Breakout Session Accomplishments

- What are minimum viable products to make progress towards increasingly autonomous flight and operations in the NAS
- Where will collaboration be most productive
- Possible collaborative demonstrations
- Steps toward operationalization of increasingly autonomous systems.

Breakout Session Recurring Themes

- Most MVPs centered around simplifying vehicle operations
  - Some agreement that the first MVP step seems to be better systems on board and design best practices to build better resilient/robust systems and as a “backup” instead of human as a backup
- Bring out the best in the “missing” pilot
  - R&R; functional allocation; HMI; CRM; pilot engagement
- Research needs & gaps are dependent on architecture and ConOps
- Balance - Acceptance of fully autonomous vision
  - Concern that the bigger advanced that are needed won’t get done if we’re too tactical in our research planning; need to invest in longer term, strategic research

REDUCED CREW OPERATIONS FOR DOMESTIC AND INTERNATIONAL AIRCRAFT

BREAKOUT SESSION 1: Identify needs, minimum viable products, progression towards their autonomous operations, and needed aircraft, ground, and cloud-based capability levels

REDUCED CREW OPERATIONS FOR DOMESTIC AND INTERNATIONAL AIRCRAFT

NEEDS OF REDUCED CREW OPERATIONS

Needs OF RCO

- Reduce cost of operations
- Address pilot shortage
- Increased demand

Needs FOR RCO

- Requirements
- Roles & Responsibilities
  - Redefinition of crew roles and responsibilities with automation support
  - Human-automation teaming research
  - Functional allocation (dynamic?)
  - Pilot workload management
- Operational standards / Concept of operations

Scope of Discussions

- All phases of flight, crew in cockpit

Missions / Use Cases Considered to Frame Conversation

- All phases of flight, crew in cockpit
- UAM
- Cargo / long-haul
- Part 121 – 2 to 1

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Needs of Reduced Crew Operations

Needs FOR RCO

- Automation needs
  - Adaptive
    - Contingency mgmt. when pilot is incapacitated
    - Rules can change by locality
    - Risk-based decision logic for piloting functions
  - Adaptable (pilots have the ability to control the level of automation)
  - Transparent “enough” (why and how things happen)
  - Trust (both ways)
  - Reliability
  - Simplicity
- Training of the human operator/pilot to match the level of automation/mode of automation
- Sensor technology and data fusion
  - For SAA
  - For decision-making process (e.g., weather threat assessment creating flight path changes)

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NEEDS OF REDUCED CREW OPERATIONS

Needs FOR RCO

- How to keep single pilot on engaged during low activity phases of flight
  - How to quickly re-engage pilot during emergency/anomaly
- Communication between human and machine "pilots"
  - Voice or other?
- Communication capability to allow automation of speech
  - Note: DoD/AFRL automation shows human comm is obsolete; current air traffic requires human interaction
- Certification changes/differences
  - Technology and the regulation to support it
  - New ways of meeting intent of rule/regulation could reduce current regulatory barriers
- V&V challenges, NAS integration challenges, etc.
- Design guide – "autonomy for dummies"
- Ground infrastructure

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NEEDS OF REDUCED CREW OPERATIONS

Needs FOR RCO

- Identify what workload tasks can be offloaded to the automation to make the tasks simpler, what tasks can be completely replaced, and what still requires human interaction
  - Who decides what needs to be automated? May be platform/mission dependent.
- Need performance-based requirements/expectations for automation – pillars of automation
  - Best practices, architecture, design, failure modes
- Maintain or improve safety
- Stakeholder acceptance
  - Public acceptance – how to communicate and demonstrate that safety is maintained

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MINIMUM VIABLE PRODUCTS

Automate monitoring functions and provide advice

1. Automation in 2nd seat/co-pilot. Architecture for allowing incremental modification to automation (increase) by functional allocation (e.g., system health monitoring)
   - Simulation of concepts while collecting pilot physiological data
2. Replace co-pilot with “operator” (i.e., less rigorous training)
3. Install safety/assurance systems (e.g,. GCAS, ACAS) on GA aircraft to build trust in automation
   - More aircraft with TCAS
   - Link systems such as DAA to autopilot
4. Decrease long-haul crew from 5/4/3 to 2; replace with “operators”
5. Automatically pull up procedures for both nominal and off-nominal scenarios to aide pilot
   - Could include checklists
   - System response guidance to deal with failures (instead of better training the human)
6. Accepting pilot input into automated system; accepting human as a “sensor”

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Minimum Viable Products

7. Provide performance computations/data [continuously] for non-normal situations for which pilot currently references safety manual and performs manually (could be dispatch function)
8. Collect relevant data to inform pilot to co-pilot interaction, co-pilot/monitoring functions, what makes a good co-pilot, DL training database, interaction between pilot and automated system, human contribution to safety, build certification basis
   - More data sharing (e.g., companies/airline data)
   - Self-reporting could help build public acceptance
9. Provide support services from the ground (dispatch?)
10. Autonomy as a backup (incapacitated pilot, work overload, insufficient engagement)
11. Platform to test products in a well understood and repeatable manner
12. Digital communication of information between ATC and the aircraft/automation to support the future ATMx.
13. Part 121, zero crew onboard, includes ground monitoring and command center
    - Include DAA, maneuvers to avoid conflicts, and maneuvers for route optimization
14. Co-pilot moved to ground

REDUCED CREW OPERATIONS FOR DOMESTIC AND INTERNATIONAL AIRCRAFT

Progression Towards Autonomous Operations

- Reduce crew required on long haul flights, work towards single pilot
  - Transition from 5/4/3 to 2, 2 to 1, 2 to operator, 1 to operator, 1 to 0
- Crawl-walk-run approach to build up to a proven safety cause, helping the pilot be better at their job.
  - Start small scale with low risk and scale up with more complexity
  - Start with cargo as a way to experiment on new missions, remote areas, etc.
- Acceptance of fully autonomous vision
  - Start with autonomy and build up complexity and risk
  - sUAS cargo, medium cargo over
  - Medium/large over
  - Medium/large over

REDUCED CREW OPERATIONS FOR DOMESTIC AND INTERNATIONAL AIRCRAFT

AIRCRAFT, GROUND, AND CLOUD-BASED CAPABILITY LEVELS

Capabilities are strongly tied to needs. Capabilities == functions

- Adaptability
- CNS?
- Capabilities are dependent on ConOps
- Verification that pilot isn't doing something wrong (i.e., Taiwan failed engine example)
- Error detection and avoidance

Other Notes:

- Assumption: Involve regulators along the way
- Consider role of ground/dispatch
- Important to consider each part of the architecture and be systematic in developing different technologies
- One operator per multiple UAS operations
- Consider mixed use case – old and new technologies working together
- Acceptance of fully autonomous vision
    - Start with autonomy and build up complexity and risk
- Retrofit into an older airframe may not be a viable path
    - Many are building new specific cargo aircraft
    - Companies are working to build optionally piloted aircraft where workload is monitored
    - Beech 19000 cargo is first step – 2 years away from first flight
- Concern that the bigger advanced that are needed won't get done if we're too tactical in our research planning; need to invest in longer term, strategic research

REDUCED CREW OPERATIONS FOR DOMESTIC AND INTERNATIONAL AIRCRAFT

BREAKOUT SESSION 2: Identify research gaps, needs, and strategy to implement increasingly autonomous operations in complex airspace and areas

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RESEARCH GAPS AND NEEDS

- Identify crew resource management characteristics if co-pilot
- Identify all tasks and how they can be re-allocated to automation
- Interoperability (ATC, dispatch, and pilot)
- Determine what additional sensors are needed onboard
- Voice vs data comm functions, sector handoffs, vehicle health data
- How do autonomous systems integrate with ATC/ATM automation (e.g., ERAM)
- Platform to test products in a well-understood and repeatable manner to make advances in system development
- Need to account for loss of comm

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STRATEGY TO IMPLEMENT INCREASINGLY AUTONOMOUS OPERATIONS IN COMPLEX AIRSPACE

- Build system that can have the automation fully integrated; however, automation functional allocation is incrementally increased
- Define architecture

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BREAKOUT SESSION 3: Identify an action plan for collective demonstrations, collaboration topics where research by NASA could help everyone (e.g., certification methods, airspace, requirements/standards for certain systems/capabilities, conops), and operational implementation of increasing autonomous systems in the NAS

REDUCED CREW OPERATIONS FOR DOMESTIC AND INTERNATIONAL AIRCRAFT

ACTION PLAN FOR COLLECTIVE DEMONSTRATIONS

Demo: Co-pilot moved to the ground

- CRM capabilities / check ride
- **Testbed** vehicle – MMRTA, reducing crew workload
- Testbed (simulation) for integrating components from different companies
  - Introduce stress cases here
- **Live** demo – enroute phase of flight
  - #1 – **nominal** flight
- **Include FAA**. Jointly work towards defining regulations.
- Oxygen masks (obstacle to overcome)
- Phase function allocation (pilot, ground, automation)
  - Experiments to evaluate the different configurations of responsibilities
- Framework for demo (the infrastructure)
  - Fixed plan with exit criteria for each/all collaborators & requirements
- Datalink bandwidth & the integrity

REDUCED CREW OPERATIONS FOR DOMESTIC AND INTERNATIONAL AIRCRAFT

ACTION PLAN FOR COLLECTIVE DEMONSTRATIONS

Demo: Co-pilot moved to the ground

- Time frame – 5-10 year vision
- Remove copilot & find functions that need/should/can be moved to the ground
- Define Functions
- Test functions in a sim environment
- HITLs
- Develop new training requirements
- Research plan and research
- Look at safety cases. Ongoing. Establishing target levels (incl. FAA)
  - Maintain safety throughout
- Common ground between commercial and GA
- Collecting the right data
- Access to onboard aircraft control & monitor systems

REDUCED CREW OPERATIONS FOR DOMESTIC AND INTERNATIONAL AIRCRAFT

COLLABORATION TOPICS WHERE NASA RESEARCH COULD HELP

- Function Re-allocation
  - **Identify candidate functions for automation, human, ground**
  - Does new team induce new functions?
  - Display design/system transparency/multi-modal displays
  - Data visualization and data fusion are critical
- Human-machine interaction
  - What is CRM? Capture crew interactions (currently)
  - Experiments replacing human with automation
- Training: What happens to on-the-job training?
- Common aircraft handling/flying qualities
  - Common autonomy interface
- Airframe induced limitations/differences that may impact automation/functions

REDUCED CREW OPERATIONS FOR DOMESTIC AND INTERNATIONAL AIRCRAFT

COLLABORATION TOPICS WHERE NASA RESEARCH COULD HELP

- Social impact/cost/benefit of a pilot without human interaction
  - How can automation introduce human-like engagement?
  - Do they need to be replaced at all? Is safety impacted by the loss of human/social interaction
  - What are pilots good at? Give them those tasks. Monitoring is not one of them.
  - Is it better/more efficient to have localized automation versus ground-based support providing data to the aircraft and certain level of automation of functions from the ground
  - How can we address the topic of public perception?
  - International version of ASRs
- What is the intent behind operations today?
- cybersecurity

REDUCED CREW OPERATIONS FOR DOMESTIC AND INTERNATIONAL AIRCRAFT

OPERATIONAL IMPLEMENTATION

- Safe implementation into highly controlled airspace
- Safety targets the same?
- Voice comms or digital comms?
- Regulatory constraints. Certify airframes & software