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
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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
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 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
Automate monitoring functions and provide advice

1. Automation in 2\textsuperscript{nd} 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”
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
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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
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
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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
ENABLING AUTONOMOUS FLIGHT & OPERATIONS IN THE NAS

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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
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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
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**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
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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
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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
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OPERATIONAL IMPLEMENTATION

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