m:N WORKING GROUP

MEETING SUMMARY

OCTOBER 2024

EXECUTIVE SUMMARY

From October 22nd to 24th, 2024 the m:N UAS working group and its subgroups (Evaluation Methodologies, Exceptions/Interventions, and Initial Operating Capability for Airspace Integration) met at the FAA Southwest Regional Office in Fort Worth, Texas for an in-person meeting, Figure 1. The subgroups meet virtually throughout the year, and twice a year participants from all the subgroups come together to further identify and discuss challenges and paths forward for incorporating UAS into the airspace. During this meeting, the sUAS working group was also in attendance, presenting insights from their latest report – *Personnel Selection, Roles, and Training for sUAS*.

The m:N UAS working group is run by Jay Shively (Adaptive Aerospace) and is comprised of members from government, industry, and academia in an effort to identify and reduce barriers to m:N operations. This includes identifying requirements, use cases, metrics, and the development of white papers to support organizations including the FAA, RTCA, and ASTM.

The goal for 2024 was for the m:N subgroups to focus on covering evaluation methodologies, interventions/exceptions, and initial operating capabilities for airspace integration; with the premise that the outcomes from these subgroups will be white papers. Additionally, these white papers can inform one another to ultimately become a master whitepaper.

Each subgroup lead is called out below:

Evaluation Methodologies Subgroup
Jay Shively, Adaptive Aerospace

Interventions/Exceptions Subgroup
Andy Thurling, DroneUp

Initial Operating Capability for Airspace Integration Subgroup
Andy Lacher, NASA

THE CHARGE FOR THE WEEK

This meeting of the m:N UAS working group focused on sharing out subgroup progress and identifying a path forward for the working group for next year and beyond.

Figure 1: m:N Working Group Attendee Photo

Day one of the working group focused on presentations from government, academia, and industry, including updates from the Metrics, Interventions, and Integration committees and the sUAS working group's report on personnel selection, roles, and training.

Day two highlighted off-site demonstrations at Wing facilities, as well as discussions on third-party services, AI certification, and airspace integration. Presentations highlighted advancements in UAS operations and emphasized collaboration between regulators, industry, and researchers.

At the culmination of the three-day meeting, the group explored high-complexity simulations, human-autonomy teaming studies, and future challenges in automation, concluding with a tour of the FAA's Regional Operations Center (ROC) facility.

OCTOBER 22ND BRIEFINGS & DISCUSSIONS

The October 22nd briefings included representatives from industry, NASA, and academia.

A summary of the briefings and presentations from the first day of the working group session are included in the following section.

OCTOBER 22ND PRESENTATIONS AND BRIEFINGS

FAA Southwest Regional Office Welcome

Doug Lane | FAA

Mr. Lane provided the group with an overview of the FAA as well as the Regional Operations Center (ROC).

Introductions

Jay Shively | Adaptive Aerospace

The m:N working group meeting was kicked off with around-the-room introductions and an overview of the agenda and goals of the in-person meeting. Mr. Shively introduced the meeting with a focus on advancing autonomous capabilities and integrating new technologies within the small Unmanned Aircraft Systems (sUAS) framework. He highlighted NASA's ongoing efforts in safety, airspace integration, and autonomy, emphasizing collaboration across government, industry, and academia to support the m:N roadmap.

FAA Welcome

Tim Beglau | FAA

Tim Beglau's welcome focused on the FAA's approach to safely integrating UAS into the airspace through the FAA's Emerging Technologies Division. Mr. Beglau outlined the FAA's structure and priorities for sUAS, explaining that the Emerging Technologies Division was created in 2023 to unify the agency's various sUAS initiatives under one organization.

The division is comprised of six branches, each with a specific area of responsibility. For example, the AFS-720 branch evaluates sUAS equipment to determine airworthiness and operational considerations, while the AFS-730 branch focuses on technology standards. Mr. Beglau noted that the FAA is working to streamline exemptions and approvals for commercial sUAS operators, especially in the package delivery space. A key initiative is the development of a UAS Traffic Management (UTM) system, which is being led by Wing and Zipline, some of the first approved providers.

Mr. Beglau emphasized that the FAA is prioritizing the development of robust detect-and-avoid capabilities to ensure the safe integration of unmanned aircraft into the National Airspace System, particularly for operations beyond an operator's line of sight. He acknowledged that the dynamic nature of this challenge requires close collaboration between the FAA, industry, and research partners to establish the necessary policies and standards.

White Paper Publication Plan

Mike Politowicz, PhD | NASA

Dr. Politowicz discussed the plan for publishing a white paper series through NASA Technical Memorandums (TMs). This approach was selected to provide broad public availability and a structured review process. Under this approach, while the NASA TM format will be used for the cover pages, the main document content can have more flexibility. Once the paper is completed, it will undergo a review process. The review process will involve several layers of internal peer review through the Scientific, Technical, and Research Information for Valuable Employee Sharing (STRIVES) program before publication on the NASA server (as a Distribution A document). Dr. Politowicz noted that care will need to be taken regarding the use of photos and diagrams, as permissions or recreations may be required for any copyrighted materials.

Metrics Safety Case Modeling

Jay Shively | Adaptive Aerospace

Mr. Shively provided a brief status update on the m:N Multi-UAS Operations Evaluation Methodologies white paper. He stated the paper is approximately 75-90% complete, with the remaining work focused on ensuring consistent terminology and flow between the different authors' contributions. One key task is integrating the Interventions paper, led by Andy Thurling, into this overarching white paper. Mr. Shively noted the need to carefully consider the treatment of intervention time and service time concepts to maintain coherence. The goal is to have the white paper ready for internal reviews within the next month.

Data for Safety Cases

Mehrnaz Sabet | Cornell University

Radhika Bhopatkar | Purdue University

Katie Constant-Coup, PhD | Crown Consulting (Formerly FAA)

Ms. Sabet, Ms. Bhopatkar, and Dr. Constant-Coup presented an integrated framework for data-driven safety cases in m:N operations. The presentation emphasized the evolving nature of safety assurance and the need for methodologies tailored to m:N operational complexities.

The framework identified three core components essential for multi-UAS safety cases, as shown in the diagram in Figure 2:

1. Aircraft and Mission Safety: Includes performance indicators (e.g., system reliability, maintenance metrics), coordination efficiency, and interoperability between UAS platforms. For m:N scenarios, data collection extends beyond individual metrics to system-wide reliability and communication integrity.
2. Human Factors: Encompasses individual competencies (e.g., experience, workload, trust in automation), team-level dynamics (e.g., communication, flexible task signaling), and human-machine interactions. The assignment of roles between humans and automation layers must be explicitly defined and validated through data collection.
3. Environmental Hazards: Considers external factors like terrain, weather, airspace structure, and the operational environment of ground control stations and flight paths.

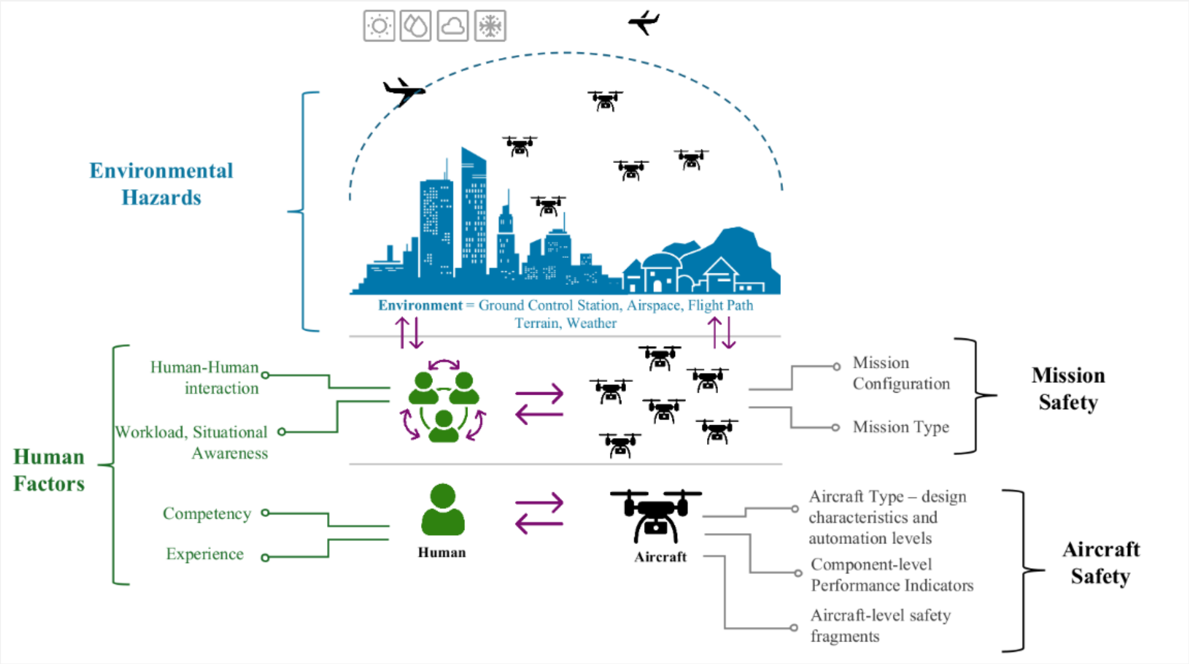


Figure 2: The key components to be included in a safety framework for multi-UAS operations, encompassing human factors, environmental hazards, and aircraft and mission safety.

The presenters emphasized the importance of integrating diverse data sources, including real-time monitoring, simulations, and sensor data, to capture both system-wide and component-level risks. Simulations were noted as crucial for testing scenarios in a risk-free environment but limited by the sim-to-real gap and the high cost of development. For m:N operations, simulations must account for communication breakdowns, tactical conflicts, and other points of failure.

A data-driven risk assessment was proposed to identify and address interdependencies between human-machine systems, including system-of-systems-level risks. The presenters highlighted the need for reliable data to validate safety in automation layers, especially in tasks like collision avoidance and real-time coordination, and to assess human operator performance during emergencies and high-stress conditions.

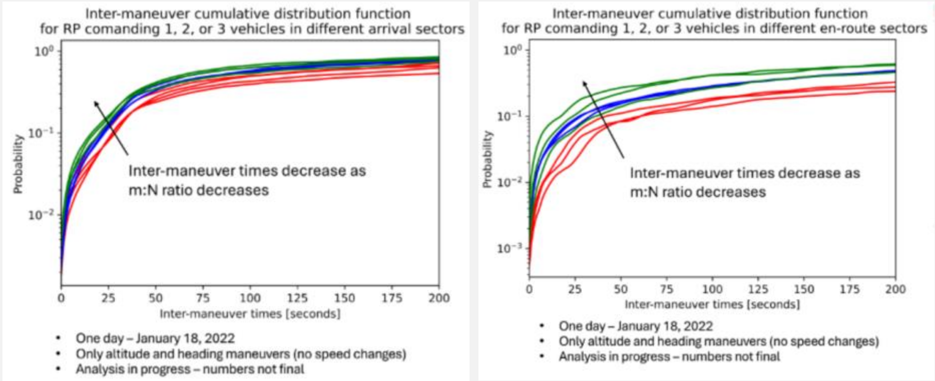
The presentation concluded with a call for feedback to refine the proposed framework and address challenges, including the complexities of automation integration and human-machine collaboration in m:N scenarios.

Modeling Inter-Maneuver Times for Multi-Vehicle Control

Husni Idris, PhD and Nadia Dimitrova | NASA

Dr. Idris and Ms. Dimitrova presented their work on modeling inter-maneuver times for multi-vehicle control, focusing on an autonomy framework with three key dimensions: task complexity, agent complexity, and environmental complexity.

The researchers analyzed the impact of remote-pilot task complexity using statistical modeling to study intervention and service times across various multi-aircraft supervision scenarios. Their preliminary analysis showed that inter-maneuver times were longer in the 1:3 supervision scenario compared to 1:1, indicating an increased workload for remote pilots as the number of supervised aircraft increased. The study also explored the nuances of inter-maneuver times across different phases of flight, such as arrival and enroute operations, and found these times to be shorter in arrival sectors. Preliminary results for arrival and enroute operations are shown in Figures 3 and 4 respectively, with inter-maneuver times shown as a function of probability.



Figures 3 (left) and 4 (right): Inter-maneuver times as a function of probability for arrival (Figure 3) and enroute (Figure 4) operations. The wider vertical spread in enroute operations suggests greater variability in inter-maneuver times in this phase when compared to arrival operations.

The presentation highlighted key metrics, including inter-maneuver times as proxies for task load and the role of thresholds to distinguish between attention, action, and communication tasks. The authors also discussed the challenges of accounting for nearly simultaneous events and emphasized the importance of incorporating cognitive factors into the modeling process.

The presenters sought feedback on refining the analysis to isolate the effects of different factors, particularly how to measure cognitive workload alongside physical task demands. Future efforts aim to validate inter-communication time metrics using audio recordings and expand the framework to include additional complexity metrics. These results will contribute to a deeper understanding of m:N crew management and inform applications in areas such as path planning and crew scheduling.

Interventions

Garrett Sadler | NASA

Mr. Sadler presented the work of the Exceptions/Interventions subgroup, which aims to develop a methodology or tool to quantify the level of safety for multi-vehicle operations. The subgroup focuses on dissecting exceptions rather than complete use cases to better understand the operational challenges of m:N configurations.

The subgroup has made progress on defining a taxonomy of exceptions and parameters that can be ingested into a machine-readable format. The ASTM WK76044 standard has been particularly useful in defining valid transitions between operational states and categorizing associated exceptions. For example, in the scenario depicted in Figure 5, a UAS experiencing a battery anomaly autonomously selects a safe landing area, and the operator approves the solution after strategic deconfliction.

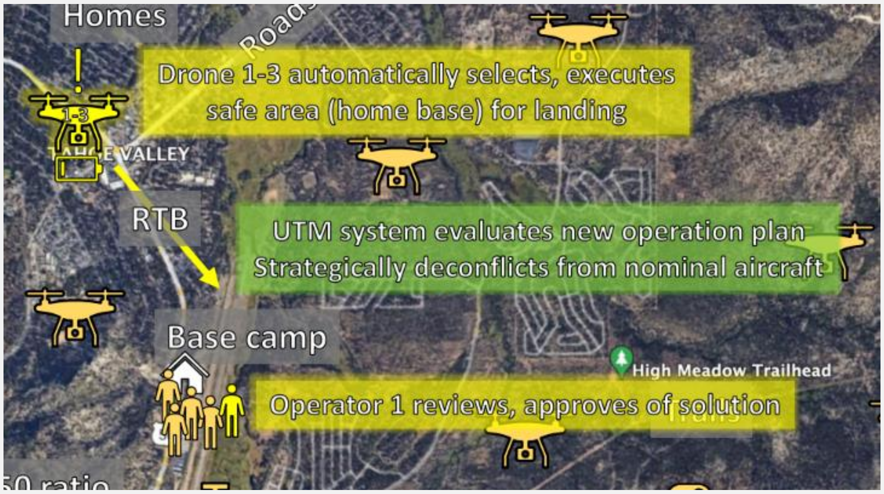


Figure 5: Illustration of an operator addressing a battery anomaly and approving a strategic deconfliction plan, showcasing the subgroup's focus on exceptions and state transitions.

The subgroup's work is guided by fundamental assumptions, such as the limited capability of operators for low-level control and the importance of a queuing strategy specific to the operation. Severity levels for exceptions are being defined, and efforts are underway to represent time budgets available before safety degradation. Additionally, the methodology incorporates transitions back to normal operations following exceptions. For instance, Figure 6 demonstrates how a system automatically lifts an incursion restriction and re-dispatches aircraft to their tasks after resolving the issue, ensuring operational continuity.

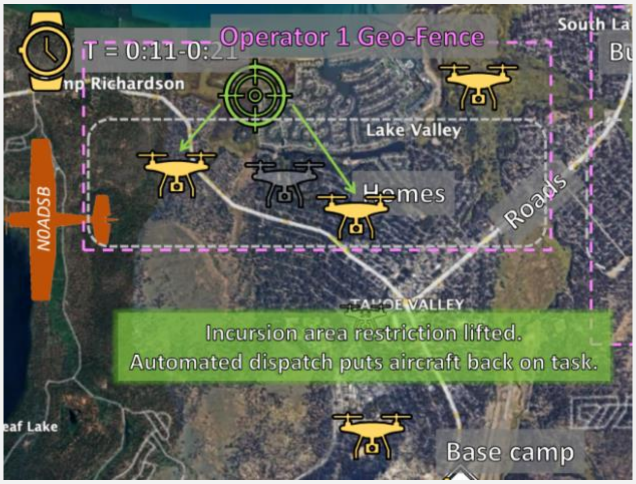


Figure 6: Following an aircraft incursion, restrictions are lifted and aircraft are automatically re-dispatched back to their tasks, illustrating the seamless integration of exception management with operational continuity.

Mr. Sadler emphasized that this methodology would allow sensitivity analyses of m:N configurations, enabling identification of exceptions that could be addressed differently to improve safety. The next steps include integrating the findings into the white paper and validating the tool's applicability through real-world scenarios and simulations.

Considerations for Airspace Integration Enabling Early Multi-Aircraft Operations

Andy Lacher | NASA

Mr. Lacher began by acknowledging the challenges of scaling the current air traffic control (ATC) system to accommodate multi-aircraft operations, especially as the industry moves beyond visual line of sight (BVLOS) operations. He noted that the FAA is expected to publish a Notice of Proposed Rulemaking (NPRM) on BVLOS operations in January 2025, with a final rule anticipated within two years. The new rule will likely designate airspace below 400 feet, or segments of Class G, as "low-risk" airspace, enabling specific unmanned operations.

The presentation outlined a strategic approach for integrating m:N operations that minimizes routine interactions with ATC by leveraging a "VFR-equivalent" mode of operation. This strategy would involve defining preapproved airspace areas using processes similar to the Low Altitude Authorization and Notification Capability (LAANC) system. These areas would allow autonomous operations while maintaining airspace accessibility for manned aircraft. Key elements of this strategic approach include:

1. Transitioning between single-aircraft (1:1) and m:N modes of operation, depending on the phase of flight and operational needs.
2. Utilizing a "conflict management framework" with strategic, tactical, and collision avoidance layers, similar to the International Civil Aviation Organization's (ICAO's) concept.
3. Leveraging LAANC-like systems to manage access to the defined airspace areas.

Mr. Lacher acknowledged the need to carefully define terminology, as terms such as "pilot", "operator", and "supervisor" have specific regulatory meanings. The group discussed the pros and cons of using more generic terms such as "multi-aircraft operations" or "multi-aircraft control/management/supervision" to avoid confusion.

The presentation also identified challenges requiring further analysis, such as:

- Defining functional requirements for m:N operations
- Understanding technology trade-offs
- Establishing principles for human operators akin to current "Aviate, Navigate, Communicate" protocols
- Developing operational environment upgrades, such as new surveillance methods, navigation precision, and automated ATC communication

The paper outlines several other approaches and challenges that require further analysis, such as the operational environment, communication with ATC, and key enabling technologies. Mr. Lacher emphasized that the intent is to share ideas, not represent a consensus, as the group works to develop a cohesive white paper.

Personnel Selection, Roles, & Training for sUAS

Scott Scheff | HF Designworks

Mr. Scheff's presentation focused on the evolving challenges pertaining to selecting, training, and defining roles for personnel operating small Unmanned Aircraft Systems (sUAS). As sUAS technology advances rapidly, organizations are grappling with how to identify the right people for these emerging roles and provide appropriate training.

Mr. Scheff noted that many first responder organizations, such as the Los Angeles Fire Department and Denver Police, are already leveraging sUAS, but their personnel selection and training processes tend to be ad-hoc. Common gaps include a lack of standardized training, particularly in managing cognitive workload and automation in multi-sUAS operations. Mr. Scheff emphasized the need to go beyond just sUAS operations skills and consider broader attributes like problem-solving, multitasking, and situational awareness. Additionally, there is a need for comprehensive training programs that cover topics specific to UAS piloting, such as cybersecurity and automation system, as depicted in Figure 7.

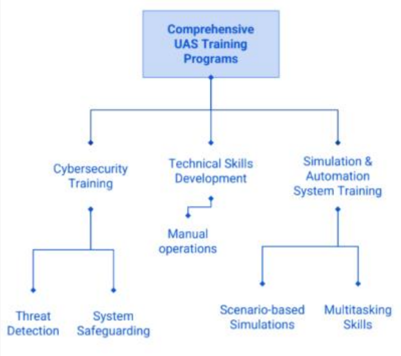


Figure 7: A Critical components and topics for a comprehensive UAS training program.

Additionally, Mr. Scheff highlighted the importance of clearly defining roles and responsibilities for sUAS operators, beyond just the operator. As depicted in Figure 8, role definitions drive personnel selection, training, and ultimately, operational readiness. As sUAS technology enables new concepts of operations, including single-operator control of multiple UAS, organizations need to rethink team structures and task allocation. This evolution requires a deeper understanding of workload management and automation integration.

Figure 8: The integral relationship between role definitions and personnel selection, training, and operational readiness.

Overall, Mr. Scheff's presentation underscored the critical importance of aligning personnel, roles, and training as sUAS capabilities continue to advance. Moving forward, he proposed developing baseline standards and principles to guide the development of comprehensive training programs that can evolve with the technology.

OCTOBER 23rd
OFF SITE, BRIEFINGS & DISCUSSIONS

Day two of the working group face-to-face meeting was focused on a morning off site to Wing facilities (both UAS operations in the field and the operations command center).

The afternoon consisted of additional briefings and discussions.

Off Site Demonstrations

Mark Blanks | Wing

Mr. Blanks organized multiple site visits for the m:N working group. Sites included both a Wing launch and recovery site (Figure 9), as well as a visit to Wing offices to observe a Wing Control Room and training center. In the control room all Wing related flight activities are monitored, highlighting Wing's automation and 1:N operations capabilities. The training center provided working group members access to Wing instructors and provided a Q&A forum allowing working group members to take a closer look at the user interfaces, learn more about training, and discuss the certification process for Wing working with the FAA.

Figure 9: Wing operations in progress.

Third-Party Services to Enable Airspace Integration

Fabrice Kunzi, PhD | SkyGrid

Dr. Kunzi discussed the role of third-party service providers in enabling airspace integration for UAS operations. These services are designed to provide critical ground-based capabilities such as traffic surveillance, hazard avoidance, validated aeronautical data, resilient navigation, and scheduling/planning/dispatch, without directly controlling the aircraft or pilot. The shift from government-provided services to private entities like SkyGrid marks a significant change in airspace management.

Kunzi emphasized that these services aim to inform and support pilot decision-making rather than replace their authority. However, regulating and approving these providers presents a significant challenge for the FAA, which lacks direct oversight of ground-based systems. Currently, FAA rules such as Part 107 and Part 135 guide UAS operations, but transitioning responsibilities to private entities raises concerns about data quality, reliability, and accountability between service providers and operators. The transition to private third-party service providers introduces critical differences between type certification and operational approval, as illustrated in Figure 10 (note figure provided and approved for use by SkyGrid).

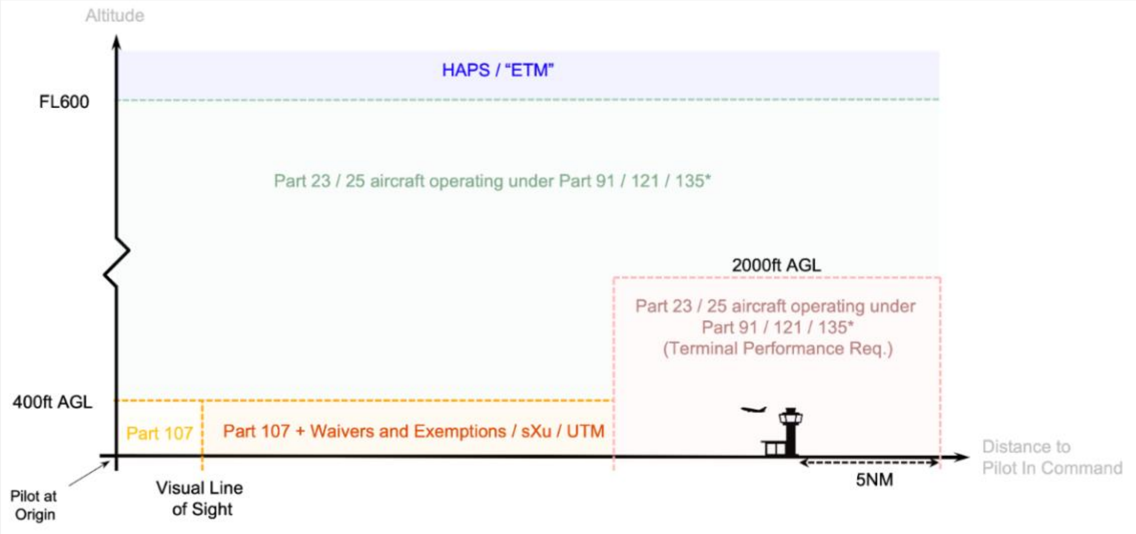


Figure 10: Target markets and key considerations for third-party service providers, including type certifications and operational approvals.

Dr. Kunzi compared the FAA's situation to the European Union Aviation Safety Agency's (EASA's) handling of third-party service providers in Europe, noting that privatizing FAA functions is politically and operationally complex. The FAA is exploring pathways to regulate and approve these entities, with Part 146 serving as a potential precedent. This regulatory framework could enable compliance for third-party providers by linking their services to operational rules, such as those defined under Parts 91, 135, or the forthcoming Part 108.

The presentation highlighted the critical role of data providers and third-party services in facilitating m:N operations, where one operator oversees multiple UAS. This ecosystem would require clear approval processes, standards for data reliability, and accountability mechanisms. An example cited was the FCC's work on datalink interference standards, which, while not directly under FAA jurisdiction, illustrates the importance of regulatory frameworks in managing emerging technologies.

Dr. Kunzi concluded by stressing the importance of developing policies and technical standards to support the safe and efficient integration of third-party services into UAS airspace operations. As the FAA moves toward broader UTM implementation, the approval and oversight of these providers will be pivotal to the success of multi-aircraft operations.

FAA AI Roadmap

Trung Pham, PhD | FAA

Dr. Pham discussed the FAA's efforts to develop a roadmap for certifying AI technologies in aviation. The FAA is taking a consensus-based, collaborative approach with industry to map out a path for product approval and certification of AI systems. As illustrated in Figure 11, the roadmap, expected to be published in August 2025, focuses on safety as the top priority and outlines principles such as differentiating between "learned AI" that cannot continue learning after training versus "learning AI" that can adapt during operation.

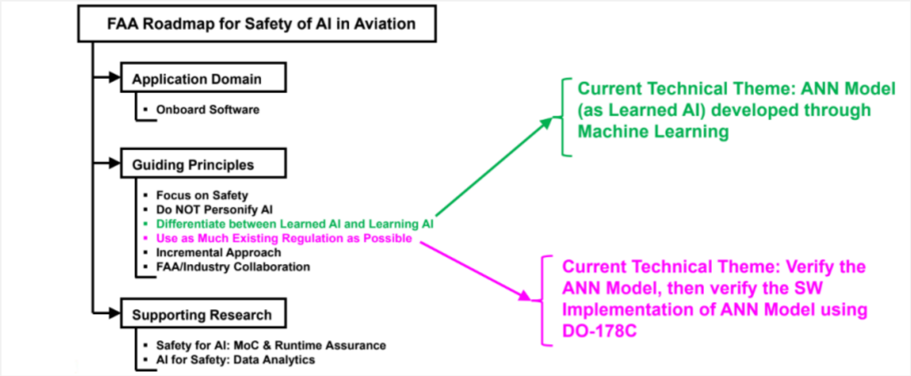


Figure 11: FAA's roadmap for certifying AI technologies in aviation, outlining the key domains of application, guiding principles, and supporting research efforts.

The FAA aims to avoid unnecessary reinvention by leveraging existing regulations, such as those defined in DO-178C, and is employing an incremental approach beginning with lower-criticality AI applications. Challenges highlighted include defining AI's role in aviation, verifying and validating learned models, and ensuring compliance through established software assurance frameworks. The roadmap stresses that AI should be treated as an engineering component, not as an intelligent being, to focus on practical, measurable outcomes.

The FAA is currently developing technical concept papers, including methods for verifying learned AI models and their software implementations, and exploring ways to extract specifications from AI training data for use in traditional assurance processes. Supporting research includes analyzing training data to identify embedded engineering characteristics and using computational tools including large language models (LLMs) to detect accident precursors in aviation safety data.

The FAA is collaborating with industry, government agencies, and regulatory bodies such as EASA to align on standards for AI assurance. This effort also includes joint participation in international forums to foster a unified understanding of AI safety in aviation. Looking forward, the agency plans to document use cases to demonstrate the practicality of its framework and anticipates publishing technical papers by mid-2025.
The presentation also emphasized that while AI has transformative potential, it requires realistic expectations and clear guidelines to ensure its effective and safe deployment in aviation systems.

Meaningful Human Control of AI Based Systems

Jay Shively | Adaptive Aerospace

Mr. Shively discussed the concept of meaningful human control (MHC) over AI-based systems, emphasizing MHC's critical importance in ensuring that human operators maintain authority over autonomous technologies. MHC was first proposed during a 2016 United Nations meeting of experts and focused on autonomous weapons. Since then, MHC has been refined through a 3-year NATO Science and Technology Organization (STO) study under the Human Factors and Medicine Panel (HFM 320).

The need for MHC arises from concerns that AI systems could make moral or ethical decisions that require human compassion and intuition. Mr. Shively then went on to provide historical and hypothetical examples, such as Stanislav Petrov's life-saving decision during a nuclear false alarm in 1983 and the ethical dilemmas faced by autonomous military technologies. These scenarios underscore the limitations of AI in addressing nuanced, human-centric judgments.

Mr. Shively defined MHC as "the ability of humans to make informed choices in sufficient time to influence AI-based systems in order to enable a desired effect or to prevent an undesired immediate or future effect." This definition raises questions about whether real-time human input is always necessary or if working agreements or advanced directives could suffice under specific conditions.

The NATO HFM 320 study developed guidelines for responsible AI use, focusing on principles such as lawfulness, responsibility/accountability, explainability/traceability, reliability, and governability. However, achieving explainability and traceability in AI remains a significant technical challenge, particularly when AI systems are embedded within larger, complex systems.

Mr. Shively highlighted examples from human factors programs, including MANPRINT (Manpower and Personnel Integration) in the Army and FDA requirements for medical devices, as frameworks for maintaining human oversight. He advocated for embedding humans within the "system of systems" AI increasingly operates in; ensuring that operators can understand and influence AI decisions.

The presentation concluded with actionable steps to enhance MHC, including mapping AI's role within systems, examining decision traceability, and developing worst-case scenarios to evaluate human-AI interactions. Mr. Shively noted that these efforts are critical to addressing the ethical and operational challenges posed by the growing reliance on AI technologies.

FAA Certifications

Tim Beglau | FAA

Mr. Beglau discussed the FAA's work on certifying Part 135 operations for UAS deliveries. Currently, five companies have Part 135 certifications for UAS operations including: Wing, Zipline, UPS Flight Forward, Amazon, and Causey Aviation Unmanned. These operations are all conducted under 400 feet AGL and involve remotely piloted aircraft; with some operating under Instrument Meteorological Conditions (IMC). Figure 12 illustrates the different operational setups currently employed by UAS operators under Part 135 certifications, including the operator's location, pilot station type, pilot-to-vehicle ratios, detect and avoid (DAA) systems, and weather conditions for each operational scenario.

Operator	Pilot Station	Ratios above PIC:UA	DAA	Weather
1	Remote in same state	1:16	VOs and ADS-B	VFR, Day
2	Co-located	1:4	ADS-B/Onboard Camera	VFR, Day
3	Remote In different state	1:6	Onboard ADS-B/Acoustic	VFR, Day/Night

Figure 12: Current state of UAS operations under Part 135 certifications. The chart outlines operator locations, pilot-to-vehicle ratios, detection and avoidance systems, and weather conditions across different operational setups.

Mr. Beglau emphasized that the FAA must grant exemptions to accommodate these operations, as existing 14 CFR regulations were not designed with UAS in mind. Exemptions address operational and airworthiness requirements, including those related to pre-flight and in-flight duties, multiple takeoff and landing locations, and the use of DAA systems. The FAA is also progressing with BVLOS rulemaking (Part 108), which will eventually provide a more comprehensive framework for these operations.

Key challenges include managing pilot-to-vehicle ratios and ensuring operators can validate their ability to safely manage higher ratios, such as transitioning from 1:8 to 1:16. The FAA closely monitors pilot interventions to assess operational safety and efficiency. For example, operators must demonstrate safe management of contingencies like ATC reroutes, unexpected weather, and system failures involving hardware, software, or communication links.

Mr. Beglau also highlighted that some UAS operate under Instrument Meteorological Conditions (IMC), relying on advanced DAA systems like ADS-B, acoustic sensors, and onboard cameras. These systems play a critical role in maintaining safe operations and minimizing risks in both controlled and uncontrolled airspace.

Finally, the FAA's role in approving third-party UAS Traffic Management (UTM) service providers was discussed. This approval process, separate from aircraft certification, ensures that operators can integrate UTM systems into their Part 135 operations. The FAA evaluates each UTM system to ensure compliance with regulatory and operational requirements, providing a foundation for scaling UAS delivery operations safely and efficiently.

Zipline Airspace Integration

Joshua Gordon | Zipline

Mr. Gordon provided a comprehensive overview of Zipline's advancements in UAS-based instant delivery; particularly in airspace management and safe integration. Zipline is a UAS delivery company with over 8 years of operational experience across three continents. Zipline has two main delivery platforms - Platform 1 (P1) which is a fixed-wing drone capable of 200-mile flights; and the more precise Platform 2 (P2) which delivers packages via a tethered UAS that descends to around 300 feet. The P1 delivery platform is depicted in Figure 13; flight launch, en route, and package delivery is shown.

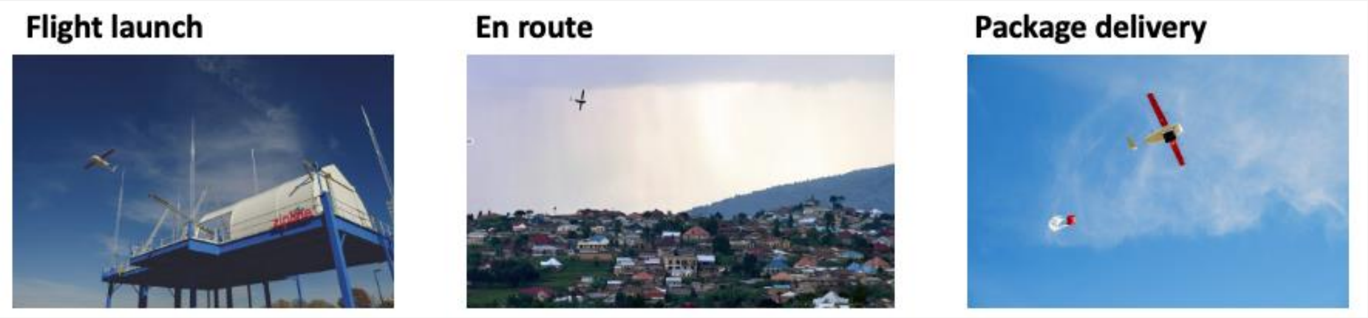


Figure 13: The P1 delivery platform as shown in the flight launch, package delivery, and zip recovery stages.

Mr. Gordon discussed the advanced safety measures integrated into Zipline’s operations, including the use of "keep out zones" around sensitive areas and robust DAA capabilities. The P1 platform uses acoustic sensors to detect intruders, while the P2 utilizes both acoustic and vision-based DAA. Zipline also works closely with UTM (Unmanned Traffic Management) service providers to coordinate operations and deconflict airspace. An example of Zipline’s UTM interface is shown in Figure 14.

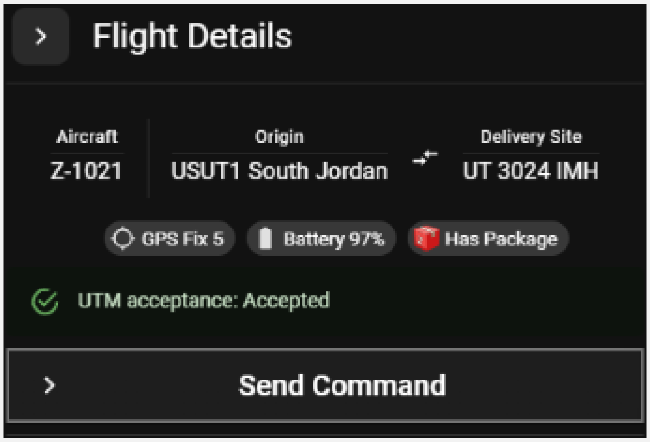


Figure 14: A screen capture of the Zipline UTM interface.

Mr. Gordon also talked about garnering community acceptance, stating one aspect of Zipline's approach is their emphasis on community engagement. Zipline organizes public events in new operating areas to inform and educate communities while addressing potential concerns.

The presentation also went into technical details on Zipline's DAA and UTM integration processes. During operations, the Zipline system automatically responds to potential conflicts, such as maneuvering to avoid intruding aircraft. The pilots have a set of predefined commands they can issue, but the system is largely autonomous. Zipline also simulates a variety of scenarios to train their operators and validate the system's responses.

OCTOBER 24th
BRIEFINGS, DISCUSSIONS, FAA TOUR

Day three of the working group face-to-face meeting was focused on continued briefings and discussions, as well as a tour of the FAA facility.

NASA Study: Interruptions in Multi-Vehicle Supervision (DRACO)

Eric Chancey, PhD and Mike Politowicz, PhD | NASA

The DRACO study is part of the RAM (Resilient Autonomy for Multi-vehicle) subproject, grounding basic research in practical applications for human-autonomy teaming (HAT). The objective is to examine the impact of interruptions on situational awareness (SA) in highly automated multi-vehicle operations, where a human operator is responsible for supervising and monitoring multiple autonomous systems. The relationship between interruptions and attention is shown in Figure 15, where an operator shifts focus between an ongoing task (OT) and an interruption task (IT) until they either complete the interruption or choose to return to the ongoing task (Wickens & Carswell, 2021).

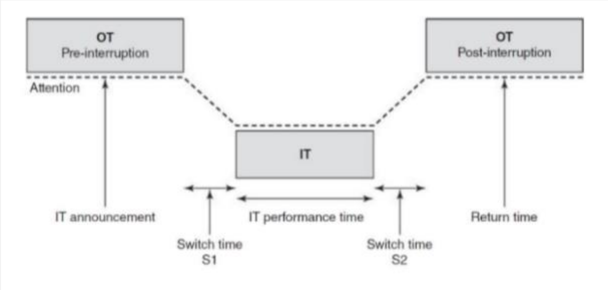


Figure 15: Depiction of the interplay between ongoing tasks (OT) and interruption tasks (IT), highlighting the operator's need to shift attention between tasks based on task completion or prioritization (adapted from Wickens & Carswell, 2021).

Dr. Chancey and Dr. Politowicz explained that the traditional "golden ratio" approach to scaling multi-vehicle supervision is problematic, as the ideal ratio depends on many contextual factors. The key issue is the division of responsibility and authority between the human operator and the automated systems.

Their study is using a within-subjects experimental design, where participants (Part 107 remote pilots or private pilots) monitor a multi-vehicle simulation and respond to periodic SA assessment probes. Interruptions are introduced at varying frequencies to examine their impact on the participants' ability to maintain situational awareness. This task progression is illustrated in Figure 16.

Figure 16: Visualization of the DRACO study task progression, depicting participants monitoring a multi-vehicle simulation, responding to situational awareness probes, and managing interruptions introduced at varying frequencies.

The primary dependent measure is the Situation Awareness Global Assessment Technique (SAGAT), which assesses the participant's comprehension of the current state (Level 1 SA), understanding of the near-term future (Level 2 SA), and ability to project future states (Level 3 SA). Eye tracking data is also collected as a accompanying measure.

In addition to the interruption task, participants also complete a spatial N-back task to induce working memory load. The researchers hypothesize that frequent interruptions will degrade the participants' SA, and that higher working memory load will exacerbate this effect.

The presenters discussed some of the challenges in the experimental design, such as ensuring the SA assessment questions are appropriately calibrated and determining how to handle "ramp up" time for participants to regain SA after an interruption. They acknowledged the tension between ecologically valid scenarios and experimental control.

The goal of the DRACO study is to provide empirical data to guide the design of future multi-vehicle supervision systems, informing guidelines for appropriate levels of automation, human monitoring responsibilities, and strategies for mitigating the detrimental effects of interruptions on situational awareness.

NASA Study: High Complexity Multi-Vehicle Simulation

Garrett Sadler and Meghan Saephan, PhD| NASA

The presentation discussed two NASA projects focused on high-complexity simulations for UAM operations, emphasizing the central concept of High Complexity Human In The Loop (HITL) simulations. These simulations are shaped by three key factors: complex environments, complex operations, and complex capabilities.

The first project is the DRACO study, planned for early spring 2025 in cooperation with researchers at NASA Langley. The objective of the DRACO study is to investigate system-level effects and disruptions on vertiports and assess system resilience through HITL simulations with multiple UAM operators. This study will use a 3x2x2 mixed-subjects design to examine variables such as the scale of vertiport disruption (low, medium, high), operator-to-vehicle ratio (2:6, 2:12), and the presence or absence of corridor-based airspace assumptions. An example of a high-disruption scenario is shown in Figure 17, where thunderstorms cause the temporary closure of multiple vertiports.

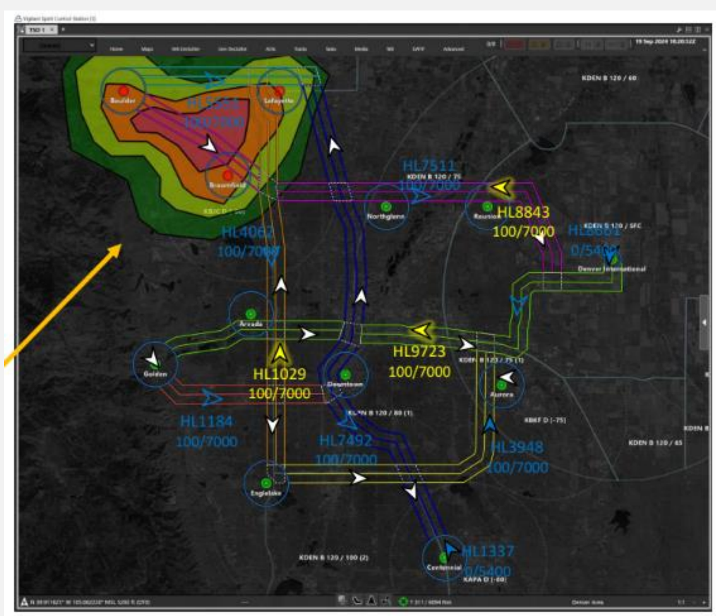


Figure 17: Worsening weather in the northwest quadrant causes temporary closures in a scenario with three or more vertiports in this scenario.

The second project, T3, is a HAT (Human-Autonomy Teaming) study that explores the relationship between human operators and autonomous systems; with a focus on augmenting human performance. This research aims to test and enhance the safety and efficiency of UAM operations within the National Airspace System (NAS). The project draws on HITL simulation research conducted at NASA Ames and emphasizes a "teammate" dynamic between humans and autonomous systems.

Both studies aim to assess the cascading effects of disruptions on capacity, efficiency, and resilience at hypothetical vertiports. Metrics for these simulations will include capacity impacts, mission cost increases, recovery rates, and human performance measures such as workload and gaze patterns. Airspace in the simulations will include controlled corridors with defined dimensions and paths.

The project team plans to consult industry partners on the simulation design, run the study in early 2025, and explore opportunities for incorporating autonomous agents or AI to assist operators in managing contingencies. This research aims to advance the understanding of high complexity UAM operations, system resilience, and the role of human-autonomy teaming in addressing disruptions.

Industry Forum

Chad Healy | Reliable Robotics
Joshua Gordon | Zipline
Mark Blanks | Wing
George Gorospe (Moderator) | NASA

The industry panel discussed the current and future challenges of integrating automation into aviation, particularly within the National Airspace System (NAS). The panelists, which included representatives from Reliable Robotics, Zipline, and Wing, highlighted the evolution of industry practices and the need to articulate counterproposals to drive industry-wide progress. The panel discussion was moderated by George Gorospe from NASA.

A key theme was the importance of measuring the right factors and using appropriate tools to assist regulators in evaluating automation. The panelists emphasized the need to focus on the right processes and metrics, rather than just the number of aircraft. They argued that measuring workload and situational awareness (SA) correctly is crucial for the success of automation integration.

The discussion also addressed the role of humans in highly automated systems. While acknowledging that human error causes 80% of accidents, the panelists stressed that humans should not be eliminated, but rather leveraged to handle critical tasks. Panelists explored the unique challenges posed by scaling operations, such as the impact on human-automation interactions, latency in communications, and lost links for large UAS.

The panel also shared insights on the future of aviation certifications and training, discussing how to better prepare professionals, including Remote Pilots-in-Command (RPICs), to handle the new tasks created by automation. Panelists explored potential recruitment pipelines, focusing on decision-making skills, and the potential of other aviation roles such as dispatchers, for RPIC training.

Throughout the discussion, the panelists emphasized the importance of academic and industry collaboration to address the challenges of scaling automation and improving human factors in aviation. This included task analysis, the evolution of certifications, and the continuous adaptation to the rapidly evolving field.

Key discussion points included:

- Measuring workload and SA correctly for automation success

- The shift toward more automation in operations, with a focus on lightweight, low-severity tasks
- Challenges of scaling from 1:1 operations to multiple operators (m) controlling multiple vehicles (N) and integrating more autonomy in systems
- Importance of maintaining human engagement in automated systems, particularly for pilots and operators
- The need to evolve the regulatory environment to keep pace with technological advancements while maintaining safety

Overall, the industry forum highlighted the complex and multifaceted challenges of integrating automation into aviation, while emphasizing the critical role of human factors and the need for ongoing collaboration between industry, academia, and regulators.

Government Forum

Tim Beglau | FAA
George Gorospe | NASA
Andy Lacher | NASA
Mike Politowicz | NASA
Jordan Sakakeeny | NASA
Summer Brandt | NASA
Scott Scheff (Moderator) | HF Designworks

The Government panel discussion centered on integrating automation and autonomy into the NAS, with an emphasis on collaboration across government, industry, and academia. The panel featured representatives from the FAA, NASA, and industry, moderated by Scott Scheff from HF Designworks.

Tim Beglau of the FAA shared his passion for UAS and insights into the evolution of remote pilot training and certification, including the FAA's Part 107 rules. Panelists highlighted challenges in the rulemaking process, especially for paradigm shifts like m:N operations, which demand both patience and collaboration. George Gorospe, NASA's technical lead for Autonomous Systems, underscored NASA's commitment to long-term investment in autonomy, explaining how NASA collaborates with industry and academia to proactively tackle emerging issues.

Jordan Sakakeeny from NASA's Pathfinding for Airspace with Autonomous Vehicles (PAAV) program discussed the potential for increasingly autonomous aviation to improve access to medical resources and fresh food in underserved areas. Integrating new technologies like large UAS and eVTOL into the NAS presents complex challenges that require careful planning.

Summer Brandt from NASA highlighted her group's focus on system-wide safety, including the development of proactive, data-driven safety management systems. One of her efforts, the Safety Demonstrator series, aims to pinpoint hazards and establish standards to assess and mitigate risks, especially in disaster response, such as hurricane relief and recovery, as highlighted in Figure 18.

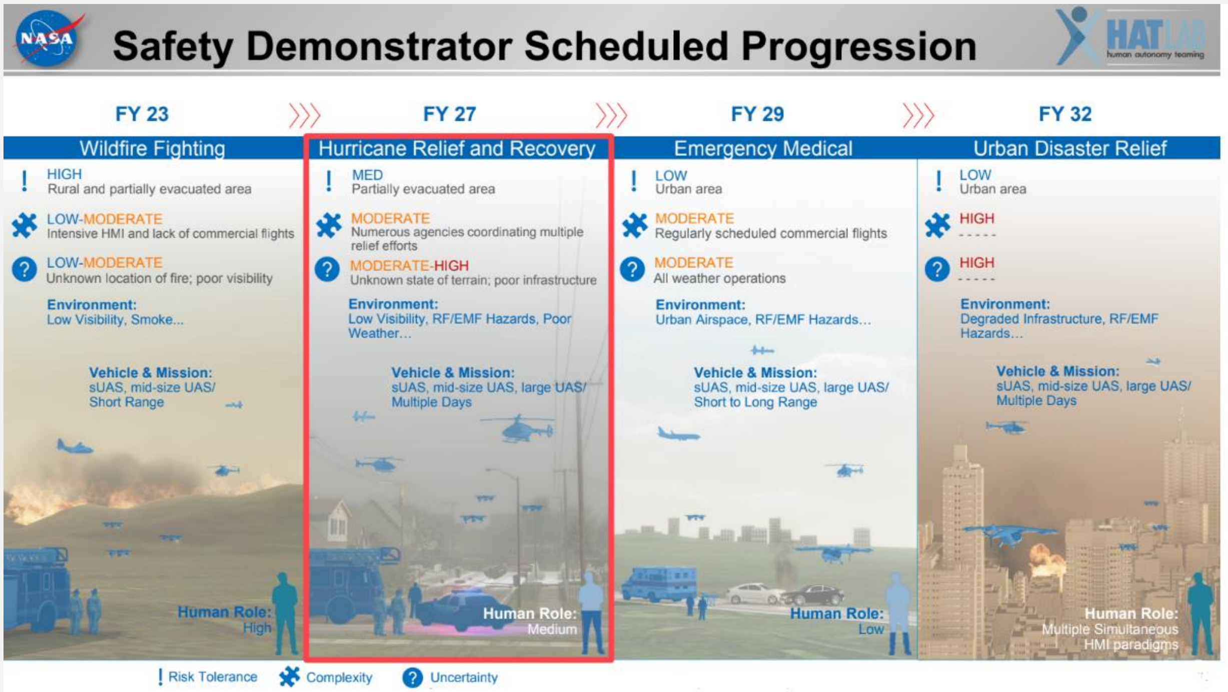


Figure 18: Various emergency response cases scheduled for the Safety Demonstrator series, along with their associated risk tolerance, complexity, uncertainty, and human involvement levels.

The panel also emphasized the value of collaboration among government, industry, and academia; and the need for effective data sharing, insights, and best practices. Panelists suggested expanding industry involvement, particularly from eVTOL companies, to address certification and integration challenges. Effective communication of the forum's value to industry participants was seen as essential, as their engagement is crucial to successful collaboration.

Key points discussed in the government panel include:

- Regulatory challenges and opportunities, including FAA Part 107 rules and remote pilot training and certification
- NASA's investment in autonomy and its role in addressing emerging challenges through partnerships
- Using autonomous aviation technologies such as large UAS and eVTOL to expand access to resources in underserved regions
- NASA's system-wide safety work, focusing on proactive, data-driven safety management
- Value of knowledge sharing and collaboration across government, industry, and academia
- Importance of broader industry involvement and effective communication of these forums' values and findings

Closing Remarks

Jay Shively | Adaptive Aerospace

Jay Shively's closing remarks discussed how best to wrap up the group's white paper. Mr. Shively emphasized the commitment to a thoughtful, quality approach. Mr. Shively also acknowledged that while there is a lot of good work that has been done in the white paper thus far, there was still some additional work required before the paper could be completed. Closing remarks also highlighted the importance of addressing specific exceptions, examples, and challenges within the paper as well as the need to maintain momentum to complete the paper. A final note of gratitude was extended to all members for their contributions and participation.

FAA Demonstrations

Tim Beglau | FAA

At the conclusion of the meeting, participants were able to tour the FAA's Regional Operations Center (ROC). The ROC is a command and control system for the FAA and handles the reporting of significant events and outages. This includes the ability to report time-critical events. Examples of events that would get reported include known and suspected accidents, aircraft incidents, emergency aircraft evacuations, inflight major component failures; as well as incidents that threaten or cause damage or injury to property, aircraft or people. The tour included viewing the ROC, observing personnel working within the ROC, and speaking with the ROC manager.

Next Steps

Next steps include each subgroup completing their whitepapers and combining them into a larger document summarizing the progress of the entire m:N working group over the past year. The sUAS WG has completed its whitepaper and has submitted that whitepaper to NASA for review and public approval.

Also note that this meeting represented the final face-to-face with Jay Shively at the helm. Jay will be retiring at the end of this year. Samantha Emerson of Aptima will be assuming Jay's duties and will continue the working group's efforts through 2025.

For additional information, or to join the m:N working group or its subgroups, please reach out to the individuals listed below.

m:N Working Group
Jay Shively jshively@adaptiveaero.com
Samantha Emerson semerson@aptima.com

m:N WORKING GROUP

A central goal of this working group is to bring together a broad collective of interested stakeholders from government, industry, and academia to identify and reduce barriers to m:N operations, an operational configuration that envisions a ratio of multiple operators (m) controlling multiple vehicles (N) between them. Barriers addressed by this working group are considered across a variety of multi-vehicle control contexts and form the bases for future research to confront operational, technical, and regulatory gaps.

https://nari.arc.nasa.gov/ttt-ram/multi-vehicle

Appendix A: Attendee List (October 2024)

Andy Lacher	NASA Langley Research Center
Barry Sullivan	NASA
Benjamin Hargis	NASA
Bryan Petty	NASA
Chadwick Healy	Reliable Robotics
Elliot Biltekoff	NASA
Eric Chancey	NASA Langley
Fabrice Kunzi	Avidyne
Faisal Omar	NASA
Garrett Sadler	NASA Ames
George Gorospe	NASA Ames
Husni Idris	NASA
Jay Shively	Adaptive Aero Group
Jonathan Nguyen	NASA
Jordan Sakakeeny	NASA
Josh Gordon	Zipline
Kara Orvis	Aptima
Marc Compere	Embry Riddle Aeronautical University
Mark Blanks	Wing
Mike Politowicz	NASA Langley
Nelson Brown	NASA
Pham Trung	FAA
Radhika Bhopatkar	Purdue University
Runbo Guo	NASA
Samantha Emerson	Aptima
Sang Xing	Embry-Riddle Aeronautical University
Scott Scheff	HF Designworks
Siena Whiteside	NASA
Srikanth Gururajan	Saint Louis University
Summer Brandt	NASA Ames
Sun Liang	Baylor University
Timothy Beglau	FAA-AFS-740
Timothy Bleakley	General Atomics
Will Stavanja	DroneUp
Yuki Niwa	PwC Japan