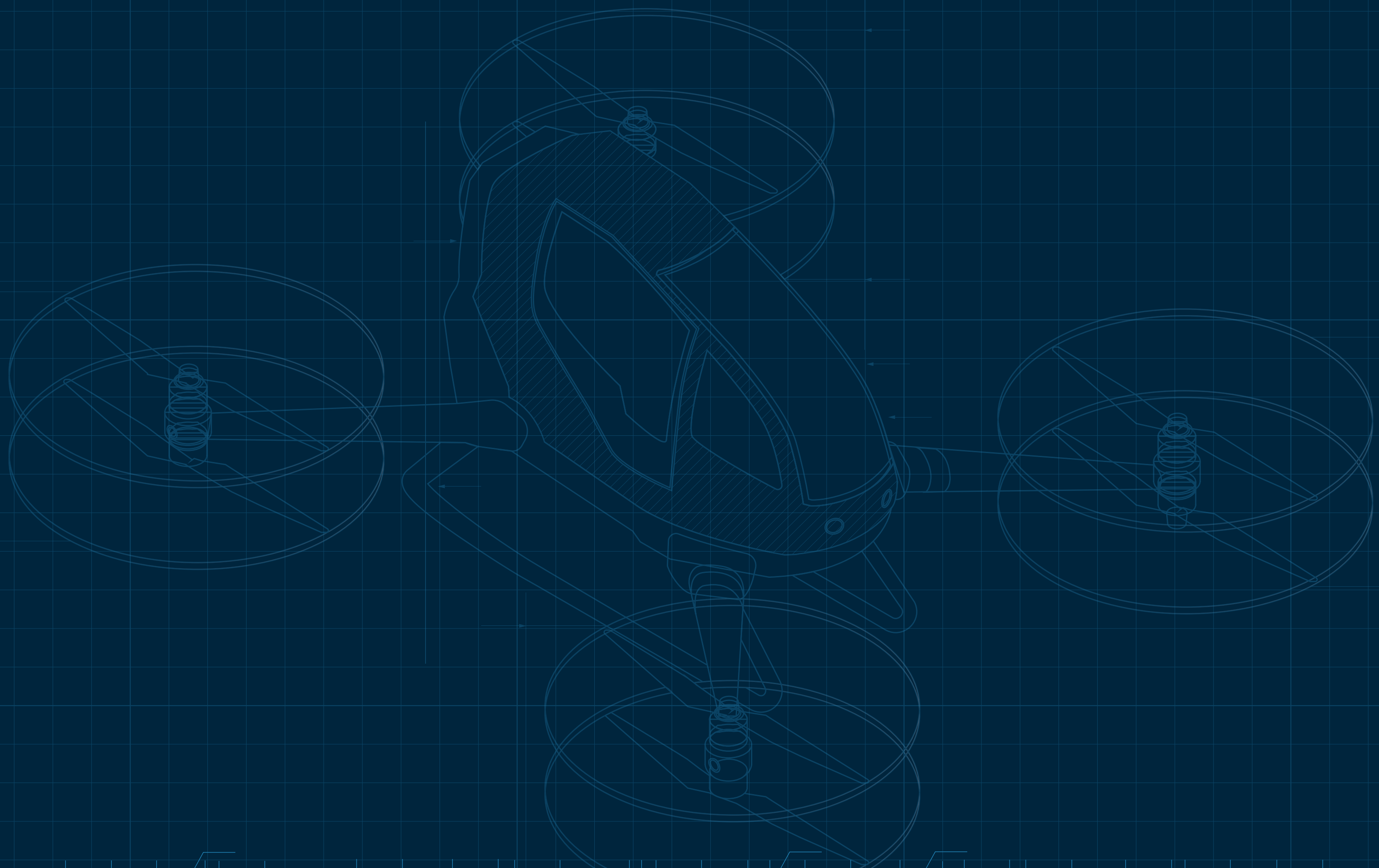

BLUEPRINT FOR AUTONOMY

From Small UAS Operations Today to Advanced Air Mobility "Tomorrow"

Explore where our community can focus our shared efforts now to accelerate the long-term realization of assured autonomy.

AUVSI™

Contents

Acronyms

AAM	Advanced Air Mobility
AI	Artificial Intelligence
ANSP	Air Navigation Service Provider
ATC	Air Traffic Control
ATM	Air Traffic Management
AUS	Unmanned Aircraft Integration Office
BVLOS	Beyond Visual Line of Sight
C2	Command and Control
CMS	Communications Management System
CONOPs	Concept of Operations
DAA	Detect and Avoid
DoD	Department of Defense
DNN	Deep Neural Network
EIS	Entry Into Service
eVTOL	Electric Vertical Takeoff and Landing
FBO	Fixed Base Operator
FES	Flight Engineer Station
GA	General Aviation
GSE	Ground Support Equipment
GCS	Ground Control Station
IFR	Instrument Flight Rules
IMC	Instrument Meteorological Conditions
KCCR	Buchanan Field in Concord, California
LOS	Line of Sight
LSA	Light Sport Aircraft
MCC	Mission Control Center
ML	Machine Learning
MOA	Military Operations Area
MOPS	Minimum Operational Performance Standards
MVS	Multi-Vehicle Supervisor
NAS	National Airspace System
NLP	Natural Language Processing
NORDO	An aircraft flying without a radio
OPA	Optionally Piloted Aircraft
PIC	Pilot in Command
POH	Pilot Operating Handbook
RAM	Regional Air Mobility
PSP	Partnership for Safety Plan
3PSP	3rd-Party Service Provider
PSU	Provider of Services for UAS
RPIC	Remote Pilot in Command
SATCOM	Satellite Communications
SMS	Safety Management System
SDO	Standards Development Organization
UA	Uncrewed Aircraft
UAS	Uncrewed Aircraft System
sUAS	Small Uncrewed Aircraft System
UAM	Urban Air Mobility
UTM	UAS Traffic Management
V2G	Vehicle to Ground
V2V	Vehicle to Vehicle
V2X	Vehicle to Anything (inclusive of V2G and V2V)
V&V	Verification and Validation
VFR	Visual Flight Rules
VLOS	Visual Line of Sight
VMC	Visual Meteorological Conditions
VO	Visual Observer

Introduction

This document is intended to guide us forward as an industry into a future that methodically enables new automation capabilities and is intended to encompass all forms of autonomous flight, from small uncrewed aircraft systems (sUAS) operating in the NAS today through urban and regional air mobility (UAM and RAM). While each concept of operations has its own unique technical, integration, and regulatory considerations, including different paths to proven capability maturity, there are common themes associated with the paradigm shift from direct human control to autonomous aircraft (with varying extents of human supervision depending on the functional and technical maturity of the automation). Some of the blocks and bricks herein are more or less appropriate to various applications of autonomy in aviation, but all of them are needed to come together to create the overall envisioned landscape. What specifically that vision is, and what specifically is meant by "autonomy" itself, is currently varied and dynamic; the term is used here in a broad sense with the goal that derived solutions be tailorable across the full safety continuum and spectrum of applications. Much of the document will focus on the Advanced Air Mobility (AAM) industry, encompassing both UAM and RAM; however, the accomplishments, as well as continued challenges of the sUAS industry, inform and guide this Blueprint.

Today, autonomous air operations are taking place in the NAS. Drone companies are conducting various sUAS missions beyond visual line of sight (BVLOS) with remote pilots monitoring the drone (or multiple drones) operation. These limited but growing drone operations occur by exemption or by waiver from existing rules for various types of operations including, but not limited to, drones as first responders (police, fire, search and rescue, and more), infrastructure inspection (rail, pipelines, utility lines, and more), and drone delivery of medical and consumer goods. While these operations are still very limited in scale due to the lack of a regulatory framework that allows for scaling operations — BVLOS rules and UTM guidance from the Federal Aviation Administration (FAA) — the ecosystem being developed by autonomous commercial sUAS operations is laying the groundwork for larger autonomous platforms to enter the NAS, eventually carrying passengers and cargo.

In this document, we attempt to map a set of actions that can be taken to more fully realize autonomous flight. Today's autonomous drone operations are the cornerstone. Autonomous beyond visual line of sight UAM and RAM operations at scale operating under digital flight rules with full vehicle-to-vehicle communication are the apex. There are five foundational building blocks of this autonomous future that we want to build upon within aviation: motivation, technology, airworthiness, operations, and integration.

Each of these five foundational building blocks contains significant areas of effort, including the role of government-sponsored automation development for non-civil use, public/private partnerships, and renewed commitment to and collaboration with industry to mature civil automation applications. The timelines for completion of these activities must be accelerated through strategic collaboration, focused resource management, and deliberate action. Just as a set of blueprints is essential to ensure that everyone working to build a house is coordinated in their effort and aligned in their vision, the purpose of this document is to offer a starting point from which the varied aviation stakeholders can build toward a shared future vision for aviation. The desire is for that future to be safer, more sustainable, more accessible, more beneficial to society, and more advanced than we have ever seen. While initially U.S.-focused with an emphasis on civil applications, many

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Introduction (cont'd)

of the themes herein can be expanded to international applicability and can both leverage technology development and operational experience from non-civil use cases and support standards development that can inform both civil and non-civil requirements. Carrying the building analogy forward, much like the blueprints for the house exist in the context of external requirements — building codes, zoning, and local considerations, etc. — this document does not exist in a vacuum. All of these pieces come together to create a building that is both safe and functional.

Carrying forward the blueprint analogy, each foundational building block is further subdivided into "bricks" that contain actions that can be taken. These actions are divided into categories based upon operations that are happening now to anticipatory action within the near term, action we need to see within the short term (no more than three years), and those that are beyond the three-year action horizon.

Separate from the medium- and longer-term goals in this document, which build upon the autonomous operations occurring in the United States in spring of 2023 and set forth a blueprint for the next decade, AUVSI has more immediate challenges that we are seeking to address to move policies for autonomous flight forward. More information on these policy goals can be found **here**.

Assumptions

As at the beginning of any complex body of work, the assumptions and boundary conditions that we set for ourselves are important to acknowledge. Some formative assumptions that were made at the beginning of this effort include:

- The fundamental shift(s) that are needed to accommodate autonomous aviation are common across the full spectrum of aviation. This does not negate the relevance of — or the need to apply — the existing safety continuum to that same spectrum, but it does point toward holistic and systematic shifts that are not confined to one type of aircraft or one concept of operations.
- The existing safety continuum can and should be applied to autonomous aircraft as it is to conventionally piloted aircraft. However, in order for new aviation technologies to flourish, the existing safety continuum must be updated and must be adaptable moving forward.
- The term "autonomous aviation" is used in this document in a holistic, fairly general sense. It is acknowledged that there are many different approaches to autonomy and a wide range in its implementation, including deterministic, automatic functions, human-directed semiautonomous behaviors, and fully autonomous mission execution without the direct involvement of a human operator. It is also understood that some business models in the AAM space utilize a pilot and some do not. Detailed technical definitions are left to the standards development organizations, regulators, and others; the reader is encouraged to apply a practical level of flexibility to their interpretation of the term herein.

Foundation: Motivation to Pursue Autonomy in Aviation

To many involved in the progressive use of autonomy in the aviation industry, the benefits of doing so are self-evident. However, from a more wholistic perspective, there is still a need to demonstrate the benefits of expanding automation capabilities enabled by new technology toward future autonomy and win over policymakers, existing aviation stakeholders, communities, and the general public. This section covers a wide range of reasons autonomy in aviation is worth the required effort from its wide range of stakeholders, which includes branches of the federal government. This section intends to help crystallize why investment in accomplishing the actions presented throughout the document is needed and is also intended to provide actions that can be taken to further motivate and justify the necessary work ahead.

The bricks that are needed to build a foundation of motivation include: a demonstrable public benefit, a high degree of safety and security, prioritization from a national competitiveness perspective, economic benefit, sustainability, and a clear path to social and environmental equity. The more these can be demonstrated through early military and well-scoped civil operations and simulation to be at a high maturity level, the more powerful the case will be to invest in expanded civil applications of aviation autonomy. Additionally, the industry should invest in ensuring that the general public is educated about and understands these motivations, as well as any potential adverse impacts that are being mitigated, so they can benefit from appropriately embracing and integrating this technology into their lives and communities.

M1. Safety and Security

Description:

One of the central promises of advanced autonomous aviation — specifically, advanced automated aviation companies and the AAM industry — is its potential to eliminate pilot and controller error as a cause of aviation accidents. Simply put, the AAM industry must deliver on this promise. It must also deliver on the promise that greater automation and autonomous behavior can be implemented with a net improvement in safety, despite potential failure modes and operational conditions that might be a challenge to accommodate in real-world automated operations.

While the public has shown a willingness to accept a certain level of risk in some forms of (both automated and more traditional) transportation, aviation — perhaps especially its autonomous components — should strive to exceed the level of operational safety that has been achieved by today's on-demand airline operators, if not that of full scheduled airline operations. Industry, regulators, and the public must determine whether legacy general aviation design safety targets will be considered an appropriate design target for commercial AAM services, particularly those in urban environments. Promisingly, the first proposed certification bases for eVTOL aircraft apply the existing safety continuum for design assurance and expected design safety levels. International agreement on an appropriate design safety target is proving to be a challenging topic and should continue to be an area of effort.

National security is another important consideration, both in terms of ensuring that any enabling regulations or data sharing appropriately protect it, but also from the perspective of the advantages that autonomy can bring to non-civil operations.

History has already shown a lack of acceptance for accidents in aviation; autonomous operations will likely only further raise operational safety expectations. The industry as a whole — from small cargo operations through autonomous uncrewed passenger-carrying operations — must continue to rise to this challenge and continue to build an impeccable safety record beginning with entry into service and continuing to the maximum extent possible. One of the hallmarks of the aviation industry has always been an agreement to not compete on safety, but rather to collaborate to create the safest ecosystem possible; this must carry forward into AAM and UAS. The entire ecosystem and regulatory landscape must be architected so as to support and ensure this safety.

Existing & Developing Over the Immediate Term	Short-Medium Term	Medium Term
• Leverage the testing and certification process to ensure an appropriate level of design rigor and operational safety targets based on intended operational and design domain • Leverage testing and self-certification of existing military applications • Mature robust incident response and management plans, including system-level data collection with feedback from operations that can be used to continuously improve design resilience and operational safety • Mature Safety Management System (SMS) procedures for autonomous UAS operations • Scale sUAS/lower-risk autonomous operations as regulations — BVLOS, UTM — come online • Implement an Aviation Safety Incident and Accident reporting system for UAS data collection • Gather experience from any autonomous capabilities that are wholly relied upon by an onboard pilot but not the final authority in the event of off-nominal performance (these may precede applications without a pilot in the loop due to certification challenges)	• Larger UAS autonomous operations begin to scale • Execute a responsible AAM entry into service that builds a strong safety record from the beginning • Practice transparency and model best practices around any incidents that do occur • Implement and refine SMS procedures for autonomy to include a best practices feedback loop that incorporates lessons learned in autonomy design and implementation	• Act in a spirit of continuous improvement to increase safety as operational experience and technical advances allow • Balance speed of market expansion with industry maturity and readiness for high-volume operations • Consider SMS requirements for autonomous operations

M2. Public Benefit

Description:
For the technology push that has defined the creation of the AAM industry to truly take root, it must provide a clear public benefit to as many members of the communities in which it operates as possible. This benefit can take many forms, including public and emergency services, national security, increased transportation options for all, reduced in-situ emissions, increased connectivity for goods and people, and both direct and indirect economic benefits and job creation, to name a few. Perhaps one of the most promising benefits is urban-to-rural connections via a hub-and-spoke model throughout the nation. This will cut down on significant travel times from rural areas to airports in urban centers. From an environmental standpoint, AAM serves to significantly cut down on traffic congestion, which will have a positive impact on emissions and the environment. AAM can and will help revolutionize the work commute. To maximize these benefits, the AAM industry must engage with communities and focus not just on short-term economic gain but also bear in mind long-term broad public benefit. Of note, significant benefit can be derived from autonomous systems that work in concert with human pilots to increase safety and/or reduce workload before, or even in lieu of, autonomous applications that do not include a human pilot in the loop; these benefits should be embraced in their own right as well as in their role as potential stepping stones to greater extents of autonomy.

Federal regulation of airspace must continue to be the national standard to maintain aviation safety standards. Beyond the federal role, local decision-makers, including state departments of transportation, zoning commissions, city councils, workforce development departments, and transportation planners, need to consider the potential advantages of AAM in their ongoing work. By appropriately incorporating AAM (and particularly UAM) into ongoing planning activities, the overall community benefits and public good of this new technology can be maximized. While local considerations will of course be a factor, a coordinated approach across jurisdictions will further increase the potential value of AAM and streamline its implementation at all levels. By including autonomous aviation into transportation planning activities, strategic investments today can yield societal benefits for decades to come.

An additional benefit to the working public can be realized by using autonomous aircraft for missions that would otherwise present a danger to the onboard pilot. Benefits of this type are seen in both civil and non-civil applications, including for defense, and can remove humans from harm's way for missions that are tedious and/or dangerous.

Existing & Developing Over the Immediate Term	Short-Medium Term	Medium Term
• Community engagement • Support of state and local decision-makers • Include AAM in transportation planning activities • Demonstrate AAM technology and operational use cases and educate the public about its benefits and potential • Coordinate across jurisdictions to share best practices and encourage consistent approaches	• Emergency services and other public aircraft operations • Execution of AAM-inclusive transportation plans • Strong communications, continued community engagement, and public outreach activities	• Multimodal integration • Increasingly accessible price points for AAM services in both urban and rural America • Ever-expanding use cases and positive societal impact, including accessibility for less-privileged communities across the nation

M3. National Competitiveness

Description:

One of the keys to national competitiveness in the autonomy space is creating an environment that inspires innovative businesses to conduct development and operations in the U.S. for civil and non-civil use cases. As such, a clearly navigable, stable, and rightsized requirements framework from both federal and state regulators that supports all aspects of development, capability maturity, and commercialization are essential. The more that framework is compatible with international regulatory landscapes, resulting in streamlined expansion and growth, the better. Predictability in this regulatory landscape and a methodical path to capability maturation (function, technology, and timing) are perhaps even more important than expedience: the public and the business community both desire safety, but it is essential that companies be able to plan for required certification activities, both from a time and financial standpoint.

To advance national competitiveness, there must be a balance between the cost of developing and certifying these technologies and the cost savings anticipated from autonomy, including from reducing pilot error, increasing the density of operations, and reducing the number of people needed to perform a given operation, among others. The potential cost of automation failures and liability must also be included in this trade space.

Funding is naturally another key. Financial support for national leadership in aviation autonomy can take multiple forms: direct contracts to businesses pursuing autonomous technologies, research and demonstration funding, and infrastructure investment, such as that required for digital ATC communications (see "brick" T4). These are all examples of how federal dollars could be effectively deployed. Providing appropriate resources (and oversight) to the FAA to support their work in the space is also essential.

Maintaining national and international competitiveness at this point in the development and deployment of aviation autonomy is particularly critical if long-term leadership is desired as the approaches and standards that are created today stand to influence the industry's path for decades to come. Differing approaches on the global stage to the appropriate balance between safety and market share will also play into the evolution and operational deployment of autonomous operations and should be kept in mind when considering the national competitiveness landscape. To effectively ensure competition across the world, regulators/air navigation service providers around the world must communicate with each other.

Existing & Developing Over the Immediate Term	Short-Medium Term	Medium Term
• Conference to set national strategy around autonomy (whole of government, including civil and non-civil development paths) • Leverage AAM Coordination and Leadership Act and specifically the work of the interagency working group • Adequately fund regulatory activities to provide a clear path for autonomy that includes appropriate design safety targets and incremental increases in operational risk • Implement/define airspace as needed to expedite entry into service autonomous operations • Begin coordination with international authorities to promote regulatory harmonization and operational growth paths • Finalize Rulemaking activities intended to normalize sUAS BVLOS operations • Continue programs such as AFWERX / Agility Prime and the Advanced Aviation Infrastructure Modernization (AAIM) Act grants to support innovative AAM businesses — this includes continuously appropriating funding for these programs so their vitality is not in question	• Deploy funding for infrastructure improvements by continuing the AAIM Act grant program • Solidify international coordination to maintain regulatory harmonization and operational growth paths without stifling U.S. competitiveness. • Leverage non-civil development programs toward capability maturity for aircraft, operations, and airspace integration of autonomous capabilities through programs such as Agility Prime to increase autonomous operational cadence and scope	• Finalize Rulemaking activities intended to normalize U.S.-based highly automated AAM operations toward autonomous AAM operations • Expand operations out of specified routes and protected airspace • Adapt bilateral and/or other agreements to facilitate international regulatory cooperation while preserving U.S. leadership and innovation

M4. Economic Benefit

Description:
Related to the broader public benefit discussed above, but perhaps easier to quantify (presuming that the assumed capability and resiliency assumptions become reality), is the economic benefit associated with autonomous AAM activities. One of the main motivating factors that is cited for autonomous aviation, beyond its promise of increased safety, is an economic one: autonomy will bring down the cost of air travel for goods and passengers faster than would otherwise be possible. This cost savings must be viewed in the context of potential economic risk due to the liability associated with potential failure: proven, resilient capability enabled by mature technology is essential.

Additionally, economic benefits are expected from direct employment, secondary services job creation, and the increased access that AAM can provide to jobs and educational opportunities within a wider radius of travel than would otherwise be practical. Even reducing the pressure on overstretched housing markets has been mentioned as a potential benefit of AAM as it will enable people to live farther from their workplace while still maintaining the same transportation time budgets in their day.

Key services may also be able to be provided at lower price point, including infrastructure surveillance, urgent medical supply and organ transplant, last-mile package delivery, and natural disaster relief applications (such as hovering AAM craft providing Wi-Fi and other services) that are starting to be offered by the UAS community today.

From a workforce development perspective, operating an autonomous aircraft from a ground control station is expected to be more capable of providing reasonable accommodations, allowing people who may not have been able to pilot a conventional aircraft access to the profession. And while the idea of autonomy replacing jobs is raised as a negative, in reality, more people are expected to be needed to support a future with fully deployed AAD, just in different capacities, than we see involved in aviation today. Generally speaking, these jobs are high-paying and highly sought-after jobs that will help spur competition in the job market and ultimately impact our nation's economy in a positive way.

Cities and counties also have the potential to open up new economic opportunities due to increased aviation activities within their jurisdiction specifically based on regional need (e.g., remote area cargo delivery in Alaska) that a lack of air travel options may have been prohibiting previously. Autonomous regional air mobility (RAM) is poised to be a more economical means by which essential air service can be provided via a hub-and-spoke and other models.

Existing & Developing Over the Immediate Term	Short-Medium Term	Medium Term
• Economic impact studies that include both direct and indirect benefits • Workforce development planning • Include economic benefit considerations in infrastructure siting decisions • Early adopter economic development authorities plan to attract drone and AAM companies and others using autonomy to their local airports and communities • Early automation capabilities are proven affordable and resilient/mature in real-world operations, demonstrating a readiness for moving toward greater autonomy.	• Execute workforce development plans • Collect early economic impact data for entry into service markets • Consider revenue-generation streams appropriate for electrified and environmentally conscious AAM operations • Revitalization of existing airport infrastructure and surrounding communities	• Include AAM in economic policy and other planning activities • Continue to track economic impact data at a local and increasingly regional level as markets and uptake of AAM expand

M5. Equity — Social and Environmental

Description:

While social equity and environmental justice are often as complex as they are important for a healthy society, at their core they are a balance of benefit and opportunity with adverse impacts: no one community should get all of one without much (any) of the other. Given the patchy history of considering equity in much prior transit infrastructure development, some integration philosophies that might seem obvious — such as aligning eVTOL corridors with existing highways where there is a higher ambient noise level — may not be in the interest of equitable AAM integration. Autonomous flight enables precise and (if desired) concentrated use of airspace, which can be leveraged to minimize their impact to the community.

If proven to be able to meet civil aviation safety requirements and societal expectations, autonomous operations are expected to result in a price point per operation that will eventually be significantly lower than what would be possible with conventional operations: more people in the community will have access to that transportation option or service.

There is another facet of the equity conversation that is connected to autonomous aviation as well: that of physical accessibility and accommodations for mobility-impaired passengers and remote operators. Passenger-carrying autonomous operations must ensure that ground support crew are available to assist as needed and that the aircraft designs themselves are accessible. Remote operations provide an opportunity for reasonable accommodation for pilots with disabilities for them to be able to perform the role of remote PIC or vehicle supervisor. Additionally, the current cost for gaining necessary licenses often excludes communities/individuals that cannot afford the cost or time to gain these qualifications. One additional aspect of autonomy-enabled equity would be a realistic review of skill needs when incorporating highly automated systems: the adoption of new technology allows more equitable entry levels, not just for those with a disability, but also those with other economic or time constraints, and could help increase the diversity of and close the demand gap for commercial pilots.

And, lastly, package delivery and other UAS/AAM applications options may increase equity of access to goods and services for individuals who face mobility challenges with leaving their property, but those who are truly housebound may not be able to benefit from a service that delivers to their front lawn, for example. These considerations should be part of the development of concepts of operations.

Existing & Developing Over the Immediate Term	Short-Medium Term	Medium Term
• Include societal equity in transportation planning for autonomous aviation • Include equity considerations for required licensing and training; rightsize to the needs of autonomous aircraft • Consider accommodations for mobility-impaired passengers on autonomous UAM and RAM aircraft at the OEM and/or standard development organization (SDO) level • Begin design standards/guidance that allow reasonable accommodations at GCS • Community engagement to support equitable and environmentally conscious deployment	• Utilize data collection systems that will allow the societal equity of early operations to be assessed • Ensure entry into service (EIS) of passenger-carrying autonomous aircraft that can accommodate mobility-impaired passengers • Complete equity-focused design standards/ guidance	• Conduct early industry-level evaluations of equity metrics • Accept equity-focused design standards • Provide reasonable accommodations and standardize appropriate training for remote PICs with disabilities • Eventual ADA compliance as operations expand and become both routine and ubiquitous

Foundation: Technology

Innovation and advances in technology have historically been at the center of, and naturally drive the use of, automation in aviation to enhance capability, utility, safety, and access. While the pace of technical advances to provide new capabilities is ever-increasing and these advances are already enhancing safety and enabling compelling early use cases, there are a few areas of technical development toward future autonomation capabilities that are worthy of an increased focus and priority as their maturation will enable a more widespread implementation of autonomous aircraft. While it is expected that most of the technological advancements discussed in the following "bricks" will be conducted by industry privately and through government partnerships, there will be meaningful opportunities for institutions such as NASA and the FAA (e.g., advancements such as ANSP) as well as academia to contribute to progress in these areas; they should be supported. The bricks that comprise the technology foundation in our blueprint include hazard avoidance sensing solutions (e.g., combined airborne and ground-based positioning data sources, radar), low-latency universal communications infrastructure (V2V and V2G), interoperable equipage solutions for all low-altitude aircraft collaborative traffic management (positioning, navigation, timing, data sharing, etc.), widespread digital data sharing and communications to enable air traffic management functions on the aircraft and for controllers that can augment and eventually replace serial voice communications, and capabilities to enable autonomous ground operations.

T1. Sensing (e.g., Radar, Cameras)

Description:

Autonomous decision-making requires high-fidelity estimates of the state of the aircraft (position, velocity, navigational intent, clearance information, etc.) and the same state information of others in the relevant environment. High-precision and high-integrity sensors and sensor fusion are essential for constructing accurate relative aircraft state and operational intent models to enable safe planning and decision-making to support automation. Safety-critical autonomous flight operations will likely require increased sensor precision, integrity, and availability (including potential recertification to higher functional criticality) in relation to existing piloted aviation and will likely require new data sources to enable envisioned automation capabilities. That data will then need to be processed by purpose-built algorithms (for traffic detection, navigation, runway detection, etc.) developed with rigor appropriate to aviation applications; this software development and maturation is also a key need in this area.

Additionally, the availability of spectrum that is appropriately classified, validated, and authorized for airborne use for sensing, radio navigation, and communication is essential. The Federal Communications Commission (FCC) must work with the FAA and industry to identify appropriate use of spectrum and ensure that needed frequency bands can be approved to enable new capabilities, as most of what is available is currently restricted to DoD and FAA applications. As part of the frequency conversation, potential interference issues due to relatively small aircraft having multiple radio frequency (RF) sources in close proximity need to be proactively addressed. It will be important to make sure there is no interference with other RF components on the aircraft from the frequencies/signals used for sensing.

Existing & Developing Over the Immediate Term	Short-Medium Term	Medium Term
• High-precision positioning, navigation, and timing sensors and other data sources necessary to enable new automation capabilities. • GPS protection and integrity monitoring, as well as initial evaluation of alternate positioning, navigation, and timing (PNT) for absolute and relative positioning technologies needed to augment GPS (particularly at low altitudes) • Detect and Avoid (DAA) technology maturation, evaluation, and demonstration across multiple implementations, including: ○ Optical ○ Acoustic ○ Radar ○ Collaborative • Implementation and initial operational evaluation of auto-land technology using absolute and relative position information beyond existing precision approach enablers (with the target of robust zero/zero auto-land and precision flight/positioning to mission points — landing, delivery, surveillance, etc.) • Technology evaluation phase needs to include frequency interference assessment while under simultaneous operation • Normalized FCC spectrum authorization process, particularly for radar-based DAA applications • Mapping of standards needs to facilitate above efforts	• Development and maturation of enabling technology, including: ○ Obstacle avoidance sensors ○ Landing aids/beacons/fiducials ○ High-precision radio navigation ○ GPS-denied navigation • Standards acceptance and certification pathways for sensing technologies that enable them to be used for operational approvals (e.g., to satisfy 14 CFR P91 and P135 without exemption)	• Development and maturation of enabling technology, including: ○ Vision-based navigation aids ○ Vision-based emergency landing systems • Standards acceptance and certification pathways for vision-based technologies that enable them to be used for operational approvals (e.g., to satisfy 14 CFR P91 and P135 without exemption)

T2. Communications and Frequency Usage

Description:

For many early-implementation CONOPs, autonomous aircraft benefit from some form of remote supervision and command/control enabled by ground control stations (GCS). (Note that even if the remote pilot in command [RPIC] is not directly manipulating the aircraft, the concept of operational control is still valid; "control" is thus used in this way even if the RPIC is primarily providing strategic direction.) This necessitates a high-integrity communication link between the aircraft and the remote operations systems. Autonomous aircraft and/or their remote operators will further need to communicate with ATC and other aircraft (piloted or otherwise) in the airspace to clearly exchange operational intent and coordinate safe and efficient shared access to airspace. The communications network needs to conform to security, integrity, availability, and latency requirements consistent with the safety and operational needs of the combined vehicle-GCS system.

In addition to vehicle-GCS communications (V2G), vehicle-to-vehicle (V2V) communications, and other vehicle connections (V2X), collaborative data sharing are key enabling capabilities necessary for autonomous cooperative aviation. Coordination between standards development organizations and the FCC will be essential to take ongoing efforts on V2V to fruition. Assignment of spectrum, and nontraditional use of spectrum will present challenges because some new capabilities will either require the use of non-aviation spectrum or a reassessment of current use of spectrum assignments.

As with other aspects of autonomous aviation discussed herein, frequency allocation and spectrum authorization are, unsurprisingly, key enablers of communications. Policies and practices must be implemented that provide adequate coverage, prevent interference, and ensure equitable access to the available frequencies. Monopolistic practices in frequency allocation would work against safety and community benefit goals.

Existing & Developing Over the Immediate Term	Short-Medium Term	Medium Term
• Multimodal comm (e.g., SATCOM/cellular) is primarily being handled in the context of more traditional aviation • Secure communication standards for UAS and GCS • FCC needs to issue rulemaking on the C-Band (5030-5091 MHz) spectrum to enable access to C2 frequencies • FAA TSO for C-Band radios exists; update to ensure coordination with FCC allowances from a ground transmitter standpoint • FAA acceptance of DO-377A/B C2 Link MASPS as a basis for the overall C2 Link network performance requirements and methods, with consideration of revised voice relay latency requirements • Need C2 link reliability information to inform the LC2L procedures conversation • ATC voice and data communications: ○ Approval of ground VHF stations, which is necessary to remove airborne VHF relays ○ FAA adoption of VoIP interoperability standards (ED-136 and ED-137), which is necessary to enable ground-ground communications with ATC ○ FCC-enabled airborne and ground-based PNT technology to facilitate V2V and V2G cooperation	• Dedicated aviation autonomy comm network (e.g., C-Band) and general Federal funding support to implement RTCA DO-362 and DO-377 • Established method of approval for the aviation autonomy comm network (e.g., DO-377A/B compliance with an FAA TSO or AC issued) • Digital vehicle-to-vehicle comm for autonomous operations (see "brick" T4) • Operational demonstration of the existing standards (e.g., under RTCA SC-228) for LC2L procedures and requirements to rightsize the rigor of these requirements • Conduct impact assessment for RTCA DO-160 (e.g., Ch 20) • FCC NPRM to allow stationary ground station transmission of aviation VHF frequencies	• Onboard natural language processing (NLP) for airspace integration and ATC comms • Bidirectional digital communication of intent and state for ATC integration • FAA voice and data communications system modernization to allow direct ground-to-ground communications instead of relaying through an onboard VHF radio; requires significant budget allocation for infrastructure (note: this is already happening in international jurisdictions such as Australia and needs to happen sooner to support U.S. competitiveness)

T3. Equipage and Avionics

Description:

Autonomous flight execution and planning bring additional requirements for onboard and off-board system equipage. Of key importance will be flexible autonomy executive, contingency management, and DAA software — as well as their miniaturized, high-performance host platforms. The more ubiquitous and interoperable this equipage can be, the safer and more efficient autonomous operations can be. Thus, efforts to cost-effectively build and certify this technology are essential, along with broader industry acceptance of its more universal benefits. Such efforts should take into consideration that enabling systems and equipment may employ automation, machine learning, and smart architectures and need additional certification tools, as discussed later in this document, or may be deterministic and fielded in a configuration that is no longer dynamically learning. Success will also be facilitated by advances in modeling and simulation and V&V of complex autonomy decision engines and other enabling software. While working to enable AI/ML certification and adoption pathways is seen by many as a key long-term enabler for the industry, nearer-term efforts to advance autonomous design and operations that can be conducted without AI/ML should not be underestimated.

Crucially, equipage presents not just a technical challenge but also one of economics and operational flexibility. Large commercial aircraft today are already equipped to operate with a high level of automation. Technologies such as advanced autopilots and CAT IIIC auto-land via instrument landing system (ILS) or ground-based augmentation systems (GBAS) can already achieve substantial end-to-end automatic flight. The real challenge is to achieve this level of automation at the same level of safety but with significantly reduced cost in onboard systems and support infrastructure to allow more aircraft to operate more autonomously over greater portions of the airspace and airdrome infrastructures.

Existing & Developing Over the Immediate Term	Short-Medium Term	Medium Term
• Continued expansion of ADS-B adoption for general aviation • Simplified Vehicle Operations (SVO) interfaces to increase cockpit automation and build an organic pathway to autonomy • Define a pathway to certify a flight deck built for SVO considering aircraft functions, operational functions, and airspace management functions as appropriate and as capability maturity allows • Development and maturation of autonomy-enabling tech in a cost-effective and certifiable manner: o Remotely operated transponder and radio o Remote operations system (1:1) o High-performance and high-assurance flight control and VMS o DAA algorithms and path planning o Miniaturized fly-by-wire • Modeling and simulation for autonomous system V&V • Initial m:N use cases (e.g., swarms)	• Remote operations system (1:n) • System health/state monitoring • Complex, deterministic contingency management • Advanced envelope protection and upset recovery • Advanced autopilot/VMS for autonomous operations • Scalable techniques for autonomous system V&V • Validation and certification standards for deep neural network (DNN) and/or other complex AI/ML architectures for perception, planning, and localization applications • Need early applications with AI/ML to use as test cases for certification activities	• Certifiable and more adaptive AI/ML-based autonomy executive (e.g., RL), possibly through new statistically driven certification methodology

T4. Digital ATC Communications

Description:
Regardless of whether a new set of flight rules is implemented, digital communication between aircraft and air traffic management services (including today's ATC) will have safety and economic benefits for all airspace users, including current and new entrants. Given the significant timeline to upgrade air traffic management infrastructure, Congress should act to implement this infrastructure improvement before the current voice-based system negatively impacts the safety and efficiency of aviation or potentially damages the public's trust in the existing ATC system.

DFR will enable new entrants such as autonomous aircraft, but it will also benefit existing airspace users. In some ways it is an extension and completion of the intention behind NextGen, allowing an easier and safer option for individual pilots than full IFR and facilitating more efficient operations for airlines, among other benefits.

The most prudent approach to implementation is to scale the industry to automate and commercialize preflight and inflight airspace integration services. Commercialization may come from third-party service providers (3PSPs, similar to "providers of services for UAS" or PSU as is sometimes used) that offer operators licensed software, potentially certified to provide these safety critical services under new Part 108 (per BVLOS ARC) on top of robust COTS firmware/hardware. This will need to be coupled with a digital Flight Information Management System (FIMS) for optimized ATC integration.

Equipage requirements in large metropolitan airspace (or other complex and densely utilized airspace) is going to have to include all operations, whether that's communications (devices capable of IP-based datacomm and advanced intent exchange) or navigation (APNT will be an important transformation for the country, and should be a public-private partnership — akin to GPS will affect more than just aviation) or surveillance (surveillance systems should begin to become commercialized per third-party providers as new flight locations are expanded for autonomous instrument flight). Any potential mandate will need to be appropriately funded such that all airspace users can be included.

To further justify the investment in DFR, its potential economic benefit needs to be well-understood and demonstrated at a proof-of-concept level. Additionally, as has been said, it is essential to ensure that airspace is integrated for, and working to improve the experience of, both autonomous and legacy aviation users.

Existing & Developing Over the Immediate Term	Short-Medium Term	Medium Term
• Support RTCA DFR effort (and other SDO activities) and incorporate results into the ICAO RPAS element so they can be promulgated appropriately • Work internationally to ensure harmonized result • Quantify expected benefit of digital ATC communications to justify investment needed • Congressional mandate, regulatory action, or other forcing function to begin necessary rulemaking • Demonstrate initial digital clearance, sharing of intent, and collaborative automated separation under human supervision • UTM/third-party service providers (3PSPs) with tactical and strategic deconfliction (including traffic, weather, and other airspace hazards — e.g., TFR) for UAM. Operating in assistive mode for passenger carrying operations — building trust in commercial software and COTS firmware/hardware to perform services. Likely in limited geographic areas.	• Continue deployment and integration of UTM/3PSPs-FIMS throughout desired geographic areas • Technologies to be matured and deployed in the US to catch up with international activities (sooner than three years is desirable): ○ Digital communication of flight intent (IP-based datacomm for flight intent filing) ○ Human-machine interface for human-machine teaming ○ Autonomous weather avoidance (see also "brick" I6 for 3PSPs)	• Complete deployment of UTM/3PSPs-FIMS tools for the full range of AAM applications throughout desired geographic areas; note that retaining the option for centralized FAA-managed ATC is still desirable • Maturation of FAA airspace management for UAS as supplement/alternative to UTM 3PSPs • New flight rules Rulemaking to modernize airspace (see DFR discussion) • Mandatory equipage driven by economic benefit from autonomous UAM and other applications

T5. Auto Ground Operational Capabilities (e.g., Taxiing)

Description:

The ability for an autonomous aircraft to safely taxi in the airport environment is essential for true gate-to-gate operations. While ground personnel may be employed, long term, this technology is a key enabler for autonomous aviation as well as a potential source of efficiency and safety for manned aviation as taxi time is significant for many commercial operations and runway incursions are a significant fraction of pilot-error incidents. True gate-to-runway/FATO/takeoff location autonomous operations have the possibility to prevent runway incursions, reduce workload for cockpit crew during taxi, especially at busy commercial airports, and integrate uncrewed aircraft into nominal airport operations. It also presents an opportunity to address safety concerns associated with runway incursions, reduce the environmental impact and costs of inefficient ground operations, and reduce controller workload.

To maximize predictability and utility, auto-taxi capabilities must be inclusive of airports, heliports, vertiports, and everything in between, allowing for ground operations optimization (potential benefits of auto-taxi at commercial airports include fuel savings, time savings to get people off the taxiways faster, more streamlined operations on the ground, etc.) and increased safety for all aviation stakeholders. For aircraft that cannot taxi (e.g., have skids or other components) or for those for which ground movement operations are not necessary (e.g., small UAS), auto-taxi capabilities may simply take the form of technology needed to successfully integrate into whatever ground operating environment is being used.

An intermediate step, such as tugs, automated or not, or manned marshaling aircraft, may be desirable. Autonomous ground vehicle technologies (e.g., ground-penetrating radar, LIDAR) may have utility in enabling auto-taxi capabilities and their adoption into aviation from a technical and certification perspective should be encouraged. And for eVTOL and other autonomous aircraft that can potentially be stored in and launched from the same location, consider vertiport design guidelines that integrate TLOFs with the stand such that taxi operations are not required.

Throughout the deployment and development process, it is important that autonomous ground operations coordinate safely and smoothly with existing ATC procedures, much as it is essential that autonomous flight operations be able to blend into legacy airspace operations and control.

Existing & Developing Over the Immediate Term	Short-Medium Term	Medium Term
• Procedural evaluation of more efficient mechanism for existing ATC to control UAS for ground operations • Demonstrate applicability of autonomous and/or uncrewed ground operations • Technology maturation and standards development for the following: ○ FMS support for auto-taxi ○ LIDAR-based (or other) auto-taxi ○ Infrastructure modifications to facilitate autonomous ground ops	• Continued operational scope expansion and procedural refinement for autonomous and/or uncrewed ground operations • Technology maturation and standards development for the following: ○ Vision-based auto-taxi ○ Radar-based auto-taxi ○ GBR-based auto-taxi	• Operational normalization of UAS ATC ground control procedures • Operational normalization of auto-taxi procedures

Foundation: Airworthiness

Airworthiness certification is the first thing that many think of when the question of barriers to autonomous aviation is mentioned. While operations and integration (the following two foundational items, below) are potentially even more in need of attention at this point in the industry, no list of what is needed for autonomous aviation would be complete without airworthiness. Autonomy in aviation is not limited to one particular type of aircraft or concept of operations, but rather may be applied across all sizes and architectures from small quadcopter UAS through large, fixed-wing airplanes, across a variety of operational environments, and with varying extents of autonomy versus human control. It is important that the approach to airworthiness certification for autonomy be able to accommodate that variety and not be connected too closely to any single set of assumptions about the aircraft on which it is being implemented. That being said, practicality may dictate that airworthiness requirements for various aircraft types and/or operations, such as cargo sUAS, or extents of autonomy, may be developed sooner than others. To acknowledge this diversity of application, the first of the “bricks” for the foundation of airworthiness certification is the application of the safety continuum to autonomous systems.

This warrants discussion as, currently, the only autonomous systems that have been certified have been done so with the assumption that either there is a human pilot on board directly overseeing the operation of the autonomy or that the system is only active in an emergency in which the onboard pilot is incapacitated. Neither of these frameworks are appropriate for the systems that are being developed to use a high degree of autonomy in nominal uncrewed operations, either in concert with or in lieu of a human pilot. Again, an approach to airworthiness that covers a broad spectrum of aircraft (though perhaps not all with the same tools) and a broad spectrum of the extent of autonomy in use (not just fully manually flown or fully autonomous) is needed.

The “bricks” being explored here are: application of the safety continuum, normalized certification basis for the spectrum of autonomous aircraft (e.g., LSA, Part 23 Level 1-4), means of compliance development and acceptance, clarity in the approach to off-board systems (e.g., ground control stations), a certification approach to “fail functional” autonomy that doesn’t rely on a human reversionary mode, and, eventually, a certification approach for nondeterministic autonomous systems across the entire spectrum of aircraft and operations.

A1. Safety Continuum

Description:
The original Safety Continuum concept was developed as a tool for aircraft certification by which the level of regulatory oversight, including the acceptable means of compliance to applicable airworthiness regulations and operational oversight, could be aligned with the public expectations for the safety of a given aircraft type. Largely driven by size, performance, and the number of passengers on board, operational safety considerations were largely handled separately in the applicable operational regulations (e.g., part 91, part 135, part 121), as were pilot training requirements. Further efforts to clarify and expand these concepts to include operational considerations (e.g., where the aircraft is operating and what its main missions will be) are underway (see EASA's SC-VTOL "enhanced" and "basic" categories). This Uniform Safety Continuum (USC) concept has been developed internally within the FAA but needs to be made more widely known and consistently applied to both crewed and autonomous uncrewed aircraft and must retain the ability for self-declarative compliance that is working well within the Light Sport Aircraft (LSA) industry and could be beneficially expanded to certain UAS where appropriate. This is in line with work that is already underway within the FAA, in part in response to the BVLOS ARC report. This should be supported and completed as it will add clarity and consistency to the determination of certification bases and minimum acceptable levels of safety for these new aircraft, many of which are being used in novel ways.

One of the key novel differentiators that should be kept in mind as airworthiness processes and requirements are developed is that without people on board and with low kinetic energy, autonomous sUAS operating today fall at a vastly different point on the safety continuum than larger autonomous uncrewed aircraft that carry larger amounts of cargo and/or passengers. As the USC is more widely disseminated and applied to certification projects, it is important that the available and accepted MOC provide specific technical requirements that are appropriate for aircraft that fall along the full USC spectrum. The technical requirements and certification processes that are appropriate for larger passenger and cargo-carrying operations should not be automatically applied to sUAS making low-risk package deliveries or performing surveillance missions, for example. An appropriate application of the USC concept across the regulatory landscape will help ensure regulatory rightsizing, prevent unnecessary costs, and support U.S. competitiveness while maintaining safety in autonomous aviation.

Existing & Developing Over the Immediate Term	Short-Medium Term	Medium Term
• FAA socializes Uniform Safety Continuum AVS Order for industry feedback, then move to publication • Bring clarity through policy regarding how the continuum applies to airworthiness, design approval, operational considerations, and airspace management expectations • Safety Continuum applicability to autonomy white paper • Tailored standard MOC documents for sUAS autonomous uncrewed aircraft accepted by FAA	• Add USC tailoring to accepted MOC documents (e.g., F44) for crewed aviation • Clarify any impacts that autonomous operations have (or don't have) on the safety continuum	• Tailored standard MOC documents for AAM autonomous uncrewed aircraft accepted by FAA

A2. Certification Basis

Description:
Arguably the first real step in the certification journey for new aviation products, the certification basis provides the regulatory anchor within the Code of Federal Regulations (CFR). There are already many CFR parts in use for different categories of aircraft today (e.g., Parts 23 and 25 for fixed-wing airplanes, Parts 27 and 29 for helicopters) that include requirements for systems and equipment which are reasonable to apply to autonomous systems based on the intended function and operational use (or operational design domain).

Autonomy systems that are being retrofitted into existing aircraft can rely heavily on the certification basis of the original aircraft — with the caveat that the most recent version may need to be used (e.g., Amendment 64 for Part 23 aircraft) per 14 CFR 21.101. Smaller or other lower-risk autonomous UAS systems may find that the Durability and Reliability approach granted through 14 CFR 21.17(b) is appropriate for their certification. One remaining challenge is the growing need to address the certification basis for automation functions that automate capabilities related to operational integration or airspace management. These do not fall in the traditional regulatory framework to be addressed solely by aircraft certification for their acceptance. This is a critical area to explore further for highly automated aircraft and future autonomous flight concepts.

Autonomous aircraft need to have clarity around their certification basis through consistent application of the safety continuum (see "brick" A1) and its associated design assurance level (DAL) requirements. Both new and retrofit autonomous systems need a consistent policy and approach for the regulatory mechanisms used to oversee and ground-based components of an autonomous aircraft system (see "brick" A4).

It is important that while airworthiness certification and the certification basis that supports it are essential aspects of the 14 CFR Part 21 process that must appropriately interface with operational approvals under 14 CFR Part 91, Part 135, etc., they are separate regulatory processes assigned to their own business units with the FAA. In addition to the certification basis and other existing regulatory mechanisms, relief through a Part 11 exemption process is also expected to be needed as part of the ultimate regulatory package for autonomous uncrewed aircraft.

Existing & Developing Over the Immediate Term	Short-Medium Term	Medium Term
• Need to address the human-centric language that is used throughout the airworthiness requirements (e.g., "pilot forces") • First G1 for an autonomous aircraft published for comment • Certification basis approved for military autonomous aircraft • Leverage Durability and Reliability lessons learned and best practices to inform TC/STC requirements • Define how operational functions and airspace integration functions will be addressed by civil authorities, where mixed responsibility exists between automation and human-centric capabilities	• Update order that MIDO uses to ensure design control for commercial-grade ground control station components • Update military airworthiness processes to accommodate autonomous aircraft • Implement changes to operational and airspace-related procedures and regulations based on proven automation capabilities	• TSOs available for autonomous equipment • Approval mechanism available for service providers (e.g., C2 provider, 3PSPs), potentially through Rulemaking associated with operating certificates (e.g., 14 CFR 135, 137, and 121)

A3. Means of Compliance

Description:

The certification basis provides the regulatory performance requirements for the system or aircraft in question; means of compliance are used to show that the system can perform its stated intended function(s) for the defined operational design domain and satisfy the requirements in the certification basis. Currently, for simple/conventional projects, there is a set of ASTM F44 standards that are accepted as a default means of compliance for 14 CFR Part 23's performance-based requirements. Other means of compliance to part 91, 135, etc., for automation of operational functions and airspace integration functions will need to be defined as soon as possible.

Means of compliance can be tailored to specific places along the Safety Continuum (considering the aircraft, operation, and intended airspace) or be more broadly applicable when dealing with aspects that are common across multiple aircraft certification mechanisms. They can be written as an industry, by the regulator, or as a project-specific proprietary document by the Applicant.

Leveraging these existing standards and the existing standards development process to the maximum extent possible will increase safety through the capture of cross-industry best practices, reduce Regulator workload by allowing review and acceptance of a given standard to apply to multiple projects, and lay the groundwork for interoperability and transferable pilot/operator skill sets.

Ideally, experience and data from non-civil operations and other operations that are currently being conducted would be leveraged to inform standards creation, especially as non-civil airworthiness processes are relying increasingly upon civil SDO work.

Existing & Developing Over the Immediate Term	Short-Medium Term	Medium Term
• Increase industry investment in SDO activities, particularly for those technologies mentioned in the "Technology Foundation" • Continue gap identification in the SDO landscape (build on ANSI work and encourage horizontal collaboration) • One-off Issue Papers as needed • "Leverage military and experimental aircraft in showing how the MoC and cert basis will relate for autonomous systems (perhaps through a white paper). FAA needs to update the CPI Guide and official policy (and 8110.4) to encompass the detailed design standard (DDS) process being rolled out to organize MoC and to address procedures for satisfying expectations for automation functions and capabilities related to operational functions and airspace management • Congressional action to force FAA legal to allow full participation of the FAA in the SDO process • Formal acceptance of a set of harmonized published standards for sUAS autonomous system MOCs	• Industry publishes standards needed to fill known gaps for both hardware and software • Standardized Issue Paper formats and ACs to fill in gaps • MOC standards landscape • International harmonization • FAA needs to update Order 8110.4 to cover the DDS process and how MoCs should be used	• Formal acceptance of a set of harmonized published standards for AAM autonomous system MOCs

A4. Off-Board Systems (a.k.a. Associated Elements)

Description:
For autonomous uncrewed aircraft, key portions of the system are not located on the aircraft. These ground-based or off-board systems, often referred to as Associated Elements (AE) in the U.S., whether located at a mission control center or elsewhere are critical to the safe execution of the intended function of the autonomous system. Thus, it makes sense that they be considered in some fashion as part of the combined airworthiness and operational certification of a UAS. They are part of the System that goes with the UA, after all. But not all AE are systems within the manufacturer's or operator's control — communications infrastructure and GPS, for instance. As such, it does not make sense to include every external aspect of the UA's operation — certifying cellular data connections, for instance, seems out of scope. (Operational limitations and analysis of acceptability related to off-board systems would take place outside of the aircraft airworthiness certification process.)

A clear approach that rightsizes effort, supports safety, and is in line with existing precedents (e.g., ground-based navigation equipment) is needed. The role of the remote pilot in command (RPIC), if one exists, that is using the ground control station (GCS) or other AE relative to the control of the aircraft, the intended functions specified in 14 CFR 23.2500, and their duties per 14 CFR 23.2600 will need to be clearly defined as part of determining an appropriate regulatory mechanism for oversight and approval of off-board systems. (This is a particularly interesting question to be answered as civil and non-civil approaches to the role of the remote pilot and GCS have differed with non-civil remote pilots performing their duties in an environment much more akin to a ground-based cockpit than that of the GCS used for many civil operations today.) Other forms of oversight, such as the self-declarative approach employed for Light Sport Aircraft, the operational approach taken for low-risk UAS AE (FAA Memo AIR600-21-AIR-600-PM01), or that from 14 CFR Part 170/171 for Navigational Facilities, might provide techniques from which to draw, especially for UAS associated elements.

As part of defining this approach, a question that will need to be answered is: who is responsible for the continued airworthiness or otherwise operational acceptability of systems that implement operational functions and airspace integration functions, including airborne or ground-based systems? Will the existing airworthiness directive (AD) process be applicable to ground-based systems? Approaches similar to those in use for navigation aids or other ground-based safety-critical equipment used in instrument flight will need to be considered along with other 14 CFR Part 21 mechanisms.

Existing & Developing Over the Immediate Term	Short-Medium Term	Medium Term
• Mature and clarify Associated Elements (AE) policy for all UAS, see AIR600-21-AIR-600-PM01, potentially separating GCS and comms equipment and systems • FAA needs to develop and communicate an approval pathway for AE, including potentially different mechanisms for ground-based systems and equipment and communication infrastructure • Internationally harmonize the approach to AE; develop equivalency approach for any FAA US AE certification	• Standards/policy/ACs to clarify requirements and approach to ground-based UAS components • While direct adoption is not appropriate, consider applying a 14 CFR Part 170/Part 171-like expansion/adaption or new Rulemaking for GCS equipment	• Interoperable approach for ground-based systems that can be used by multiple aircraft

A5. Alternative Certification Approaches (e.g., Fail-Functional and Runtime Assurance)

Description:
Fail-functional systems architecture and runtime assurance are two essential tools being employed to facilitate a safe shift away from having the human pilot be the last line of defense in the event of a system failure. This is a foundational shift in airworthiness certification and airman certification and will require careful consideration and bold action. Some important early steps have been taken but need to be integrated into existing civil airworthiness best practices and certification.

ASTM F3269 Standard Practice for Methods to Safely Bound Behavior of Aircraft Systems Containing Complex Functions Using Run-Time Assurance [https://www.astm.org/f3269-21.html] was one of the first attempts at requirements definition for autonomous systems that did not rely on a human pilot to step in and take over in the event of a system failure. The ability for the autonomy to have multiple layers of functionality — possibly reverting to a simplified, smaller set of capabilities in the event of a failure but not immediately relying on a human pilot — is essential for the mature vision for autonomous aircraft where the human pilot has a supervisory role. This fundamental shift in certification methodology needs to be codified into a robust set of means of compliance. It is important to recognize the potential of RTA as an architectural consideration for resilient automation design and not just a formal method of bounding behavior of complex systems.

A certification pathway for fail-functional autonomy is also essential for near-term automation capability maturity for singular systems and for getting to M:N operations and more advanced extents of autonomy, such as those defined in the Automated Flight Rules (AFR) Level 4 in the BVLOS ARC report.

Existing & Developing Over the Immediate Term	Short-Medium Term	Medium Term
• Clearly define the certification philosophy that we are trying to capture in moving away from a human pilot backup (possible white paper); leverage existing fly-by-wire system certification approach • Continue to build MOC library for "trustworthy" and fail-functional autonomous systems • Gap analysis of regulatory, requirements landscape in consideration of removing the human backup • Leverage military experience in RTA (e.g., USAF ACT3) to inform run-time assurance architectures	• Accepted MOC package for fail-functional autonomous systems • Build operational experience and safety track record with fail-functional systems; how are safety improvements made?	• Fail-functional capabilities reflected in pilot/operator training requirements and operational procedures, including 1:many requirements

A6. Certification of Software Developed with AI/ML

Description:

One of the challenges of advanced autonomous systems is how to apply traditional software certification methodology to systems that were developed using artificial intelligence (AI) and machine learning (ML; note that AI is more than ML), regardless of whether the resulting code actually performs in a nondeterministic way. (Some complex software systems may appear to a human observer to be nondeterministic due to the wide variety of nuance and variation in potential inputs but is actually performing deterministically given the exact inputs provided and specifically bounded performance outcomes.) The challenge will be even larger for those eventual systems that are actually nondeterministic, display emergent behavior, or utilize active machine learning that allows the system to change behavior models in real time. The potential for these technologies to increase the safety and capability of autonomous systems is significant, however, so it is worth considering new certification approaches that retain the appropriate level of oversight that works with them. One such new approach could leverage simulation: by running numerous tests in simulation, a variety of circumstances and potential failure conditions can be evaluated rapidly and safely to demonstrate predictable, bounded, outcomes-based system performance. This could be done before real-world testing and/or as a supplement to real-world testing.

In addition to having software certification approaches that are appropriate to these technologies, the operational approval process for aircraft utilizing AI/ML should also be considered. What are the appropriate considerations for an aircraft that autonomously makes the decision to reroute to avoid weather, for example? How should we approach operational decisions that are traditionally made by a pilot but are now being made autonomously? The answers to these questions and the eventual resilience in behavior of adaptive systems with learning agents will largely be dependent upon the training data used to develop the learning agent behavioral models. It is essential that training data covers the entire operational design domain and represents real-world operations as closely as possible. It is also imperative that training data be separate and independent from validation and/or certification data.

As an interim, urgent step, there is a need to streamline the software update process so that safety-critical improvements in code can be implemented in a timely fashion instead of batched into lengthy and expensive certification projects that may only be attempted once every two to five years. Of course, this depends on the nature of the software impact analysis for proposed changes, the resiliency of the software/learning agent in question, and its functional criticality.

It is important for the industry to agree on a classification scheme for the practical implementation of AI/ML, including consideration for functional criticality and the associated risk, as well as "algorithmic risk," or the ability to safely implement AI/ML in the specific operational design domain versus traditional algorithms without learning agents[1].

Existing & Developing Over the Immediate Term	Short-Medium Term	Medium Term
• Approve certification bases for existing ML certification projects • Complete at least one ML software certification program • Clear problem statement/gap analysis for operational approvals of AI/ML decision-making • Streamline the software certification process for safety-enhancing updates • Leverage DARPA and other military work in this space to advance industry efforts as possible	• Standards development work to create MOC that accommodate a wide range of autonomous systems (encompassing a spectrum of extents of autonomy) and software development techniques (e.g., agile methodology)	• Road map for certification of nondeterministic/complex autonomous systems • Road map for operational integration of highly autonomous systems

Foundation: Operations

Operational certification, most often in the form of civil Part 135 on demand operations, is often traditionally considered only after airworthiness certification is achieved. Unfortunately, this serialized approach will result in unnecessary and costly delays for entry into service and further erode U.S. leadership in global aviation. From a timing perspective, there is increasing pressure to have initial entry into service operations within the next five to eight years for passenger-carrying autonomy applications with smaller aircraft applications of autonomous aviation already underway and in need of a more robust regulatory environment. International competition for UAS primacy is also driving the urgency for operational certification. More importantly, however, due to the unique nature of the autonomous future that is being built, it is essential that airworthiness certification, operational approvals, infrastructure development, and airspace integration be undertaken in a coordinated manner. Operational requirements may well end up driving the system capabilities and characteristics that an airworthiness certification will verify.

The “bricks” covered here for the operational certification foundation are: normalization of 14 CFR Part 135 uncrewed autonomous aircraft operations; normalization of 14 CFR Part 91 as it relates to PIC responsibilities (note that 14 CFR 91.113 is also included in Integration, below) and adaptation to uncrewed aircraft operation; definition of training and qualifications for remote pilots/supervisors of autonomous uncrewed aircraft; definition of training and qualifications for operators of uncrewed aircraft; development of a standardized approach to functional breakdown and allocation for varying extents of aircraft autonomy; an exploration of alternate approaches and concepts to the definition of “pilot in command” for highly autonomous aircraft operations; lost link procedures; and an understanding of maintenance and continued operational safety for autonomous aircraft.

O1. Part 135 for Autonomous Aircraft

Description:

As 14 CFR Part 135 was written with the assumption that there would be at least one human pilot on board each aircraft being operated thereunder, it is not a perfect fit for uncrewed autonomous aircraft or highly autonomous aircraft operations (with M:N enabled). Relief has already been granted for multiple Part 135 sUAS operators, highlighting specific areas of mismatch. Moving away from the Part 11 exemption process and toward a normalized UAS/autonomy-friendly adaptation of Part 135 is key for industry maturation when technology can be proven mature in its capability to replace human-centric functions in real-world operations. Deeper than that, consistent approaches to and concepts in the generation and FAA evaluation (e.g., AED) of the manuals and procedures (including maintenance, training, and operations) that are essential components of a certified Part 135 operation are also needed.

Additionally, just as with airworthiness requirements, operational risk should be kept in mind when rightsizing P135 requirements for autonomous operations. Autonomous sUAS operating today may serve a critical role as an operational test bed for P135 adaptations that unlock future larger autonomous uncrewed aircraft that carry larger amounts of cargo and/or passengers.

Note that the rulemaking activities here may be handled within an S-FAR/Rulemaking process in combination with Part 191 and Part 61 changes.

Existing & Developing Over the Immediate Term	Short-Medium Term	Medium Term
• Complete 14 CFR Part 108 rulemaking process • Combine lessons learned from the various exemptions granted for Part 135 UAS operations and evaluate their applicability to other operational design domains and use cases • ASTM AC377 white paper on operational control for UAS	• FAA should publish a policy paper to standardize approach to uncrewed autonomous Part 135 operations	• Final Rule to adjust Part 135 to accommodate the unique approach to operating uncrewed autonomous aircraft for on-demand commercial ops

O2. Part 91 for Autonomous Aircraft

Description:
As with 14 CFR 135, 14 CFR Part 91 was written with the assumption that there would be at least one human pilot on board each aircraft being operated thereunder; it is not a perfect fit for uncrewed autonomous aircraft or highly autonomous aircraft operations with M:N enabled. Relief has already been granted to selected paragraphs of 14 CFR Part 91 as part of exemptions granted to multiple Part 135 sUAS operators, highlighting specific areas of mismatch. Moving away from the Part 11 exemption process and toward a normalized UAS/autonomy-friendly adaptation of Part 91 is key for industry maturation. A comprehensive review and revision of Part 91 language to remove human-centric terminology is needed here as well.

Specifically, ASTM AC377 published a technical report in March 2022 on barriers to autonomous aviation within 14 CFR Part 91. Beyond this, 91.113 is covered as its own topic, “brick” I1. Digital Flight Rules, also covered under its own “brick”, I4, promises to be a key enabler for autonomous and uncrewed operations.

Note that the rulemaking activities here may be handled within an S-FAR/Rulemaking process in combination with Part 135 and Part 61 changes.

Existing & Developing Over the Immediate Term	Short-Medium Term	Medium Term
• Legislation to define “see” as including other than a human eye to unlock the current legal barrier to application of 14 CFR 91.113 to UAS • Revisit ASTM AC377 TR-3 with an eye to large barriers and items that would significantly slow progress for autonomous uncrewed aviation within P91 • Adapt Part 91 to get away from “see” and other terminology that requires a crewmember on board the aircraft (see BVLOS ARC report) • Standardized set of exemptions and alternative means of compliance heading toward DFR for autonomous aircraft	• FAA should publish a policy paper to standardize approach to uncrewed autonomous Part 91 operations • Initial DFR that can be implemented with existing NAS infrastructure	• Final Rule to adjust 14 CFR 91 to accommodate the unique approach to being the PIC of an uncrewed autonomous aircraft • Full DFR implementation in the NAS incorporating infrastructure upgrades needed for the FAA to accommodate automation

03. Part 61 for Autonomous Aircraft

Description:
Currently, the available training requirements predominantly found in 14 CFR Part 61 are written with the assumption that the pilot is onboard the aircraft and that, as a result, there is only ever one aircraft for which a pilot is responsible. This is not a perfect fit for uncrewed autonomous aircraft or highly autonomous aircraft operations with M:N enabled. (Efforts focused on the type of aircraft, e.g., powered lift, that a pilot is being trained to fly are related but separate from the work referenced here.) With ever-increasing extents of autonomy, and with the interface that the pilot uses to interact with the UA often radically different from a traditional cockpit, there is a need for a reevaluation of and shift in training. Traditional stick-and-rudder and visual traffic detection skills may be of lower priority while aircraft supervision, systems management, communications, and other skills may be of much greater importance. The Part 107 sUAS remote pilot certification is an example of how pilot certification can be reimagined to accommodate new technology.

Rightsizing medical requirements for remote operators is another area that needs attention going forward. There is a potential to open the door for people that may have mobility challenges or other conditions who can't serve as an onboard pilot but could safely be remote pilots/operators. Getting this right, along with appropriately scaling the training requirements in general, has the potential to open the door for many people who might not have been previously able to pursue an airman career due to physical or financial constraints.

One of the key operational efficiencies that high extents of automation promise is the potential for one remote pilot or multivehicle supervisor to monitor more than one aircraft at any given time. This 1:many operation has training requirements and implications for Op Specs / Pilot ratings, currencies, training, etc. that need to be considered in an S-FAR or rulemaking effort that should be released as soon as possible.

Additionally, as technology evolves and aircraft become more complex, just because an aircraft is manned doesn't mean there isn't a significant extent of autonomy on that aircraft (e.g., SVO, envelope protection, stability augmentation). There can be implications for pilot training for onboard pilots as well as remote pilots. The human factor considerations for both autonomous unmanned and SVO aircraft will need to be carefully considered and appropriate requirements developed.

Note that the rulemaking activities here may be handled within an S-FAR/Rulemaking process in combination with Part 135 and Part 91 changes.

Existing & Developing Over the Immediate Term	Short-Medium Term	Medium Term
• Rely on 14 CFR Part 108 Rulemaking as much as possible for training requirements for UAS • In lieu of beginning with an S-FAR, develop and implement training programs under 14 CFR 135 • Finalize pilot training requirements for SVO aircraft	• NPRM should build on experience gained from 14 CFR Part 135 training programs	• Final Rule that combines piloted eVTOL S-FAR and autonomous lessons learned that is broadly encompassing of aircraft and autonomy

04. Part 108 Rulemaking

Description:

Currently, 14 CFR Part 107 Small Unmanned Aircraft Systems exists for sUAS below 55 lbs. in weight. Based on the recommendations of the Beyond Visual Line of Sight (BVLOS) Aviation Rulemaking Committee (ARC) that were published in March 2022, a second UAS-focused part is being developed under 14 CFR. Known as Part 108, it would focus on BVLOS operations and cover a larger range of UA sizes than Part 107, with applicability expected to go up to aircraft comparable in size to current Light Sport Aircraft (LSA). This would go a long way toward the normalization of BVLOS operations, but its limited scope — likely to below 400′ AGL or within 100′ of an obstacle — means that it is necessarily just a first step toward the realization of the long-term vision for BVLOS autonomous uncrewed flight.

It is expected that Part 108 will include operational rules and UAS operator training requirements for BVLOS flight.

Existing & Developing Over the Immediate Term	Short-Medium Term	Medium Term
• Part 108 proposed rule language out for public comment and quick adjudication of the comments • Begin any necessary supporting activities (e.g., pilot training program development and industry-based certification standards, for Part 108 implementation)	• Finalize Part 108 Rulemaking (ideally sooner) • Mature/expand real-world application of Part 108 to BVLOS operations • Expansion of BVLOS regulatory landscape beyond low altitude and shielded operations	• Gain operational experience from Part 108 and expand to other airspace / UA applications

O5. Functional Breakdown and Allocation

Description:

One of the key components of the ASTM AC377 first technical report was a suggestion for how to approach requirements definition for autonomous aircraft systems through a functional breakdown. This approach allows each function/system to be assessed in a tailored fashion that takes into account its individual characteristics (complexity/maturity, risk/benefit, etc.) instead of lumping every system on an aircraft into the same "level." Roles and responsibilities for each function or comprising task would then be assigned to a system or a person for both nominal and off-nominal operations and requirements determined as appropriate. This will facilitate conversations around the extent of autonomy present in a given system and the requirements that are appropriate thereto.

Existing & Developing Over the Immediate Term	Short-Medium Term	Medium Term
• Build upon the AC377 TR1 framework for a standardized functional allocation approach that can be leveraged for internal FAA policy/procedures to support its application at the local project level	• Connect functional allocations to requirements for systems and training programs for RPICs and multi-vehicle supervisors • Write performance-based rules that allow FAA to recognized MOC for functions that are aligned with the safety continuum and can be used in connection with existing airworthiness rules (e.g., Part 23)	• Finalize performance-based rules that allow FAA to accept, and have FAA acceptance of, MOC for common functions • Standardization of RPIC and multi-vehicle supervisor requirements based on defined roles/functions (see "brick" O3)

O6. Exploration of the RPIC Role

Description:

The role of the pilot in command (PIC) as defined foundationally in 14 CFR 91.3 must be adapted to that of a remote PIC (RPIC) for autonomous uncrewed aircraft and multi-vehicle supervisor for highly autonomous aircraft operations in a 1:many operation. While many commonalities remain, a few key differences need to be explored and requirements clarified. ASTM AC377 TR3 explored the barriers within 14 CFR Part 91 to fully autonomous operations. Starting with 1:1 operations, this exploration will need to expand to 1:many (or m:N operations, where a group of RPICs are responsible for a fleet of autonomous aircraft) and cover ever-increasing extents of autonomy as can be defined through functional breakdowns (see "brick" O4 above).

When considering the development of a multi-vehicle supervisor role, the definition of RPIC functions and responsibilities shall not only be derived from the current PIC foundation described in Part 91 but serve as a steppingstone for full integration of the MVS concept promoting 1:many (or m:N) functionality for highly autonomous aircraft operations. As part of this process, some hands-on PIC functions will be assumed by autonomous behaviors, framing MVS responsibilities to be more closely synonymous (but not the same) to that of a flight follower with an ultimate authority over safety of flight. The question of ultimate responsibility for the flight remains, however: without significant new thinking around the definition of a PIC (e.g., what does "person" mean within that definition?) the possibility of a mismatch between this responsibility and actual ability to influence the flight in real time will need to be addressed. Examples and lessons from airline operational control (e.g., dispatchers) functions that contribute to the operation of the fleet may be useful here. In order to enable near-term and evolutionary change, it will be necessary to explicitly connect any roles defined around the operation of an autonomous aircraft to those currently specified within the CFRs.

Existing & Developing Over the Immediate Term	Short-Medium Term	Medium Term
• Expand upon the work of ASTM AC377 TR3, exploring both the "large barriers" and those items that "slow progress" for autonomous aviation in Part 91 • Leverage the BVLOS ARC work on the role of the PIC • Leverage existing P135/P91 sUAS exemptions, create a standardized gap analysis for uncrewed autonomous RPIC requirements • RPIC training/role definition for initial m:N use cases (e.g., swarms) and early 1:many operations	• Policy paper(s) to standardize approach to the RPIC roles and responsibilities. • 1:many (and m:N) research and best practices compilation to inform requirement standardization and evaluation of training/licensing requirements (align with P91/P61 work)	• Rulemaking efforts to align 14 CFR Part 91 with the needs of autonomous uncrewed aircraft RPIC responsibilities and requirements • 1:many (and m:N) training and licensing standardization (align with P91/P61 work)

O7. Lost C2 Link Procedures

Description:

Depending on the extent of onboard autonomy, the ability of a UA to communicate with its human supervisor/RPIC is expected. While, by definition, autonomous aircraft are capable of functioning to at least some basic level of capability for a finite amount of time without direct connection to a human, and many are intended to be able to perform their missions without any remote input, the command/control (C2) link can serve a key role in being able to respond to air traffic management direction and interact with legacy airspace users as well as providing contingency management and strategic direction to the aircraft (e.g., flight plan updates based on weather or other dynamic situations).

While 14 CFR 91.185 is applicable to lost link communications operations and significant standards development activity has already been accomplished in defining requirements for the C2 link, it will be critical that autonomous aircraft continue to operate predictably in the event of a lost link. ATM and other airspace users need to also understand how to interact with and/or accommodate an autonomous aircraft that is no longer in communication with its remote operator/supervisor. This necessitates a set of common procedures that an autonomous UA can follow in the event of a lost link. Defining these procedures must be collaborative between ATO, AFS, and industry.

Existing & Developing Over the Immediate Term	Short-Medium Term	Medium Term
• Confirm applicability of 14 CFR 91.185 to UA lost link • Finalize and accept C2 link requirements (e.g., via RTCA DO-362) • Complete initial collaborative draft of LC2L procedures for key CONOPs • Demonstrate LC2L procedure performance • Mature and accept standards for supporting technology as appropriate for LC2L procedures (e.g., GPS RTK)	• Finalize and accept LC2L procedures for autonomous aircraft • Appropriate reliability and frequency requirements to support LC2L procedures and severities	• Normalized LC2L UA operations in the NAS

O8. Continued Operational Safety (COS) for Autonomous UAS

Description:

While initial airworthiness certification and personnel training are obviously important for safe autonomous aviation, equally important for the long-term safety and success of the industry is an appropriate approach to continued operational safety. This includes (at a minimum) maintenance, recurrent training requirements, reporting systems for incidents and accidents, and a methodology by which safety-enhancing updates to the autonomous system(s) can be efficiently made, as the current approach to amending a type certificate (TC) or supplemental type certificate (STC) takes long enough that it is prohibitive to dynamic safety improvements (particularly for software).

Many aspects of COS will be drawn from existing aviation practices for systems and equipment, such as the 14 CFR Part 5 Safety Management System (SMS) program currently undergoing a Rulemaking process, and applied to autonomous aircraft. To the maximum extent possible, existing tools should be used to avoid creating new regulatory burdens. However, new COS practices may need to be developed for associated elements, including necessary data links. (See the Off-board Systems "brick", A4). It is essential that COS considerations include an evaluation of automation and its components to determine whether it is reasonably expected to be able to perform its intended function, such as sensor inspection and replacement intervals, evaluation of incidents where automation was unable to perform its intended function but the flight ended successfully, and evaluation of safety escapes where automation lessons learned can be fed back into design changes to avoid repetition.

Existing & Developing Over the Immediate Term	Short-Medium Term	Medium Term
• Develop a plan for a streamlined approach to COS for autonomous aircraft based on an analysis of existing COS requirements and best practices • Define requirements for a reporting system for autonomous aircraft incidents (may be different from that for existing crewed operations); unexpected, not just unsafe, may be a reason to report	• Develop a plan for streamlining ongoing system safety updates • Policy documents, ACs, and/or standards for autonomous COS	• Ongoing streamlined system update procedure(s) in place • Full COS requirements package for autonomous aircraft in place

Foundation: Integration

Safe integration of autonomous aircraft into the existing airspace and aviation landscape is essential for the realization of the technology's full potential. As long as autonomous aircraft are confined to limited airspace options or are limited to effectively just extended visual line of sight operations (e.g., using visual observers, instead of true beyond visual line of sight operations), their full value will not be realized. However, to safely integrate widespread autonomous aircraft operations into the NAS, both incremental advances and larger, longer-term evolution in air traffic management and airspace usage will be required. A more conducive regulatory environment from the FAA is also required. The safety and economic impacts of these shifts must be carefully considered and demonstrated in order to both justify and inspire the necessary changes.

Airspace integration here comprises the following "bricks": mitigation(s) to the risk of midair collision addressed by the right-of-way rules in 14 CFR 91.113 to enable true BVLOS operations, digital air traffic management communications to support communication with autonomous aircraft, standardization of vehicle-to-vehicle communication for use in dense autonomous aircraft operations, digital/autonomous flight rules to supplement existing visual and instrument flight rules, and techniques for integrating UAS with legacy users of the airspace. Third Party Service Providers may also have a key role in the safe integration of UAS within the NAS; they are covered in their own "brick" as well.

Additionally, integration and coordination with existing transportation and communities is essential. This includes clarity of jurisdictions, roles and responsibilities, data management, and multimodal considerations. There are broader community integration considerations for various types of advanced air mobility which will likely utilize autonomy; here the discussion is constrained to items that are shared across the majority of the anticipated applications of autonomy in aviation.

I1. Midair Risk Mitigations (e.g., 91.113 solutions)

Description:

One of the most notable paragraphs in Part 91 that is cited as a barrier to BVLOS autonomous UAS operations is 91.113, which provides right-of-way rules and mentions "see and avoid" as a responsibility of the (onboard) pilot. Technical and strategic solution combinations that provide an equivalent level of safety to existing manned operations will need to be identified and authorized as alternatives to the human vision interpretation that has been given for this requirement. The simplest and most important way to address this concern would be to adjust the definition of "see" to include means that are other than the human eye as this definition from FAA Legal is arbitrarily restrictive; without it, the existing regulatory and operational structure is expected to be applicable to UAS.

Existing & Developing Over the Immediate Term	Short-Medium Term	Medium Term
• Congressional action to force FAA legal to allow full participation of the FAA in the SDO process • Complete the work that has been begun with the BVLOS NPRM • Continue to expand scope covered by industry standards (e.g., RTCA DO-365 and DO-381) • Determine funding source(s) for infrastructure that is needed to satisfy requirements being developed likely requiring federal support • Build upon BVLOS ARC report suggestions RE 91.113 • Strategic + technical mitigation plan standardization	• Rulemaking to expand "see and avoid" to "detect and avoid" • Additional/expanded TSO options for more DAA applications • Normalized IFR and low-altitude BVLOS UAS operations • Implement required infrastructure deployment	• Normalized technical solution to maintaining separation in BVLOS VFR and IFR operations through the NAS • Ensure coordination between changes to 91.113 (and other references to "see") with DFR implementation

I2. Info-Centric NAS

Description:

While voice communications between the RPIC and ATC is a feasible EIS solution, it will not support operations at the mature scale envisioned in the future. To facilitate the density of operations envisioned in the future, and initial m:N operations, a digital communications solution that enables more automation in the communications between the operator/aircraft and ATC needs to be deployed. Building APIs and other security protocols to facilitate the secure exchange of digital ATC data could also benefit Class A airspace operations and those in any controlled airspace with increased accuracy and traffic density.

Most air traffic network providers (Collins, L3Harris) believe that IP-based infrastructure is already in place and that modification for digital ATC communication will mostly be needed on the terminals of the network. MITRE is already working on an IP-based version of DataComm (DataComm is only currently limited to the CPDLC architecture) that can be hosted on COTS OS/firmware/hardware, and on the ATC side will connect to back-end ATC systems (e.g., ERAM).

While this goal is in alignment with the vision for future airspace management put forward by NASA's Sky for All and CANSO, the timing needed for the industry to benefit is significantly more compressed than theirs; stakeholders need to collaborate to figure out how to accelerate implementation.

While digital ATC communications are an enabling technology for Digital Flight Rules (DFR), as discussed in "brick" I4, they stand alone as having their own significant benefits for both autonomous and legacy aviation. The ability to digitally file 4D flight plans directly to a controller (and potentially other aircraft) without a human in the loop has significant efficiency and safety benefits for many users of the airspace, not just autonomous UAS.

Existing & Developing Over the Immediate Term	Short-Medium Term	Medium Term
• ATO-industry collaboration on vision for digital ATC communications • Lobby for (significant) funding to support the digitization of ATC infrastructure, especially direct connection of remote pilot to controller (with rebroadcast) • Begin development of onboard automation for voice comms processing; connection to autonomous flight ops is key • Detailed definition of the aviation environment to be enabled via Data Comm • Identification of necessary operations, and inclusion of such functionality within future revisions of Data Comm standards	• Initial "real world" trials of digital ATC • Infrastructure investment needed to support digital ATC communications • FAA/industry adoption and widespread deployment of capability (Data Comm is presently with a limited number of ARTCC and needs to be deployed widely with TRACON, ATCT, etc., for "bidirectional digital communication" to exist) • Maturation and research for autonomous voice processing and autonomous flight response • Set reliability requirements for autonomous voice processing technology (above) • Direct connection for terminal comms of remote pilot to controller (with rebroadcast) • Definition of Data Comm performance requirements	• Rollout of digital ATC for all users of the NAS • Automated responses for ATC voice messages (NASA research?) • En route solution in addition to terminal area

I3. Vehicle-to-Vehicle (V2V) Communications

Description:

In addition to centralized ATC, digital V2V communications has the potential to support autonomous uncrewed aviation by providing a means for cooperative aircraft to self-separate and coordinate within protected airspace (e.g., corridors). For those who choose to utilize this technology, secure V2V communication can also lower the risk of a cyberattack on autonomous aircraft by reducing the need for third-party coordination, increases the potential density of operations, and reduces the burden on ATC.

(For additional context, see "bricks" I2 and I4.)

Existing & Developing Over the Immediate Term	Short-Medium Term	Medium Term
• Support and coordinate with info-centric NAS development efforts • Coordinate across industry V2V efforts, including ASTM F38 and GAMA, and NASA UTM to produce a path forward • Coordinate with FAA ATO and controllers around V2V vision • V2V standards development • Need clear coordination and leadership within industry/SDOs in this space • Determine spectrum allocation request and bandwidth requirements, acknowledging that current voice communications are not an efficient use of existing spectrum • Leverage spectrum-enhancing technologies (e.g., 5G protocols) • Define security requirements for V2V; move beyond current ground-based validation of each signal	• Adoption of V2V standards and common technology/protocols • Demonstration of V2V operations within protected airspace • Spectrum allocation	• Real-world V2V implementation with normalized policy and appropriate controller training

I4. Digital Flight Rules (DFR)

Description:
Related to (and building upon) digital ATC and V2V communication (see "brick" I2) is the creation of a new set of flight rules that is developed to enhance the safety and efficiency benefits of autonomous aircraft, enabling the number of operations to significantly scale within key environments. Existing visual and instrument flight rules (V/IFR) were developed with the assumption of an onboard human pilot and their associated limitations. IFR was also built with the assumption of centralized, human controller services. A set of digital flight rules (DFR) developed specifically with the capabilities of autonomous aircraft systems with advanced DAA capabilities as well as autonomous, extensible traffic management (xTM) systems in mind would allow for safer and more efficient operations for autonomous aircraft. DFR would also benefit crewed operations through improvements in safety and efficiency.

While this goal is in alignment with the vision for future airspace management put forward by NASA's Sky for All and CANSO, the timing needed for the industry to benefit is significantly more compressed than theirs; stakeholders need to collaborate to figure out how to accelerate implementation.

As a specific example, by the end of the decade, or early into the next at the latest, autonomous UAM aircraft should be capable of scaling NAS operations without the limits of human-centric IFR (which are near capacity with respect to TRACON controllers and workstations). The scaling will be accomplished by the expansion of urban vertiports along with the authorization, under a new rule set (Part 108), of airspace integration software platforms that will provide xTM services for UAM aircraft.

Significant exploratory work has been done on what DFR might look like: several NASA papers have been published on the topic, which has also been covered within the BVLOS ARC proposals. There is a clear need for something that is neither true VFR nor IFR but bridges the two for autonomous aircraft. In addition to facilitating autonomous aircraft operations, DFR, along with the digital communications that will underpin it, is in some ways a natural completion of the original intent of NextGen. Legacy users of the airspace that are willing to equip and fly under DFR will benefit as well.

Existing & Developing Over the Immediate Term	Short-Medium Term	Medium Term
• Support existing Info-Centric NAS development • FAA (e.g., ATO, AFS, NextGen) and industry collaboration on vision for DFR (build on NASA FR work, BVLOS ARC report, etc.) • Work to build consensus with controllers on path forward for DFR • Lobby for reauthorization language to encourage FAA to move forward with the rulemaking that is necessary for DFR • Harmonization with EU and ICAO efforts to have an international solution	• Procedures development and publication for DFR • Road map for DFR implementation	• Adoption of DFR alongside IFR and VFR in the NAS

15. Integration with Legacy Aviation

Description:

The existing aviation systems constitute one of the safest forms of transportation in the world. Those that are currently using this system, whether as individuals or commercial operators, constitute "legacy aviation" and are obviously a critical set of stakeholders in the future of the industry as well as its past and present. However, non-cooperative traffic (a.k.a. unequipped legacy aviation) presents a significant challenge to the more widespread integration of autonomous UAS into the NAS. Navigating an acceptable path forward that continues to respect the needs of these legacy users while setting the stage for the safety and efficiency benefits that are possible through the adoption of autonomous aviation is critical to the future success of aviation in general. Enabling technology and regulation for integrating autonomous aviation into the existing NAS also should include the involvement of the national security community.

As part of integration with legacy traffic, the potential for an increase in equipage requirements is a politically sensitive topic, but one that is important to continue to consider. While the political challenges and aviation community concerns associated with equipage are not trivial, the safety and economic benefits of equipage will be overwhelming, and not just for new entrants.

Existing & Developing Over the Immediate Term	Short-Medium Term	Medium Term
• Maturation of technical and strategic solutions to prevent midair collisions with both cooperative and uncooperative traffic, including technology, standards, and policy • Map existing landscape and propose path forward, potentially including ground-based infrastructure • Incentivize and fund equipage of legacy aviation • Strategic coordination on how to proceed with the equipage and integration of legacy aviation and uncrewed aircraft • Move beyond segregated/protected airspace for normalized, integrated sUAS BVLOS operations	• Demonstration of public good and economic impact for autonomous aviation sufficient to inspire adoption of additional equipage • Full integration of BVLOS autonomous UAS and legacy aircraft throughout the NAS	• Updated equipage requirements to increase safety for all airspace users, including expanded airspace restrictions for non-equipped aircraft • Integration of BVLOS autonomous AAM and legacy aircraft throughout the NAS

16. Third-Party Service Providers (3PSPs)

Description:

Third Party Service Providers (3PSPs) are independent non-FAA and non-applicant entities that support UAS operators by offering services and/or AE that are used in the operation of UA. These services may include weather, communications, or other information used for situational awareness. 3PSPs may function as an alternative to traditional ATM within segregated airspace and/or facilitate UAS BVLOS operations but are not ANSPs. While the BVLOS ARC report stopped short of requiring the use of 3PSPs, it did recommend that a certificate for 3PSPs be created and based on a declaration of compliance with a set of FAA-accepted MOC or other acceptable industry standard. The development of these services and the standards needed to support this certification activity is needed to ensure that UA operators and ATM can reply appropriately to them.

Existing & Developing Over the Immediate Term	Short-Medium Term	Medium Term
• Complete 14 CFR part 108 rulemaking activity • Define common vision for roles and responsibilities of third-party services and the autonomous aircraft and ATM they serve • Initial 3PSP-supported autonomous operations	• Standards development for 3PSPs with appropriate tailoring as related to extent of autonomy and other risk-influencing factors	• FAA acceptance of MOC for 3PSPs • Normalized self-declarative certification process for 3PSPs • Need common airspace picture that ANSPs have access to (and vice versa); key to enabling self-separation

17. Local Integration & Engagement

Description:
To maximize the broader societal benefit for advanced aviation, inclusive of autonomous aviation, it needs to be integrated with existing transportation options. This will require local integration both from an infrastructure perspective and from a data-sharing perspective. Local and community engagement will also be important for many applications of autonomous aviation. In particular, urban operations that change how aviation interacts with the day-to-day activities of a community will require engagement and integration to be successful from a logistics perspective. To have an efficient and consistent approach to local engagement, a common legal framework upon which to base state and local coordination should be produced at the federal level. Societal acceptance of autonomous aviation, or passengers' willingness to board a remotely piloted aircraft, is obviously critically important but is out of the scope of this document.

Communications infrastructure will also need to be evaluated and potentially enhanced in each local operating environment to support autonomous urban aircraft operations.

While autonomous aircraft are not exclusively electric, a significant number of the aircraft that are being developed with high extents of automation are electric. To support those aircraft, electric generation, transmission, and charging infrastructure in the urban environment will be essential.

Existing & Developing Over the Immediate Term	Short-Medium Term	Medium Term
• Continue engagement with and education of local decision-makers, planners, and others responsible for integration (e.g., CAMI's UAPC program, NLC) • Publish NASA Playbook for Communities and AAM • Clarify how autonomy changes (or not) engagement over crewed AAM applications • Continue to build on AUVSI state "Drone Prepared" activities with sample legislation and state-level advocacy • Federal clarification of preemption and generation of a legal framework to facilitate state and local regulatory coordination	• Guidance documents/playbooks for integration and engagement for autonomous aviation with communities • Data-sharing procedures to connect autonomous aviation to local transit and planning • EIS operations in coordination with local decision-makers • Data sharing of airspace usage with the general public to support acceptance (without compromising security or privacy considerations)	• Widespread consistent approach to autonomous aviation engagement and integration with communities • Multiple locations successfully integrated with multimodal autonomous operations

Conclusions

This document was produced in collaboration with a wide range of stakeholders within the autonomous aviation industry, spanning both civil and military applications, and highlights many critical tasks that must be accomplished in order to advance the shared future vision of autonomous aviation. While it attempts to cover the entire spectrum of aviation, from sUAS through passenger-carrying large aircraft, there is of course no one-size-fits-all solution nor a single driving timeline. Lower-risk solutions should be promulgated before higher-risk ones. Areas of greatest agreement and clearest path forward should be accomplished expeditiously. Areas requiring additional alignment, information, and collaborative strategic thinking should be tackled with boldness, vision, and some element of patience such that safety remains the highest priority. Both civil and non-civil applications should be considered, ideally with permitted information exchange around best practices and standards development between the two.

We believe the actionable steps within this document will help focus the efforts of the wider autonomous aviation industry and facilitate industry and regulator alignment. This is an exciting and dynamic time in the history of aviation; this document should also be dynamic. With safety and innovation front of mind, let us move forward boldly, together.

To provide feedback on the Blueprint for Autonomy, please click below:

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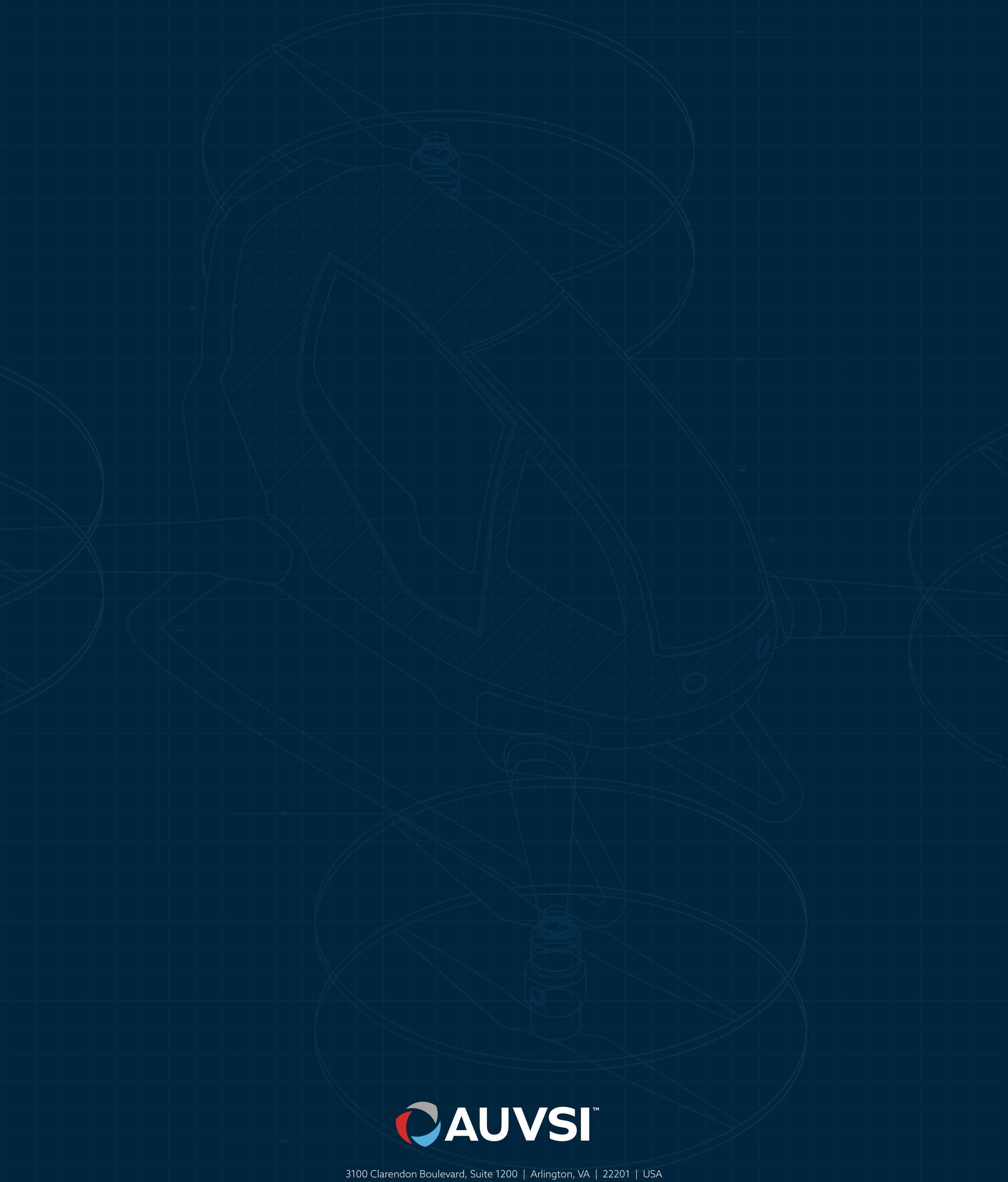

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