NextGen: Primer, Challenges, and Opportunities

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Topics

- The Next Generation Air Transportation System (NextGen)
- The William J. Hughes Technical Center
- Testing NextGen: The Challenge
- Research Opportunities
The Air Transportation System
Today’s US Air Transportation System

- Independent Surveillance (RADAR)
- Massive (Expensive) Infrastructure
- Ground Based Navaids (“Highways in the sky”)
- Voice Communications
NextGen JPDO Partner Agencies
What is NextGen

• NextGen represents the transformation of our national airspace system, making it flexible and sustainable.

• It is not a single program or procedure but a comprehensive initiative that integrates new and existing technologies, procedures and policies.
Major Features of NextGen

- Required Navigational Performance/Area Navigation
- Dependent Surveillance
- Digital Communications
- Four Dimensional Trajectories
Performance Based Navigation

WAAS LPV Approaches, 2011
Dependent Surveillance: ADS-B

Map showing the distribution of ADS-B surveillance systems in the United States, with points marked for 2010 and 2013.
Digital Communications

- Data Communications
- System Wide Information Management (SWIM)
- NextGen Network Enabled Weather (NNEW)
4D Trajectories
Collaboration is Key to NextGen
The William J. Hughes Technical Center
50 Years of NAFEC History

New Jersey: Long History of High Technology Involvement

- Birthplace of the Industrial Research Laboratory (Menlo Park, Bell Laboratories, Sarnoff Laboratory)

Rich History of Aviation in South Jersey

- First Air “Carnival” in 1910

Established 1 July 1958

- Formerly NASAC
- Unique National Asset
- Federal/State Agencies Co-Located
- Key Participant in National Air Traffic Control System Development/Testing
The FAA William J. Hughes Technical Center

Nation’s leading institution for the research, development, test, and evaluation of air transportation systems

FAA’s RDT&E Organization:

Federal Laboratory for R&D of aviation systems

Independent operational test and evaluation agent for FAA
WJHTC Quick Facts

- 5,000 Acres
- 250+ Buildings
- 4,500 employees (3,000 FAA/Contractor)
- 200,000 sq ft automation laboratories
  (climate controlled, raised floor, robust power)
- “NAS under one roof”
- R&D, T&E, 24/7 engineering support
- Operational Tower/TRACON
- Non-FAA tenants… (more later)
Interagency, Whole of Government Mission

Federal Lab
- Patent law
- Tech Transfer

JPDO Agency engagement
- Director co-chairs OSTP Aeronautics subcommittee
- Pete McHugh at DoT
- Col Anthony LaSure, NJANG
- Kevin Carbajal, NASA
- DHS/DoC to be worked

One part of our partnerships and outreach work
NextGen Integration

“ATO staff at the William J. Hughes Technical Center in New Jersey will lead the testing and prototype development of the actual systems that will make the JPDO’s vision a reality.”

*ATO Performance Report: 2006*
Featured Publications

- Peer reviewed journal articles
- Numerous other technical articles, conference proceedings, and reports
- Annual “Contributions” collection

Featured on cover of ITEA Journal and in FLC calendar
William J. Hughes Technical Center: Tenants

- FAA Technical Facilities
- 177th Fighter Wing NJ Air National Guard
- Federal Air Marshal Service
- United States Coast Guard Air Station AC
- Transportation Security Laboratory
- Atlantic City International Airport (ACY) SJTA
- Aviation Research Park
A significant feature of NextGen testing will be airborne verification of system performance

- Fire Research, Aircraft Structures, HF, Pavement Test
- NIEC
177th Fighter Wing NJ Air National Guard
US Coast Guard Air Station Atlantic City
Transportation Security Lab
Atlantic City International Airport (ACY) South Jersey Transportation Authority
The NextGen Testing Challenge
Challenging Features of NextGen

- New systems have elements which cannot be brought into the lab for testing, e.g.:
  - Some elements are acquired as services, or depend on avionics and/or procedures
  - The Airspace System is becoming a “Engineered” Complex System

Each of these features demands new approaches to V&V
Why is this happening?

- Industrial revolution v. information revolution
- Technology cycle is inside the development cycle
- Cannot be managed with the dogma of the Industrial Revolution ("What would Henry Gantt do?")
Data Comm makes NextGen a Complex System

- Understanding the characteristics of a system is important for V&V of that system

- Complex systems have scary features
  - Morphing requirements
  - Emergent behavior
  - Self-organization

- We have probably started to see implications of complex system behavior with ERAM

Baldwin, et al, (2011) IJISE v9 no3
Ideas about Complex Systems

- Nassim Taleb: “essential unpredictability”
- SEI ULS research: “unknowable requirements”
- Ali Minai: “core system components”
  - De Laurentis “Essential Complexity”
- Bruce Sawhill et al: “Chaos surfing”
  adaptability = forward compatibility
Challenging Features of NextGen

New systems have elements which cannot be brought into the lab for testing, e.g.:

- For the first time, avionics are part of the air traffic control system
- “Come as you are system” with random participants, some foreign
- Increased dependence on procedures and airspace as part of the system

24/7/365 Environment
NextGen Implications for V&V

- Must be able to deal with emergent behavior of new functions
- Incremental safety analysis will not work because changes have systemic impact
- Little experience with validation of system-of-systems with complex air/ground and human/machine interaction
- **Software issues**
  - Agent-based (non-deterministic) software
  - Complex software
- Must be able to validate that a function continues to behave correctly as NextGen evolves
- Need to keep multiple stakeholders involved

24/7/365 Environment
FAA Investment in Three Areas

First: Standardization of Existing Processes
- ISO 9000 registration, CMMI audit
- T&E benchmarking activities
- V&V Handbook and FAA best practices

Second: Refinement of New Procedural Test Practices
- Extension of Reduced Vertical Separation Minimum, Flight Services 21 testing concepts
- Continuous system monitoring
- Modeling and simulation

Third: Exploration of a New “Theory of Test” for Highly Flexible and Complex Systems
- 1: New policies and procedures
- 2: New integrated environment
- 3: New workforce
1: NextGen Life Cycle V&V Policies and Procedures

Current:
- Stovepiped
- Limited interdependency issues

Net-Centric:
- SoS level performance
- Performance relies on data integration

Provides ability to track the benefits throughout the life cycle
2: Integrated Environment Elements

NextGen V&V: Current & Future Capabilities

V&V Effort

NextGen V&V Environment (variable fidelity)

Integrated Laboratories

SOS NEXTGEN V&V Capability

Physical Laboratory Transformation

Stove Pipe Laboratories

One Integrated Toolset

Full Scale Scenarios
Symptomatic Modeling
Thread Testing
Constructive Simulation

Project Toolsets

Models
Scenarios
NAS Data

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Research Opportunities
Research Needs

- The World Post-GPS
  - Mid Term: APNT
  - Long Term: Evolved INS

- Avionics
  - Military Avionics
  - Affordable ADS-B
  - Next Generation FMS

- Affordable Aircraft

- Trajectory Based Operations
Inertial Navigation Systems

- No good backup to GPS for the future
- Space systems are inherently frail
- DARPA initiative
- ONR initiative
Current NAS Precise Time Requirements

- Multi-lateration
- RNAV/RNP
- Network Time Sync
- Asterix Time Stamping
- 3-mile Separation Assurance
- Automation Data Stamping
- RVR Data Stamping
- Sensor Fusion
- Weather Data Stamping

Time Scales:
- $10^{-9}$
- $10^{-8}$
- $10^{-7}$
- $10^{-6}$
- $10^{-5}$
- $10^{-4}$
- $10^{-3}$
- $10^{-2}$
- $10^{-1}$
- $10^{0}$

- GPS
- Cs
- Rb
- PTP
- NTP
- WWVB

Applications:
- Communications
- Navigation
- Automation
- Weather
- Surveillance
- Flight/Manual Activities

GMU CATSR
6 February 2012
Flight Management Systems

- Upload/download of 4D trajectories
- Logic matched to proposed ground systems
- Open system philosophy to standards
Military Avionics

- 15,000 DoD aircraft have to fly in system
- New avionics required
  - Precision altimeters
  - TCAS
  - Dependent surveillance
- Work together to determine
  - Applicability of existing military Link systems
  - Applicability of commercial avionics
Affordable ADS-B

- Garmin GDL-90 only UAT entry
- 1090ES exist for GA – not being “pushed”
- Consolidated solution needed
Affordable Aircraft

- Automated manufacturing concepts
Final Observations

What can we do together to foster the next generation of aviation (beyond NextGen)?
Questions/Discussion
Extra Credit 1