AIA Task Force on Autonomy (TFA)

Introduction

With over a century of leadership in global aviation, the United States' next chapter of aviation history is currently being developed by the autonomous aviation sector. This emerging sector will enable and advance the utility of and access to aviation, as well as enhance safety. Autonomous aviation can be used for a range of applications, including cargo delivery, humanitarian missions, and passenger transport.

The United States already leads in military uses of autonomous aviation, and that is likely to continue. However, to retain its broader aviation industry leadership, the U.S. civil aviation policy and regulatory landscapes must evolve to meet the opportunities of the future. The current regulatory and policy environments were not created with autonomy in mind and if not properly adapted, present barriers to autonomous operations that will delay its benefits. For the United States to remain broadly competitive, it must adopt a civil aviation regulatory system that accommodates autonomy within a framework designed to both ensure safety and facilitate innovation. Without this change, the United States will quickly fall behind, cede its historical position of thought and institutional leadership in aviation, and be in a situation of trying to catch up with the rest of the world.

U.S. AUTONOMOUS AVIATION REPRESENTS:

- Enhanced safety
- Future global aviation leadership
- Technical advancement
- Transportation concept development and realization
- Environmental benefits through more efficient route planning/execution and by enabling new electric aircraft architectures
- Economic growth across a spectrum of direct and indirect drivers

The Aerospace Industries Association (AIA) created a **Task Force on Autonomy** to bring U.S. industry together to promote this new technology and shepherd in an era of more accessible, affordable, and equitable flight — ultimately sharing the benefits of improved mobility to more citizens across the United States.

- The **goal** of AIA's TFA is to ensure the United States remains the leader in civil aviation innovation and integration.

- The **method** to achieve that goal will be through a single, unified voice of civil aviation industry stakeholders.

- Anticipated **activities** for the TFA include engaging in research and development, policy, regulatory, advocacy, stakeholder engagement, and thought leadership efforts to achieve its goal. Members of the TFA will work together to shape the regulatory framework needed to unlock the next revolution of flight in the United States.

Autonomy

What is it?

The concept of "autonomous aviation" often finds itself entangled at the intersection of interpretations, perspectives, and opinions. The TFA has distilled these into a central theme: "Autonomous aviation" is easier understood as a *spectrum* of capabilities (and an associated timeline) more so than a specific endpoint or goal. Examples of this can be found throughout today's latest thinking on advanced air mobility, such as the AIA/Avascent report "Continuing to Think Bigger" (figure 1 below).

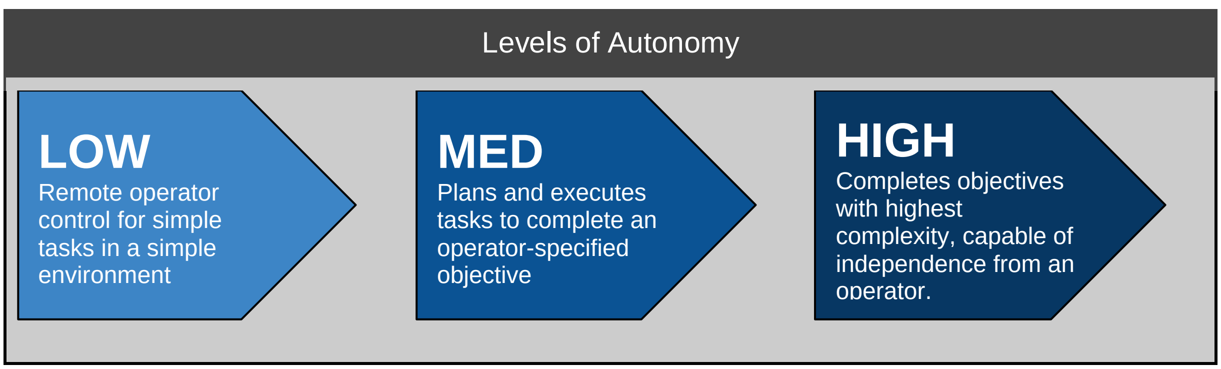

Figure 1 - Source: Continuing to Think Bigger, AIA & Avascent 2022

To further articulate this definition of autonomous aviation as a spectrum, consider that today, the latest generation of transport category aircraft contain some functions that are performed automatically within flight control systems that cannot be disabled by the onboard pilot, this is rightly called "autonomy". Consider also that almost all uncrewed aircraft are either remotely piloted, controlled by an operator, or perform pre-programmed tasks, which include even more autonomous functions in the autopilot and navigation functions. Over time, the number of functions that are fully autonomous and the sophistication of that autonomy will continue to grow. This will eventually lead to uncrewed systems that can fly without human inputs or pre-programmed instructions, which represent an end of the spectrum of autonomy. Advances in machine-learning algorithms, though they require a new approach to software certification, are central to this growth in capability.

The path through an autonomous spectrum will be driven by what has always driven progress in aviation: an economically motivated business case that considers safety as the number one priority. The operational control that humans exercise over aircraft will always be in place, but new roles and responsibilities will develop. Communications, cybersecurity, collision-avoidance technology, avionics, and sensors are among the crucial solutions that play a role in autonomy becoming central to aviation.

Additional definitions on autonomy are included in Appendix 1.0.

How much autonomy are we using today? Where?

A high degree of autonomy — in which aircraft can operate with limited human supervision — is a critical enabler for the widespread usage of uncrewed aircraft of all sizes across a multitude of sectors. With crowded airspace and ever-changing conditions, aircraft must quickly detect and avoid potential hazards, coordinate with others in the airspace, reroute around deteriorating weather, and flexibly navigate airport taxiways. In addition to performing these functions, an autonomous aircraft has the advantage of incorporating aviation's collective best practices and lessons learned - increasing the overall safety of flight operations. The ability for an aircraft to do this effectively on its own requires new technology to be developed and certified, but operationally, this is not as big of a paradigm shift as most people assume. Many commercial aircraft operations today occur with little or no interaction with ATC or other airspace users, for example, low level inspection and agriculture flights under VFR. Over time greater confidence will be gained among pilots, air traffic controllers, operators, and the public, which will facilitate greater integration with dense and complex airspace such as around major airports. While earlier versions of large uncrewed aircraft will continue to rely on fewer autonomous capabilities, U.S. leadership in aviation requires building scale in the market through establishing confidence and demonstrating performance necessitates what will appear to an outside observer to be real-time, automated decision-making similar to a pilot under VFR today.

In general, this spectrum of autonomous aviation ranges from "increased automation" to "fully autonomous." The AIA/Avacent "Continuing to Think Bigger" report[1] articulates the individual elements of what this spectrum includes, so this document will not repeat those here. The TFA encourages the reader to leverage this AIA/Avascent report to obtain a deeper understanding of the "spectrum of autonomy."

In addition to AIA's efforts, ASTM International has conducted extensive research on autonomy resulting in the following three Technical Reports[2]:

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[1] https://www.aia-aerospace.org/report/aia-avascent-report-autonomous-aircraft-market/

[2] https://www.astm.org/products-services/standards-and-publications/technical-reports.html

1. TR1-EB Autonomy Design and Operations in Aviation: Terminology and Requirements Framework
2. TR2-EB Development Pillars for Increased Autonomy for Aircraft Systems
3. TR3-EB Regulatory Barriers to Autonomy in Aviation

In TR2-EB , the following conceptual steps for automating functions are introduced in Figure 2.

Figure 2 - Source: ASTM TR2-EB Development Pillars for Increased Autonomy for Aircraft Systems

The report goes on to lay out the conceptual "buildup" from piloted, human-centric operations to automation-centric operations, shown below in Figure 3.

Buildup Progression →

Phase (Mission Task)	Key Functions	Current Part 91	Current UAS	Step A	Step B	Step ••••	Step ••••	Step ?
All Phases	Contingency	Pilot	Pilot	Pilot	Pilot	Pilot	Pilot	Auto
Preflight	Flight Plan	Pilot	Pilot	Pilot	Pilot	Auto	Auto	Auto
Preflight	Walk Around	Pilot	Pilot	Pilot	Pilot	Auto	Auto	Auto
Ground Ops	Taxi	Pilot	Pilot	Pilot	Auto	Auto	Auto	Auto
Takeoff	Takeoff	Pilot	Pilot	Pilot	Auto	Auto	Auto	Auto
En route	Aviate	Pilot	Pilot	Auto	Auto	Auto	Auto	Auto
En route	Navigate	Pilot	Pilot	Pilot	Auto	Auto	Auto	Auto
En route	Communicate	Pilot	Pilot	Pilot	Pilot	Pilot	Auto	Auto
En route	VFR- Like Separation	Pilot	Pilot	Pilot	Pilot	Pilot	Auto	Auto
Approach	Approach	Pilot	Pilot	Pilot	Pilot	Auto	Auto	Auto
Approach	Missed	Pilot	Pilot	Pilot	Pilot	Auto	Auto	Auto
Landing	Landing	Pilot	Pilot	Pilot	Pilot	Pilot	Auto	Auto

Figure 3 - Source: ASTM TR2-EB Development Pillars for Increased Autonomy for Aircraft Systems

This operational buildup is one way of implementing the functional breakdown technique that was outlined in TR1-EB. Along with terminology, TR1-EB lays out a framework by which requirements for autonomy in aviation can be tailored more finely than what is traditionally possible with overarching "levels of autonomy."[3] Tailoring requirements for autonomous and highly automated systems allow a function or task-level assessment of where on the spectrum that particular system falls, rather than taking a one-size-fits-all approach for the entire aircraft. This allows for operational context, risk-vs.-benefit tradeoffs, the role of the automation (including the human(s) role), system complexity or maturity, and other key factors to be considered in a tractable fashion. For any given function or task, the role of the on-board system, remote system, and on-board human can be defined. Ultimate authority must always be defined, but by parsing out the performance of that function between the various actors in the system (for both nominal and off-nominal operations), a more nuanced picture of who or what is performing a task becomes clear. For each of those functions, and the system(s) or human(s) performing them, appropriate requirements can then be determined.

There are a variety of examples of functional breakdowns provided in the Appendix B of TR1-EB. One of the most straightforward and widely known examples is the Deconstructed Pilot from General Aviation Manufacturers Association's (GAMA) Electric Propulsion and Innovation Committee (EPIC):

- Planning & Decision-Making
- Systems Management
- Basic Airmanship
- Takeoff & Landing
- Terminal Procedures
- Navigation
- Communication
- Detect and Avoid (DAA)
- Emergency Procedures

The TFA would encourage the use of functional decomposition to provide a modular path for autonomy requirements to be developed, implemented, and certified. Specific functions can be certified to perform with little to no human intervention while maintaining an overall level of oversight and safety that is necessary for entry into service. As the extent of autonomy increases, an increasing number of functions will move towards being 100 percent allocated to the system(s) on (or off) the aircraft.

Global competition and U.S. leadership

If one accepts that autonomous aviation is a path into the future (versus a destination), the question is then posed: what path does the United States chart for its leadership in autonomous aviation? And how quickly are we prepared to walk that path? At its current pace, the United

[3] See SAE J-3016 for the most cited example.

States is on a course to have its leadership in civil autonomous aviation overtaken by other countries like China, Germany, and South Korea.[4] This means that, in just over seven years, the U.S. is likely to be beholden to foreign technologies, developmental concepts, and standards for civil uses of autonomous aviation. The following sections capture how the U.S. can keep this leadership role into the next decade and beyond.

[4] https://www2.deloitte.com/us/en/insights/industry/aerospace-defense/advanced-air-mobility.html

Regulatory and Policy Landscapes

Current autonomy policies

The majority of the U.S. Department of Transportation (USDOT) policies have been directed at automated ground vehicles. The experience, development, and implementation of policies for road vehicles could be used as a foundation for aviation applications.

In early 2021, the USDOT released its Automated Vehicles Comprehensive Plan, which defined three goals to achieve the Department's vision for Automated Driving Systems (ADS), including:

1. **Promote Collaboration and Transparency** - USDOT will promote access to clear and reliable information to its partners and stakeholders, including the public, regarding the capabilities and limitations of Automated Driving Systems (ADS).
2. **Modernize the Regulatory Environment** - USDOT will modernize regulations to remove unintended and unnecessary barriers to innovative vehicle designs, features, and operational models and will develop safety focused frameworks and tools to assess the safe performance of ADS technologies.
3. **Prepare the Transportation System** - USDOT will conduct, in partnership with stakeholders, the foundational research and demonstration activities needed to safely evaluate and integrate ADS, while working to improve the safety, efficiency, and accessibility of the transportation system.

Prior to the Comprehensive Plan, the USDOT and the White House Office of Science and Technology Policy developed a document titled *Ensuring American Leadership in Automated Vehicle Technologies: Automated Vehicles 4.0* - which built upon earlier versions of the plan, *Preparing for the Future of Transportation version 3.0, Automated Driving Systems, a Vision for Safety version 2.0*, and the original USDOT Federal Autonomy Vehicles Policy.

Based upon the excellent work USDOT has already accomplished by defining a vision and goals for automated road vehicles, USDOT should adopt similar plans and policy to help enable autonomous aviation by leveraging similar constructs. Further, the U.S. Department of Defense and U.S. Department of Homeland Security have decades of research and development investment and experience in uncrewed aviation. The USDOT should engage with and leverage this experience and expertise by utilizing current studies and concept development activities in areas such as multi-aircraft control and integrating artificial intelligence.

Regulatory landscape

Currently, the assumption that there is an on-board, human pilot in command (PIC) flying with each aircraft in the national airspace is pervasive in the operational regulatory landscape. This assumption especially impacts the applicability of 14 CFR Parts 91 and 135 as they are applied to uncrewed aircraft systems (UAS) operations. ASTM AC377 TRB-03 looked at the regulatory barriers to autonomy present in Part 91. About 115 subparagraphs (out of over 3,000) were identified as potentially large barriers; and approximately 370 additional subparagraphs were identified as posing a hurdle to the operational certification of an autonomous uncrewed aircraft.

In the relief that has been granted from parts 91 and 135 to commercial on-demand small UAS (sUAS) operators such as Wing, UPS Flight Forward, and Amazon; between 20 and 30 paragraphs in parts 91 and 135 were identified as areas needing relief to be able to conduct their remotely operated sUAS commercial operations. As these have all been sUAS carrying cargo and not larger aircraft carrying passengers, this list serves only as a starting point for exemptions that autonomous passenger-carrying aircraft could expect to need.

While there is the existing petition and waiver process used by the operators above to obtain relief on an applicant-by-applicant basis, eventually these items will have to move from one-by-one exemptions to a more consistently available and applicable policy or rule. In this vein, several efforts outside the Federal Aviation Administration (FAA) have been working to create Digital Flight Rules (DFR), also described as Automated Flight Rules (AFR), that would address these challenges in the current regulatory structure. Similar early efforts in the United States should receive support as they stand to benefit legacy aviation users as well as new entrants.

Examples of requirements that will need to be addressed are those that deal with the role of the physical on-board flight crew. The assumption that there will be a human physically looking out from the flightdeck, pilot training requirements that don’t translate to performance requirements for an autonomous system, and generally referring to the role of a “person” performing key functions have been identified as posing challenges for significantly automated uncrewed aircraft. Operational requirements and airworthiness requirements are also connected for autonomous aircraft in a way that challenges assumptions as well, posing a fundamental question, how should or can an autonomous capability be compared to the reliability of a human pilot?

The aviation system relies on humans to perform many tasks without necessarily understanding how well they will perform in real-time. As industry develops systems to perform these tasks, we will be required to place requirements and metrics on the performance of those functions, inevitably leading to numerous “chicken or egg” type challenges. Determining how well a function must perform within a particular system design is very different from determining how well humans have historically or can physically perform. Fundamentally, this is why automation can enhance safety, both practically by reducing human workload and quantitatively by ensuring performance in unexpected or unpredicted situations.

Developing and advancing a successful, unified, efficient, and safe path forward for autonomy that draws upon lessons learned by both sUAS and legacy aircraft is central to the motivation of creating this document. Coordinating with existing groups such as the FAA’s Advanced Aviation Advisory Committee (AAAC), while leveraging recent efforts such as the Beyond Visual Line of Sight (BVLOS) Aviation Rulemaking Committee (ARC) Report and UAS in Controlled Airspace ARC report and recommendations, will be important components of this unified strategy. Additionally, the FAA’s safety continuum that has been in use for GA must be adapted.

Key assumptions needed to establish commercially viable autonomous operations

What is the ideal end-state for autonomous operations in the United States? What are the milestones that we need to achieve to get there?

While highly focused standalone operations may be acceptable for sUAS operators working in extremely low altitude airspace over limited geographic regions, many other players in the autonomy industry, including both passenger-carrying UAM operators and longer-range cargo and passenger regional air mobility (RAM) operators, desire full National Airspace System (NAS) integration. Eventually airspace design and air traffic management should evolve to encourage adoption of new technology that enhances safety and increases efficiency. From a technical perspective, there is nothing fundamentally stopping multiple autonomous aircraft under the supervision of a single remote operator, similar to the way that a dispatcher or air traffic controller supervises and assists pilots onboard an aircraft today.

The Task Force has compiled the following list of near-term concrete actions that should be taken:

- Further definition and acceptance of Detect and Avoid (DAA) systems:
    - As a first step, as recommended by the UAS in Controlled Airspace ARC, the FAA should adopt both ground-based and airborne DAA system standards (e.g. RTCA DO-365C) through Technical Standard Orders (TSOs) and Advisory Circular (AC) guidance.
    - The FAA should fully support the deployment of Airborne Collision Avoidance System for UAS (ACAS XU) and its evolution into ACAS XR as a comprehensive algorithm for DAA alerting and guidance for all operations.
    - The International Civil Aviation Organization (ICAO) is working to publish an Annex to the Chicago Convention dedicated to DAA systems, which will contain Risk Ratios to measure DAA system performance. Therefore, the FAA must be ready to implement these high-level requirements.
    - The FAA should support the installation of DAA systems on aircraft with pilots onboard to enable new operations, such as transition through IMC. Such operations could increase operational efficiency and lead to UAS performing IFR operations with the flexibility of VFR.
    - Detecting and tracking non-cooperative aircraft will remain a challenge whose solution could benefit all aviation, both legacy aircraft and new entrants. Therefore, the FAA should clarify its willingness to accept the operational assumption that all non-cooperative aircraft are operating under VFR and therefore DAA systems can be designed with an operational requirement to remain well clear of such aircraft without ATC permission under IFR.
    - Ground-based primary radar systems could be established at airports with tracks broadcast through terrestrial networks and over the air (e.g. TIS-B) to support all airspace users.

- An air traffic control (ATC) system that can accommodate automated aircraft at scale.
    - A modernized ATC communication infrastructure should include voice over Internet Protocol (VoIP) capability that enables ground-ground voice communications between remote operators/pilots and ATC.
    - Expand the use of digital ATC communications (datacomm) in the NAS and enable more technical pathways to implement in Electronic Flight Bags.
    - Develop and standardize new digital technologies, such as vehicle-to-vehicle communications (V2V) to facilitate more dense and complex operations.
    - Embrace digital data sharing and connectivity by setting a goal for Digital Flight Rules that would facilitate the operational flexibility of VFR and the all-weather and airspace access of IFR to benefit all airspace users.

- Reliable connections between the aircraft and the remote crewmembers are critical to efficient operations, this connection is known as Control and Non-Payload Communication (CNPC) C2 Links.
    - The FAA must issue TSOs and guidance to support Radio Line of Sight (RLOS) datalinks in the allocated 5030-5091MHz frequency spectrum.
    - The FAA and Federal Communications Commission (FCC) must work together to publish operating rules in that band.
    - A relaxation of the FAA's pilot-ATC voice communication requirement, either by airspace or operation, will enable satcomm-based C2 Links in the NAS.
    - The FAA should leverage published standards (e.g. RTCA DO-362), to facilitate a process for the necessary infrastructure investments to install and operate C2 Links across the NAS.

- Explicitly recognize that "person" within the definition of "pilot in command", including its subparts, can be understood as it is defined in 14 CFR Part 1 as inclusive of the entire operational organization responsible for the safety of the flight.
    - This concept is consistent with that of a Part 135 certificated operator: There are multiple roles defined within that operational construct, each of which are responsible for different facets of safety of flight.
    - This will be particularly valuable as the extent of autonomy on the aircraft increases and the human remote operator is directly in control of fewer and fewer functions. Clear roles and responsibilities will be essential for safe operations.

- Develop training, qualification, and certification requirements that are performance-based, mission-appropriate and focused on the skills that are needed for overseeing an autonomous UAS.
    - The FAA should evolve its Remote Pilot's License framework to include aircraft outside of Part 107 and follow ICAO's Remote Pilot Licensing SARPs, which are based on a competency-based approach. This should lead to a qualification path that does not require flight time at the controls of an aircraft.

    - Remote Pilot Licensing should assume the use of simulation and performance-based skill and knowledge evaluations.
    - Variations in the autonomy and other systems characteristics between one autonomous UAS and another may necessitate highly specific Remote Pilot in Command (RPIC) qualifications or type ratings. Performance based training and certification standards would allow for system-specific criteria to be determined, simplify development of training materials, and encourage increased consistency across aircraft platforms.
    - Eventually, the FAA's remote pilot certificate should enable a person to conduct all of their training and experience to be qualified to fly a transport-category remotely piloted aircraft (RPA) without having to fly a legacy aircraft.
    - A pathway to expand from a one-to-one (1:1) human to aircraft ratio to a one-to-many (M:N) that tailors requirements for human-machine teaming with the operations, the role of the human remote operator/pilot, and the extent of autonomy in use on board the aircraft.

- A clear and consistent pathway for operations BVLOS of the RPIC is needed, not just for smaller UAS but for all users of the airspace.
    - The BVLOS ARC proposed one possible approach for BVLOS operations of smaller UAS below 400' and within 100' of a structure; this should be considered with all due efficiency.
    - Updates to parts of 14 CFR that will be common to sUAS and other automated aircraft should be modified in a way that provides a consistent policy and process for larger aircraft used in UAM and RAM use cases as well.

- Clear and durable airworthiness systems certification requirements and processes for autonomous systems, including both aircraft and ground control stations (GCS).
    - The application of the FAA's safety continuum that has guided airworthiness certification for aircraft of all sizes and types from sUAS up through large commercial airliners to UAS aircraft — including retrofits of existing aircraft to be flown autonomously as UAS — needs to be made clear.
    - If there is to be an operational component brought into the airworthiness safety continuum thought process, this needs to be made clear and consistently applied.
    - Development of industry consensus standards in support of autonomous UAS aircraft needs to be continued and done in a coordinated and internationally harmonized way to the maximum possible extent.
    - The certification requirements that are to be applied to the GCS need to be clarified and consistently applied.

- Airworthiness, operations, pilot certification, and airspace integration need to be closely coordinated with their respective FAA lines of business (as well as legal and others) within the agency, collaborating in a timely and efficient manner.

    - Existing coordination tools need to be strengthened and more widely disseminated within agency.
    - FAA staffing needs to be increased to a level that adequately supports the emerging autonomous aviation industry.

- Third-Party Service Providers (3PSPs) will play a key role in enabling autonomous aviation without over burdening the U.S. Air Navigation Service Provider (ANSP) and/or the FAA.
    - The FAA must establish a process by which safety-critical service providers can be approved for certain services independent of a particular operator.
    - The FAA must streamline the process to grant access to NAS data for use in safety-critical services, including data that may be protected for national security reasons.

- Develop a resilient and sustainable supply chain.
    - U.S. leadership in the procurement and supply of materials (e.g. LiON batteries) and technologies is required.
    - Leverage the implementation of United States Innovation and Competition Act (USICA) (S. 1260) and America Competes Act (H.R. 4521).

- The United States must take steps to promote global standardization and harmonization.
    - U.S. support for the ICAO Remotely Piloted Aircraft System (RPAS) Panel and implementation of Standards and Recommended Practices (SARPs) and Procedures for Air Navigation Services (PANS) is critical to global leadership.
    - Create standardization around policies, regulations, consensus standards, and implementation to harmonize global efforts and applications.
    - Utilize Standards Development Organizations (SDOs) as a forum for collaboration and global alignment.

Policy and Regulatory Objectives

The Task Force intends to advocate for the following policy and regulatory objectives:

Autonomy

Administration/USDOT/FAA commitment

- Relevant Executive Branch agencies must support the growth in U.S. aviation autonomy efforts (e.g., agency resource allocation for certification and operations), entry into service, and other dependencies.

Legislative efforts

- Congress must utilize legislation, hearings, the appropriations process and other opportunities to advance U.S. leadership in autonomy. This should include prioritizing resource allocation and leadership at FAA, NASA, and FCC to focus on the enabling regulations, guidance, policies and infrastructure investments necessary to support autonomy.

Implementation of enacted bills to focus on autonomy

- FAA, NASA, FCC, and other relevant agencies must develop and execute plans to drive the implementation-phase of enacted bills, such as the FAA reauthorization and appropriations measures, to prioritize congressional direction that focuses agency resources on autonomy.

NASA engagement

- NASA must utilize its budget and authorization process to prioritize airspace integration efforts for autonomous aviation technology / capabilities.

Airspace Integration

Roadmap for autonomous airspace integration

- Publish FAA Roadmap for autonomous operations in the NAS.

Roadmap for requirements for operational approvals of passenger-carrying, uncrewed aircraft

- Publish FAA Roadmap to allocate functions of pilots to autonomous aircraft and systems (e.g. operational considerations under part 135).

Rulemaking for C2 link requirements

- FCC must allocate dedicated/protected C2 spectrum (5030-5091 MHz).

Roadmap for long-term 3PSPs rulemaking

- Publish FAA Roadmap with timelines and milestones for rulemaking to establish safety-critical 3PSPs that can be approved independently of a particular operator.

Digital Flight Rules (DFR)

- FAA and NASA should commit on DFR with a clear implementation plan.

Appendix 1.0 - Autonomy Definitions

This section highlights work in the aviation community to bring consensus to terms such as “autonomous” and “autonomy”. While the task force does not endorse any particular definition, it advocates moving beyond system-level definitions and towards a more nuanced approach describing functions and/or capabilities.

ASTM AC377 TR1 Definitions

AC377-TR1-AutonomyDesignAndOpsInAviation_TerminologyAndFramework.pdf
Also: See Appendix 1 of ASTM AC77 TR1 for a summary of “levels of autonomy”

3.8 AUTONOMOUS
An entity that can, and has the authority to, independently determine a new course of action in the absence of a predefined plan to accomplish goals based on its knowledge and understanding of its operational environment and situation. Having the ability and authority to make decisions independently and self-sufficiently.

3.11 AUTONOMY
The quality of being autonomous (i.e., without the need to be controlled by outside entities; self-determination).

U.S. DOD unmanned systems integrated roadmap levels of autonomy:

https://www.defensedaily.com/wp-content/uploads/post_attachment/206477.pdf

Fully Autonomous: The system receives goals from humans and translates them into tasks to be performed without human interaction. A human could still enter the loop in an emergency or change the goals, although in practice there may be significant time delays before human intervention occurs.

P17: “Autonomy is defined as the ability of an entity to independently develop and select among different courses of action to achieve goals based on the entity’s knowledge and understanding of the world, itself, and the situation. Autonomous systems are governed by broad rules that allow the system to deviate from the baseline. This is in contrast to automated systems, which are governed by prescriptive rules that allow for no deviations.”

EASA

https://www.easa.europa.eu/faq/116449

Question: What is the difference between autonomous and automatic drone?

Answer: An autonomous drone is able to conduct a safe flight without the intervention of a pilot. It does so with the help of artificial intelligence, enabling it to cope with all kinds of unforeseen and unpredictable emergency situations.

This is different from automatic operations, where the drone flies pre-determined routes defined by the drone operator before starting the flight. For this type of drone, it is essential for the remote pilot to take control of the drone to intervene in unforeseen events for which the drone has not been programmed.

While automatic drones are allowed in all categories, autonomous drones are not allowed in the “open” category.

Autonomous drones need a level of verification of compliance with the technical requirements that is not compatible with the system put in place for the ’open’ category. Autonomous operations are, instead, allowed in the ’specific’ category, where the regulation includes a tool flexible enough to verify requirements with the appropriate level of robustness.

Autonomous operations are also allowed in the “certified” category.

ASTM Committee F38 on Unmanned Aircraft Systems

F3341-20a Standard Terminology for Unmanned Aircraft Systems

Automatic flight control system, n. - a system which includes all equipment to control automatically the flight of an aircraft to a path or altitude described by references, internal or external, to the aircraft.

FAA BVLOS ARC Report

Autonomous Flight System. The autonomous flight system conducts all control, guidance and navigation, monitoring, and communication functions with Airspace Users including ATC.

Autonomous Systems. Systems that have the ability and authority of decision making, problem solving and/or self-governance under possibly bounded, variable or abnormal conditions (deterministic or non-deterministic).

The four proposed AFR Levels are as follows:

- AFR Level 4: Autonomous, Human Out-of-the-Loop
    - No possibility of human engagement with the aircraft during flight.
    - No human roles or training specified.
    - No restrictions on 1:many operations (one human pilot being responsible for more than one UAS).
- AFR Level 3: Fully/Highly Automated, Human Over-the-Loop
    - No tactical intervention by a human pilot during the flight, but there is human supervision.
    - The human would be a certificated RPIC with a BVLOS rating OR.
    - Operations would be done under a Remote Air Carrier or Remote Operating Certificate with a Designated Remote Flight Operations Supervisor (RFOS).
    - Any limits on 1:many operations would be determined by demonstrated capabilities.
- AFR Level 2: Increased Automation, Human On-the-Loop
    - The remote pilot is directing the UAS but not directly commanding aircraft movement and can intervene when necessary.
    - The human would be a certificated RPIC with a BVLOS rating OR.
    - Operations would be done under a Remote Air Carrier or Remote Operating Certificate with a Designated RFOS.

    - Limits on 1:many operations would depend on whether it was an RPIC or a RFOS.
- AFR Level 1: Manual, Human In-the-Loop
    - The pilot exercises direct control over the UAS through manual control inputs.
    - The human pilot must be an RPIC with an sUAS rating.
    - No 1:many operations are allowed.

JARUS Ops A&B (JAR_DEL_WG2_D.04)

http://jarus-rpas.org/sites/jarus-rpas.org/files/jar_doc_14_ops_cat_a_b_edition1.0.pdf

“Autonomous Operation” means a phase of a UA flight, during which a remotely piloted aircraft is operating, by design and under normal conditions, without possibility of immediate pilot intervention in the control of the flight.

SAE AIR6987 Draft as of 18 Nov 2021

AUTOMATION [2]: The use of control systems and information technologies reducing the need for human input, typically for repetitive tasks.

AUTONOMOUS [3]: Operations of an unmanned system (UMS) wherein the UMS receives its mission from the human or agent and accomplishes that mission with or without further human-robot interaction (HRI). The level of HRI, along with other factors such as mission complexity, and environmental difficulty, determine the level of autonomy for the UMS.

- Finer-grained autonomy level designations can also be applied to the tasks, lower in scope than mission.
- Fully Autonomous: a mode of UMS operations wherein the UMS is expected to accomplish its mission, within a defined scope, without human intervention.
- Semi-Autonomous: a mode of UMS operations wherein the human operator and/or the UMS plan(s) and conduct(s) a mission and requires various levels of HRI.
- For automotive industry, 6 levels of autonomy have been defined (see SAE J3016 [4]).

AUTONOMY [2]: The ability to perform one or more tasks in a changing environment following a decision-making process without input by a human.