Airborne Systems
Competency Overview

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**NASA’s Vision**
To improve life here,
To extend life to there,
To find life beyond.

**NASA’s Mission**
To understand and protect our home planet
To explore the Universe and search for life
To inspire the next generation of explorers
...as only NASA can.
Langley Mission

In alliance with industry, other agencies, academia, and the atmospheric research community,
in the areas of aerospace vehicles, aerospace systems analysis and atmospheric science,
we undertake innovative, high-payoff activities beyond the risk limit or capability of commercial enterprises
and deliver validated technology, scientific knowledge and an understanding of the Earth’s atmosphere.

Our success is measured by the extent to which our research results improve the quality of life.
Areas of Expertise (AoE’s)

Flight Dynamics, Guidance & Control
- Stability and Control Characteristics
- Control Concepts and Requirements
- Mathematical Modeling and System ID
- Guidance & Control Law Design

Crew Systems and Aviation Operations
- Integrated Flight Deck Systems (terrain, traffic, WX)
- Aircraft Self-Separation and Distributed ATM
- Atmospheric Hazard Awareness and Avoidance
- Human-Centered Design

Research Aircraft & Piloted Simulation Systems
- B-757 ARIES
- OV-10A
- Cessna 206X
- Lancair 300X
- Cirrus SR-22X
- Integration Flight Deck
- Research Flight Deck
- Cockpit Motion Facility
- Differential Maneuvering Simulator

Reliable Digital Systems
- Design Integrity and Fault Tolerance
- Formal Methods
- Real-Time Upset

Electromagnetics
- Antennas and Sensors
- Radar Cross Section
- High Intensity Radiated Fields
FY03 AirSC Workforce by Areas of Expertise

Total NASA CS workforce - 258 FTE

- Research A/C & Piloted Sim: 24%
- Flt Dynamics: 7%
- Electromagnetics: 12%
- Reliable Digital Sys: 11%
- Guid & Control: 12%
- Crew Sys & Av Ops: 19%
- Mgmt & Admin: 15%

AST’s
- PhD: 16%
- MS: 43%
- BS: 28%
Flight Dynamics AoE

Vehicle Stability and Control

Spin Characteristics

Control Concepts

- Synthetic jet port
- Synthetic jet slot

Design Criteria

- Stick-fixed state angle, 7°
- Blended wing body

Control Power Requirements

Hazard Criteria

Langley Research Center • Airborne System Competency Overview
Guidance & Control AoE

Robust Theory

Dynamic Aeroelasticity

Frequency/Time Dependency

Multidisciplinary Integration

Transatmospheric Flight

Multidisciplinary Modeling & Analysis

Guidance & Control Theory

Controls Allocation/Reconfiguration

Control Law Design
Crew Systems & Aviation Operations AoE

- Situation Awareness Assessment
- Synthetic Vision
- Aircraft Self-Separation

- Human-Centered Design
- Weather Awareness & Avoidance
- Strategic Route Planning

N/A
Reliable Digital Systems AoE

**Research Capabilities**

- **Design Integrity**
  - Mathematical Proof of Safety Properties for Software & Hardware (Formal Methods)
  - Fault Tolerant Architectures

- **Self-Healing Systems**
  - Fault Modeling & Emulation
  - Real-Time Upset Detection & Recovery

- **Vehicle Health Management**
- **Structurally Conformant Avionics**

- **Systems & Airframe Failure Emulation Testing & Integration (SAFETI) Lab**
- **High Intensity Radiated Fields (HIRF) Lab**
Electromagnetics AoE

- Antennas
- Scattering
- Radar Cross Section (RCS)
- High Intensity Radiated Fields
- Material EM Characteristics

- Antennas Performance
- Scattering Models
- HIRF Analysis
- Hazardous Weather Algorithms
- Enhanced Vision
- Image Enhancement
- Remote Sensing
- Radar Simulation

- Airborne Sensors
  - Doppler Radar
  - LIDAR
  - Infrared Camera
- Spaceborne Sensors
  - Radiometers
Transport Research Facilities
(“Simulation to Flight”)

Aries B-757 Aircraft

Research Flight Deck Simulator

Integration Flight Deck Simulator

Transport Research System (TRS)

Flight Deck Research Station (FDRS)

Conventional B-757
1. ARIES 757-200
2. Lancair Columbia 300X
3. Cirrus SR-22X
4. OV-10A
5. Cessna 206X
Research Piloted Simulators

- Cockpit Motion Facility (CMF)
- Research Flight Deck (RFD)
- Visual Motion Simulator (VMS)
- Integration Flight Deck (IFD)
- Generic Flight Deck (GFD)
- Differential Maneuvering Simulator (DMS)
Current Growth Areas

- Flight Dynamics and Guidance & Control AoE’s
  - Multidisciplinary-oriented modeling/control methods and test techniques for nonlinear dynamics, including emerging approaches (neural nets, genetic algorithms, distributed systems)

- Crew Systems & Aviation Operations AoE
  - All areas except for Psychophysiological measurements research

- Reliable Digital Systems AoE
  - Technologies for developing/verifying highly reliable digital and/or hybrid systems, including software
  - Inexpensive, high performance “avionics-on-chips” components and systems (multidisciplinary with SMC/SEC)

- Electromagnetics AoE
  - Integrated RF/Optical sensor systems for aerospace vehicles (with SEC)
  - Electromagnetic Interference and Lightning Effects prediction and measurement methods
Programs or Program Areas by AoE

Flight Dynamics, Guidance & Control
- Aviation Safety & Security
- Vehicle Systems
- Planetary Exploration, Space Access

Crew Systems and Aviation Operations
- Aviation Safety & Security
- Airspace Systems
- Vehicle Systems

Research Aircraft & Piloted Simulation Systems
- Aviation Safety & Security
- Vehicle Systems (QAT)
- Airspace Systems
- Atmospheric Sensing

Mothballed in FY03

Reliable Digital Systems
- Aviation Safety & Security, Airspace Systems
- Vehicle Systems
- Planetary Exploration, Space Access

Electromagnetics
- Aviation Safety & Security
- Vehicle Systems (including AAP)
- Planetary Exploration, Atmospheric Sensing
Future Challenges in Airborne Systems

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Future System Challenges?

National Airspace System as Economic Enabler

Accelerating pace of IT developments

Increased DOD/Homeland Security flight activity in NAS

Avionics Systems

- Increasing Complexity/Integration
- Distributed Control
- Un-crewed Vehicle Operations
- Blurring of System Boundaries
- Ubiquitous automation/computing
- Increasing Certification Challenges

Demand for safety

Security Threats, Physical and IT

Passenger/Cargo demand growth
What Might the Future Bring?

1950

- Planar Semiconductor/Photolithograph Architecture
- Sparse, Switched Information Flow
- Bit-based Information Representation
- Back Plane Architecture
- Pattern-based Information Representation (e.g. Chemical Computing)

Million point Interconnectivity, $10^{60}$ Calculations/sec

2050?

- 10^{-9} m Molecular Adaptive Architecture
- Massive, Parallel Continuous, Information Flow
Information Enables Level of “Distributed Control”

- Information leads naturally to maximum level of decision-making/control at lowest level information exists (“Free Market” of Information)
- Studies/experience show “distributed control” more effective when
  – “system” gets large and complex enough
  – some “shared goals/objectives” and/or “rules” exist
- Distributed decision-making/control is probable (or inevitable)
  – At Airspace System level (among vehicles, between vehicles & ground)
  – At Individual Vehicle level (among on-board systems)

**Opportunity:** Distributed decision-making/control can create additional overall system robustness to element failures or malicious elements

**Challenge:** Operating Concepts and Design Methods for Distributed decision-making/control to achieve performance goals and avoid systemic failure modes
Some Other Major Issues/Trends in Airborne Systems

“Near-Term”
- Affordable, reliable and secure 2-way communication link(s)
- Meeting life-critical requirements while using “COTS” or “COTS-like” components
- Integrating “hardware” and “software” in system design

“Longer-term”
- Moving away from “test-based” certification to “design-based” certification
- Ubiquitous automation and its interaction with human operator (whether on vehicle or not)
- Unprecedented levels of vehicle integration, interactions with other disciplines (aerodynamics, structures/materials, etc)
- “Standards-based” systems engineering for mission-critical “virtual” systems (aka, ‘Windows XP’ approach won’t get us there)
Built to Last: Airframe versus Avionics

- “Technology lifespan” of computers/electronics at least an order of magnitude shorter than modern aircraft

- Many real-time, reliable information technologies are rapidly advancing, but aviation industry is neither driving market (anymore) nor keeping up
  - Hardware (processors, displays, human/computer interfaces)
  - Software (code and architectures)

- Approach needed to enable integrated, extendible functionality
  - Common operator interface paradigm for same or similar functions
  - Enable “upgrades” and new “applications” to be added after initial design
Unforeseen Damage or Problems Identified & Vehicle Reconfigured By Central Monitor/Control System
- Limited Abilities to Sense Problems
- Limited Ability to Reconfigure around Problems
- No Ability to Repair Damage
- Limit New Flight Characteristics to Allow Human to Continue Flying
- Loss of Link to Central Monitor/Control System is Fatal

Unforeseen Damage or Problems Identified & with Solutions Developed & Implemented Locally but Monitored by "Central" System
- Mimics Biological Processes (e.g. healing of a cut finger)
- Inherent Neurodynamic Materials for necessary & efficient information distribution
- "Central" System function only to provide overall guidance to local systems

Tomorrow’s Vehicle - Possible Avionics Evolution

100 Control Surfaces (Systems)

20 Control Surfaces (Systems)

< 10 Control Surfaces
Tomorrow’s Airspace “System”

- Operational concept based on Required System Performance (RSP) -- defines “protected volume” to maintain aircraft separation

- **Questions**
  - Will existing airspace system “control structure” (lots of humans, little automation) provide desired levels of RSP?
    - If number of aircraft strictly limited -- not acceptable in medium-term
    - If highly-skilled ATC specialists exist -- unlikely in long-term
  - How much will airspace system users rely on airspace system providers to achieve a given level of RSP?
    - As little as possible!

- **Probable outcome**: aircraft will “self-separate” from other aircraft, terrain, hazardous weather, restricted airspace, etc
  - today’s ATC will orient toward overall traffic management (flows, entry into congested airspace, etc)
  - New problem: How to design/certify “mission-critical systems” with air/ground elements
Concluding Remarks

• Massive, Parallel, Continuous Information Flow will lead to Distributed Decision-making and Control in a self-reinforcing manner

• Defining the “boundary” of the “system” will become increasingly problematic
  – there will be no overall “system” design in traditional sense
  – Can our design and certification methodologies cope?

• DoD applications will most likely be “pathfinders” for these concepts (though other “niche” opportunities exist)

• Need researchers that can work at the intersection between disciplines
  – Requires investment in certain disciplines to bring up to same level (e.g., computational electromagnetics is decades behind computational fluid dynamics)
  – Education in cross-discipline communications and prepare students for “trans-discipline” technical work activities