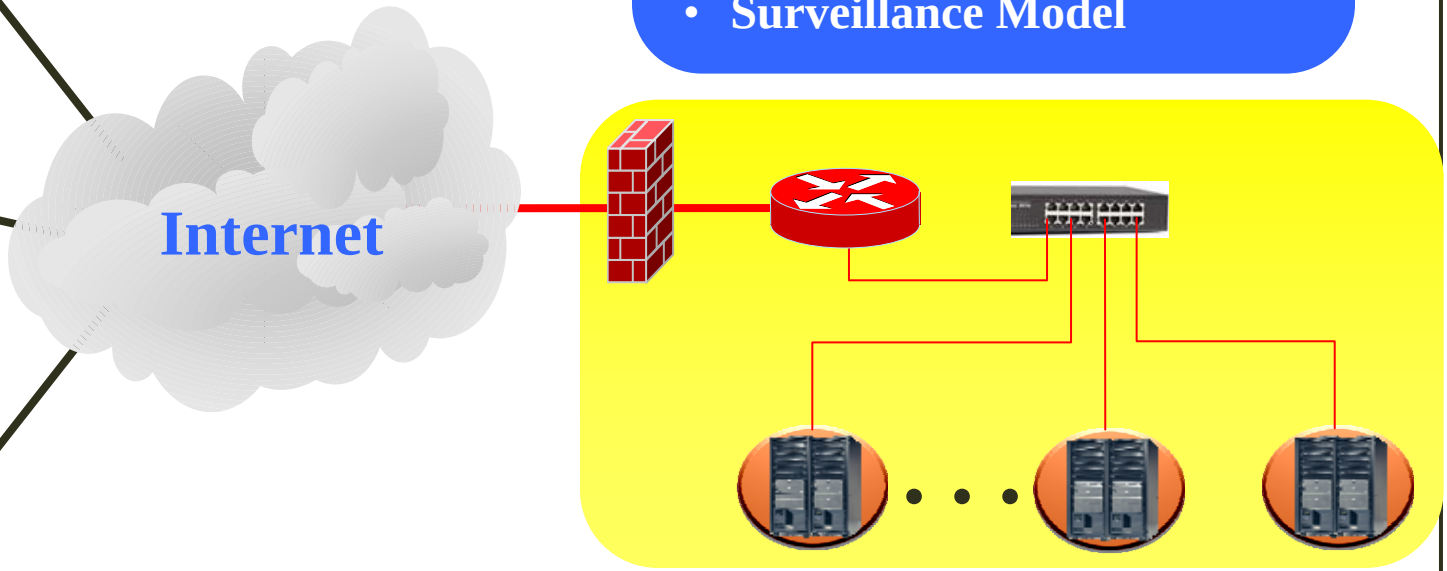
Universities

**Steps**

- Define message set
- Media selection
- Communications Profile
- Communications load profile

## *Capabilities*

- User Management
- Load/ Frequency Calculation
- Communication Model
- Navigation Model
- Surveillance Model



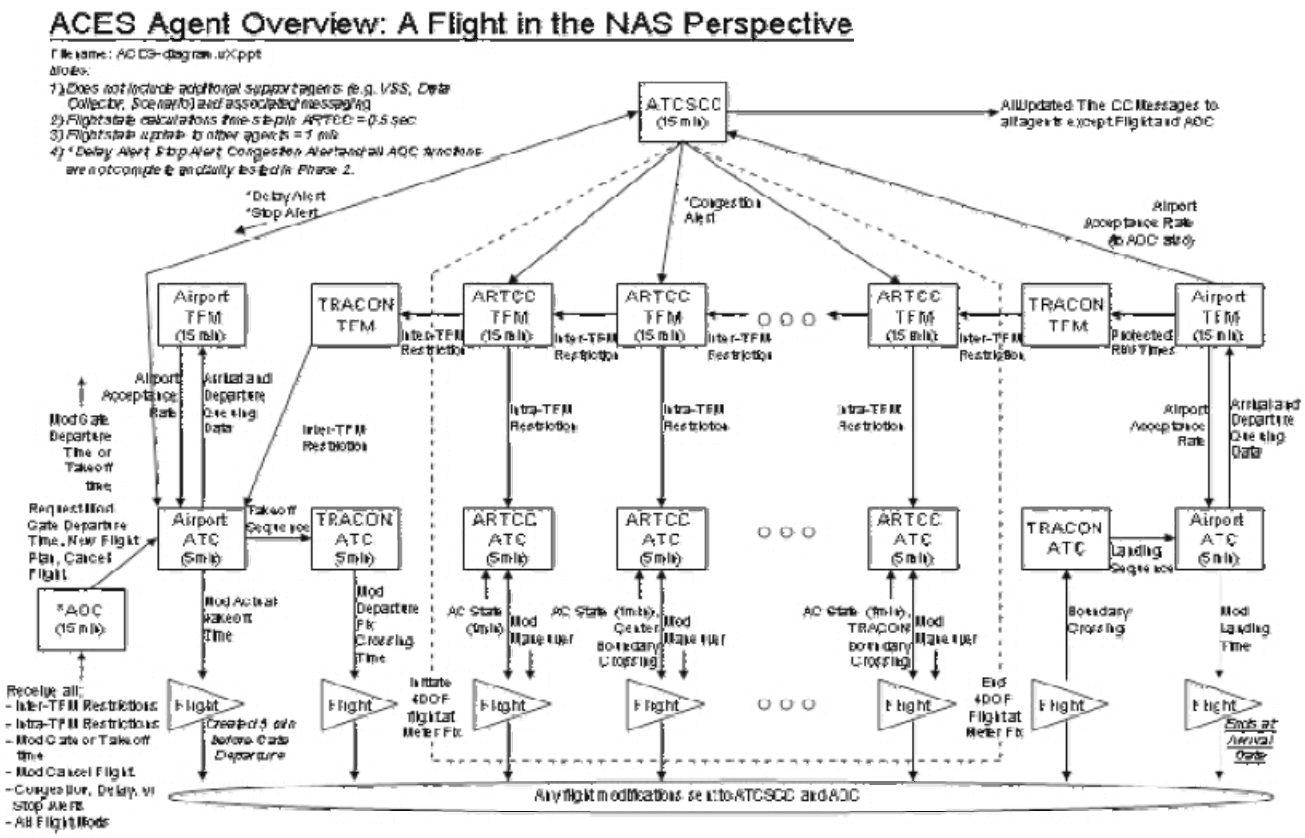

Performance models
C: VHF Voice, ACARS and VDL Mode 2
N: VOR/DME, GPS
S: Secondary Radar, ADS-B (UAT)

Goal: Turn into net-centric developers tool

# Issue: Air Traffic Nationwide Test & Simulation

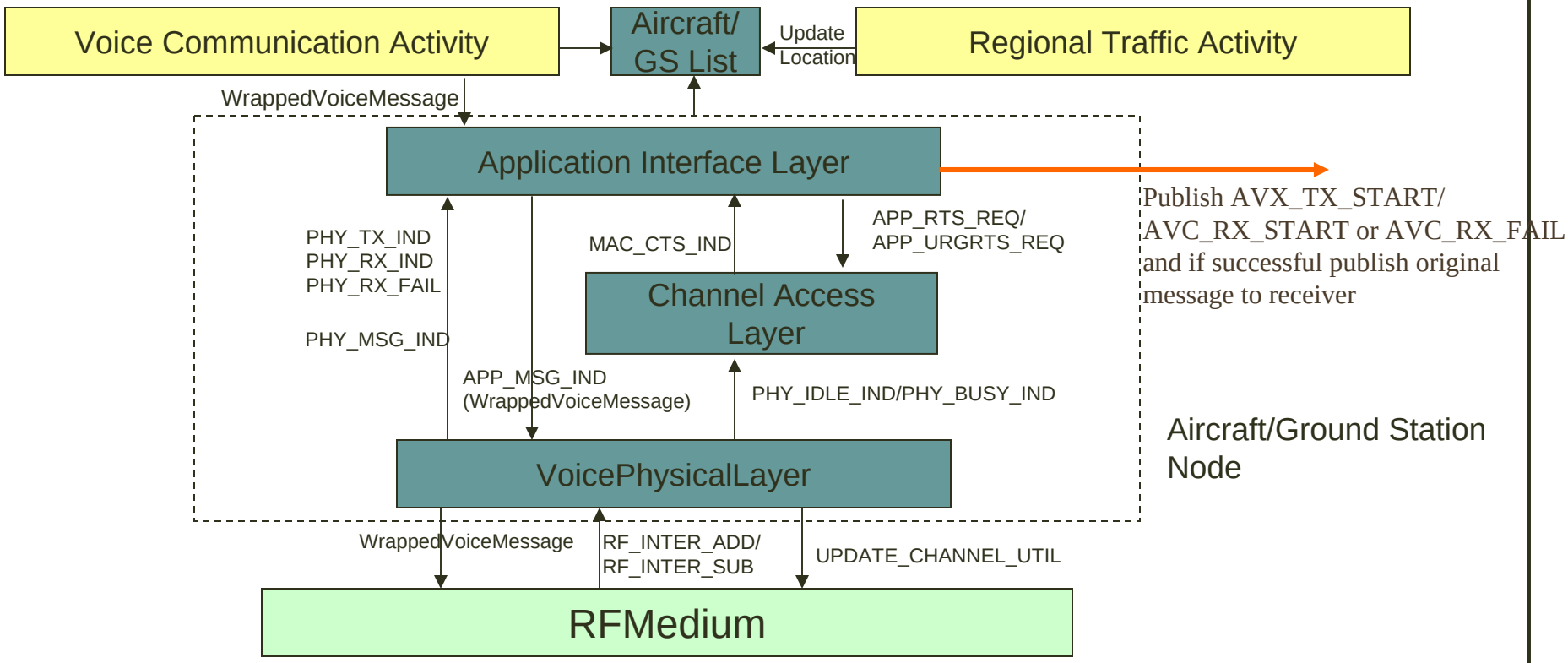
- **Problem:**
  - ATM designers often do not consider communications system performance in the study of new operational approaches
  - NASA developing a nation level air traffic simulator to evaluate future ATM processes but without CNS simulation
- **Solution:**
  - NASA developed a simulator suite called Advanced Concept Evaluations Simulation System
  - Under NASA GRC lead project CNS with IAI as a subcontractor has added agents to the simulator to process all inter-agents messages as if communicated by the radio system
  - Models were sourced from communication software agents developed in FASTE

# ACES Model and Message Exchange




Solution – added CNS agents between operation entities

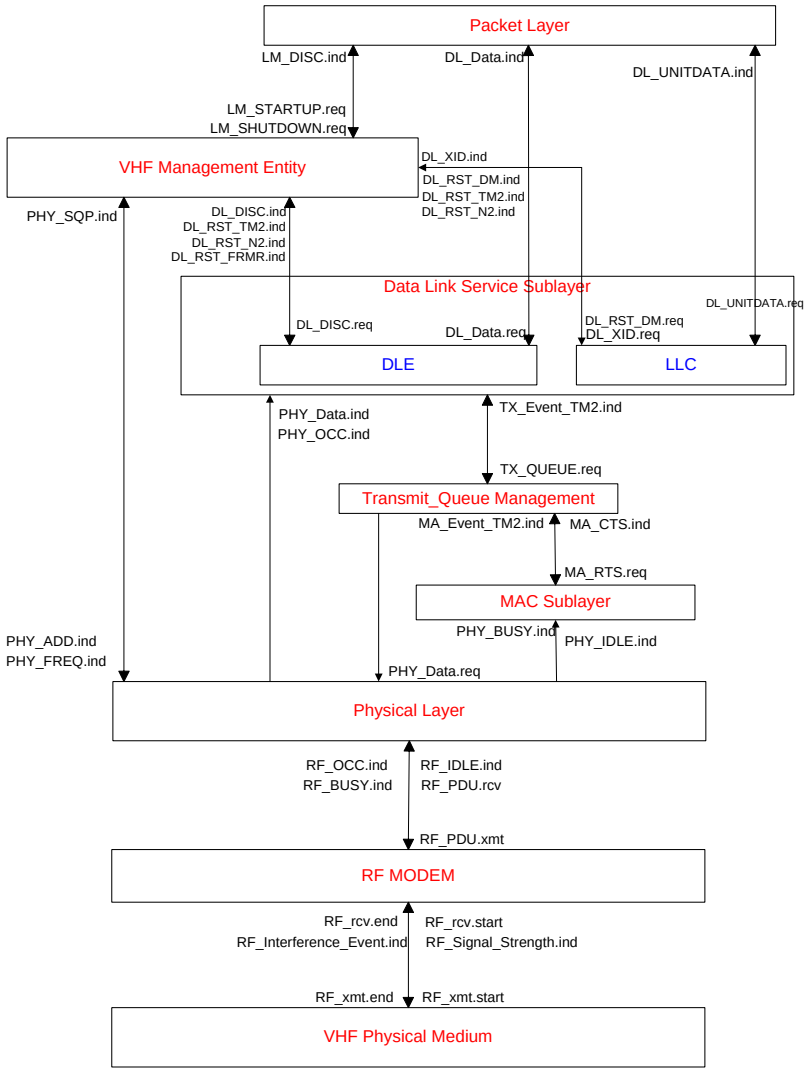
# Voice Agent Message Interactions Voice)



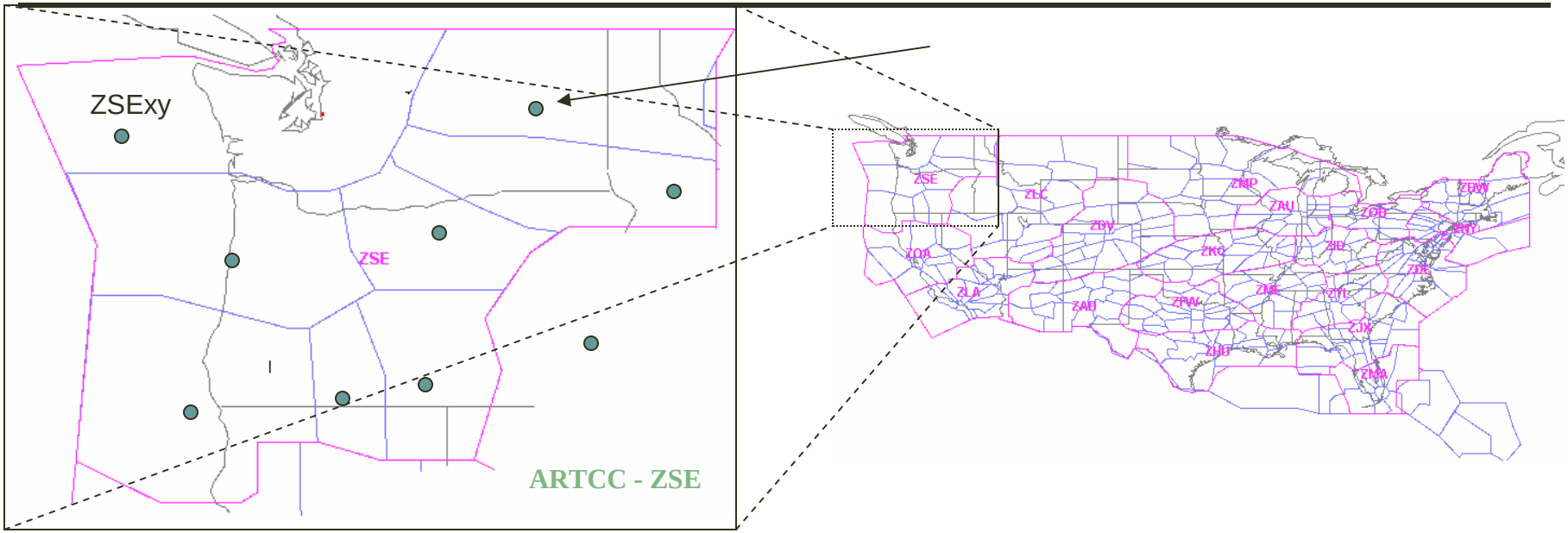

- Function call based message passing using service primitives at the nodes

# Data Agent Message Interactions (Data)

## VDL 2 Node Primitive Flow Diagram



# Communication Model (Infrastructure)

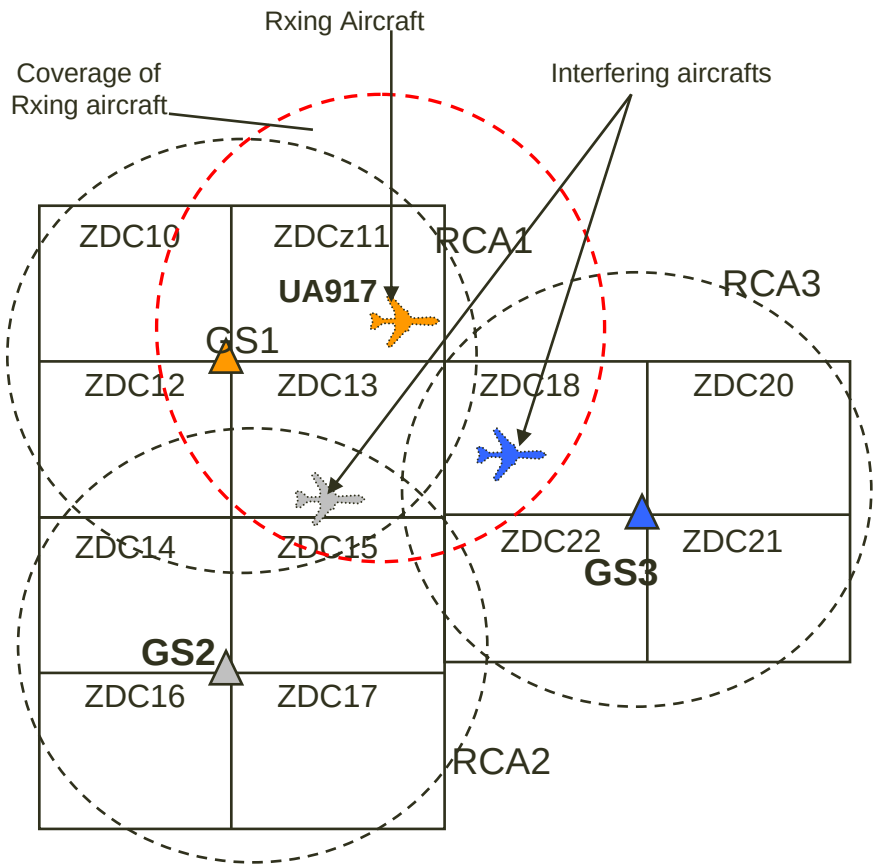



## Ground stations/ Radio Tower

| | | |
|---|---|---|
| ARTCC | - | GS located at the center of the each sector |
| TRACON | - | GS located at the first airport in the TRACON |
| AIRPORT | - | GS location near airport |

# Interference Update Mechanism

- A list of aircraft operating with each ground station is maintained
- UA917 in Receiving state, using neighborhood GS list and aircraft list, possible interfering aircrafts are identified



- CNS National Center Study

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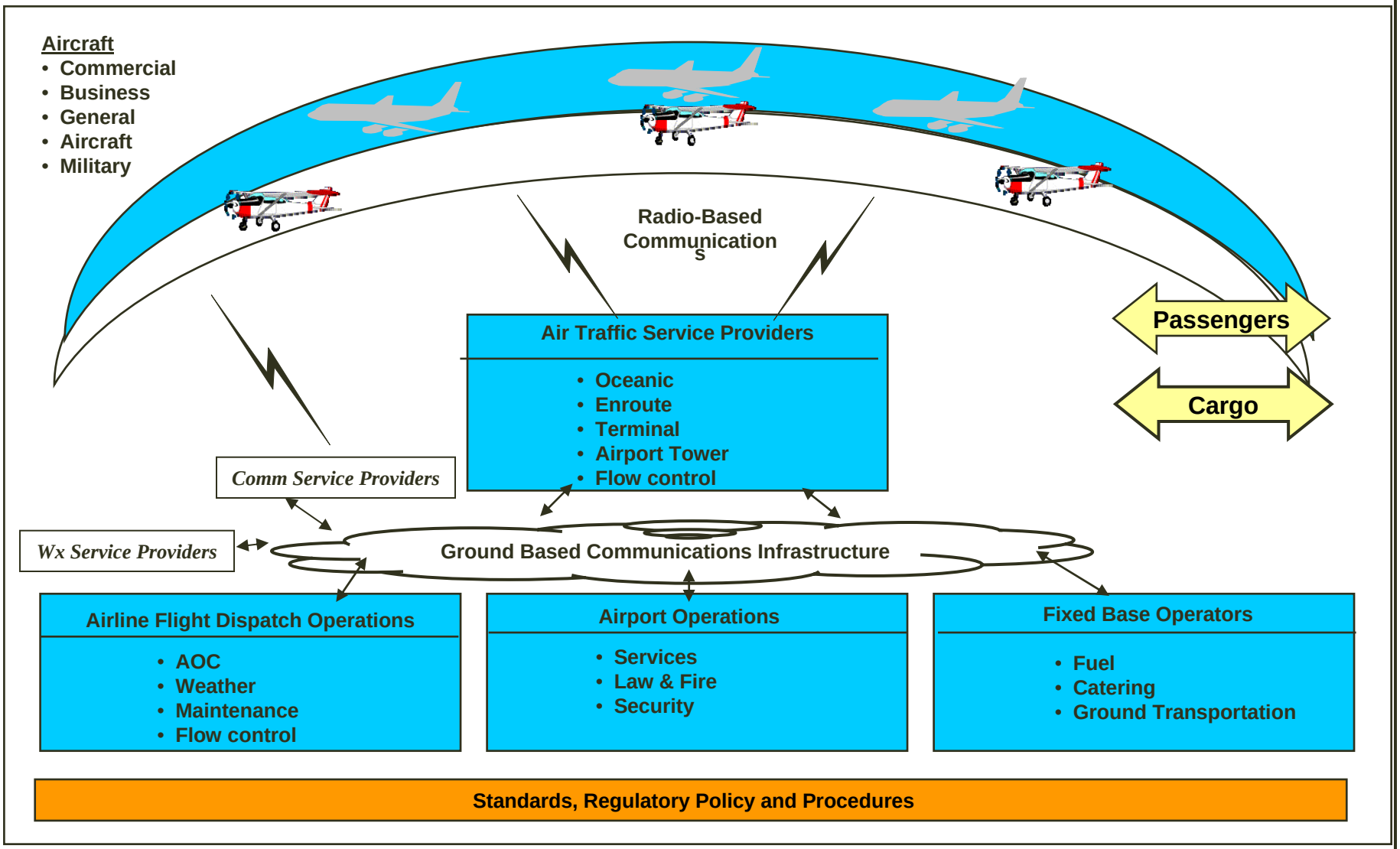
# The US Air Transport Sector – A CNS Perspective

**Industry challenge discussion**

**Can the DoD solutions that are being pushed into the air transport sector do the job?**

**Why large-scale system simulations including all elements (like communications) will be the key to implementing the next generation air transport system (NGATS)**

# Air Transportation System Overview



# U.S. Air Transportation Needs1

- **Projections show the need to support continued future growth:**
  - Passenger Travel
  - Cargo Movements
  - Demand for Aircraft Flights for business leisure and travel
- **Above means a growth in the numbers of future flights**
  - Commercial Transport Aircraft
  - Small Aircraft (on demand service and recreational)
  - Unmanned Aerial Vehicles
- **Government has created a Multi-Agency program office to response to:**
  - Build the next air transportation system by 2025
  - Satisfy the future growth in demand (up to 3 times current levels)

1. *Next Generation Air Transportation System Integrated Plan*, Joint Planning and Development Office, December 2004

# NAS Transformation Challenges

- **The Joint Planning and Development Office (JPDO) is basing the achievement of transformation on eight capabilities:**
  - Network-enabled information access
  - Performance-based services
  - Assimilation of weather into decision making
  - Layered adaptive security
  - Aircraft 4D trajectory
  - Broad-area precision navigation
  - Equivalent visual operations
  - Super density operations
- **The technologies required to implement these capabilities are still emerging or being tested for feasibility – thus there is performance and integration challenge**
- **Can the industry and government afford the transformation? New system will cost:**
  - FAA: 10's of Billions
  - Airlines: 12-18 Billion
  - GA: 10 Billion
- **Question: At this scale of investment, what information and confidence measures will the stakeholders need make the level of capital decisions to support transformation?**
  - Answer lies in seeing benefits through large scale simulations and by understanding the impacts of a user centric approach

# The FAA Maintains Many Simulation and Modeling Tools to Support Our Air Transport System

***Representative tools:***

- AWSIM
- DPAT – Detailed Policy Assessment Tool
- NARIM – National Airspace Resource Investment Model
- NASPAC – National Air System Performance Analysis
- PMAC – Performance Monitoring Analysis Capability
- POET – Post Operations Evaluation Tool
- RAMS – Reorganized ATC Mathematical Simulator
- SDAT – Sector Design and Analysis Tool
- SIMMOD – FAA's Simulation and Modeling Tool
- SODM – System Outage Disruption Model
- Airport Capacity Tool
- Analytica
- ATS NDC (National Data Center)
- Crystal Ball
- ETMS Visualization Tool
- OPL Studio RDTS (Radar Data Tracking Software)
- VOR Heuristic Model

**Extensive Analytical Capabilities:**

- **Future projected airport capacities**
- **Route Traffic Loading**
- **View/Analyze Flights within Terminals for Closest Approach**
- **Risk Analysis Assessment**

***Today's Tools Do Not Meet Our Nation's Emerging Challenges***

AND, NGATS will change the ATM "Goalposts" and a whole new set of tools are required

# Today's Simulation and Modeling Tools Do Not Meet Our Nation's Emerging Challenges

***Representative tools:***

- AWSIM
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## The Problems:

- Tools are not integrated – communications, operations and cost
- Ability to examine "what-if's" limited
- Need to understand security impact of new technology options
- New net-centric and wireless systems "changing the rules" – demands new models
- Time is of the essence – integrated perspectives and options needed quickly to address nation's air security and operational needs

NGATS will change the ATM "Goalposts" and a whole new set of tools are required

# “Human Bottom line”

***The real system development challenge will be to change the way people in the system to their job***

- **Pilot and controller voice communications transition to a machine to machine communications**
- **Controller changing from “control” to “monitor” role**
- **Pilots become responsible for self separation**
- **Trust in the automation system to identify and to respond to conflicts and bundlers:**
  - Equipment failures
  - Weather
  - Pilot error

***The first system engineering challenge is to get government to invest in the development of the simulation capabilities to show that the benefits can be achieved***

- ***With our experience, we can do this job for the industry***

# Performance of NAS Systems with CNS Simulation Components

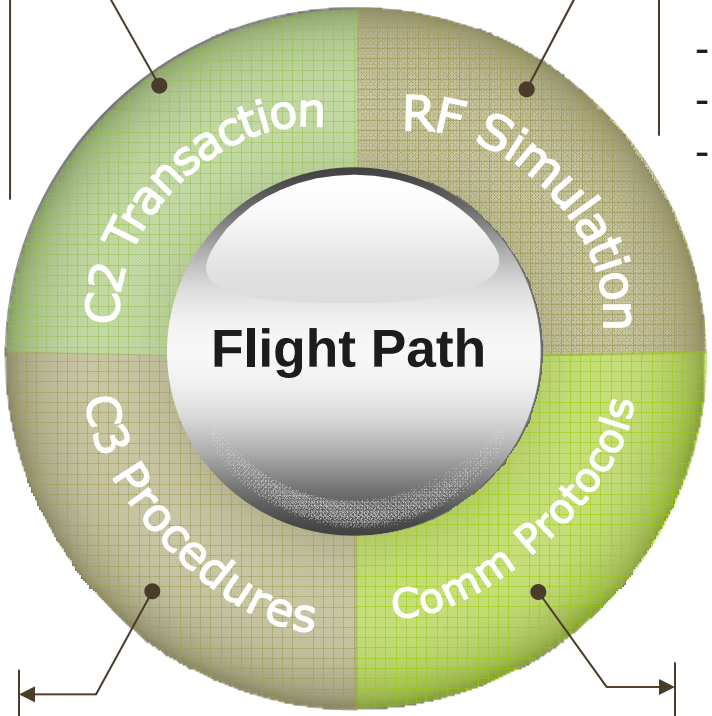
***Simulation systems contain all the key areas***

**Transactions Mapped to applications**

- Real world stimulus
  - Data, voice
  - Type

**Physical Layer - Signal Characteristics**

- Waveforms
- Propagation
- Geospatial relationships



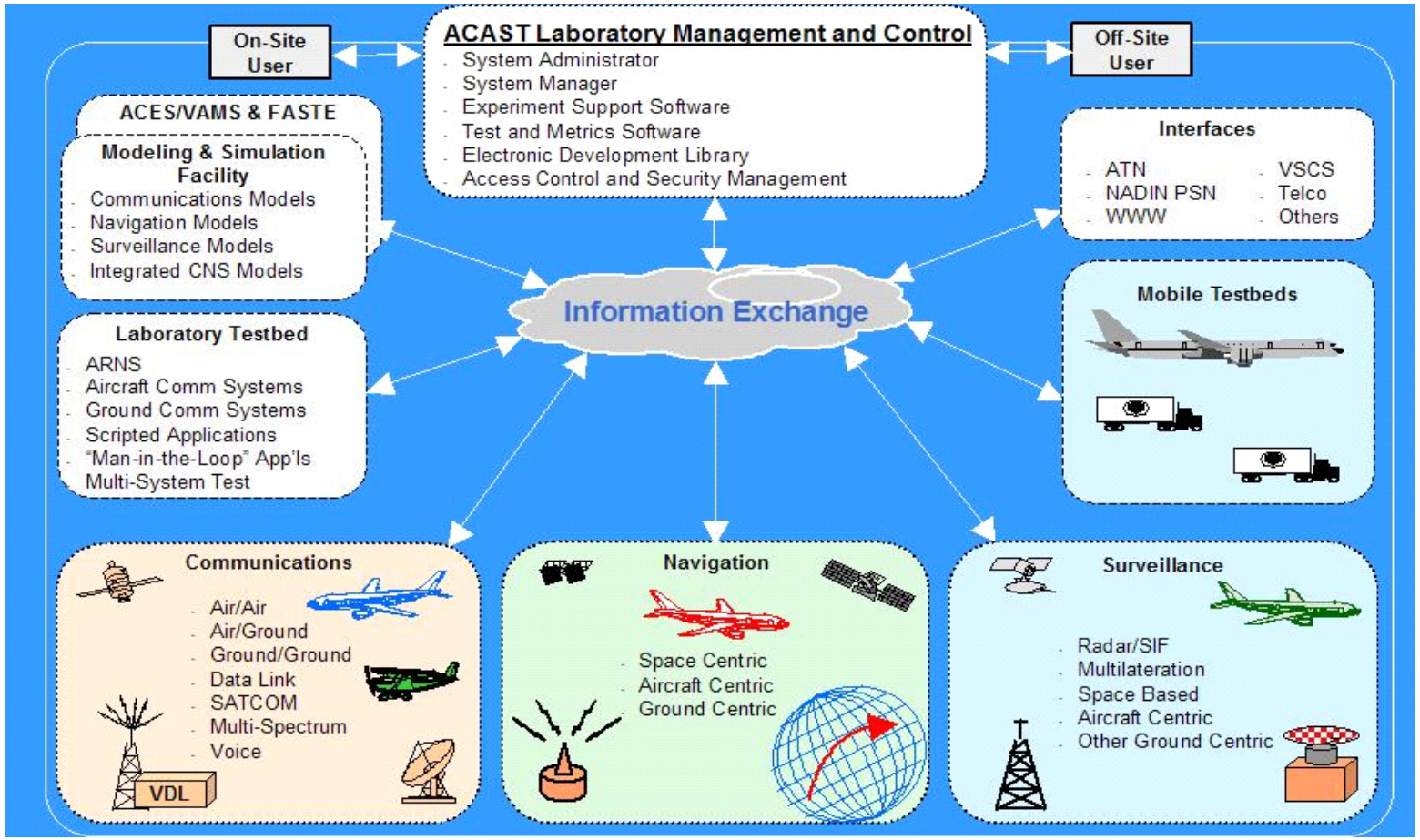

**Conformance to Procedures**

- Services linked to transactions
  - Net-centric
  - Open-close
- E.g. CPDLC per ATN

**Link/Network/Transport Layers**

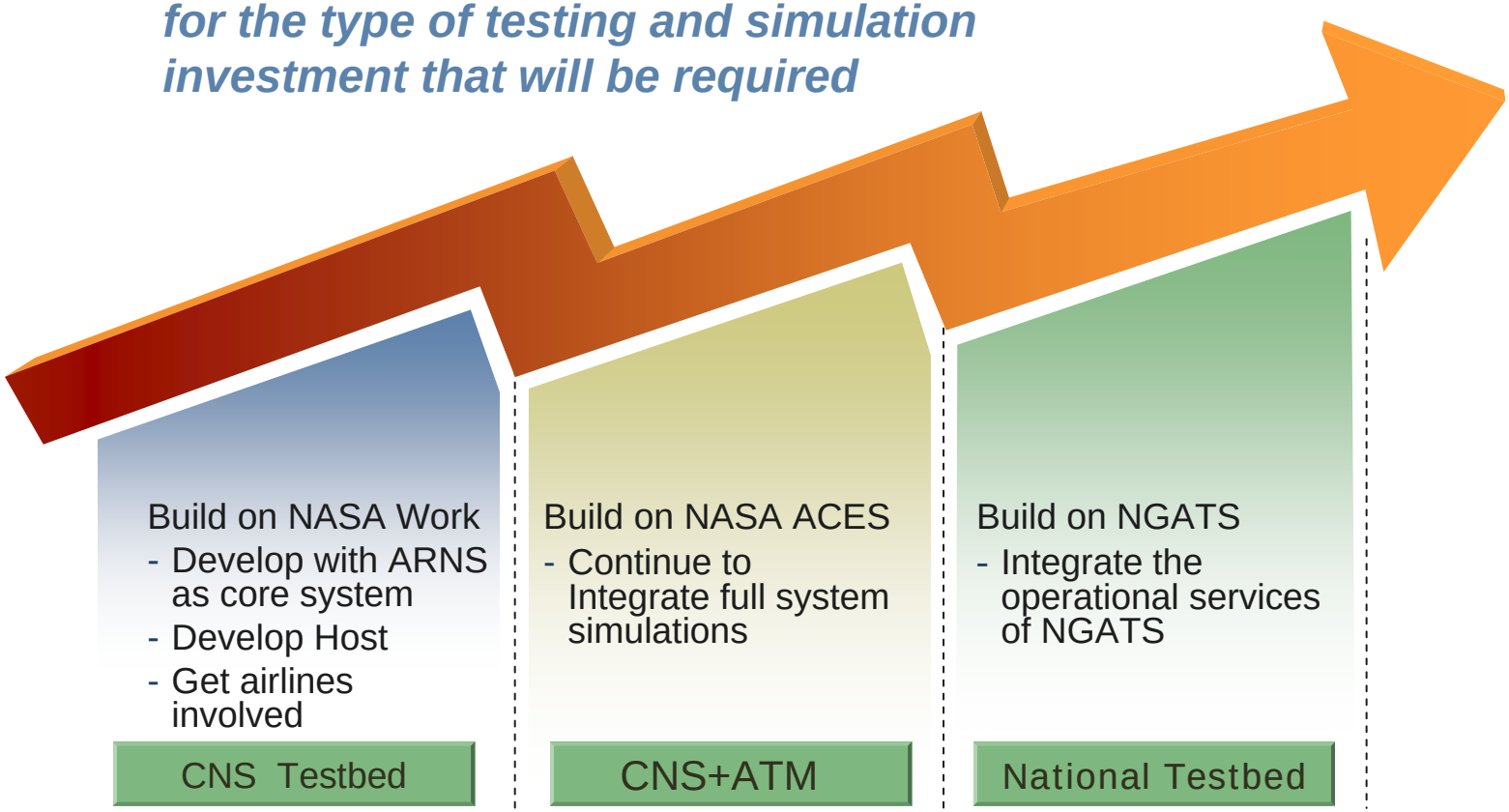
- IP based
- Full layer emulation

# Initiative . National Test & Modeling Center Concept



# Next Steps – Concept Development

***Industry needs to get congressional push to DoD, FAA and NASA to develop the funding for the type of testing and simulation investment that will be required***



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# Thank You !

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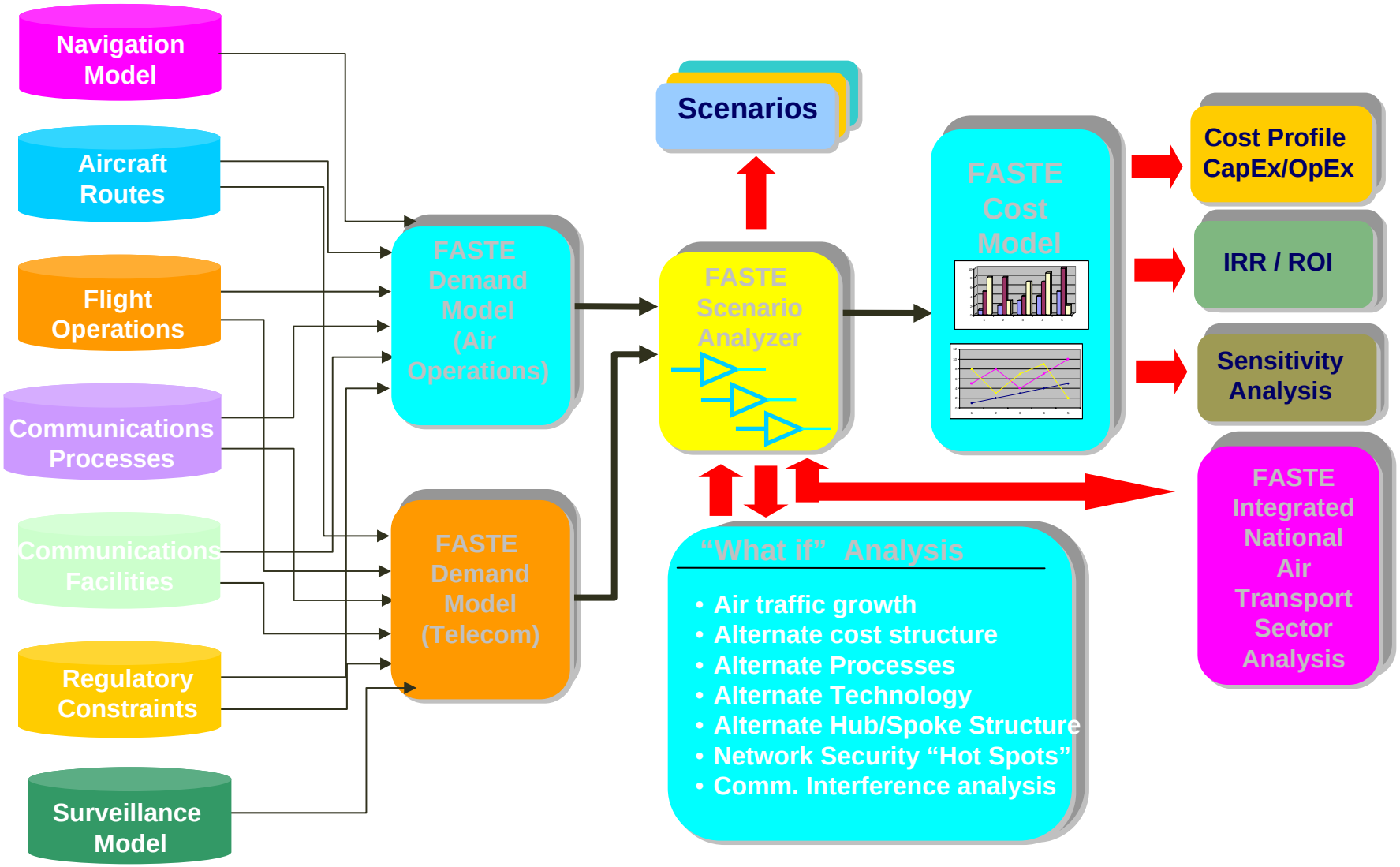
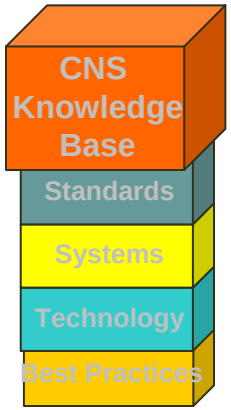
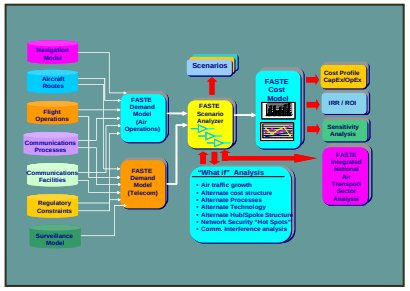
# Highlights : The FASTE - CNS$^{sm}$ Model



# How We Work With Clients : A Three Level Approach




The FASTE CNS$^{SM}$ Model




**Strategic Assessments**

**Business and Performance Assessments**

**Technical Analysis**

***Representative Engagements:***

- ***Strategic Assessment – Impact of Next Generation Air Transport Standards and Technology on Operation, Policy and National Security***
- ***Strategic Assessment – Reshaping National Communications and Security Policies to Meet the Air Transport Sector Challenges Year 2010 and Beyond***

- ***Comparative Cost/Benefit Analysis of Alternative Air Transport Policies and Technology Platforms***
- ***Diagnostic Analysis - Key Performance Indicators for Current and Emerging Passenger and Cargo Communications Technologies***

- ***Task Orders to meet global clients' needs***

***Representative Task Orders***

| Design | Analysis | Testing | Standards | Pilot Programs | Support |
|---|---|---|---|---|---|

# The Three Key Air Transport Sector Challenges…

- How do we ensure safe,efficient and reliable movement of large number of people and goods in next 30 years?
- How do we manage technology transition from traditional voice communications to new automated data messaging for navigation, aircraft control and operations?
- How do we design, plan and implement expanded air transport sector ‘reach’ while preserving safety and security standards?

# …The Three Key Air Transport Sector Challenges…

- How do we ensure safe,efficient and reliable movement of large number of people and goods in next 30 years?
  - **Strong growth anticipated**
    - Year 2005 Statistics:
      - 18 million passenger flights; +4% vs. 2004
      - +8.8% passenger growth (Jan-June)
      - +3.4% cargo growth (Jan-June)
  - **New Infrastructure Needed**
    - Airports
      - Total US Airports ~19,000
      - Public Airports ~5,000
      - Commercial Service Airports ~546
      - **Commercial Service Airports handle ~99.9 of all US air traffic**
    - Operations
      - Technology to reduce separation and fly “green”

# …The Three Key Air Transport Sector Challenges…

- **How do we manage technology transition from traditional voice communications to new automated data messaging for navigation, aircraft control and operations?**
  - Today:
    - Controllers and pilots are going from a world using their longtime experience with friendly voice contacts to a world of automated digital computer to computer messaging
  - The Obstacles:
    - Need to secure the trust of pilots, controllers, airline industry, global aviation agencies that the new "digital ' paradigm is safer, more efficient , cost effective and secure
    - Migration to new national air traffic control architectures and systems will demand large investment which must be justified
  - The Technology Transition Challenges:
    - New systems move critical flight data via new IP and wireless technologies
    - Interference with existing services, hacking and security, other critical issues
    - Technical migration – managing the transition with legacy systems
    - Pilot performing self-separation and controllers becoming monitors

# …The Three Key Air Transport Sector Challenges

- How do we design, plan and implement expanded air transport sector 'reach' while preserving safety and security standards?
  - **Feasibility of "SATS approach"**
    - Capitalize on smaller, unmanned airports
    - Moving from centralized network control to "net-centric", automated, user controlled facilities
    - Many operational, technical and security implications
  - **Next generation air traffic control protocols are emerging**
    - Meeting of ICAO,RTCA,AEEC Working Groups
    - Use of commercial Internet protocol for Air Traffic Control
    - New standards create **many tradeoffs**: cost, technology, operations, security, system adaptability
  - **Need to address complex, multidimensional planning challenge**
    - **New tools and models** needed to provide integrated perspectives
    - Need to define future demand, scope and scale of systems needed to meet demand using alternative communications technologies, cost projections, communications traffic and operations profiles, business cases and "what-if" scenarios