NASA Research and Transition to the FAA
Human/Systems Focus

Tom Prevot
Human Systems Integration Division
NASA Ames Research Center
NASA Sites

- Glenn Research Center
- Software Independent Verification and Validation (IV&V) Facility (GSFC)
- Goddard Institute for Space Studies
- Goddard Space Flight Center
- Wallops Flight Facility (GSFC)
- NASA Headquarters
- Langley Research Center
- Marshall Space Flight Center
- Kennedy Space Center
- Stennis Space Center
- Michoud Assembly Facility (MSFC)
- Ames Research Center
- Vandenberg Air Force Base (KSC)
- Jet Propulsion Laboratory
- Armstrong Flight Research Center
- White Sands Test Facility (JSC)
- Johnson Space Center
- NASA Shared Services Center
Human factors research at NASA is largely embedded in overarching research effort. All organizations addressing HF have a mix of engineers, computer scientists, and HF specialists. Human/Systems integration is the primary focus rather than classic HF.
NASA Aeronautics Research and FAA involvement

• NASA’s lower TRL research informs FAA and other stakeholders via publications and presentations
  – NASA Aeronautics Mission Directorate (ARMD) determines the research according to NASA’s research strategy, funds and conducts the research
  – NASA engages stakeholders and partners in research process and publishes/presents results

• NASA’s higher TRL research and technologies transitions to FAA via Research Transition Team
  – NASA develops relevant concepts and technologies to higher TRL
  – NASA/FAA Research Transition Team (RTT) is formed and technology transfer is coordinated
  – Coordinated and joint activities transition NASA research results, concepts and technologies for FAA implementation

• NASA research can be directly funded by FAA
  – FAA determines that NASA has the required expertise/capabilities and funds NASA directly to conduct specific research

• Other: E.g. Commercial Aviation Safety Team (CAST) Research Safety Enhancements
  – NASA takes responsibility for Airplane State Awareness (ASA) research elements proposed by CAST
FROM NASA’S STRATEGIC VISION TO POTENTIAL FAA IMPLEMENTATION
NASA Aeronautics Research Six Strategic Thrusts

- **Safe, Efficient Growth in Global Operations**
  - Enable full NextGen and develop technologies to substantially reduce aircraft safety risks

- **Innovation in Commercial Supersonic Aircraft**
  - Achieve a low-boom standard

- **Ultra-Efficient Commercial Vehicles**
  - Pioneer technologies for big leaps in efficiency and environmental performance

- **Transition to Low-Carbon Propulsion**
  - Characterize drop-in alternative fuels and pioneer low-carbon propulsion technology

- **Real-Time System-Wide Safety Assurance**
  - Develop an integrated prototype of a real-time safety monitoring and assurance system

- **Assured Autonomy for Aviation Transformation**
  - Develop high impact aviation autonomy applications
How are the vision’s research thrusts used?

All of the programs address more than one, or all, of the research thrusts.
What is the Airspace Operations and Safety Program?

This program integrates the Airspace Systems Program and Aviation System-Safety work.

Mission Program

Projects

Airspace Technology Demonstrations

SMART NAS—Testbed for Safe Trajectory-Based Operations

Safe Autonomous System Operations

Airspace Operations and Safety Program

Develops and explores fundamental concepts, algorithms, and technologies to increase throughput and efficiency of the National Airspace System safely.

Provides knowledge, concepts, and methods to the aviation community to manage increasing complexity in the design and operation of vehicles and the air transportation system.

Continues Airspace Systems Program research, and the aircraft state awareness research and system wide safety research that was previously conducted within the Aviation Safety Program.
Research Transition via NASA/FAA Research Transition Teams (RTT)

• NASA Aeronautics Mission Directorate (ARMD) determines the research according to NASA’s research strategy, funds and conducts the research
• NASA engages stakeholders and partners in research process and publishes/presents results

*If suitable for near-term implementation and highly promising*

• NASA develops relevant concepts and technologies to higher TRL
• May become Airspace Technology Demonstration (ATD) project
• NASA/FAA Research Transition Team (RTT) is formed and technology transfer is coordinated
• Coordinated and joint activities transition NASA research results, concepts and technologies for FAA implementation
NASA’s work on these technologies

**MULTI-SECTOR PLANNER (MSP)**
- Contributes to bridging the gap between strategic flow contingency management and the tactical separation management functions

**Efficient Descent Advisor (EDA)**
- Speed Advisories
- Path Stretch Advisories
- Operational in Albuquerque Center in 2014
- Potential FAA deployment 2018
- $97M/yr savings - improved meter-fix delivery accuracy
- $31M/yr savings - reduced fuel burn in en route airspace
- $143M/yr savings - improved meter-fix delivery accuracy
- $46M/yr savings - reduced fuel burn in en route airspace
- 60% reduction in metering-related clearances

**Precision Departure Release Capability (PDRC)**
- Precision release of tactical departures for efficient en route stream merge
- Analogous to cars merging onto a busy freeway
- FAA expected deployment 2018
- 50% increase in departure time conformance
- $20M/yr savings to airlines from increased en route slot merge compliance

**TERMINAL SEQUENCING & SPACING TOOL (TSAS)**
- Advanced scheduling and sequencing of arrivals and runway
- Terminal controller advisories to maintain precision schedules implemented on FAA’s STARS system
- FAA Final Investment Decision (FID) December 2014
- FAA expected deployment 2019
- Precision scheduling (+/- 15 sec) to runway for increased throughput
- 98% PBN conformance during high density, mixed equipage operations for fuel-efficient operations
- $300-400M – Annual savings to airline

**Product Benefits**
- 15% reduction in total delay
- Avg. delay reduced 24–37min/flt to 2.2–2.8 min/flt
- 1/3 of reroutes were shortened an avg of 11.2nm/flt
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**For Government Use Only**

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## Research Transition Teams

### RTT Membership

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<th>Efficient Flow Into Congested Airspace</th>
<th>Integrated Arrival Departure Surface Operations</th>
<th>Data Management</th>
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Example Research Transition Activities

• Terminal Sequencing and Spacing (TSAS)
  • Advanced scheduling and sequencing of arrivals and runway
  • Terminal controller advisories to maintain precision schedules implemented on FAA’s STARS system

• Unmanned Arial System Traffic Management (UTM)
  – Safely Enabling UAS Operations in Low-Altitude Airspace
Objectives

• Demonstrate routine use of Performance-Based Navigation (PBN) during busy traffic periods

• Accelerate transfer of NASA scheduling and spacing technologies for inclusion in late mid-term NAS
ATM Technology Demonstration #1 (ATD-1): Integrated Arrival Solution

FIM  Flight Deck Interval Management for Arrival Operations

CMS  Controller-Managed Spacing in Terminal Airspace

TBFM  Time-Based Flow Management (TBFM) with Terminal Metering

NASA Technologies plus ADS-B Infrastructure
Area Navigation (RNAV) Arrivals
Required Navigation Performance (RNP)
Optimized Profile Descents (OPD)
Terminal Sequencing and Spacing (TSAS): Planned FAA Capabilities

Time-Based Flow Management (TBFM) with Terminal Metering

Controller-Managed Spacing (CMS) in Terminal Airspace

NASA Technologies plus
ADS-B Infrastructure
Area Navigation (RNAV) Arrivals
Required Navigation Performance (RNP)
Optimized Profile Descents (OPD)
NASA TSAS Prototype Capabilities

Graphic courtesy of MITRE Corporation.
During high-fidelity human-in-the-loop simulations of Terminal Sequencing and Spacing, air traffic controllers have significantly improved their use of PBN procedures during busy traffic periods without increased workload.
Results

PBN Route Conformance

Without TSS

With TSS
Integration with other new concepts/technologies
(Risk mitigation simulation at NASA Ames summer 2015)
Identifying interoperability issues

Condition 5: Concurrent

- Time sharing:

Exploratory Condition

- Dwell to show slot maker (staggered)
NASA Transitions TSAS to FAA

- ATD-1 transferred Terminal Sequencing and Spacing (TSAS) technologies to the FAA

- TSAS intended to enable routine use of underutilized advanced avionics and PBN procedures
  - Potential benefits to airlines operating at initial TSS sites estimated to be $300-400M/year

- FAA is planning for an initial capability in the NAS in 2019
Example Research Transition Activities

• Terminal Sequencing and Spacing (TSAS)
  • Advanced scheduling and sequencing of arrivals and runway
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• Unmanned Arial System Traffic Management (UTM)
  – Safely Enabling UAS Operations in Low-Altitude Airspace
Unmanned Aerial System Traffic Management (UTM)

Near-term Goal: Safely enable initial low-altitude UAS as early as possible
Long-term Goal: Accommodate increased demand with highest safety, efficiency, and capacity
UTM Design Functionality: Cloud-based

Self-driving car does not eliminate lanes and rules for efficient and safe operations

**Digital, Virtual, & Flexible Risk-based Approach and Service Infrastructure**

- Safe low-altitude UAS operations with
  - Airspace management and geofencing
  - Weather and severe wind integration
  - Predict and manage congestion
  - Terrain and man-made objects: database and avoidance
  - Maintain safe separation (Airspace reservation, V2V, & V2UTM)
  - Allow only authenticated operations

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**LINE-OF-SIGHT TO BEYOND LINE-OF-SIGHT: PILOTED TO AUTONOMOUS**

- **Multiple customers with differing mission needs**
  - Tracking
    - ADS-B, cell, and satellite
    - Low-altitude radar/sensors at key locations (uncooperative)
  - UTM SERVICES
    - Authentication
    - Airspace design and geofence definition
    - Weather integration
    - Constraint management
    - Sequencing and spacing
    - Trajectory changes
    - Separation management
    - Contingency management
  - Transition between UTM and ATM airspace
  - Constraints: noise, sensitive areas, privacy, etc.
  - 3D maps: terrain and human-made structures
  - Real-time Weather & Wind
  - Weather & Wind Predictions
  - Airspace Constraints
  - Other Low-altitude Operations

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**UTM SERVICES**

- **UTM Design Functionality**
  - Cloud-based
  - Airspace management and geofencing
  - Weather and severe wind integration
  - Predict and manage congestion
  - Terrain and man-made objects: database and avoidance
  - Maintain safe separation (Airspace reservation, V2V, & V2UTM)
  - Allow only authenticated operations
Each build is independent and deployable

**Build 1 (August 2015)**
- Reservation of airspace volume
- Over unpopulated land or water
- Minimal general aviation traffic in area
- Contingencies handled by UAS pilot
- Enable agriculture, firefighting, infrastructure monitoring

**Build 2 (October 2016)**
- Beyond visual line-of-sight
- Tracking and low density operations
- Sparsely populated areas
- Procedures and “rules-of-the road”
- Longer range applications

**Build 3 (January 2018)**
- Beyond visual line-of-sight
- Over moderately populated land
- Some interaction with manned aircraft
- Tracking, V2V, V2UTM and internet connected
- Public safety, limited package delivery

**Build 4 (March 2019)**
- Beyond visual line-of-sight
- Urban environments, higher density
- Autonomous V2V, internet connected
- Large-scale contingencies mitigation
- News gathering, deliveries, personal use
Progress

- Research Transition Team with FAA, DHS, and DoD
- 125+ industry and academia collaborators and increasing
- Initial UTM Concept of Operations: Industry, academia, and government
- Client interface is ready – You can connect with UTM
- Build 1 tests with 12 partners begin at the end of August
- International interest
COMMERCIAL AVIATION SAFETY TEAM (CAST) RESEARCH SAFETY ENHANCEMENTS
Aircraft State Awareness (ASA) Joint Safety Implementation Teams (JSIT) – Safety Enhancements

Fatalities by CAST/ICAO Common Taxonomy Team (CICTT)
Aviation Occurrence Categories
Fatal Accidents on Worldwide Commercial Jet Fleet 2001 Through 2010

- External fatalities [Total 231]
- Onboard fatalities [Total 4774]
- Airplane state awareness [1036] *

Events: 11

Note: Principal categories as assigned by CAST.
* Does not include Air France 447 (228) or Colgan Air 3407 (50)
Joint Implementation Measurement Data Analysis Team (JIMDAT) identified loss of control in-flight (LOC-I) as an area of ongoing concern, particularly:

- **Attitude (bank or pitch angle) awareness**
  - ~15% of all fatalities in worldwide scheduled air carrier operations since 2002
  - FOQA: Rate of high-risk overbanks in the US = 4.9 per million flights

- **Low airspeed / energy state awareness**
  - ~12% of all fatalities in worldwide scheduled air carrier operations since 2002, including last fatal accident in the US (Colgan Air 3407, Feb 2009)
  - FOQA: Rate of high-risk stall warning events in the US = 6.1 per million flights

ASA Joint Safety Implementation Teams (JSAT) analyzed 18 events in which flight crew lost awareness of airplane attitude or energy state:

- 9 loss of attitude awareness: 8 accidents, 1 incident
- 9 loss of energy state awareness: 5 accidents, 4 incidents
- 161 standard problem statements (SPS’s)
- 274 intervention strategies (IS’s)
- 12 major themes
## ASA JSIT – Safety Enhancements

### Brief Review of ASA Study

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ASA JSIT – Safety Enhancements
SE Concepts from August 2012

**Design**
- D-1 Energy State Awareness
- D-2 Attitude Awareness
- D-3 Airplane Sensor Anomalies
- D-4 System Mode Awareness
- D-5 Flight Envelope Protection

**Training**
- T-1.1 Critical Flt Crew Actions
- T-1.2 Training V & V
- T-2 Revised CRM Training
- T-3.1 SBT for Stall Recovery
- T-3.2 SBT for Go-Arounds
- T-3.3 SBT for Attention Issues
- R-5 Simulator Fidelity
- R-6 Human Perf - Attention

**Operations**
- O-1 ATC Enhancements
- O-2.1 Maintenance Processes
- O-2.2 Non-Standard Ops
- O-3 SOP Effectiveness
- O-4.1 Flt Crew Sys Proficiency
- O-4.2 Flt Crew Roles & Resp
### ASA JSIT – All Safety Enhancements

**2025 Risk Reduction:**
- **92.4%**

**Duration:**
- **84 months**

**Cost:**
- **$177.4M**

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| **207**  
ASA - Research – Attitude and Energy State Awareness |
| Output 1  | AOA Benefits  | Lead Agency  | FAA/AIR |
| Output 2  | Pitch Guidance for Recovery  |  | NASA   |
| Output 3  | LESA Countermeasures  |  | NASA   |
| Output 4  | SD Alerting  |  | NASA   |
|  |  |  |  |
| **208**  
ASA – Research – Airplane Systems Awareness |
| Output 1  | Automated Systems Awareness  |  | NASA   |
| Output 2  | System State Alerting  |  | NASA   |
|  |  |  |  |
| **209**  
ASA – Research - Simulator Fidelity |
| Output 1  | URT Learning Objectives  | Lead Agency  | FAA/AFS |
| Output 2  | Stall Aero Model Reqrnnts  |  | FAA/AFS |
| Output 3  | Stall Aero Model Definition  |  | NASA   |
| Output 4  | Stall Sim Reqrntns  |  | FAA/AFS |
|  |  |  |  |
| **210**  
ASA - Research - Flight Crew Performance Data |
| Output 1  | Human FOQA  | Lead Agency  | FAA |
| Output 2  | Human Perf Eval Methods in Design  |  | NASA   |
| Output 3  | Attention Eval in Design  |  | NASA   |
|  |  |  |  |
| **211**  
ASA - Research – Training for Attention Management |
| Output 1  | Attention Detection in situ  | Lead Agency  | NASA   |
| Output 2  | Attention Training Methods  |  | NASA   |
|  |  |  |  |
| **200**  
ASA – Design – Virtual Day-VMC Displays |
| Output 1  | MASPS for Virtual VMC Displays  | Lead Agency  | NASA |
| Output 2  | DO-/ARC- for Virtual VMC Displays  |  | FAA/AIR |
| Output 3  | Virtual VMC Displays Implementation  |  | AIA   |

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Mike Feary (ARC)  
Angela Harrivel (LaRC)  
Kyle Ellis (LaRC)
Questions ?