Mr. Dan Elwell
Acting Administrator
Federal Aviation Administration
800 Independence Avenue
Washington, DC 20591

June 5, 2019

Ms. Teri Bristol
Chief Operating Officer for Air Traffic Organization
Federal Aviation Administration
800 Independence Avenue
Washington, DC 20591

Dear Mr. Elwell and Ms. Bristol,

On behalf of the members of the FAA's Aviation Rulemaking Committee for Unmanned Aircraft Systems (UAS) in Controlled Airspace, we hereby present to the FAA recommendations for the integration of UAS into the NAS. These recommendations were derived from scenarios that encompass the most desired operations in Class A airspace for large civil UAS. The ARC was composed from diverse set of aviation stakeholders, including UAS Industry and associations. The FAA provided numerous agency stakeholders representing offices in the ATO, AVS, APL, and AGC. External members included public operators of large UAS including DoD, DHS and NASA and nationally recognized industry and association subject matter experts. The recommendations provided are from scenarios that are more advantageous to both federal and civil entities. The foundation of these recommendations is based upon a mature set of recommendations provided by a previous UAS ARC and emphasize implementation of NextGen concepts and technology to enable normalized UAS operations including ADS-B, En Route Automation Modernization (ERAM), Performance Based Navigation (PBN), and initial Trajectory Based Operations. The recommendations focus on increasing the standardization and predictability of UAS operations in controlled airspace, updates to NAS automation systems and changes to rulemaking to eliminate the need for all UAS operations to be operated under a Certificate of Waiver or Authorization (COA) or exemption process.

The ARC presents to the FAA recommendations on the following topics – (1) Changes to 14 Code of Federal Regulations (CFR) Part 91 to enable normalized operations, (2) FAA development of standardized Loss of Command and Control (C2) Link procedures, (3) Implementation of NAS automation changes to facilitate UAS operational integration, (4) Development of a process to enable commercial UAS operators to request a Local Area of Operations, (5) Updates to performance standards and FAA guidance material to enable the use of Global Navigation Satellite System (GNSS) as a means of performance navigation. These recommendations also include consideration of how UAS will transit to and from Class A airspace as well. The ARC decided not to prioritize the recommendations because all of them are considered critical to enabling normalized operations in controlled airspace. While many of the recommendations require rulemaking changes for full implementation, the ARC provided recommended near-term actions by the FAA while rulemaking is in progress.

We also recommend the FAA continue its support of UAS Airspace integration by establishing a follow-on airspace ARC related to industry collaboration based on recommendations within this report. Specifically, the ARC believes that the recommendations in this report can be applied to other classes of controlled airspace with additional work to address the unique challenges outside of Class A airspace.

Members of the UASCA ARC wish to thank the FAA for the opportunity to contribute towards safely advancing UAS airspace integration within the United States as well as influencing Global regulations.

Sincerely,

Craig Hoover
Industry Co-Chair
UASCA ARC

Cc Gary Norek, FAA Co-Chair, UASCA ARC
Jay Merkle, Executive Director, UAS Integration Office
Earl Lawrence, Executive Director, Aircraft Certification
Ali Bahrami, Associate Administrator for Aviation Safety

Unmanned Aircraft Systems (UAS) in Controlled Airspace Aviation Rulemaking Committee (ARC)

Final ARC Recommendations Report

June 4, 2019

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1 Executive Summary

There is a strong and growing interest in the large-scale, routine, commercial application of Unmanned Aircraft Systems (UAS) in and through all classes of controlled airspace. Demand for access to Class A and Upper E airspace continues to grow, and this work will not only posture the United States (U.S.) to provide greater access to federal agencies, but also continue to lead in influencing the development of international standards and global airspace procedures. The Federal Aviation Administration (FAA) is committed to safe integration of UAS into the National Airspace System (NAS) and has identified a near-term need for normalized routine airspace operations and procedures that will allow for future use of civil UAS.As a result, the FAA established a UAS in Controlled Airspace (UASCA) Aviation Rulemaking Committee (ARC) in June 2017 to achieve further engagement with industry and stakeholders before conducting rulemaking to address the regulatory framework for airspace integration. These efforts build upon a mature set of specific recommendations focused on large UAS operations in controlled airspace, capable of flight in Class A, produced by the previous UAS ARC that was formed in June 2011 and expired in June 2016.The committee placed an emphasis on implementation of NextGen concepts and technology to enable normalized UAS operations including ADS-B, En Route Automation Modernization (ERAM), Performance Based Navigation (PBN), and initial Trajectory Based Operations. The recommendations focus on increasing the standardization and predictability of UAS operations in controlled airspace, updates to NAS automation systems that were not designed to manage UAS operations and changes to rulemaking to eliminate the need for all UAS operations to be operated under a Certificate of Waiver or Authorization (COA) or exemption process.

The FAA tasked the UASCA ARC to develop recommendations for the integration of UAS into controlled airspace by undertaking the following actions:

a. Develop and recommend scenarios that encompass the most desired operations

b. Identify where gaps exist in research and development needed

c. Develop and recommend up to five prioritized changes and/or additions to policies, capabilities, and/or procedures required

Recommended Scenarios

The committee began with the list of assumptions contained in the Class A and Upper Class E Safety Risk Management Document (SRMD) to determine how the resulting recommendations would impact the safety of more normalized UAS operations in controlled airspace. Normalized operations are defined as the ability to integrate into Class A operations without exemptions or waivers, which implies the need for regulatory changes. One key difference in the recommended scenarios are the removal of restrictions on the flight path and the ability to request and grant changes in flight path or altitude to accommodate the types of operations that most piloted aircraft perform in controlled airspace. The other key difference is the assumption that UAS flying in Class A airspace will be flying under Instrument Flight Rules (IFR), which includes UAS flying a local area (loiter) or search pattern. Building on the Early Implementation Plan (EIP) Report submitted by the previous UAS ARC in 2015, the ARC validates that the desired operations can be summarized into two use cases; (i) Transit and (ii) Local Area of Operation. Industry members of the ARC agreed that, because these two use cases comprise most of the business applications, significant economic advantage will be realized.

The Transit Use Case is the most highly desired because it is considered the most likely near term operation that can be conducted by a UAS in controlled airspace under IFR without adding undue burden to the existing Air Traffic Management (ATM) system and with the least impact to other airspace users. Transiting through airspace is the foundational building block of all further operational concepts and use cases. The ARC also recommends development of a process to request Local Areas of Operation to increase the safety of loitering and search operations by designating the geographic location, altitudes and timing of the operations.

While the UASCA ARC was commissioned to focus on integration of UAS into Class A airspace, we could not ignore elements of how a UAS transits to and from Class A from other classes of airspace below or above. While the recommendations included in this report are not sufficient to address all the hazards posed by other classes of airspace, many of them are applicable outside of Class A and target key issues associated with transit to and from Class A.

Gaps in Research and Development

The UASCA ARC believes that implementation of the recommendations in this report will enable normalized operations in controlled airspace, but also recognizes that additional research is required by the FAA and industry to allow full implementation in the longer term. This additional research and development are not required to enable implementation of the UASCA ARC recommendations, but to increase the safety and efficiency of UAS operations especially when scaled to large volumes of traffic. Research and development activities could also facilitate the transfer of the proposed use cases to classes of airspace outside of Class A. Key research gaps identified by the committee include:

- Research into operating rules and procedures in controlled airspace to enable safe and efficient IFR aircraft operations with sole reference to instruments in visual and instrumental meteorological conditions.
- Standard operating procedures for requesting Local Areas of Operation in other classes of controlled airspace.
- Research on scalability of the recommendations to enable normalized operations for large numbers of UAS that are anticipated in the long term.

Recommended changes and/or additions to policies, capabilities, and/or procedures

The ARC presents to the FAA recommendations on the following topics – (1) Changes to 14 Code of Federal Regulations (CFR) Part 91 to enable normalized operations, (2) FAA development of standardized Loss of Command and Control (C2) Link procedures, (3) Implementation of NAS automation changes to facilitate UAS operational integration, (4) Development of a process to enable commercial UAS operators to request a Local Area of Operations, (5) Updates to performance standards and FAA guidance material to enable the use of Global Navigation Satellite System (GNSS) as a means of performance navigation without ground-based navigation aids. The UASCA ARC Charter instructed the ARC to prioritize recommended changes to policies, capabilities, and/or procedures. The ARC decided not to prioritize the recommendations because all of them are considered critical to enabling normalized UAS operations in controlled airspace. All five areas of recommendation must be implemented to successfully integrate UAS into controlled airspace. While many of these recommendations require rulemaking changes for full implementation, the ARC recognized the need to speed near term UAS access to controlled airspace and has also provided recommendations for near term actions by the FAA while rulemaking is in progress.

Table 1: Summary of ARC Recommendations

Recommendation	Rulemaking and Long Term Recommendations	Near Term FAA Actions
Changes to 14 CFR Part 91	The UASCA ARC recommends that all the 14 CFR Part 91 rulemaking	Establish an expedited exemption/waiver process for UAS to operate in Class A

Recommendation	Rulemaking and Long Term Recommendations	Near Term FAA Actions
	changes submitted by the previous UAS ARC be implemented, to include: Amend 14 CFR Part 91.113 (Right-of-way rules) to provide for an electronic means of compliance to see and avoid requirements. And in addition: Amend 14 CFR Part 91.135 to require that UAS operating in Class A provide a level of performance for Area Navigation (RNAV) equal to or better than RNAV 2.	airspace or introduce policy changes that will facilitate this outside the waiver or exemption process. Develop Advisory Circular (AC) material for UAS-level installation and operational approval related to Detect and Avoid (DAA) Systems and Control and Non-Payload Communications (CNPC) Datalinks.
Standardized Loss of C2 Link procedures,	Include procedures for Air Traffic Control (ATC) handling of UAS experiencing a Loss of C2 Link condition in the applicable FAA Orders and regulations.	Establish standards for Loss of C2 Link procedures for UAS. Establish a policy of listing the phone number of the Ground Control Station (GCS) in the flight plan. Partner with one or more UAS operators to prototype UAS-specific chart annotations into existing procedures to establish best practices and inform future rulemaking.
NAS automation changes	Implement ERAM changes to support unusual UAS flight/route patterns such as Local Area Operations. Implement ERAM changes to support long duration UAS flight plans. Implement route sector automation enhancements to ensure air traffic controllers have easily accessible and clear information about UAS lost link routings when needed.	Establish a web portal or web service that allows operators to submit their proposed Local Area of Operations to the FAA to inform the relevant ATC facilities.
Local Areas of Operations	FAA develop a process to request temporary airspace volumes for UAS Local Area of Operation missions. Implement recommended changes to automation to improve safety and predictability.	FAA work with one or more UAS operators to develop a prototype process that will inform future rulemaking or guidance material development.
GNSS-based navigation for UAS	Update performance standards and FAA guidance material to enable GNSS-based UAS operations to meet navigation requirements for all phases of flight without the use of legacy ground-based navigation aids.	Leverage ongoing UAS Type Certification projects to include a detailed analysis of navigation functions based on GNSS. Engage with RTCA to update Minimum Operational Performance Standards

Recommendation	Rulemaking and Long Term Recommendations	Near Term FAA Actions
	Update performance standards and FAA guidance material to enable GNSS-based precision approach capability with auto-takeoff and autoland features for UAS.	(MOPS) for certain navigation related technologies. FAA partner with one or more UAS operators to collect data on auto-takeoff/land capabilities to inform updates to performance standards and guidance material.

The UASCA ARC recommends that the FAA move forward on all these recommendations as quickly as possible to affect measurable progress to move from segregated UAS operations to truly integrated operations in controlled airspace. While the recommendations are not in a prioritized order, it is essential that the FAA address the full set of actions to bring about meaningful change on operations in controlled airspace. The recommendations contained in this report will streamline approval of existing UAS operations and remove barriers to entry for new types of operations. These barriers include lack of standardized procedures and performance standards, NAS automation limitations, and FAA rules, policies and procedures designed for manned aviation. This will bring solid economic benefits to multiple stakeholders and will open the airspace for new highly automated cargo and industrial applications. The introduction of UAS and their associated technologies will generate new, UAS-enabled economic activity as well as impact existing economic activity. The ARC and it's FAA sponsors believe that normalizing operations in Class A airspace is a first step to integration of UAS in other classes of airspace as that may lead to broader economic benefits beyond the impact of implementing these recommendations.

Finally, ARC recommendations can also help address recommendations provided by the Department of Transportation Office of Inspector General (DOT OIG) and recent Congressional requirements. The Inspector General for Aviation Audits issued FAA Report No. AV-2014-061[1] "FAA Faces Significant Barriers To Safely Integrate Unmanned Aircraft Systems Into the National Airspace System," in response to concerns with the progress of integrating UAS into the NAS. Congress established specific UAS provisions and deadlines for FAA in the FAA Modernization and Reform Act of 2012. It is the understanding of the ARC that the FAA has tracked actions to respond to all the recommendations of the 2014 DOT OIG report and have closed out all but two:

- Recommendation No. 2 to the FAA: Establish milestones for the work needed to determine the appropriate classification system for unmanned aircraft as a basis for developing the UAS regulatory framework.
- Recommendation No. 4 to the FAA: Assess and determine the requirements for automated tools to assist air traffic controllers in managing UAS operations in the NAS.

The UASCA ARC recommendations directly address the two open recommendations from the 2014 DOT OIG report and provide a path to close out these elements.

[1] DOT OIG Audit Report, "FAA Faces Significant Barriers To Safely Integrate Unmanned Aircraft Systems Into the National Airspace System," Report Number AV-2014-061, https://www.oig.dot.gov/library-item/31975, June 26, 2014.

Through the FAA Reauthorization Act of 2018, the U.S. Congress outlined several requirements for the FAA pertaining to UAS operations. Specifically, the UASCA ARC recommendations may help address the Congressional requirements summarized below:

- Section 346 (a,b) Public UAS – provide guidance on operation of public UAS including streamlining and expediting the COA process.
- Section 347 Special authority for certain UAS – use a risk-based approach to determine if certain UAS may operate safely in the NAS notwithstanding completion of the comprehensive plan and rulemaking
- Section 721 UAS research and development roadmap – submit the UAS research and development roadmap to Congress on an annual basis.

2 Background

The FAA formed a UAS ARC in June 2011 that expired in June 2016 [1].That ARC had a mission of full integration of UAS into the NAS. To digest this large and lengthy goal it created sub groups to address specific issues and make incremental progress. One of the sub groups under this ARC was the Airspace Management - Early Implementation Plan (EIP) Working Group. This working group produced a mature set of specific recommendations focused on large UAS in Class A airspace, also known as Group 5 UAS in the Department of Defense (DoD) UAS classification [2].The DoD defines Group 5 UAS as those UAS that weigh more than 1,320 lbs. and are capable of flight above 18,000 feet. Previous evaluations for airspace integration identified Class A airspace as the lowest risk portion of airspace for UAS integration because it is positive controlled IFR airspace and a cooperative environment.

The FAA is committed to safe and efficient integration of UAS into the NAS. The FAA's *2013 Integration of Civil UAS in the NAS Roadmap* is an Airspace Management Plan detailing the activities required to accomplish full integration of UAS in the NAS [3]. Figure 1 illustrates the priorities and expected evolution of UAS milestones as described in the FAA 2013 Roadmap.

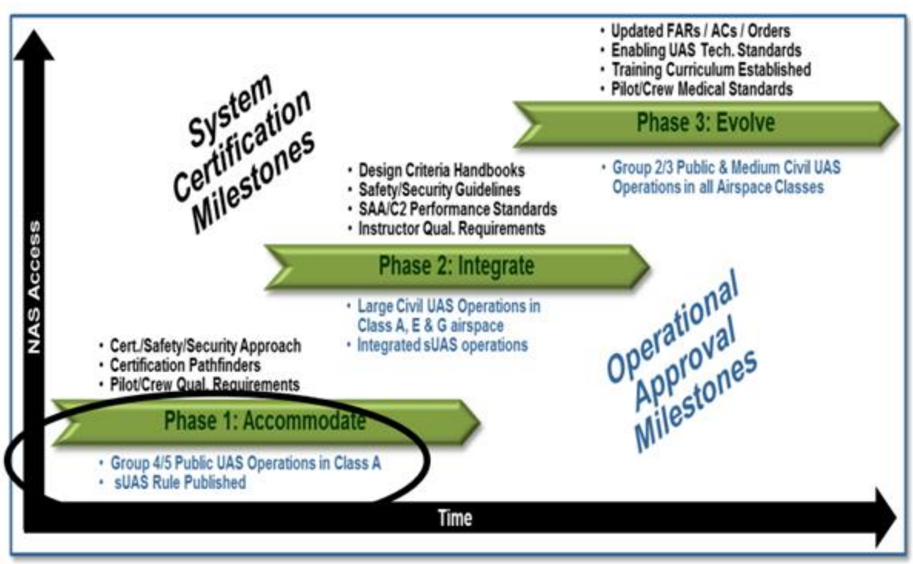

Figure 1: Early Class A Integration in FAA *2013 Integration of Civil UAS in the NAS Roadmap*

The Director of Airspace Services (AJV-1) sponsored the UASCA ARC in June 2017 to provide recommendations to the FAA that enable safe and efficient integration of UAS in Class A airspace by building on the mature, industry developed recommendation plan developed by the EIP Working Group [4]. Key federal and industry partners involved in the work of the previous UAS ARC have continued their participation through the UASCA ARC. The UASCA ARC was focused on large UAS operating in controlled airspace and on delivering benefits to both public and civil entities more quickly. Demand for access to Class A and Upper Class E airspace is expected to grow, and this work not only enables the U.S. to provide greater access to UAS operators, but also to continue to lead in influencing the development of international standards and global airspace procedures.

While this plan addresses the larger scope of airspace integration, the FAA has identified a near-term need for routine operations and procedures to support the future use of public and civil UAS in Class A airspace. To achieve this, further engagement with industry and stakeholders was needed before conducting rulemaking to address the regulatory framework for airspace integration. The UASCA ARC collected industry recommendations to enable near-term safe and efficient integration of UAS operations in Class A airspace.

ARC Objectives

The UASCA ARC is an industry forum to discuss and provide recommendations to the FAA. The ARC was tasked specifically to develop recommendations for the integration of UAS into the NAS, with a focus on airspace management for Class A UAS operations. Recommendations provided by the ARC have a target implementation timeframe of one to five years involving both interim and long-term solutions. The ARC established five working groups to accomplish the tasks defined by the Charter. These working groups include: Airspace and Procedures, NAS Automation, Navigation and Performance Standards, Policy and Rulemaking, and Transit to and from Class A Airspace.

ARC discussions and proposed recommendations to the FAA were guided by a set of questions defined in the ARC Charter listed below.

1. *Develop and recommend scenarios that encompass the most desired operations. In developing the recommendation, the ARC should consider including, at a minimum: operational capability of the aircraft, air traffic separation services required, air traffic control automation capabilities, the outcome of fast time modeling and simulation data, and the outcome of real time human-in-the-loop modeling and simulation data.*
2. *Identify where gaps exist in research and development needed to inform the successful integration of UAS into controlled airspace. The ARC should evaluate research currently being conducted and its applicability and alignment to operations in all classes of airspace.*
3. *Develop and recommend up to five prioritized changes and/or additions to capabilities and/or procedures required to achieve the successful integration of UAS into controlled airspace. In developing the recommendation, the ARC should consider the scenarios that encompass the most desired operations. Of particular interest are items with mutual benefit to the FAA and Industry, which may be implemented in the next one to five years.*

ARC Membership and Process

The FAA selected and established a committee consisting of a diverse group of stakeholders based on their familiarity with and likelihood of being impacted by UAS operations in controlled airspace. The ARC industry membership included 14 UAS manufacturers, six potential operators, seven aviation industry associations and representation from the research and development community. A complete list of ARC members, meetings, and actions can be found in Appendix A. The industry team was supported by 15-20 FAA Subject Matter Experts (SMEs) and had participation from the National Aeronautics and Space Administration (NASA) Aeronautics, DoD, Air National Guard and Department of Homeland Security. International observers from Transport Canada, Eurocontrol, and the Japan Civil Aviation Bureau (JCAB) were included to provide input on the implementability of the ARC recommendations in international airspace.

The Committee began by reviewing the EIP plan submitted by the previous UAS ARC and the volume of existing research related to UAS operations in controlled airspace from the FAA William J. Hughes Technical Center (WJHTC), NASA, MITRE and other industry sources. This approach helped to baseline the entire team on the volume of existing research and lessons learned to help inform development of recommendations. From this, we defined key areas to explore and set up five key working groups to investigate and develop position papers to be used in developing the final set of recommendations. The five working groups are listed in Table 2 with each of their objectives. The position papers were debated through multiple plenaries to drive consensus on the ARC position on each of these topics before moving on to develop recommendations.

Table 2: Key Working Groups Commissioned by the ARC

Working Group	Key Area	Tasking
1	Class A Airspace Procedures	Recommend national standardized procedures including lost link procedures to enable normalized UAS operation in Class A airspace
2	Class A Navigation and Performance Standards	Recommend minimum navigation and performance standards for normalized access to Class A airspace to include a timeline for implementation of these standards
3	NAS Automation	Develop prioritized list of enhancements to NAS Automation inclusive of current programmed ERAM updates intended to advance routine UAS Class A operations
4	Transit to/from Class A	Recommend updates to FAA policies, procedures and guidance material to enable routine transit to/from Class A airspace through Class B, C, D, E, and G airspace below Flight Level (FL)180
5	Policy and Rulemaking	Prioritized changes and/or additions to policies and rulemaking to achieve successful integration of UAS into Class A airspace.

Finally, the Committee moved to draft five recommendations drawing from the work, research and debate associated with developing the position papers. The group centered on five key recommendations:

- Changes to 14 CFR Part 91
- Standardized Loss of C2 Link procedures,
- NAS automation changes
- Local Areas of Operations
- GNSS as a means of navigation without ground-based navigation aids

These recommendations were drafted and debated through multiple plenaries and this summary document went through two formal comment periods where ARC member and SME inputs were received and adjudicated resulting in this final approved report.

3 Assumptions

The Committee began with the list of assumptions contained in the Class A and Upper Class E Airspace SRMD in order to determine which of the assumptions are still valid given the scope of this ARC and which assumptions need to be updated [5]. The following assumptions evolved from the SRMD and were generally agreed to by the working groups and ARC participants:

- All UAS operating in domestic Class A airspace have been granted airworthiness certification[2].
- Each pilot complies with all ATC instructions.
- Implementation can be achieved by a Single Overarching COA for Class A airspace operations, or equivalent guidance replacing COA[3], before regulations are fully in place.
- Each remote pilot operating in Class A airspace will have a pilot certificate similar to today's commercial pilot certificate with an instrument rating[4].
- Each UAS operating in Class A airspace will have direct two-way radio voice communication with ATC and equipment per 14 CFR Parts 91.135, 91.215 and 91.225.
- Aim to use existing NextGen technology, when possible, including near-term programmed updates to ERAM.
- The terms UAS and Remotely Piloted Aircraft System (RPAS) are defined in Appendix H. UAS is considered a general term as defined by the International Civil Aviation Organization (ICAO) and include RPAS as a subset.
- UAS operations that never reach Class A are considered out of scope for this ARC.
- Loss of communication between the remote pilot and the unmanned aircraft (UA) will be a rare event.
- “Fly-away”, i.e. when the aircraft deviates its flight path from the remote pilot’s intention, will be extremely improbable for this large class of UAS.
- UAS flying in Class A airspace will be flying under IFR, which includes UAS flying a local area (loiter) or search pattern.
- Normalized operations are defined as the ability to integrate into Class A operations without exemptions or waivers, which implies the need for regulatory changes.
- CNPC is defined in Appendix H and is considered the relevant concept when considering the C2 Link between the remote pilot and the UA. CNPC explicitly omits any other communications that may be used for the mission that are not needed for control of the aircraft.

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[2] Airworthiness certification could be granted in the form of design approval via 14 CFR Part 135 or Part 121

[3] The ARC recognizes that even when a UAS has been granted a Type Certificate, a COA will be required to cover the approval of operations until sufficient regulatory material is in place.

[4] The International Civil Aviation Organization (ICAO) has defined ***Remote Pilot*** for large UAS. It is anticipated that FAA will likely issue Remote Pilot certificates for UAS operating in Class A in the future.

- The term "Loss of C2 Link State" is defined in Appendix H and is colloquially known as "Lost Link." A Loss of C2 Link State will be triggered by the Lost C2 Link Decision Time, which may be different for various airspace classes, operations, and/or phases of flight. When the pre-defined Lost C2 Link Decision Time has passed, a Loss of C2 Link State is triggered and a pre-defined, pre-coordinated procedure is initiated.
- The committee understands that Visual Flight Rules (VFR) operations under today's rules are not possible for UA operating beyond visual line of sight (BVLOS). This would be true until a new set of operating rules is established for UAS operating BVLOS or existing operating rules are modified to enable a technological means of compliance for VFR flight. This creates challenges for enabling routine operations in today's NAS.
- Separation standards between UAS and manned aircraft, and between UAS and UAS in controlled airspace during IFR operations, will be no different than today's separation standards.
- The committee explicitly attempted to avoid use of the likelihood language of the FAA Safety Risk System (SMS) (i.e., Probable, Remote, Extremely Remote or Extremely Improbable) when discussing off nominal scenarios as it was beyond the scope of this group to assess likelihood of specific events.
- When referencing flight crew, the following convention is used:
    - "Pilot" is used when generally discussing a crew member that may manipulate the controls of an aircraft.
    - "Remote Pilot" is used to specifically refer to a pilot of an unmanned aircraft system.
    - "In-command" is appended to either of the above when the context is explicitly regarding the legal authority and responsibility of the specific pilot in charge of that flight. There may be other pilots involved in the flight, but not with the oversight responsibility.

4 Most-Desired UAS Operations in Class A

The UASCA ARC Charter tasked the ARC to "*Develop and recommend scenarios that encompass the most desired operations."* The two use cases summarized here are the ARC response to this tasking by the FAA. Building on the EIP Report submitted in 2015, the ARC validates that the desired UAS operations can be summarized into two use cases; (i) Transit and (ii) Local Area of Operation. The ARC worked with the assumption that UAS flying in Class A will be required to operate under IFR. Industry members of the ARC agreed that, because these two use cases comprise most of the business applications, significant economic advantage will be realized.

Each of the use cases will be discussed in more detail in the following sections.

4.1 Transit Operations Use Case

The Transit Operations use case encompasses operations that enter Class A airspace, transit through Class A, and then exit Class A into upper or lower airspace. When operating under IFR, it is assumed that UAS will transit through controlled airspace, in the same way as today's manned aircraft operating under IFR. In this use case (see Figure 2), the UAS operator will file an IFR flight plan, potentially with some modifications, which will be discussed in Section 5. Since UAS will meet all equipment requirements associated with IFR operations, the UA will navigate along established airways or between established waypoints while communicating with ATC to change altitudes and dynamically route around severe weather and other hazards. Standardized and certified DAA systems and C2 Datalinks will reduce anomalous behavior by UAS, such as Loss of C2 Link, that may be a concern for other airspace users and ATC. Standardized procedures for Loss of C2 Link events will ensure this contingency is handled in a predictable, repeatable, safe, and efficient way. In addition to operations that will take place primarily in Class A airspace, there are UAS operations that will transit through Class A airspace on their way to "Class E above A" (i.e. Above FL600 in U.S. NAS). Lastly, a unique feature of UAS is the ways in which control authority can be transferred, either within the system (e.g. datalink radio station switch overs), between systems (e.g. one Ground Control Station [GCS] to another GCS), or between remote pilots (e.g. remote pilot transfer during long duration flights). The procedures for all these types of transfers of control authority will need to be approved.

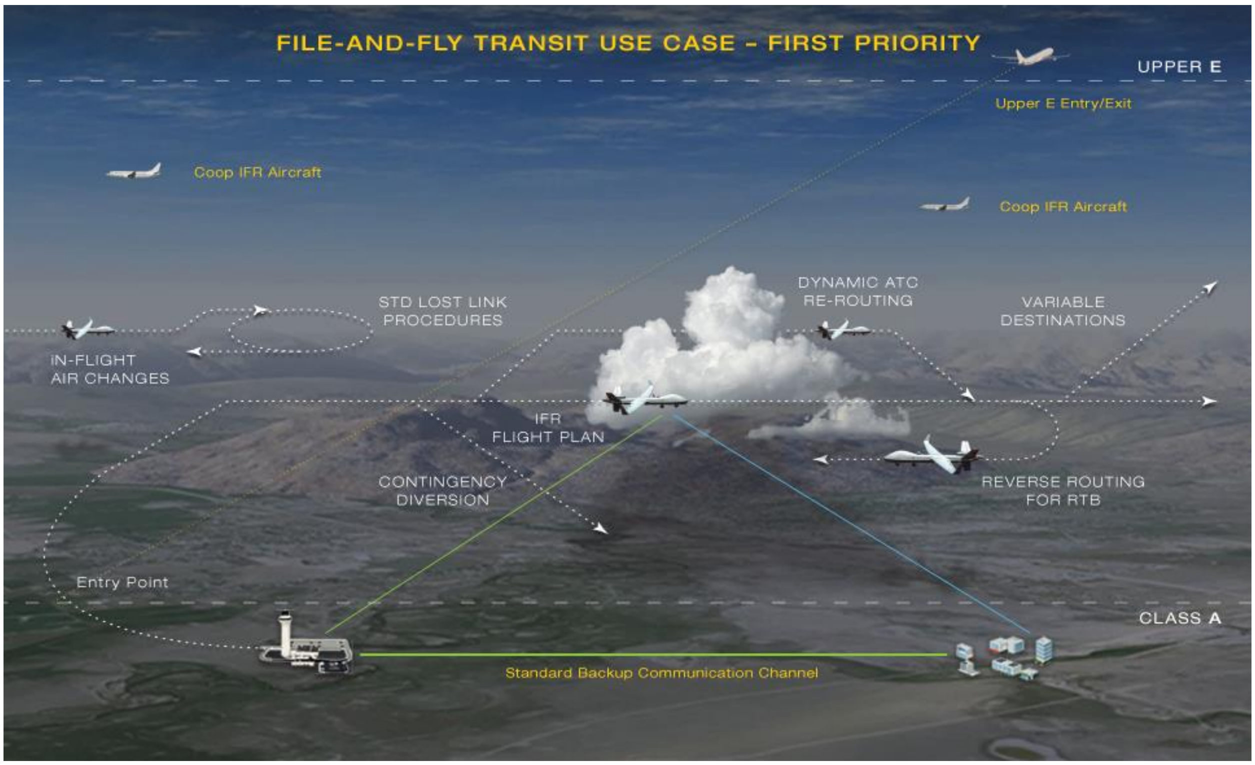

Figure 2: UAS will "file and fly" under IFR in Controlled Airspace with the safety and operational flexibility of today's IFR operations.

The Transit use case is considered highly desired because it is the most near term operation that can be conducted by a UAS in controlled airspace under IFR without adding undue burden to the existing ATM system and with the least impact to other airspace users. Furthermore, transiting through airspace is the foundational building block of all further operational concepts and use cases. Several industry members of the ARC have expressed a near term desire to conduct routine transit operations, and all understand there to be a substantial business opportunity that can be serviced with this use case. This use case would also support public UAS operators, who currently face many operational limitations when trying to conduct this type of operation.

Transit through Class D, E, and G airspace was the scope for RTCA SC-228's Phase 1 Minimum Operational Performance Standards (MOPS) development effort [6]. It was also recognized that the Traffic Alert and Collision Avoidance System (TCAS)-based Phase 1 DAA System (i.e. Class 2 equipment in DO-365) could be safely operated in Class A airspace. Appendix A of RTCA DO-365 contains a detailed description of UAS transit operations and has been reviewed by the ARC.

The Transit use case is also consistent with the industry's desire to operate internationally under ICAO procedures. While work remains to define the responsibilities of a remote pilot and a remote pilot in command (PIC), it is widely accepted that routine UAS operations will remain remotely piloted rather than autonomous. The ARC recognizes the FAA's leadership role on the ICAO RPAS Panel and encourages strong participation to ensure a timely adoption of new ICAO Standards and Recommended Practices (SARPs) and Procedures for Air Navigation Services (PANS) related to UAS operations. ARC members also believe that the changes to regulations, policies, and procedures to enable this Transit use case, will provide a model for the rest of the world, thus accelerating the operations of UAS globally.

4.2 Local Area of Operations Use Case

In the near term, UAS offer potential commercial advantages over manned aircraft in the "dull, dirty, dangerous" type of mission that have historically characterized the military applications of UAS. This is due, in part, to the long endurance capability enabled by relocating the pilot to the GCS, but this also means that desired flight profiles may not exclusively look like today's IFR flight paths (i.e., point-to-point). Some examples include loitering and search patterns, which are routinely conducted under VFR in today's NAS with manned aircraft. These flight profiles often put pilots and crew members over remote areas or open water for long periods of time, exposing them by necessity to higher levels of operational risk than is experienced in typical general aviation flying. Professional flight organizations conduct these types of missions safely every day with manned aircraft, but companies are eager to remove people from harm's way, where practical. The EIP Report rolled all these flight profiles into the term "Local Area of Operation". Figure 3 illustrates this use case. One concept for implementation would be the desire of the UAS operator to be able to file a flight plan and designate a volume of airspace to conduct the operation. This desire for the simplicity of receiving a clearance for a volume of airspace for the duration of the mission segment must be balanced against the needs of other airspace users based on the particular volume location, size, and time. If this concept is adopted, the UAS operating under IFR would request the lateral boundaries, vertical boundaries, and time limits of the desired airspace volume. The UA would be free to move within the defined volume, subject to ATC intervention if necessary, to address safety or other operational priorities, and the remote pilot could be able to dynamically request extensions to areas based on size or time and new areas based on changing mission requirements.

As with any use of airspace in the NAS, overlapping desires will lead to scheduling conflicts which will require collaboration among ATC and industry. The committee recognizes that the frequency of these operations in the next few years will be limited, resulting in a small number of conflicts to be resolved. As for the Transit use case, many transfers of authority could occur during a Local Area of Operation flight.

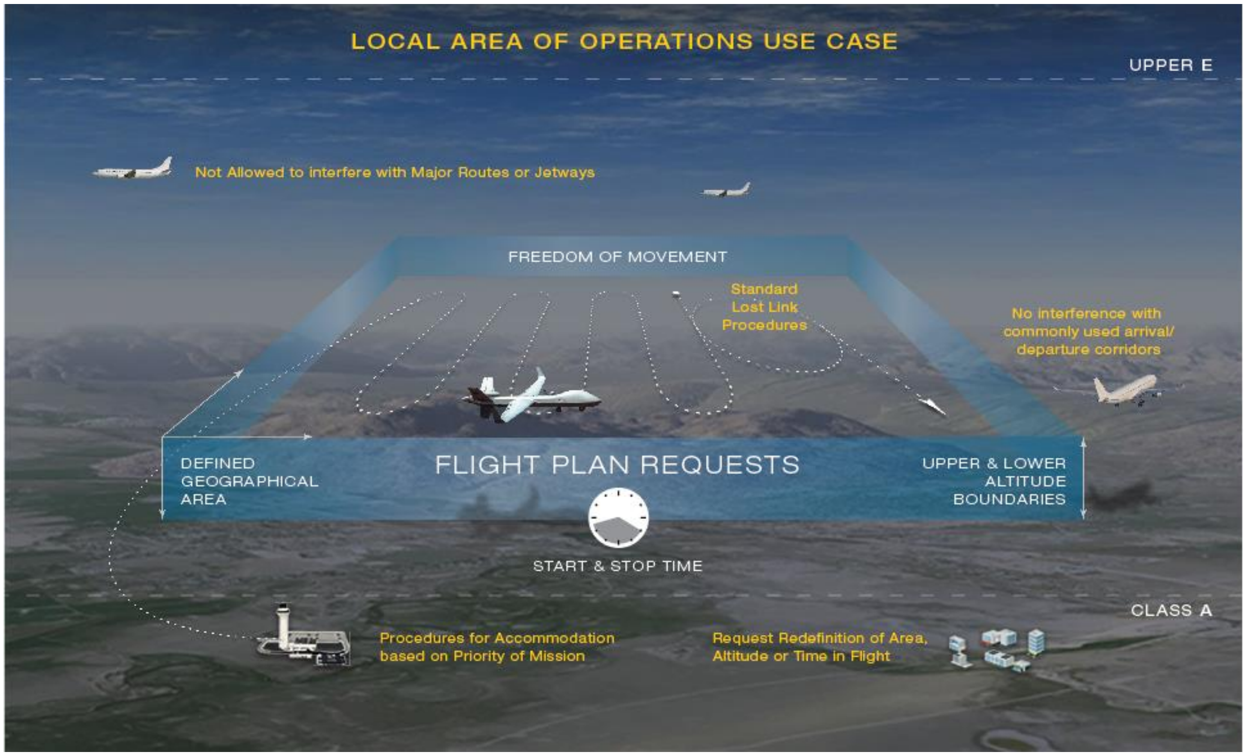

Figure 3: The unique capabilities of today's long-endurance UAS are best utilized in Local Area Operations under IFR.

An example of such a desired operation would be UAS Local Area Operations, as shown in Figure 4. Manned Local Area Operations are conducted today both below and within Class A airspace. Such an operation in a manned aircraft today would be conducted, weather permitting, under VFR, but if done by a UAS, then this operation will have to be integrated into the IFR system. Local Area Operations in Class A are required to be performed under IFR. By extending existing PBN standards and concepts, such as Required Navigation Performance (RNP) and integrated Trajectory Based Operations, ATC will have options when determining separation and service strategies for Local Area of Operations missions. Separation from the Local Area Operations airspace volume significantly simplifies both the UAS operations and amount of communication needed between ATC and the remote pilot; however, it may be a less efficient use of airspace. The balance between these competing values must be determined based on time and location.

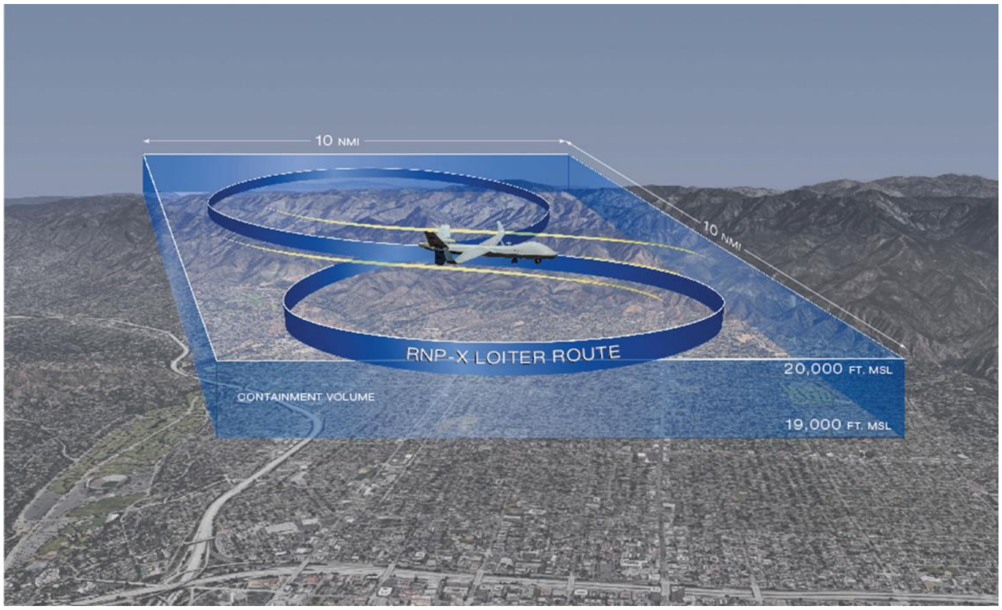

Figure 4: Application of existing PBN standards to new procedures, could enable Local Area of Operations being integrated into the IFR system.

RTCA SC-228's Phase II scope includes, among other operations, the Local Area of Operation use case [7]. Specifically, DAA technology is being standardized that will explicitly consider the flight dynamics and encounter geometries, which will emerge in the NAS due to the introduction of this use case.

Members of the committee have expressed a near term desire to conduct routine Local Area of Operations and all understand there to be a substantial business opportunity that can be serviced with this use case. This use case would also support public UAS operators, who currently face many operational limitations when trying to conduct this type of operation.

5 ARC Recommendations

This section outlines ARC recommendations on the following topics – 14 CFR Part 91 updates, standardized Loss of C2 Link procedures, updates to automation, a process to enable Local Area of Operations, and the use of GNSS as a means of navigation without ground-based navigation aids. Note that the ordering of these recommendations does not reflect a preferred order for implementation and all these recommendations are considered critical to enabling normalized UAS operations in controlled airspace. If any one of these recommendations is achieved, it will reduce the burden on UAS operators, however, waivers, exceptions, and workarounds will still be required for UAS operations to be conducted.

5.1 Recommendation A: Recommend Changes to 14 CFR Part 91 that Enable Normalized Operations (Not Requiring Exemption or Waiver) and Introduce an Interim Process to Expedite Operations via Exemption or Waiver

The UAS ARC submitted a report to the FAA in 2015 detailing modifications and additions to 14 CFR Part 91 to enable routine UAS operations (see Appendix B). The UASCA ARC fully endorses those recommendations and recommends that the FAA undertake a rulemaking activity consistent with that report.

We recommend that the FAA amend portions of 14 CFR Part 91[5] (General Operating and Flight Rules) as denoted in this report to enable continuous, normalized operations of UAS in Class A airspace without the need for exemptions or waivers. Most notably, we recommend that 14 CFR Part 91.113 (Right-of-way rules) be amended to provide for an electronic means of compliance to the see and avoid vigilance requirements, and that 14 CFR Part 91.135 (Operations in Class A airspace) be amended to mandate that UAS be Area Navigation (RNAV) 2 compliant. There needs to be a means for operators to legally mitigate the lack of direct human vision in the "see-and-avoid" verbiage used in the right-of-way rules. FAA could publish an alternative means of compliance with the existing rule in lieu of this rule change. Regardless of the legal method, FAA should have policy and provide guidance for operators to fly beyond the visual range of the remote pilot without the need for exemptions or waivers.

We anticipate that achieving normalized operations may take a longer period of time given that it requires amendments to 14 CFR Part 91. As an interim measure we recommend that the FAA introduce a consistent, streamlined exemption and waiver process that allows UAS applicants to gain access to Class A airspace in an expedited manner. Waiver approvals can be granted if applicants meet sufficient performance requirements that enable aircraft to maintain altitude, maintain two-way communications, have reliable C2 Link performance and standardized Loss of C2 Link procedures, meet 14 CFR Part 91 transponder and Reduced Vertical Separation Minimum (RVSM) equipage, as required, and are capable of minimum RNAV performance levels.

5.1.1 Rationale

There are few current UAS operations in Class A airspace other than limited public use/DoD operations, and industry feedback on deployment timelines has been sparse. However, given the long lead times associated with rulemaking there is still a need to accommodate future projected needs via

[5] The scope of this recommendation was limited to part 14 CFR 91. However, there may be additional operating requirements such as those under Part 119 that will need to be considered to enable normalized operations.

changes to current rules as well as develop to provide an interim bridge that will help inform rulemaking and accommodate near term operations.

A study by the FAA revealed 41 items indexed to Predator and Global Hawk operations that did not conform to guidelines published in FAA Order JO 7110.65: Air Traffic Control [8]. As these platforms were not developed with integration into the NAS in mind, this non-conformities list (see Appendix C) proved extremely helpful in understanding how divergent UAS operations potentially could be when compared to manned instances. The non-conformities list also helped to narrow the focus to just the core equipage and performance requirement that all operations, regardless of whether they are manned or unmanned, should have to adhere to.

There are pathways emerging to introducing technologies into UAS that support DAA and C2 Datalink requirements into the NAS, such as those referenced in RTCA DO-365, DO-366, and DO-362, and Technical Standards Order (TSO)-c211,TSO-c212, and TSO-c213, respectively [9, 10, 11, 12, 13]. We encourage development of Advisory Circulars (ACs) and the incorporation of DAA-related training and procedures in ATC publications. We recommend that the FAA continue work on other DAA systems that provide an equivalence to 91.113. For C2 Datalinks, we recommend that the FAA publish AC material, formalize near term spectrum management policy, and define predictable lost link contingency procedures. It is assumed that C2 Link standards referenced in FAA material will define acceptable performance requirements such as latency for particular operational environments.

There are manned operations capable of accessing Class A volumes of airspace without any special exemptions or waivers, yet due to limitations of their performance, ATC has to make special accommodations, and in some cases limit access. This treatment ultimately should be no different for UAS, and as with some of the manned operations referenced above, the viability of those operations then becomes defined by ATC's ability to merge the operations through the combination of automation and procedures.

5.1.2 Summary of Recommendations

Table 3: Summary of Recommended Changes to 14 CFR Part 91 and Interim Process Changes

14 CFR Part 91	Top Level Description	Implementation Details
Rulemaking Recommendations	Allow UAS to conduct operations to, in, and from Class A without a COA or exemption.	The UASCA ARC recommends that all the 14 CFR Part 91 rulemaking changes submitted by the previous UAS ARC be implemented, to include: Amend 14 CFR Part 91.113 (Right-of-way rules) to provide for an electronic means of compliance to see and avoid requirements. And in addition: Amend 14 CFR Part 91.135 to require that UAS operating in Class A provide a level of performance for RNAV equal to or better than RNAV 2.

14 CFR Part 91	Top Level Description	Implementation Details
Near Term FAA Action	Introduce expedited exemption/waiver process for UAS to operate in Class A or introduce policy changes that will facilitate this outside the waiver or exemption process.	Develop AC material for UAS-level installation and operational approval related to DAA Systems and CNPC Datalinks. Require compliance with existing 14 CFR Part 91 operating requirements to include: • Two-way communications with ATC • Transponder equipage IAW 14 CFR Part 91.225/227 • 14 CFR Part 91 Appendix G compliance for RVSM operations (where applicable) • Sufficient aircraft performance that enables aircraft to maintain altitude As well as: • DAA systems that provide an equivalence to 14 CFR Part 91.113 • A C2 datalink that meet an acceptable minimum operational performance. • Navigation database and system performance that meets RNAV 2 compliance requirements.

5.1.3 Recommendation Element 1: Amendments to 14 CFR Part 91

The long term goal is normalized operations (defined as the ability to integrate into Class A operations without exemptions or waivers), and the goal is to promote UAS operations that conform to general operating and flight rules contained in 14 CFR Part 91 to the greatest extent possible. However, there are parts of the existing rules that do not lend themselves to routine operations. Current 14 CFR 91.113 right-of-way rules, which state that "vigilance shall be maintained by each person operating an aircraft so as to see and avoid other aircraft," are demonstrative of those limitations. This was addressed by the FAA UAS ARC in that body's 14 CFR Part 91 Working Group where it was proposed that an electronic DAA function be introduced as a means to satisfy the vigilance requirement that would otherwise be performed by a pilot onboard the aircraft. The intent of the proposed language change was to enable an alternate means of compliance without requiring an exemption to the rule. The UAS ARC submitted a report to the FAA in 2015 detailing modifications and additions to 14 CFR Part 91 to enable routine UAS operations (see Appendix B). The UAS in Controlled Airspace ARC endorses those recommendations.

With regards to navigational performance requirements, we refer to the FAA's 2016 Performance Based Navigation Strategy [14], which specifies: "In the en route environment, the default performance requirement is RNAV 2." For example, a database coupled RNAV 2 enroute capability would enable a UA to fly a heading to join an airway, then continue to fly a published route, and in general navigate within the NAS infrastructure. Since UAS do not have an onboard pilot and it is difficult to envision any system capable of high altitude beyond line of sight operations that would not be equipped with a precision navigation capability, it is reasonable to expect that it be mandated that UAS operating in Class A meet this performance requirement. This could be met either through installation of a GNSS system or system that uses ground based Navigational Aids (NAVAIDs) that are RNAV 2 compliant. This leads us to the next recommended change to 14 CFR Part 91.135 - Operations in Class A Airspace, which introduces this requirement specifically for UAS operations.

5.1.4 Recommendation Element 2: Interim Implementation Plan

In the FAA Modernization and Reform Act of 2012, Public Law 112-95 (P.L. 112-95), Congress mandated the safe and expedient integration of UAS into the NAS [15]. The FAA's authority to issue exemptions from operating rules, and the Secretary's authority granted by Section 333 of P.L. 112-95, *Special Rules for Certain Unmanned Aircraft Systems*, provided an opportunity to authorize certain UAS operations in the NAS prior to implementation of the small UAS rule (14 CFR Part 107)[6]. With regards to the use of waivers to expedite Class A operations prior to rulemaking changes, there are several steps FAA should take to streamline that process.

The FAA should fully adopt and operationalize standardized systems for DAA and CNPC Radio Line of Sight (RLOS) Datalinks such as RTCA DO-362 for CNPC Datalinks[7] and RTCA DO-365/366 for DAA Systems. The FAA has invoked these standards in TSO-c213 and TSO-c211/212, respectively. In the near term, the FAA can publish installation guidance in form of ACs, provide operational guidance on the use of DAA, and provide guidance on the use and management of frequency spectrum for CNPC RLOS Datalinks.

To expand beyond the standard Part 107 operations, commercial UAS operations will generally need some form of airworthiness certification. However, additional forms of airworthiness certification, beyond the standard type certificate, and based on a risk-based approach associated with the kind of operation being performed should be explored. However, those UAS that do, and especially those UAS that routinely interact with controlled airspace and manned aircraft operations, will also require FAA approved avionics, either at the component-level or the aircraft system level. Until guidance on the installation, certification, and operational use of DAA and C2 is available, industry applicants will have to rely on issues papers and special conditions, adding uncertainty and complexity to Type Certification projects. See Appendix D (Acceptable Technology for Means of Compliance with Performance-based updates to 14 CFR Part 91) for more detail.

5.2 Recommendations B: FAA Should Develop Standardized Procedures for Loss of C2 Link for UAS

We recommend that the FAA develop standardized procedures for Loss of C2 Link for UA operating in controlled airspace during the following phases of flight: take-off and landing, terminal departure, terminal arrival, local area of operations (loitering), en route, and oceanic. A key concept for working with C2 Links is the acceptable duration of unavailability, interruptions, or discontinuity, before the UA should automatically perform a contingency action (e.g. change transponder code or heading change). We assume the existence of an on-board transaction expiration timer, which will count down from a pre-defined time since last successful communication. The standardized procedures for Loss of C2 Link should include:

- Establishing Lost C2 Link Decision Times for each phase of flight and/or transaction expiration timers associated with a certain trigger. For example, UAS squawks 7400; or, UAS enters holding at a predetermined waypoint. Use of timers will require additional research and refinement.

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[6] The FAA Reauthorization Act of 2018 repealed section 333 of P.L. 112-95 but codified the authority previously provided in section 333 at 49 U.S.C. 44807.

[7] ASTM F3002-14a "Standard Specification for Design of the Command and Control System for Small Unmanned Aircraft Systems (sUAS)" also covers UAS datalinks, but is focused on small UAS, which is not directly applicable to UAS in Class A.

- Establishing, when practical, routes or waypoints to be used by UAS experiencing a Loss of C2 Link condition. These routes or waypoints may be charted or contained in a Memorandum of Agreement between an ATC facility and the UAS operator.

The FAA has established a working group with the National Air Traffic Controllers Association (NATCA) on the topic of standardizing procedures of Loss of C2 Link events., The leadership of that working group has worked closely with the ARC plenary and individual members of the ARC. In general, the ARC has been very supportive of the work that the FAA-NATCA Working Group has conducted to date and looks forward to reviewing the recommendations once complete.

The committee recommends that the FAA amend the instrument procedure development process to include the addition of UAS-specific features, specifically Contingency Hold Points, but not change terrain or obstacle clearance criteria. As an interim step, to fully implement this recommendation, the FAA should partner with one or more UAS operators to prototype UAS-specific features into existing procedures in order to establish best practices and inform future rulemaking.

5.2.1 Rationale

UAS are unique from today's manned aircraft in several ways, but the relocation of the pilot from the aircraft to the GCS has the most significant impact on the operation. The remote pilot is connected from the GCS to the UA by a C2 Link (aka, Datalink). Due to natural interference (e.g., weather phenomenon) and unanticipated aircraft dynamics (e.g., severe turbulence) the C2 Link may experience short or long interruptions. Procedures are needed to handle these interruptions, or even complete C2 failures, in a manner that is safe, predictable, and repeatable. This recommendation covers both the Transit and Local Area of Operation use cases, as well as terminal-area instrument procedures.

A fundamental requirement for the air traffic control system when an off-nominal event occurs is predictability. The responsible controller and other operators must have an idea what the UAS will do should it experience a Loss of C2 Link condition. Procedures that to the maximum extent practical, are standardized for each phase of flight, ensure safety and minimize negative impacts to operational efficiency. In addition, standardized procedures provide manufacturers of UAS and associated avionics a framework from which to develop and produce technological capabilities that enable compliance with those procedures.

In order to facilitate discussion, the list of definitions from the ICAO RPAS Panel meeting #7 Working Paper 4 (March 2017) is contained in Appendix G [16].

5.2.2 Summary of Recommendations

Table 4: Summary of Recommendations for Standardized Procedures for Loss of C2 Link

	Top Level Description	Implementation Details
Rulemaking recommendation	Include procedures for ATC handling of UAS experiencing a Loss of C2 Link condition in the applicable Orders and regulations.	
Long-term Recommendation	Establish standards for Loss of C2 Link procedures for UAS	• Provide guidance on acceptable Lost C2 Link Decision Time(s) • Determine if UAS should be represented differently than other aircraft to controllers • Give direction to air traffic facilities to evaluate current airspace design, flow

	Top Level Description	Implementation Details
		strategies and other local idiosyncrasies and determine how a Loss of C2 Link could most safely and efficiently be accommodated. • Add UAS specific elements to flight procedure design to allow for hold points during loss of C2
Near Term FAA Action	• Establish a policy of listing the phone number of the GCS in the flight plan • Encourage UAS operators that routinely interact with certain ATC facilities to develop agreements with those facilities to standardize Loss of C2 Link procedures and increase predictability.	• ATO service centers must monitor facility evaluations to ensure consistency in design and application of procedures for Loss of C2 Link. • Until a standard alternative means of voice communication protocol is established, the policy of listing a phone number for the GCS in the flight plan is the simplest means to ensure communication can be established in the event of a Loss of C2 Link, although other means may be established on a local level. • Partner with one or more UAS operators to prototype UAS-specific features into existing procedures in order to establish best practices and inform future rulemaking.

5.2.3 Recommendation Element 1: Standardized Loss of C2 Link Procedures for En Route

As part of the set of procedures to be developed for the Lost C2 Link State, the ARC highlights the importance of handling the enroute phase of flight. The enroute phase of flight, be it continental or oceanic, provides a unique set of constraints within which to prescribe procedures for a Lost C2 Link State. For example, the Lost C2 Link Decision Time may be much longer in the Class A enroute environment than it would be in the terminal area. Drastic maneuvering may also be highly discouraged in the enroute environment.

5.2.4 Recommendation Element 2: Updates to Terminal Area Instrument Procedures for Loss of C2 Link

Operating under IFR, UAS will benefit from adhering to existing standard instrument procedures to achieve a high level of safety, predictability, and repeatability. While procedures for Loss of C2 Link in the en route phase of flight could be descriptive rather than prescriptive, the terminal area introduces additional challenges, which must be dealt with in prescriptive ways. Adapting departure, arrival, and approach procedures for UAS will include adding UAS-specific chart annotations to new or existing RNAV procedures. This could include airports in uncontrolled airspace that meet the requirements of 14 CFR Part 91.305.

In developing this recommendation, the ARC drew heavily from the DoD's Joint Test, conducted in collaboration with the FAA, from 2012 to 2015 [17]. Selected details from the DoD's Joint Test report are captured in Appendix E.

UAS Specific Chart Annotations

Integration of UAS into the NAS at all levels may require the creation of additional symbols or terminologies. Details are outlined in the sections below. Importantly, the ARC is not recommending changes to terrain and obstacle clearance criteria and recognizes that any changes to public 14 CFR Part 97 procedures would require working through the FAA's Aeronautical Charting Forum. Since the

Aeronautical Charting Forum is made of a diverse set of stakeholders, it will be critical for the FAA to provide resources to support changes that are needed based on these recommendations. It will also be critical for the UAS industry and groups that represent the UAS industry to bring resources to the Forum to support the changes.

Contingency Hold Points

Contingency Hold Points are unique to UAS, intended for use when the system experiences malfunctions unique to UAS flight, and are known to ATC. These points are usually programmed in the navigation system as hold points during Loss of C2 Link situations but may also be used during loss of voice communications or loss of DAA. It was desired by the community of interest during the DoD Joint Test that these points be separate from currently charted hold points, they not conflict with normal arriving/departing traffic, and that they not be assigned by ATC for other than UA.

Initial looks through cognitive walkthroughs at the FAA WJHTC have indicated potential issues with this approach near terminal areas where multiple UA may require to hold. During live-fly integration testing conducted by the DoD in partnership with the FAA, these points proved useful and relatively easy to manage. However, this was based on a small number of participating aircraft. The building blocks for concepts surrounding these specific points currently exist based on the results of many agencies' efforts. It is suggested that cognitive walkthroughs be advanced to the next stage, which could include computer-based modeling and simulation of these specific areas of concern. Manned aircraft procedures can be followed to the greatest extent possible. For instance, manned aircraft in an IFR flight plan are each given specific departure procedures that allow for deconfliction with other aircraft in the event of a contingency or emergency. These already established procedures could form the basis for early establishment of deconflicted UAS departures until such time that technology can more efficiently handle these situations. At this time, the ARC does not foresee any additional research needed to implement this concept, however, it is recognized that lessons will be learned when UAS operators first work with the FAA on special procedures.

Autoland Considerations

It is assumed that commercial UAS operating routinely in controlled airspace will have an autoland capability, however there is not a need to mandate this. There is an open question as to whether a UA without an autoland capability, or one without remote control (i.e. manual) land capability should be restricted from certain approaches. The DoD Joint Test addressed this by making approaches that were specific and complementary to a UA's specific landing capabilities. This approach was similar to manned aircraft having different types of instrument approaches based on their capabilities such as Instrument Landing System (ILS), RNAV, Very High Frequency (VHF) Omnidirectional Range (VOR), etc. Deciding whether a specific UAS landing capability is allowed at an airport or specific runway might depend on many factors such as category of aircraft, level of activity at the airport, number of runways, type of owning agency, and ground to UAS communications equipment on site, etc. These considerations also require more testing and/or feedback from the community of interest but could be dealt with procedurally on an individual basis until enough data exists to form a policy or regulation. Additional discussion related to UAS autoland capabilities is contained in Section 5.5.4.

Alternative Means of Communication

When operating beyond line of sight, most UAS combine radio communications links with its CNPC link. A standalone lost communications condition can occur, or one will usually occur simultaneously with a Loss of C2 Link State. The UAS GCS should possess an alternate means of communicating with an ATC facility (approach, departure, tower, center, etc.) regardless of where the aircraft is at the time of equipment malfunction. Telephones (landline and cell) were used successfully during the DoD Joint

Test to meet this requirement and are the primary means of establishing secondary voice communications by today's UAS operators. During the DoD Joint Test, secondary radios worked well for operations in the terminal environment but did not have the range to talk to center controllers. Phones were selected as a standard method for all phases of flight to avoid confusion.

Until advanced technical solutions can be deployed, the UAS flight plan must include a telephone number for the GCS that the ATC facility can call in the event of a loss of voice communications. If this number changes during the UAS flight, this change must be communicated to ATC.

The FAA is currently looking at requirements for the National Airspace System Voice Switch (NVS) to include the ability of Voice over Internet Protocol (VOIP) communications with ATC positions, which would allow remote pilots to speak directly to ATC through ground based VOIP, versus through C2 Link relay.

5.3 Recommendation C: Implement NAS Automation Changes to Facilitate UAS Operational Integration

We recommend the FAA implement changes to the ERAM ATC system to support UAS transit and local area operations. En route sector automation enhancements are needed to provide ATC with easily accessible information about UAS contingency routing for a lost link event.

The implementation of requirements that have been previously developed for ERAM will support longer duration flight operations. A capability to allow ATC to define temporary airspace volumes that are ingested and monitored by ERAM's conflict probe capability is needed. In addition, the FAA should develop a capability to quickly and effectively inform controllers of a UAS's expected loss link routing when a lost link event is detected. The committee recommends that the FAA fold these enhancements into the program plans for each of these systems and into the NextGen and New Entrants' Roadmaps as soon as possible.

5.3.1 Rationale

The objective of the Automation Working Group of the UASCA ARC was to recommend changes to NAS systems including automation, communication, navigation, and surveillance to enable normalized UAS operations within Class A Airspace without unduly increasing risk to the NAS, or controller workload.

The Automation Working Group spent considerable time assessing each of the FAA's automation systems used for Class A NAS operations including ERAM, NVS, Data Communications (Datacomm), and Flight Planning, including the roadmaps for each program and how or if UAS operational needs were incorporated into planning moving forward. The discussion was limited to ERAM based on the UASCA ARC terms of reference and the fact that the FAA's Class A and Upper Class E Airspace SRMD references only ERAM [4].While UAS operations have been discussed in some limited program planning, most FAA automation roadmaps and implementation plans do not adequately incorporate or integrate UAS operations in the overall system and automation plans.

The FAA's SRMD for Establishing a Baseline Hazard Analysis for Unmanned Aircraft Operations in Class A & High E Airspace, completed in 2015, identified potential hazards for UAS operating in Class A airspace. These hazards have the potential to increase controller workload and reduce operational efficiency and ATC services to aircraft in Class A airspace. The Class A SRMD indicated that key enhancements to NAS automation systems such as ERAM need to be considered to address the following issues:

- ERAM flight planning capability does not support UAS missions that operate for several days, transit multiple facilities/sectors, or include Local Area Operations
- Controller access to UAS routing information during lost C2 Link event not readily available
- Controller access to COA information not readily available in a usable format

5.3.2 Summary of Recommendations

Table 5: Summary for Recommendations on NAS Automation Changes

NAS Automation	Top Level Description	Implementation Details
Long-Term Recommendations	Modify NAS automation to support UAS flight planning and routing needs and to facilitate air traffic controllers in managing UAS flights.	• Implement ERAM changes to support unusual UAS flight/route patterns such as Local Area Operations. • Implement ERAM changes to support long duration UAS flight plans. • Implement route sector automation enhancements to ensure air traffic controllers have easily accessible and clear information about UAS lost link routings when needed.
Near Term FAA Action	Enable UAS operators to request Local Area of Operations.	Establish a web portal or web service that allows operators to submit their proposed Local Area of Operations to the FAA to inform the relevant ATC facilities.

5.3.3 Recommendation Element 1: Implement ERAM Changes to Support Unusual UAS Flight/Route Patterns Such as Local Area Operations

ERAM modifications are needed to implement a capability to allow ATC to easily define temporary airspace volumes (i.e., Local Area Operations use case) that are ingested and processed in ERAM. This must include the ability to monitor these temporary airspace volumes using conflict probe to temporarily alert the controller of an aircraft that will enter the Local Area of Operations. Altitude blocks (i.e. upper and lower bounds of the altitude component of a clearance) must be considered and may require changes to ERAM. In addition, the committee recommends the implementation of an external interface capability to enable UAS operators to designate their desired criteria and location for non-point-to-point operations. Currently, ATC must procedurally and manually monitor the airspace needed for these unusual route patterns, which causes increased controller workload and reduces airspace efficiency and ATC services.

Based on the understanding of the working group, previous internal research and development work at Lockheed Martin (now Leidos) developed this concept and prototyped this capability through the Flight Service FS21 system and ERAM so the actual concept and development work has already been initiated and could be useful as the FAA pursues this capability [18].In discussions with the Commercial Spaceport Categorization ARC and the Airspace Access Prioritization ARC, it was clear this capability is needed for other new entrants and existing NAS users such as DoD [19, 20].

Consequently, the benefits case for this capability is strong making this a top priority automation recommendation.

5.3.4 Recommendation Element 2: Implement ERAM Changes to Support Long Duration UAS Flight Plans

ERAM modifications are required to accept flight plans for UAS with long routes, multi-day flights, or unusual route patterns. Currently, long UAS flights that cannot be accommodated in a normal ERAM flight plan must be divided up and filed as separate flight plans, causing additional workload for both FAA ATC personnel and the UAS operators. FAA has and should continue to work with UAS industry to define specific requirements for desired length of routes, flight times, and route patterns needed. Other NAS systems that use ERAM flight plan data may need to be updated accordingly. We investigated the FAA's ERAM Program plans and determined that requirements have been developed for a longer flight plan route field (character limit expansion) to support UAS operations. In addition to the longer route field, ERAM needs to handle multi-day flight plans and address any related potential issues such as increased number of sector crossings. These requirements should be implemented in the next ERAM enhancement schedule opportunity.

5.3.5 Recommendation Element 3: Implement Automation Enhancements to Provide Clear Information to ATC about UAS Lost Link Routings

The committee recommends the development of an automated capability to quickly and effectively inform controllers at affected sector positions of a UAS's expected lost link routing when a lost link event is detected. The SRMD identified UAS lost link events as a primary area of concern because of the lack of standardized lost link procedures and lack of quickly and easily accessible information for sector controllers about UAS lost link routing/procedure when a lost link event occurs. The SRMD recommendation to provide lost link procedures "in usable medium for controller operational reference" should be implemented through automation enhancements at the ATC sector (e.g., on the Enterprise Information Display System or ERAM) to address this potential safety issue.

5.3.6 Recommendation Element 4: Interim Establishment of Web Portal or Web Service for Local Area of Operations Submittal

Since automation updates to ERAM will take time, we recommend the FAA enable a web portal or a web service that provides a mechanism for operators to submit their proposed Local Area of Operations. This capability has been prototyped and demonstrated in the past by Leidos, which will enable ingestion into both Flight Service systems and ERAM.A web service could provide front-end flexibility for the operators to determine the type of user interface needed (e.g., graphical, latitude/longitudes, NAS waypoints) for their needs, and subsequently translate that information into the format needed to submit to ERAM and the flight plan. If ERAM changes are required to accept this input and until those changes are implemented, the Local Area of Operations information should be provided and displayable to the relevant ATC sectors/positions through some other mechanism.

5.4 Recommendation D: Develop Process for Commercial UAS Operator to Request a Local Area of Operation

The committee recommends that the FAA develop a process to request temporary airspace volumes for UAS Local Area of Operation missions. These types of operations are conducted today by manned aircraft (e.g., photo shoot missions) but they are primarily conducted under VFR, even in controlled airspace. The assumption that UAS operations will be conducted under IFR introduces several complexities, which can be overcome in the future through a standardized process.

5.4.1 Rationale

UAS operators, primarily public but some civil, are currently conducting Local Area of Operation missions under COAs that cover the extent of the mission that they wish to conduct. The COA application process can take 60-90 days. The UAS operator must also coordinate with the local ATC facility (i.e., Tower, Approach, and/or Center) to establish local procedures and negotiate time and place restrictions for the UAS operations, a process that can take weeks or months. Special Use Airspace (e.g., Restricted, Temporary Restricted, or Military Operating Areas) is often utilized to increase the operational flexibility and decrease the burden on ATC and other airspace users, however, this airspace is not routinely available to commercial UAS operators. The UAS operator must also coordinate days, hours, and minutes before take-off to ensure that flight plans have been properly received and that the ATC facilities are ready for the UAS to enter their airspace. While this process has evolved and become more streamlined over the past decade, it is a significant burden for a commercial operator compared to the process today for 14 CFR Part 91 operations under IFR. Also, while public operators such as the DoD and the Department of Homeland Security (DHS) are operating these aircraft for national security needs, the concept of an airspace volume designation for a commercial entity must assume flexibility in the event that safety or operational priorities require intervention by ATC and must consider other airspace users and their commercial benefit or loss. Conducting these operations under IFR introduces the potential for interference with other IFR operations and established instrument procedures, therefore a standardized process is required in order to ensure equity among airspace users and to minimize the burden placed on the ATM system by the integration of UAS.

Experience from public UAS operations (e.g. DHS/ Customs and Border Protection) provides a good starting point for these procedures, but more flexibility will be required by commercial operators. Over the decades, scheduled air carriers have faced similar challenges and have developed comprehensive systems to deal with flight scheduling, flight planning, flight plan deconfliction, and other coordination challenges. The ARC has gathered input from public and civil UAS operators as well as experience from joint DoD/FAA flight test demonstration campaigns to inform the development of a process for the local area of operation use case.

5.4.2 Summary of Recommendation

Table 6: Summary of Recommendations for Process to establish Local Area of Operations

Local Area of Operations	Top Level Description	Implementation Details
Long-term Recommendation	FAA develop a process to request temporary airspace volumes for UAS Local Area of Operation missions.	This process includes: • The ability to define lateral boundary, vertical boundary, and time limits of a Local Area of Operation • The ability to reduce pre-coordination and planning requirements to be consistent with today's IFR Flight Planning process under 14 CFR Part 91 operations • The ability to identify flight in the vicinity of existing routes, procedures, or areas that

Local Area of Operations	Top Level Description	Implementation Details
		would negatively impact routine airspace operations, indicating that overlap with these would result in higher likelihood of rejection • The ability to include airspace volume features in an IFR flight plan or something similar • The ability to dynamically change or file a new airspace volume for the operation • Monitoring to ensure fair and equitable use of the process and timely dispute resolution
Near Term FAA Actions	• FAA partner with one or more UAS operators to develop a prototype process that will inform future rulemaking or guidance material development • Encourage UAS operators to work with the FAA to develop a template for requesting Local Area of Operation missions in Class A airspace, while considering the details contained in this report	This partnership should address, at a minimum: • Defined lateral boundaries, vertical boundaries, time limits • Pre-planned but non-static airspace volume • Flight plan • Dynamic changes and real-time communication • Multiple airspace volume requests • Coordination with ATC and other airspace users • ATC separation services • Communication, navigation, and surveillance

5.4.3 Recommendation Element 1: Key Features of Local Area of Operation Process

The section below outlines key features of a process for requesting an airspace volume to conduct the Local Area of Operation mission.

- Defined lateral boundaries: The airspace volume must have defined lateral boundaries. In the near-term, these boundaries could be based on latitudes and longitudes, similar to today's search and rescue procedures. In the long-term, lateral boundaries should also be defined by distance and directions from defined waypoints, which would allow an airspace volume to be offset from an established airway or instrument procedure waypoint.
- Defined vertical boundaries: The airspace volume must have defined vertical boundaries. In the near-term, these boundaries should be reduced to an assigned altitude, which would enable ATC to provide nominal vertical separation between the UA and other aircraft. In the long-term, vertical boundaries could span one or more altitudes or Flight Levels, which would give the UA flexibility to change altitude based on mission requirements, hazardous weather, or aircraft limits. This has a larger operational impact since ATC would then be separating aircraft from a larger volume of airspace, so it is reasonable to assume that it may not be feasible in congested areas.
- Defined time limits: The airspace volume must have defined time limits. ATC would be providing IFR-IFR separation services for a defined period.

- Pre-planned but non-static airspace volume: The UAS community does not seek to establish segregated airspace of any kind for routine commercial UAS operations and there is no desire for the airspace volume to become static (i.e., so established as to be charted). Airspace volumes will be pre-planned and, ideally, part of the UAS flight plan, but this should not be confused with segregation. In the interest of minimizing the burden on ATC and other airspace users, airspace volumes should only be as large as necessary for legitimate mission requirements, and when possible, should be split into two smaller volumes with defined temporal limits.

- Flight plan: Information to request an airspace volume needs to be shared between the remote pilot and ATC. In the near-term, this could be accomplished by utilizing the space available in the "Remarks" section. This approach will not scale with density of UAS operations or with increased complexity associated with filing multiple airspace volumes with complex polygon shapes. As mentioned in Section 5.3.3, Leidos has worked with the FAA to prototype a web-based interface to define Local Area of Operation volumes, which could be a solution to this challenge.

- Dynamic changes and real-time communication: In the near term, requests to change airspace volume boundaries can be coordinated through the established voice communication channels, similar to how requests for changes to IFR routing are accomplished today. However, this approach is not scalable. In the long-term, dynamic changes should be accomplished by a non-voice means such as Datacomm or System Wide Information Management.

- Multiple airspace volume requests: A single UA may conduct missions in multiple airspace volumes on the same flight. In the near-term, a finite number of airspace volumes should be selected with the understanding that it will be expanded over time. In the long-term, it is preferred that provisions are made for UAS to operate under VFR-like rules in controlled airspace.

- Coordination with ATC and other airspace users: Designating airspace volumes to conduct Local Area of Operation missions will require coordination with ATC to assess operational impacts and enable UAS operations under IFR. As is done today for public UAS operations, close engagement with other airspace users will also be needed in areas where routine interactions between UAS and other airspace users are expected. Also in the near-term, the FAA and Standards Development Organizations (e.g., RTCA and ASTM, International) could explore ways to incorporate the concept of Local Area of Operation into existing Communication, Navigation, and Surveillance (CNS) standards. For example, a concept for requesting, modifying, and accepting an airspace volume could be included in Datacomm standards. In the long-term, as UAS operations scale up, some forum, analogous to Collaborative Decision Making (CDM) may be required.

- ATC separation services: Since the UAS will be operating under IFR, it will receive the same services as any other IFR aircraft, including separation services. One of the benefits of the Local Area of Operation concept is that it increases the predictability of the UA for the controller, thereby reducing the risk of loss of separation. This enables a more dynamic flight profile within the airspace volume without disrupting the established IFR-IFR separation criteria. Since UAS operating in controlled airspace will all be utilizing the established process outlined here, there is an opportunity for the civil UAS operator to flight plan away from other NAS operators.

- Communication, Navigation, and Surveillance: While commercial UAS operating in controlled airspace under IFR are assumed to meet all CNS requirements for the airspace and operation they are conducting, there are most likely opportunities for new requirements specific to Local

Area of Operation use cases. For example, navigation consistent with stringent RNP capabilities (e.g., RNP 0.3) could enable the same UAS with the same flight profile to require a smaller airspace volume.

5.4.4 Recommendation Element 2: Process Development Roadmap

The committee recommends that the FAA partner with one or more UAS operators to develop the guidance material necessary to establish a process to enable normalized Local Area of Operation missions. Civilian UAS operators today establish Letters of Agreement (LOA) with the local ATC facility to enable their operations in controlled airspace, so the items contained in those LOAs could be a starting point for this work. At a minimum, this partnership between one or more UAS operators and the FAA should address the following items:

- How to define lateral and vertical boundaries
- How to define time limits and how far in advance operations can reasonably be planned
- How does the operator request airspace volumes and how does ATC approve or amend them
- How to make dynamic changes to airspace volumes
- How to manage multiple conflicting airspace volume requests
- How to strategically deconflict airspace volumes from other airspace users
- Type of ATC Separation Services
- Requirements for Communication, Navigation, and Surveillance

Ongoing monitoring of this process will be key to resolving issues or disputes that are expected to arise. Similar to the issues that gave rise to the CDM process, it is easy to imagine that when UAS are routinely operating in controlled airspace, several operators will file for Local Area of Operation missions in the same location, at the same altitude, and around the same time. Altitude stacking could resolve this at first, but this may not be scalable and a more comprehensive strategic deconfliction procedure will be needed.

5.5 Recommendation E: Develop Standards, Guidance Material, and Regulations to Enable GNSS Based Navigation for UAS

The committee recommends that the FAA work with industry to enable navigation requirements, for all phases of flight, to be met using GNSS equipment without the need for ground-based navigation aid (e.g. Distance Measuring Equipment [DME]) backup, starting with RNAV 2 for en route in Class A. In addition, the committee recommends that the FAA work with industry to develop a GNSS-based capability for auto-takeoff and autoland features, including a landing capability in a Loss of C2 Link State.

The FAA has already established a working group to engage with industry and government stakeholders on the known vulnerabilities of GNSS, called the GNSS Intentional Interference and Spoofing Study Team (GIISST). This working group could incorporate UAS stakeholders to ensure that the particular needs of UAS are being considered. The RTCA Tactical Operations Committee (TOC) has published a report detailing known intentional Global Positioning System (GPS) interference issues and possible solutions [21].

5.5.1 Rationale

Satellite-Based Augmentation Systems (SBAS) are now available in many regions of the world, including the U.S. through the Wide Area Augmentation System (WAAS). This has led the FAA to allow non-commercial operations under 14 CFR Part 91 to be conducted under IFR in IMC, through the entire duration of a flight, with SBAS as the sole electronic means of navigation. It is reasonable to assume that UAS capable of flying in Class A airspace will be equipped with sophisticated navigation and autopilot capabilities. The advanced autopilot systems onboard these highly capable UAS will, by default, rely on precision Inertial Measurement Units (IMU) and Inertial Reference Units (IRU) to maintain stabilized flight and on Inertial Navigation Systems (INS) to maintain accurate navigation. Industry experience has shown that these onboard capabilities (e.g., IMU, IRU, INS) enable highly precise UA navigation even in the presence of GNSS discontinuities. Commercially available systems are accurate enough that it is possible to continue a flight to a safe landing, as a contingency, when GNSS is permanently lost.

In the near-term, the committee members believe it is reasonable to assume that UAS will not have human life onboard. Historically, the goal of safety assessments for navigation functions has been to a level consistent with the size of the aircraft and the complexity of the operation through performance metrics such as accuracy and system level metrics such as integrity. The safety assessment will still be dependent on protecting people and property on the ground and in the air, as has always historically been the case. Operational efficiency is historically considered through requirements on availability and continuity, as well as redundancy on larger aircraft engaged in more complex operations. By reassessing the safety case and updating performance standards and guidance material to compensate for known vulnerabilities to GNSS (e.g. anti-jam), UAS can take full advantage of the GNSS infrastructure that exists today without having to rely on legacy ground-based technology (e.g. ILS). Additionally, the lack of a pilot onboard the UA means that certain functions (e.g. performance monitoring) will have to be replaced by software, which adds some level of complexity.

It is important to note that in the long-term, there is strong interest from industry members of the committee in operating UAS that carry passengers, but it is assumed that existing navigation requirements, or future manned aircraft equivalents, will apply to those UAS.

5.5.2 Summary of Recommendations

Table 7: Summary for Recommendations on GNSS-based Navigation

GNSS-based Navigation	Top-Level Description	Implementation Details
Long-term Recommendation	• Update performance standards and FAA guidance material to enable GNSS-based UAS operations to meet navigation requirements for all phases of flight without the use of legacy ground-based navigation aids • Update performance standards and FAA guidance material to enable GNSS-based precision approach capability with auto-takeoff and autoland features for UAS	Updates may be needed to [22, 23, 24, 25]: • RTCA DO-283B • RTCA DO-236C • AC 90-108 • AC 20-138D New standards and guidance material may be needed to support: • Anti-jam capability for GNSS receivers • Anti-spoof capability for GNSS receivers

GNSS-based Navigation	Top-Level Description	Implementation Details
		• Inertial navigation system (INS) performance requirements to coast through GNSS outages Updates may be needed to ([26] [27] [28]): • AC 120-118 • RTCA DO-245A • AC 90-101A New standards and guidance material may be needed to support: • UAS autoland capabilities • UAS auto-takeoff capabilities • INS performance requirements to coast through GNSS outages
Near Term FAA Actions	The FAA can leverage ongoing UAS Type Certification Projects to include a detailed analysis of navigation functions based on GNSS without ground-based navigation aids The FAA can engage with RTCA to update MOPS for certain navigation related technologies The FAA should partner with one or more UAS operators to collect data on auto-takeoff/land capabilities. This data can be used to inform updates to performance standards and guidance material	

5.5.3 Recommendation Element 1: Update Performance Standards and FAA Guidance Material to Enable GNSS-based UAS Operations to Meet Navigation Requirements for All Phases of Flight

The objective of this recommendation element is to enable GNSS-based navigation for commercial UAS operations for all phases of flight, without the need for a ground-based NAVAID (e.g. VOR or DME) backup, recognizing that other mitigations may be needed to achieve desired availability, continuity, and integrity. Fundamentally, this approach to navigation will be facilitated by the fact that there will be other inertial navigation and stabilization capabilities onboard the UA.

Performance Specifications

The FAA's PBN NAS Navigation Strategy calls for all aircraft operating in Class A airspace to be capable of navigating to RNAV 2 standards. GPS receivers certified to TSO-c146e can, on today's manned aircraft, enable compliance with RNAV 2 requirements and will provide the same compliance for UAS [29]. However, the PBN NAS Navigation Strategy also calls for the FAA to maintain a minimum set of DME transceivers throughout the NAS to ensure that DME/DME coverage is sufficient to act as a backup to GPS for RNAV 2 operations. The FAA's PBN NAS Navigation Strategy calls for different RNAV performance levels in different phases of flight and airspace types. Outside of the final landing phase (i.e. below 200 ft AGL), these can all be met with TSO-c146e certified equipment on today's manned aircraft.

Without a DME/DME capability, it is envisioned that additional features or capabilities will be required to enable a UAS to navigate based on GNSS through all phases of flight without ground-based navigation aids. The FAA and RTCA published several reports detailing known intentional GPS interference and documenting the impact to NAS users from those events. Specifically, it is anticipated that the following features or capabilities will require standardization and acceptance:

- An anti-jam feature[8] on GNSS receivers would allow the receiver to react to jamming events to ensure continuity of service. The critical work in this area is to determine what level of unintentional or intentional jamming should be considered in terms of power, location, etc. This is not an area of research since there are commercially available anti-jam antennas and military grade systems provide much higher levels of performance than those commercially available.
- An anti-spoof feature on GNSS receivers would allow the receiver to react to spoofing events to ensure accuracy and integrity. A GPS spoofing attack attempts to deceive a GPS receiver by broadcasting incorrect GPS signals, structured to resemble a set of normal GPS signals, or by rebroadcasting genuine signals captured elsewhere or at a different time. The critical work in this area is to determine what types of spoofing should be considered. Several U.S. Government agencies have considered this in depth in published reports.
- An onboard INS, even with the above technologies, would allow for the UA navigation system to coast through GNSS outages and maintain navigation performance criteria for some period of time. In addition to determining INS performance requirements, work is needed to develop a standard contingency procedure that allows the UA to safely navigate out of an area of known or suspected GNSS interference.

The committee recognizes that governments around the world will maintain an interest in ensuring the non-proliferation of certain advanced GNSS technologies and that threats of malicious actors and state actors will always pose a substantial threat to the use of GNSS in aviation. Historically, the FAA has taken a position that threats of sophisticated actors' intent on interfering with GNSS should not be considered in safety analyses and this should remain true for civil UAS. Presidential Directive NSPD-39[9] states

> "The Secretary of Transportation shall…In coordination with the Secretary of Homeland Security, develop, acquire, operate, and maintain backup position, navigation, and timing capabilities that can support critical transportation, homeland security, and other critical civil and commercial infrastructure applications within the United States, in the event of a disruption of the Global Positioning System or other space-based positioning, navigation, and timing services, consistent with Homeland Security Presidential Directive-7, Critical Infrastructure Identification, Prioritization, and Protection, dated December 17, 2003."

The committee recognizes that based on Presidential Directive NSPD 39, U.S. government agencies, including the FAA, are working to reduce their dependence on GPS for critical infrastructure.

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[8] http://gpsworld.com/anti-jam-technology-demystifying-the-crpa/

[9] https://www.gps.gov/policy/docs/2004/

Support for Industry Standards

While industry will carry most of the burden in creating performance standards and developing equipment, the FAA plays a key role in sponsoring the MOPS development activities at RTCA and engaging with other parts of the U.S. Government on technology export controls. As it relates to export control, several GPS anti-jam and anti-spoof capabilities are currently controlled by the U.S. Department of State under the International Traffic in Arms Regulations. Some of these capabilities will need to be reevaluated and thresholds may have to be increased to enable standardization and commercial use of certain capabilities.

5.5.4 Recommendation Element 2: Update Performance Standards and FAA Guidance Material to enable GNSS-based Precision Approach Capability with Auto-Takeoff and Autoland Features

The objective of this recommendation element is to enable aircraft to perform precision approaches with automatic takeoffs and automatic landings using GNSS navigation equipment without the need for ground-based navigation aid backup or natural human vision below a Decision Height (DH). Onboard systems necessary for automatic landings, such as radar or laser altimeters and 'weight on wheels' sensors, can be used to augment GNSS vertical accuracy. Since the scope of this ARC is UAS, the desire of the ARC is for these capabilities to enable take off and landing without the need for visual acquisition of the airport environment or the UA prior to landing. Currently, the only landing system that enables full autoland without visual requirements is a Category III ILS, which is designed for large transport category aircraft with (potentially) hundreds of people onboard. With no human life onboard, the safety requirements of autoland systems when applied to UAS, can be reconsidered. These capabilities could also serve as an emergency landing system on small aircraft, in the case of pilot incapacitation, as is currently being demonstrated by several general aviation aircraft manufacturers.

Performance Specifications

Many UAS operating in controlled airspace would be expected to use an automatic take-off and landing capability. The ILS is a widely deployed landing system that provides both lateral and vertical guidance. Landing systems that permit an aircraft to descend all the way to the runway without the pilot having visual contact with the runway are called Category III (CAT III) landing systems. CAT III operations require the use of an autoland system which allows the aircraft to descend to the runway without pilot intervention. To conduct a CAT III automatic landing, the airborne system and the ILS ground equipment must meet CAT III integrity and continuity of service requirements. Additionally, the pilots need to be specifically trained and qualified to conduct CAT III approaches with autoland. Annual recurrent training and testing is required for pilots to maintain their CAT III qualifications.

GPS augmented with WAAS[10] provides a landing system that allows a pilot to descend as low as 200 feet above the touchdown zone before having visual contact with the runway environment without most of the ground infrastructure required by ILS. A RNAV approach with a localizer performance with vertical guidance (LPV) line of minima is an approach using WAAS for both horizontal and vertical guidance. UAS autoland could rely on WAAS LPV guidance (along with the radar altimeter [or equivalent], inertial reference system, and autoland flight control system) to achieve an "LPV autoland"; for the UAS operation[11], the lower level of integrity (1×10^{-7}vs 1×10^{-9}) may be adequate

[10] Other SBAS capabilities provide similar performance improvements to WAAS for GPS and other GNSS constellations.

[11] It is a widely accepted practice in current UAS operations to use a crew member on the ground to visually acquire the unmanned aircraft before the Minimum Descent Altitude or Decision Height.

since safety of life onboard the aircraft is not a factor. Approval would be based on demonstrating adequate touchdown dispersion, runway containment, and ground personnel and other aircraft remaining well clear during touchdown and rollout. GPS WAAS guidance also could be used to support automatic UAS take-off operations. Onboard systems necessary for automatic landing, such as radar or laser altimeters, can be used to augment the vertical accuracy of GPS WAAS, as well as to initiate landing and rollout guidance.

Requirements for these auto-takeoff and autoland features, should not affect existing AC 120-118 [26]. There may be a need for new training requirements for remote pilots (e.g., conditions for initiating a go-around), and requirements for airport certification (e.g. landing system critical areas) and operational approval for UAS auto-takeoff and autoland. It is noted that these ACs provide one way, but not the only way, to achieve autoland operations. If these standards cannot be met, the FAA allows an applicant to propose a mitigation strategy to meet an equivalent or acceptable level of safety with different inputs.

Support for Industry Standards

To facilitate the adaptation of WAAS augmented GPS for auto-take-off and autoland systems for UAS, the FAA will need to provide support for industry standards and certification guidance. ASTM F2849 "Practice for Handling of Unmanned Aircraft Systems at Divert Airfields," could potentially be updated following ARC recommendations [30].

Additional Research

Industry members of the ARC have shared examples of UAS that have demonstrated over 100,000 automatic landings (e.g. GA-ASI MQ-1C) without an incident utilizing commercial GPS signals and commercially available onboard augmentation (i.e. Laser Altimeters). While these systems have proven incredibly robust to date and in limited numbers, and thus acceptable for near term use by commercial UAS in the NAS, there is a concern about the long-term scalability of such capabilities when there are tens of thousands of UAS in the NAS because of the implications of widespread, persistent disruptions to GPS. Vision-based (infrared and/or visible spectrum) landing systems that can match a given runway with one in an onboard database could enable a direct replacement for an onboard human pilot performing a visual approach and landing in VMC. This is not the only method to enable automatic landing functions without external navigation sources (e.g. GPS and ILS), but it is one promising method. Enhanced Vision Systems (EVS) and Combined Vision Systems (CVS) are currently used on manned aircraft to enable CAT I and CAT II landings but are not currently authorized for CAT III autoland. Research and development are currently being done to enable CAT III autoland, but additional research is needed in the area of automatically matching runway environments to a database in order to validate and monitor the landing phase without human involvement.

6 Emerging Economic Benefits

Conceptual Framework

The introduction of UAS and their associated technologies will both generate new economic activity and have an impact on existing economic activities. The following economic benefits assessment, focused on domestic U.S. operations, is based on possible uses of UAS and provides a qualitative description of benefits enabled by the recommendations developed by the ARC. It is anticipated that the FAA will develop quantitative estimates of costs and benefits based on acceptance of specific ARC recommendations. Other regulatory changes beyond those recommended by the ARC may be also needed to facilitate operations and could be achieved through exemption, waiver, or rulemaking changes. Future benefits will depend on the marketplace, business considerations, and policy related decisions. The FAA's Aerospace Forecast, Bureau of Transportation Statistics data, as well as other sources listed in Figure 5 provide a forecast for the growth in aviation expenditures [31] [32] [33] [34] [35].

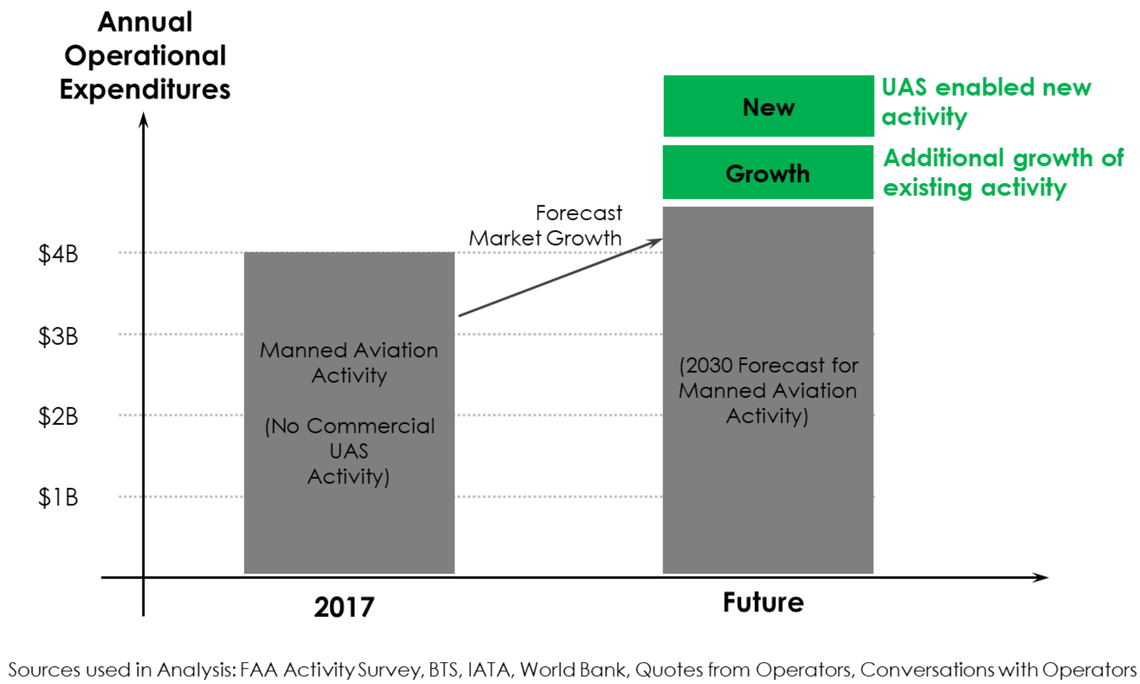

Figure 5: Conceptual Approach and Summary of Annual Economic Impact: Three Types of Economic Impact

The ARC considered the range of activities described in the FAA Activity Survey and selected market segments that could potentially benefit from UAS. Figure 5 shows the economic activity related to the operation of manned aircraft in select market segments and notional economic activity from UAS operations. In 2017, the total annual expenditures related to operating manned aircraft in the segments considered for this analysis (listed in Table 8) amounted to a total of $4B. Using the predicted segment growth rates from the FAA Aerospace Forecast for fiscal year 2017, the selected market segments for manned aviation are forecasted to grow to $4.6B by 2030 [35]. UAS operating in controlled airspace are expected to generate additional growth within those segments as well as generate new aviation activity that is currently not possible with humans on board (e.g. ultra-long endurance flights). The ARC recommendations may also benefit manned aviation operations as they are intended to increase safety and refine operating procedures.

Market Segments and Reference Missions

To quantify the benefits that UAS and their associated technologies can provide, it is important to understand the scope of today's manned activity where aircraft are commercially operated for the purposes of generating a profit. The following markets segments were identified as falling into the operational environments that could potentially be performed by future UAS flying in Class A airspace when the UASCA ARCs recommendations are implemented:

- **Local Observation:** Local loiter with a single engine aircraft. Transit segment is 30 minutes or less and is conducted with a single pilot. The mission benefits from high endurance and not range or airspeed. Examples include news gathering or aerial observation above a population center.

- **Aerial Work:** Airborne surveillance/sensing of distributed elements on the ground with a single engine aircraft and is conducted with a single pilot. Majority of cruise is revenue generating flight. Operation is such that range is more important that endurance. Examples of these activities include linear infrastructure inspection (rail, powerline, pipeline, automobile traffic monitoring, etc.), resource management (logging, mining, etc.)
- **Remote Observation:** For example, a twin-engine aircraft, flying out over open water, to survey with high value sensors for a long cruise to area of interest and a long cruise back. Most commonly today this is done with a turboprop aircraft and a two-person crew. Revenue generating part of the flight is short compared to total mission duration. Examples include ice flow monitoring in the arctic or observation other areas of off-shore areas of interest.
- **Large Cargo Feeder:** For example, a twin-engine turboprop on a one-hour feeder mission to a hub location. The cruise phase is short, but at higher altitudes and further distances than smaller feeder aircraft.
- **Narrow-body Cargo:** For example, a trunk route of a cargo converted large narrow body aircraft. Majority cruise, flight duration is such that a single crew of two pilots can fly the aircraft from point A to point B (3500 NM range, up to 80 tons).

Markets segments that were excluded include any operations related to carrying passengers or large cargo aircraft, "specialty operations" such as external load operations, small cargo feeder aircraft operations which occur at lower altitudes due to the lack of pressurization, and international, long range operations. Table 8 provides a breakdown of the economic activity summarized in Figure 5 by market segments.

Table 8: Forecasted Growth in Manned Aviation Activity (in millions USD per year)

	2017 Operational Expenditures	Forecast Segment Annual Growth Rate	Forecast 2030 Operational Expenditures
Local Observation	$94	-0.80%[1]	$85
Aerial Work	$294	-0.80%[1]	$267
Remote Observation	$1,090	2.40%[2]	$1,453
Large Cargo Feeder	$86	1.30%[3]	$101
Narrow-Body Cargo	$2,341	1.30%[3]	$2,737
Total:	**$3,905**	**--**	**$4,643**

Notes:

[1] *FAA Aerospace Forecast Fiscal Year 2017, p. 22* [35]

[2] *FAA Aerospace Forecast Fiscal Year 2017, p. 23*

[3] *FAA Aerospace Forecast Fiscal Year 2017, p. 20*

Data available from the FAA's General Aviation Survey as well as the Bureau of Transportation Statistics specific to each market segment of interest is summarized in Table 9 [31] [32] [33] [34] [35]. Multiplying the annual number of hours for each market segment by the nominal cost per flight hour provided in Table 9 then provides the total amount of annual expenditures related to the operation of the existing aircraft associated with that market segment.

Table 9: Number of Aircraft, Annual Flight Hours and Reference Mission Assumptions for Each Market Segment

Segment/Mission	# of Active Aircraft	Segment Annual Flight Hours	Annual Average Hours per Aircraft	Annual Growth Forecast	Nominal $/flight-hour
Local Observation	5,581	1.3M	241	-0.8%	$140
Aerial Work					$437
Remote Observation	1,156	.4M	316	2.4%	$2986
Large Cargo Feeder	47	16,584	350	1.3%	$5,209
Narrow-Body Cargo	308	246,664	800	1.3%	$9,415

Potential Economic Benefits for Normalized UAS Operations

Listed below are potential economic benefit pathways resulting from normalized UAS operations in controlled airspace as enabled by the recommendations developed by this ARC.

<u>Benefits to existing UAS operations</u> such as:

- Future and emerging UAS services, capabilities, and technology through continuation of U.S. government and FAA support for the safe integration of UAS in the NAS.
- Alignment of government efforts across NASA, DHS, and other agencies that can work together more effectively without having to work the COA process.
- Increased operational flexibility that can facilitate operations currently not enabled by the existing COA process.

<u>Reduction of cost for operational approval</u> including:

- Reduced manpower and administrative burden on the FAA to address continued COAs for UAS operations and services.
- Reduced cost and time for government and private sector operators to obtain regulatory approvals for operations.

<u>Moving from segregated to integrated operations</u> will result in:

- Reductions in Traffic Flow Restrictions (TFRs) and other accommodations that have negative impacts on manned aircraft operations.
- Optimized use of airspace to increase efficiency, benefiting all users of controlled airspace.
- Standardized practices and procedures for controllers and all users of the NAS.
- Increased efficiency in industry operations and an increase in the numbers of operations due to reduction in operational approvals (i.e. waivers and exemptions).
- A larger set of services marketed by industry and introduction of new market segments based on emerging technologies.

<u>Standardized contingency operations (e.g. lost-link, cost avoidance)</u> will lead to:

- Predicable and reliable air traffic services to all controlled airspace operators for unpredictable or irregular operations.
- Reduced training costs and standardized training for controllers and pilots to expect consistent behavior in contingency situations.
- Increased confidence in the general public due to increased safety that will result in public acceptance of increased UAS operations in the NAS.

Increased manufacturing jobs will be enabled by:

- Clear regulatory guidance that provides a basis for industry to realize investments in UAS technology, services and manufacturing.
- An increase in the number and frequency of UAS operations in controlled airspace. This increase in operations will result in more demand for UAS to be manufactured, thus resulting in a corresponding employment impact.

FAA leadership will benefit global UAS operations by:

- Shaping the development of emerging technologies and capabilities in the US market and benefiting the U.S. industry globally.
- Advancing the development of international standards, which could lead to increased export of UAS and UAS services globally.

New Types of Operations will lead to:

- Reduced cost to deploy and operate UAS systems in lieu of space-based and ground-based systems and networks.
- Provision of services not currently enabled by current COA based operational approvals.

Expanded number and pace of operations in existing market segments will be enabled by:

- Normalization of UAS operations in controlled airspace. This will enable some UAS to enter existing market segments thus adding to the projected growth in manned operations and expenditures. Increased pace of operations will have a positive impact on economic impact in these market sectors.
- Implementing recommended changes to NAS automation systems will enable other market segments (e.g. commercial space) to realize additional benefits.

These potential economic benefits come with a cost to implement them on the part of the FAA and operators of manned and UAS. The realizable benefits must always be balanced with the cost to implement for all parties to justify implementation in the NAS. The FAA is better equipped to estimate the costs for implementation than the membership of the ARC and we will defer that analysis to the FAA.

Air Line Pilots Association, International (ALPA) Dissenting Opinion

The Air Line Pilots Association, International (ALPA), representing the safety interests of over 62,000 pilots flying for 33 air carriers in the US and Canada, concurs with the UAS in Controlled Air Space (UASCA) Aviation Rulemaking Committee (ARC) Final Report, with the following exception.

Section 6; Emerging Economic Benefits:

Based on ALPA's analysis of the discussion with regards to remotely piloted transport category aircraft operations (identified in the ARC report as large cargo feeder and narrow body cargo), the costs and benefits data for these operations is questionable, and therefore should be removed.

The ARC's recommendations are focused on normalization of UAS operations in controlled airspace in the next five years, which is in-line with the direction provided by the FAA in the ARC's charter. The ARC did not evaluate the feasibility of large cargo feeder and narrow body cargo operations within that timeline. As such, the ARC did not provide recommendations to change policy, regulations, procedures or any other changes needed for transport category remotely piloted aircraft operations in the National Airspace System (NAS).

In addition to a lack of analysis of the operational viability, there was no analysis of financial viability of large cargo feeder and narrow body cargo operations by the ARC. Currently, both large cargo feeder and narrow body cargo flight operations are operated by two pilots. It cannot be assumed that relocating the pilots to a remote ground station will provide any economic benefit. With the assistance of a third party validator, ALPA has conducted our own analysis of costs and benefits associated with remotely piloted transport category aircraft operations, and have concluded that the savings for remote pilot operations are very small. The costs to implement, however, are significant due to the need to develop new technology, develop new Infrastructure, develop and conduct new training, and several other significant cost drivers such as the process of testing and certifying the aircraft and associated subsystems to appropriate certification standards.

In addition, transport category remotely piloted operations will require significant changes, waivers, and/or exemptions to existing aircraft certification (i.e. Part 23 and 25) regulations and operational rules (i.e. 119, 121, 125, and 135). The timing and feasibility of those changes were not evaluated nor addressed by the UASCA ARC. However, the necessary rulemaking alone would likely push these types of operations beyond the 5-year timeline horizon as requested by the FAA.

The facts are clear and reinforce ALPA's position, that there are many hurdles to clear before taking the first step towards a move of pilots from the transport category cockpit to a remote location. Given that the time lines for transport category remotely piloted operations are beyond the scope of the ARC, and given that there are unvalidated costs, savings, a lack of technical feasibility analysis, and no current plan for needed regulatory changes, the inclusion of this segment of aviation in the economic analysis is unjustified.

As such, ALPA recommends that the market segments and reference mission for large cargo feeder and narrow body cargo mission segments be removed from the Emerging Economic Benefits documentation in the ARC report to the FAA.

7 Gaps in Research and Development

The committee believes that if the recommendations in this report are fully implemented, normalized UAS operations in controlled airspace will be achieved enabling certain use cases for a class of UAS. While not considered "Research and Development" in the academic sense of the phrase (i.e. there may not be a research question), the ARC has detailed near-term actions that the FAA can take to enable UAS operations in Class A airspace before rulemaking and the long term recommendations contained in this report are achieved. These near-term actions are compiled here:

- Introduce an expedited exemption/waiver process for UAS to operate in Class A, based on the explicit performance, equipage, and capability requirements.

- Establish a policy of listing the phone number of the ground control station in the flight plan.
- Partner with one or more UAS operators to prototype UAS-specific features into existing instrument procedures to establish best practices and inform future policy.
- Establish a web portal or web service that allows operators to submit their proposed Local Area of Operations to the FAA to inform the relevant ATC facilities.
- Partner with one or more UAS operators to develop a prototype process for establishing a Local Area of Operation that will inform future policy or guidance material development.
- Leverage ongoing UAS Type Certification Projects to include a detailed analysis of navigation functions based on GNSS without ground-based navigation aids.
- Engage with RTCA to update MOPS for certain navigation related technologies, as detailed in Recommendation E.
- Partner with one or more UAS operators to collect data on auto-takeoff/land capabilities. This data can be used to inform updates to performance standards and guidance material.

The use cases specified in Section 4 and the associated class of UAS do not exhaustively represent the aspirations of the UAS community and therefore, the committee has identified several gaps, which will require additional research both by the FAA and industry.

7.1 Research Gap A: Research into Specific Operating Rules in Controlled Airspace

The UAS industry recognizes the rationale behind the policy that the routine operation of UAS in controlled airspace will be conducted under IFR and that it is important to demonstrate that routine IFR UAS operations can be conducted safely and efficiently in the NAS to build experience and confidence among aviation stakeholders. However, this policy may not be scalable to a large number of UAS operating in controlled airspace and will not unlock the full potential of UAS in the NAS (and by extension around the world). In order to unlock the full commercial potential of UAS in the NAS, a set of flight rules that (i) enables flight with sole reference to instruments and electronic signals[12] and (ii) enables the operational flexibility of VFR, will be needed. This set of flight rules does not need to be limited to UAS but could have broad applicability.

The FAA should continue the research necessary to enable the full range of UAS operations in controlled airspace. This should include updates to 14 CFR Part 91 to enable electronic systems to perform all functions traditionally performed by an onboard pilot without regard to weather conditions. To illustrate this point, the committee considered a UA operating with an all-weather (e.g. radar based) airborne DAA system enabling the remote pilot to remain well clear of and avoid collisions with other aircraft, which could, in theory, allow it to operate in controlled airspace in Instrument Meteorological Conditions (IMC) without the need for ATC to provide separation services. This new set of flight rules would also allow, for example, a UAS to operate below Minimum Enroute Altitudes along and around IFR routes with an electronic means of terrain and obstacle avoidance. Some gaps include:

- Use of DAA systems in VFR-like operations in IMC
- Use of terrain avoidance systems to enable operations below Minimum Safe Altitudes in IMC

[12] "Instrument Flying Handbook" (PDF), Instrument Flight Rules (defined), Oklahoma City, OK: Federal Aviation Administration, 2008, pp. G–9

- Use of obstacle avoidance systems to enable operations below Obstacle Clearance Surfaces in IMC
- Use of ground-ground voice and data communication to enable operations below Minimum Communication Altitudes
- Understanding the operational implications of UAS operations in a VFR traffic pattern at airports
- Understanding the operational implications of UAS flying through IMC without the need for ATC clearances
- Use of weather radars, ice detection systems, and other environmental sensors to gain awareness of the operating environment

The U.S. Army has been conducting UAS operations under VFR for several years now and the ARC encourages that their experience be leveraged.

7.2 Research Gap B: Local Area of Operations Use Case in Controlled Airspace Other Than Class A Airspace

Conceptually, the Local Area of Operation use case can also be conducted in other classes of airspace beyond Class A. However, with positive control over all aircraft, ATC may feel most comfortable enabling these operations above FL180 initially with the goal of extending to other classes of airspace. There is a strong desire by industry members of the ARC to perform this use case at all altitudes, however below Class A airspace, the remote pilot would be responsible for remaining well clear of VFR aircraft, which might be flying through the Local Area of Operation airspace volume. Outside of Class A airspace, ATC would still be responsible for separating IFR aircraft from aircraft operating in a Local Area of Operation airspace, but with the free movement of the UA within the airspace, geometries may be established between aircraft that would otherwise be considered operationally unacceptable.

It is important to note that the scope of RTCA SC-228's Phase II standardization effort includes these types of operations. Continued leadership and SME support from the FAA is needed to ensure the successful completion of MASPS and MOPS within RTCA SC-228.

7.3 Research Gap C: Scalability to Large Number of UAS Operations

Within the timeframe considered by this ARC (i.e. 1-5 years), it is accepted that operations in controlled airspace by UAS capable of reaching Class A airspace will remain limited, compared to the other traditional NAS users, because of the timelines associated with design, development, and certification of large aircraft. However, over the next 10-20 years, a proliferation of UAS in controlled airspace could introduce unforeseen challenges to the NAS. Some examples of identified research gaps associated with this scalability are:

- Research must be conducted on UAS ground operations at towered and untowered airports where seamless integration will be required.
- Research must be conducted into acceptable Lost C2 Link Decision Time(s) in dense and/or complex airspace. This should include both human factors and human-in-the-loop testing.
- Research should be conducted to determine whether air traffic controllers require unique UAS-centric symbology on controller displays to facilitate handling of off-nominal events.

- Research should be conducted to determine how UAS specific elements for procedure design could scale. This includes: contingency hold points, Loss of C2 Link missed approach procedure, minimum frequency reception altitudes for radio line of sight control, contingency flight routing, emergency hold points and alternate means of communication.
- Research should be conducted on the extension of EVS and CVS to enable full automatic emergency landing performance in the case of widespread, persistent GPS outages.

There are agencies within the FAA who are working on human-in-the-loop simulation objectives with regard to UAS operations. It is recommended that their scope be increased to include human-in-the-loop considerations specific to UAS operating in the terminal area. The outcome of these efforts could include remote pilot and controller interactions (between themselves as well as their technologies) from take-off, through departure, then from arrival through approach and landing.

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Appendix A ARC Membership and Summary of Activities

ARC Membership and Structure

The FAA selected a committee consisting of a diverse group from the aviation community and industry organizations that have a vested interest in UAS policies and procedures. The ARC membership includes manufacturers, pilot associations, research organizations, and commercial and cargo carriers. The DoD, NASA, FAA and other air navigation service providers served as Observers to provide technical support to UASCA ARC members.

ARC member organizations include:

- A3 by Airbus
- Aerospace Industries Association (AIA)
- AeroVironment
- Air Line Pilots Association (ALPA)
- Aircraft Owners and Pilots Association (AOPA)
- Airlines for America (A4A)
- Amazon Prime Air
- Association for Unmanned Vehicle Systems International (AUVSI)
- ASSURE UAS Center of Excellence
- Aurora Flight Sciences
- Boeing
- DJI
- Facebook
- Federal Express
- GE Global Research
- General Atomics
- Honeywell
- Lockheed Martin
- Management Association for Private Photogrammetric Surveyors (MAPPS)
- National Business Aviation Association (NBAA)
- Northrop Grumman
- Praxis Aerospace Concepts International, Inc.
- Raytheon
- Regional Air Cargo Carriers Association (RACCA)
- Rockwell Collins

- The MITRE Corporation
- The Padina Group
- Uber
- United Parcel Service (UPS)
- X

Summary of ARC Meetings and Actions

The full ARC convened at nine plenary meetings between September 2017 and February 2019.The first three meetings identified the industry needs, framework and areas of focus for these recommendations. This led to the workgroup position papers that were discussed and refined by the ARC during the summer of 2017. The first draft of the report and recommendations were written during September 2018 and released to the full ARC for review. During the final three meetings the ARC adjudicated comments to the report and finally reached consensus on their final recommendations to the FAA.

Below is a summary of each meeting. These meetings do not include the numerous workgroup meetings and topic-related discussions that were essential in developing the content of this report.

- The ARC kick-off meeting was hosted by MITRE in McLean, Virginia on September 26 and 27, 2017.It provided an overview of the FAA rulemaking process, Class A airspace, ARC objectives from the EIP, and current research gaps. Membership and the scope of each of the Workgroups—Airspace Procedures, NAS Automation, Navigation and Performance, and Transit To/From Class A—were established.
- The second meeting, at the FAA WJHTC in New Jersey on October 24 and 25, 2017, focused on current research on the integration of UAS in the NAS. During this meeting, the ARC established key working assumptions. The group toured the WJHTC laboratories and participated in discussions on advanced research.
- The third meeting occurred at Boeing Government Operations offices in Arlington, Virginia, on January 17 and 18, 2018. The first day consisted of breakout sessions among the five workgroups. The second day consisted of a discussion on the current conformance gaps between UAS and current air traffic rules and a presentation by representatives from European Organisation for the Safety of Air Navigation (Eurocontrol) on European UAS traffic management. Each of the five workgroup leads gave presentations on the progress from their respective groups and discussion topics for the full ARC.
- The fourth meeting occurred at the Amazon, Inc. offices in Washington, DC, on March 22, 2018. The ARC received briefings on NASA's System Integration and Operationalization plan, updates on FAA/NATCA Lost Link Standards, and the FAA approach for conducting economic cost-benefit analysis. The ARC was briefed from the leads from each workgroup. Each of the workgroups were tasked to develop position papers for discussion at the next meeting.
- The fifth meeting took place at the General Electric, Co. offices in Washington, DC, on May 30 and 31, 2018. The Committee discussed initial feedback on the workgroup position papers and identified candidate recommendations for further refinement. The authors for each section were selected for this report and were tasked to develop draft language for full committee review.
- The sixth meeting occurred at National Business Aviation Association (NBAA) offices in Washington, DC, on July 26, 2018. The scope of the overall report was refined, and the ARC agreed on the areas to recommend. The authors of the report were tasked to put together the first

working draft of the ARC Report and recommendations for Committee review and comment. This led to the release of the first draft report to the full ARC on September 25, 2018 for review. A total of 91 comments were subsequently received on this first draft.

- The seventh meeting took place at Lockheed Martin offices in Arlington, Virginia, on October 22, 2018. The comments on the first draft were prioritized, discussed, and dispositioned. The ARC took actions to resolve open comments and develop the economic and research areas of the report.
- The eight meeting was held at MITRE in McLean, Virginia, on March 20, 2019. This ARC reviewed comments received on the draft report v4.0 and discussed next steps to refine the economic analysis section and to add an appendix on the mapping of ARC recommendations to the hazards identified by the Class A and Upper Class E Airspace SRMD.
- The final ARC plenary took place at MITRE in McLean, Virginia, on May 17, 2019. This meeting was focused on refining and finalizing the economic analysis section and addressing any other outstanding items in the ARC report.

Appendix B FAA UAS ARC Recommendations for Changes to 14 CFR Part 91

This appendix provides a summary of changes to 14 CFR Part 91 recommended by the UAS ARC. Principal changes to 14 CFR Part 91 were focused on updating existing rules that reference requirements “in the aircraft” or apply to a person or crewmember “on board”. These references needed to be modified to include the UA GCS. The UAS ARC also introduces two new rules under 14 CFR Part 91. This appendix provides a consolidated summary of the UAS ARC recommendations; the original UAS ARC report should be referenced for a more complete explanation of these changes.

The new rules recommended by the UAS ARC are provided below:

1. Transfer of Control of Civil UA.

(a) Civil unmanned aircraft operations that involve a transfer of control between unmanned aircraft system control stations must have an established and documented transfer of control process to ensure the safe transfer of aircraft control.

(b) When transferring control of civil unmanned aircraft from one control station to another, procedures intended to ensure continuity of control and monitoring of the unmanned aircraft shall be followed.

2. Civil UAS Lost Link.

(a) Unless otherwise authorized by the Administrator, civil unmanned aircraft system pilots shall comply with the rules of this section.

(b) Each civil unmanned aircraft system pilot, as part of the preflight inspection of so equipped unmanned aircraft, will confirm that the aircraft is pre-programmed to automatically squawk the established lost link transponder code, flash navigation/position lights, and execute the appropriate contingency procedures in the event of loss of the command and control link. At a minimum, the pre-programmed elements for the contingency procedure will include:

(i) Route

(ii) Altitude

(iii) Speed

(iv) Lost link holding waypoint

(iv) Time in holding prior to executing an approach to land

(c) Civil unmanned aircraft system pilots shall be prohibited from acting as pilot in command for any unmanned aircraft system that does not have a pre-programmed loss of command and control link procedure.

(d) Civil unmanned aircraft system pilots shall notify ATC of the executed lost link contingency procedure and communicate with ATC as necessary during the contingency.

(e) Civil unmanned aircraft system pilots will update the loss of command and control link contingency procedure as necessary during flight.

Table 10 below provides the 14 CFR Part 91 amendments recommended by the UAS ARC. The first column lists the applicable section, the second and third columns provide current and amended wording respectively while the last column provides rationale.

Table 10: UAS ARC Recommended Amendments to 14 CFR Part 91

Section	Current Wording	Amendment	Rationale
§91.1 (c)	"…person on board an aircraft…"	"…person on board an aircraft *or controlling an unmanned aircraft*…"	Addresses unique UAS configuration
§91.1 (d)	"…airworthiness of each airplane."	"…each *aircraft or unmanned aircraft system*."	Aircraft is a more inclusive term. Covers the airworthiness of the entire UA system and not just the aircraft portion.
§91.9 (a)	"…Airplane or Rotorcraft Flight Manual…"	"Airplane, Rotorcraft *or Unmanned Aircraft System* Flight Manual…"	Allows UAS pilots to comply with the intent of the current rule
§91.9 (b)(1)	"…an Airplane or Rotorcraft Flight Manual is required by §21.5 of this chapter unless there is available in the aircraft a current, approved Airplane or Rotorcraft Flight Manual…"	"…an Airplane, Rotorcraft, *or Unmanned Aircraft System* Flight Manual is required by §21.5 of this chapter unless there is available in the aircraft, *or readily accessible to the Unmanned Aircraft System pilot in command*, a current, approved Airplane, Rotorcraft, *or Unmanned Aircraft System* Flight Manual…"	Allows UAS pilots to comply with the intent of the current rule
§91.9 (b)(2)	"…an Airplane or Rotorcraft Flight Manual is not required by §21.5 of this chapter, unless there is available in the aircraft a current approved Airplane or Rotorcraft Flight Manual…"	"… an Airplane, Rotorcraft *or Unmanned Aircraft System* Flight Manual is not required by §21.5 of this chapter, unless there is available in the aircraft *or readily accessible to the Unmanned Aircraft System pilot in command*, a current approved Airplane, Rotorcraft, *or Unmanned Aircraft System* Flight Manual…"	Changes allow UAS pilots to comply with the intent of the current rule
§91.11	"…crewmember's duties aboard an aircraft being operated."	"…crewmember's duties *when the crew member's* aircraft *is* being operated.*"*	Addresses unique UAS configuration.
§91.21 (a)(3)	N/A	*"(3) For unmanned aircraft this section also applies to the control station."*	Added new wording to include a control station
§91.103 (c)	N/A	*"(c) Additionally, for civil unmanned aircraft flight, information needed to*	Added new wording to address missing C2 Link

Section	Current Wording	Amendment	Rationale
		plan for uninterrupted control and non-payload communications data links, ATC communication links, as well as for proper functioning of sensors required for safe flight operations."	and DAA sensor information /checks
§91.105 (a)(2)	"Keep the safety belt fastened…station."	"Keep the safety belt fastened…station*; unless the crewmember is operating from a static or handheld unmanned aircraft system control station."*	Addresses UAS control station configuration
§91.105 (b)(3)	N/A	"*(3) The crewmember is operating from a static or handheld unmanned aircraft system control station."*	Added new wording to address UAS control station configuration
§91.191 (a)(1)	"…as appropriate, for that aircraft;"	"…as appropriate, for that aircraft; *or readily accessible to the unmanned aircraft system pilot in command;"*	Allows UAS pilots to comply with the intent of the current rule
§91.203 (a)	"…aircraft unless it has within it the following:"	"…aircraft unless it has within it, *or for civil unmanned aircraft, available to the pilot in command* the following:*"*	Allows UAS pilots to comply with the intent of the current rule
§91.203 (b)	"…legible to passengers and crew."	"legible to passengers or crew*; or for civil unmanned aircraft, available to the pilot in command."*	Allows UAS pilots to comply with the intent of the current rule
§91.205 (a)	"…unless that aircraft contains…"	"…unless that aircraft *or the unmanned aircraft system control station* contains…"	Allows UAS pilots to comply with the intent of the current rule
§91.211 (a)(1), (a)(2)	"…at cabin pressure altitudes …"	"…at cabin *or unmanned aircraft system control station* pressure altitudes…"	Addresses situations when the control station is at or above the specified pressure altitudes
§91.213 (a)	"…equipment installed unless,…"	"…installed on the aircraft, *to include the control station for unmanned aircraft systems*, unless…"	Allows UAS pilots to comply with the intent of the current rule
§91.213 (a)(2)	"The aircraft has within it a letter…"	"The aircraft has within it, *or the unmanned aircraft system pilot in command has access to* a letter…"	Allows UAS pilots to comply with the intent of the current rule
§91.219 (a)	"…unless that airplane is equipped…"	"…unless that airplane *or unmanned aircraft system control station, as applicable,* is equipped…"	UA should have an equivalent level of flight instruments as required to be installed and operable in manned aircraft.

Section	Current Wording	Amendment	Rationale
§91.313 (g)	"No person may operate a small restricted category civil airplane…"	"*Except for unmanned aircraft with static or handheld control stations,* no person may operate…"	Addresses unique UAS configuration.
§91.1027 (d)	"…load manifest in the aircraft to its destination. The program manager.…"	"…load manifest in the aircraft to its destination. *For unmanned aircraft systems, the pilot in command must have access to a copy of the load manifest and ensure a copy accompanies the cargo on the unmanned aircraft*. The program manager…"	Allows UAS pilots to comply with the intent of the current rule
1053 (a)	"…met the applicable requirements of Part 61 of this chapter…"	"…met the applicable requirements of Part 61 *or Part 62* of this chapter…"	Addresses UAS work underway to create a standalone UAS version of Part 61 (currently called "Part 62")
1065 (a)(1)	"…appropriate provisions of parts 61 and 91…"	"…appropriate provisions of parts 61, *62,* and 91…"	Addresses UAS work underway to create a standalone UAS version of Part 61 (currently called "Part 62")

Appendix C FAA Report on Non-Conformity Issues with Global Hawk and Predator

It is important to understand how the performance attributes of UAS operating in Class A airspace could potentially lead to divergent air traffic management practices and consequently higher workloads to ATC. Accordingly, the Class A Navigation and Performance Standards sought out any documentation where these issues juxtaposed against guidance found in the FAA Order JO 7110.65W, Air Traffic Control, and the Briefing Guide.

The most relevant information available was borne out of study conducted by the FAA Air Traffic Organization, which provides a summary of non-conformity issues specific to operations in Class A airspace conducted with the Global Hawk and Predator. Although it should be noted that this was a very small sample set, and the performance capabilities of future UAS capable of conducting continuous operations in Class A airspace will likely prove highly varied, this was still a helpful starting point in assessing the divergence. The high-level findings of that report are summarized below for Predator and Global Hawk operations:

1. Cannot be cleared for a visual approach.
2. Cannot instruct UA to follow another aircraft.
3. Cannot comply with visual sequencing in a visual traffic pattern.
4. Cannot ask a UA to “maintain visual separation” on another aircraft.
5. Cannot apply wake turbulence criteria on final or at an airport.
6. Cannot clear a UA for an instrument approach.
7. Cannot instruct a UA to hold short of the ILS critical area while taxiing.
8. Cannot instruct a taxiing UA to pass behind United, then taxi across runway 28L.
9. Cannot conduct simultaneous parallel runway operations.
10. Cannot always use standard ATC phraseology.
11. Cannot always make a controlled landing when beyond line of site signal range.
12. Cannot land if there is a power disruption to either the Control Station or the Ground Data Terminal line-of-site dish.
13. Cannot always maintain ATC assigned altitude.
14. Cannot perform standard rate of turns.
15. Cannot perform half standard rate of turns.
16. Cannot be used in same runway separation criteria.
17. Cannot conform to standard nomenclature for aircraft type identification.
18. Cannot file flight plans using standardized ATC system requirements.
19. Cannot be assigned to an aircraft approach category.
20. Cannot arc about a NAVAID.
21. Cannot enter and hold in a standard holding pattern.

22. Cannot be used in Land and Hold Short Operations (LAHSO).
23. Cannot participate in and “Miles-In-Trail” implementation (Traffic Flow).
24. Cannot cruise in RVSM airspace.
25. Cannot see light gun signals from the tower.
26. Cannot conduct a contact approach.
27. Cannot conduct Special Visual Flight Rules.
28. Cannot always provide critical emergency information to ATC in lost link.
29. Cannot provide a Pilot Report.
30. Cannot navigate within the NAS infrastructure.
31. Cannot fly an ILS, VOR, DME or RNAV Standard Instrument Approach Procedure.
32. Cannot fly a heading to join an airway radial.
33. Cannot fly a victor or jet airway.
34. Cannot fly any GPS procedure that’s not pre-translated and programed.
35. Cannot proceed to any unexpected fix or waypoint.
36. Cannot navigate along a Q-route or T-route.
37. Cannot operate within a complex traffic environment requiring multiple ATC instructions.
38. Cannot immediately detect an inadvertent climb or descent.
39. Cannot instruct a UA to expedite.
40. Cannot instruct a UA to take an immediate action.
41. Cannot instruct a UA to be ready for a possible Go Around.

Although this was a non-conformities study for a narrow range of aircraft, this helped our working group tailor our approach to rulemaking recommendations. First, we eliminated any instances that did not conform to continuous operations in Class A. Next, we narrowed the list further and inverted it to identify those minimum conditions (e.g. Part 91 compliance, and not those conditions required for Parts 121 and 135) that had to be met from a navigation and performance standpoint to conduct continuous operations in Class A airspace, which resulted in the following matrix shown in Table 11:

Table 11: UAS Performance & Navigation Expectations for Class A Normalized Operations

	Capability	Recommended	Minimum
Communication	Reliable communications between UAS PIC and ATC, integrated with ATC radio	X	X
	Able to comply with ATC instructions to take immediate action	X	X
	Comm latency equivalent to manned aircraft	X	X
	Good C2 Link reliability (low probability of lost link)	X	X

	Capability	Recommended	Minimum
	Able to provide critical emergency info to ATC in lost link	X	X
	Ability for ATC to know easily where aircraft will navigate during lost link events	X	X
Horizontal Navigation	GNSS equipped	X	X
	RNAV capable	X	X
	Navigation database with aeronautical fixes, waypoints, and procedures; coupled with RNAV	X	X
	Ability to safely operate in GNSS fault event (e.g., safely exit Class A or continue to meet RNAV requirements without GNSS)	X	X
	Dual independent navigation sources	X	
Vertical Navigation & Performance	Able to maintain ATC assigned altitude	X	
	Able to perform basic climbs and descents in a timely fashion	X	X
	RVSM-required equipage if cruising in RVSM altitudes	X	X
	Able to maintain minimum airspeed	X	
	Able to maintain minimum climb rate	X	
	Capable of standard turn rate	X	
	Able to enter and hold in standard holding pattern	X	
Surveillance	Transponder equipped IAW 14 CFR 91.225/227 (ADS-B) and 91.215/217	X	X

Appendix D Acceptable Technology for Means of Compliance with Performance-based Updates to 14 CFR Part 91

The changes to 14 CFR Part 91 proposed by the previous UAS ARC and contained in Appendix B are, by design, performance based. While performance-based regulations allow for flexibility and the incorporation of new technology, they often require substantial guidance on acceptable means of compliance to reduce the burden of certification placed on applicants. The UAS industry is diverse and there are some members who prefer a non-prescriptive approach to complying with performance-based regulations. There are other members who prefer to take the traditional approach and follow established and accepted means of compliance, which has historically been codified in ACs and TSOs.

The industry standards that have been developed to date that explicitly apply to UAS operations in Class A and throughout the transit to/from Class A are RTCA DO-362 for CNPC Datalinks and RTCA DO-365/366 for DAA Systems. The FAA has invoked these standards in TSO-c213 and TSO-c211/212, respectively. The FAA can publish installation guidance in form of ACs, provide operational guidance on the use of DAA, and provide guidance on the use and management of frequency spectrum for CNPC RLOS Datalinks.

Advisory Circulars

To expand beyond the standard Part 107 operations, commercial UAS operations will generally need some form of airworthiness certification. However, additional forms of airworthiness certification, beyond the standard type certificate, and based on a risk-based approach associated with the kind of operation being performed should be explored. However, those UAS that do, and especially those UAS that routinely interact with controlled airspace and manned aircraft operations, will also require certified avionics, both at the component-level and the aircraft system level. For this reason, it is important that the FAA establish clear guidance material on the installation, certification, and operations use of DAA Systems and CNPC RLOS Datalinks. Until such guidance is available, industry applicants will have to rely on issues papers and special conditions, adding uncertainty and complexity to Type Certification projects.

AC-20-187 (CNPC)

The FAA is publishing AC 20-187 recognizing RTCA DO-362. The AC concerns aircraft installation, ground system siting and implementation issues. It recognizes work on the near-far problem that has proceeded since the MOPS development.

AC-20-TBD (DAA)

Currently, the AC for the installation of TSO-C211, Phase 1 DAA System, has been developed and is in coordination. Expected release of the AC is June 2019.This AC provides guidance for designing acceptable installations for a TSO-C211 Phase 1 DAA compliant system. It includes, but not limited to, minimum aircraft performance considerations for installation, ATAR spectrum considerations, display considerations, control station considerations, environmental considerations, safety assessments, ground and flight testing.

Industry has noted that, although this AC will focus on the installation and certification of the DAA system equipment, it will not discuss the larger operational context and approval, nor how the DAA system fits into the NAS as a complex system of systems.

AC-90-TBD

Due to the unique safety, interoperability, and operational issues addressed by DAA systems, it is important that the FAA issue additional guidance on the approval and operation of DAA systems in the NAS. This guidance could take many forms, but a Part 90 AC would be the most comprehensive and authoritative way to do it. Similar to PBN where AC-90-105 expands, explains, and implements 14 CFR Part 91.205, the regulations around DAA could be structured the same way. This assumes that the regulatory change to 14 CFR Part 91.113 and other rules affected by the lack of a remote pilot's ability to strictly comply with existing "see and avoid" requirements, will be performance based and not technology prescriptive, as was recommended by the prior UAS ARC. Similar to navigation regulations, there is a framework in place to support the high level, performance-based language in 14 CFR Part 91 with design, certification, and operational approval guidance through ACs, TSOs, Type Certificates, and Operating Certificates. A similar framework is needed for DAA to ensure a flexible and adaptable regulatory environment that enables integration of sophisticated systems while also allowing accommodation of more simple approaches for certain operations.

NASA recently completed the first operational flight of an airborne DAA system in the NAS in close coordination with the FAA and other NAS stakeholders. That project clearly demonstrated that introducing DAA systems is a multidisciplinary problem that touches diverse areas of the FAA. A single, coordinated approach to approving DAA systems in the NAS is needed.

Of particular note is the FAA's Safety Risk Management (SRM) process, which was utilized to justify the introduction of the DAA System specified in DO-365 and DO-366 into the NAS. The convening of a Safety Risk Management Panel (SRMP) to create an SRMD appears to be the appropriate way to assess the suitability of DAA systems across FAA lines of business with input from all relevant stakeholders. An SRMD was developed to correspond with DO-365 and DO-366, but it was never signed by the FAA lines of business and as a result, much of the content was re-adjudicated as part of NASA's project to fly Ikhana with a DAA system in the NAS. Furthermore, with RTCA working on a second phase of DAA MOPS, the SRMD will need to be updated for the new equipment and operational environments. The FAA is the only organization that can accomplish this and therefore it is critical that they plan for it and execute when the time comes.

CNPC Frequency Spectrum Management

In January 2018, a Petition for Rulemaking was filed with the Federal Communications Commission (FCC) seeking the establishment of service rules to authorize terrestrial CNPC operations to provide C2 services to commercial UAS in the 5030-5091 MHz band. Included in the Petition is a recommendation that FCC adopt a dynamic frequency management system framework, consistent with the recommendations of DO-362, Appendix I, and identify one of more frequency managers in support of such operations. The FCC Petition is expected to be placed on Public Notice by mid-2018.

A further FCC Petition is contemplated for additional service rules upon completion of the Phase 2 MOPS, to support C-band satellite communications CNPC links. The ultimate regulatory framework in support of C-band satellite communications is intended to overcome current limitations imposed by terrestrial-only operations.

In the meantime, we encourage FAA collaborate closely with other federal stakeholders (FCC, National Telecommunications and Information Administration (NTIA), and DoD, in particular) to (1) develop a comprehensive spectrum roadmap for UAS operations in controlled airspace using all available[13]

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[13] The community has identified several other bands that are appropriately allocated in the U.S. (at least) but may not acceptable to the International Telecommunications Union (ITU).

spectrum resources; (2) identify additional frequency spectrum resources to support CNPC operations, in addition to those frequencies already internationally allocated in the L-band for such operations; (3) establish and coordinate the underlying dynamic frequency assignment system procedures and processes for both federal[14] and non-federal user access; and (4) facilitate the development of hand-off procedures and policies between cellular carrier operations for C2 at low altitudes and non-cellular command and control services at higher altitudes.

ATC Policy and Training

The NASA No Chase COA demonstrated the ability for a UAS with an acceptably designed DAA system to transit the NAS in an equivalent manner as a manned aircraft. Several items were brought to light to enhance ATC awareness of the subtle differences with manned operations, which were briefed in prepared training for the facilities involved. The heightened awareness and high profile of this event required focus on not only the nominal but also on any contingency issues that may have arisen. Coordination between numerous parties allowed planning to resolve unknown issues, and thus the flight occurred without incident when flown without the Chase aircraft.

It is recognized that some minor changes to the FAA Joint Oder 7110.65 will be needed to ensure consistent handling of DAA-equipped UAS throughout the NAS. For example, some minor changes to ATC phraseology are needed.

[14] The DoD will also have access to this spectrum, so the process will automatically involve DOD and NTIA, at least.

Appendix E Example Terminal Area Procedures with UAS-specific Features

E.1 Sample UAS Terminal Operations Procedures

Listed below are examples of UAS terminal integration procedures that were developed, tested, refined, and then re-tested during the DoD's UAS Airspace Integration Joint Test. These procedures were developed in close coordination with the community of interest, which includes, but is not limited to, the Services, the Joint Staff, FAA, Customs and Border Protection, and NASA. UAS routine and contingency operations procedures were designed to align with manned aviation standards to the greatest extent possible.

UAS Departure Procedure (UDP)—A locally coordinated UAS departure route published in graphic or textual form (chart or diagram) that provides a transition from the terminal area departure phase to the en route, operating area, or in the case of tower en route services, terminal arrival phase. UDPs have a Terminal Area Departure Point (TADP) that serves as a departure Contingency Hold Point (CHP) and as a changeover point to a en route, operating area, or terminal arrival contingency mission plan.

Terminal Area Departure Point (TADP)—The last waypoint on a UDP where the UA leaves the terminal departure phase and enters the en-route, operating area, or terminal arrival phase. The importance of this point is to identify a location in which the remote pilot would switch the contingency flight plan logic from the Departure Phase, to one of the three subsequent phases just listed. All TADPs serve as the departure CHP and must depict a CHP holding pattern on the chart or diagram.

Standard UAS Terminal Arrival (SUTA)—A locally coordinated arrival route published in graphic (chart) format that provides a transition from the en-route or operating area phase of flight to the terminal area arrival phase. A SUTA begins at a Terminal Area Arrival Point (TAAP) and ends at an Initial Approach Fix (IAF).

Terminal Area Arrival Point (TAAP)—A waypoint on a SUTA where the remote pilot, regardless of altitude or frequency, changes the UAS contingency mission plan from en-route or operating area contingency mission plan to terminal arrival contingency mission plan.

UAS Approach Procedure (UAP)—A locally coordinated UAS procedure published in graphic or textual form (chart or diagram) to allow a descent and landing on an active surface area. The first waypoint on a UAP is the IAF.

E.1.1 Sample UAS Chart Legend

The legend, shown below, is an example of what mirrors those in manned aircraft flight publications. Note that this excerpt contains explanations for what each of the UAS specific symbols means that are contained on the charts that follow. Each symbol was carefully selected for their ease of recognition and potential future adherence with Terminal Instrument Procedures (TERPS) criteria. A second note is that missed approach routing is currently depicted on manned charts with a black dashed line. The depiction of routing for lost communications routing looks very similar to this. During testing, many pros and cons of having them look similar or very different arose. Future discussions or recommendations should take this into account.

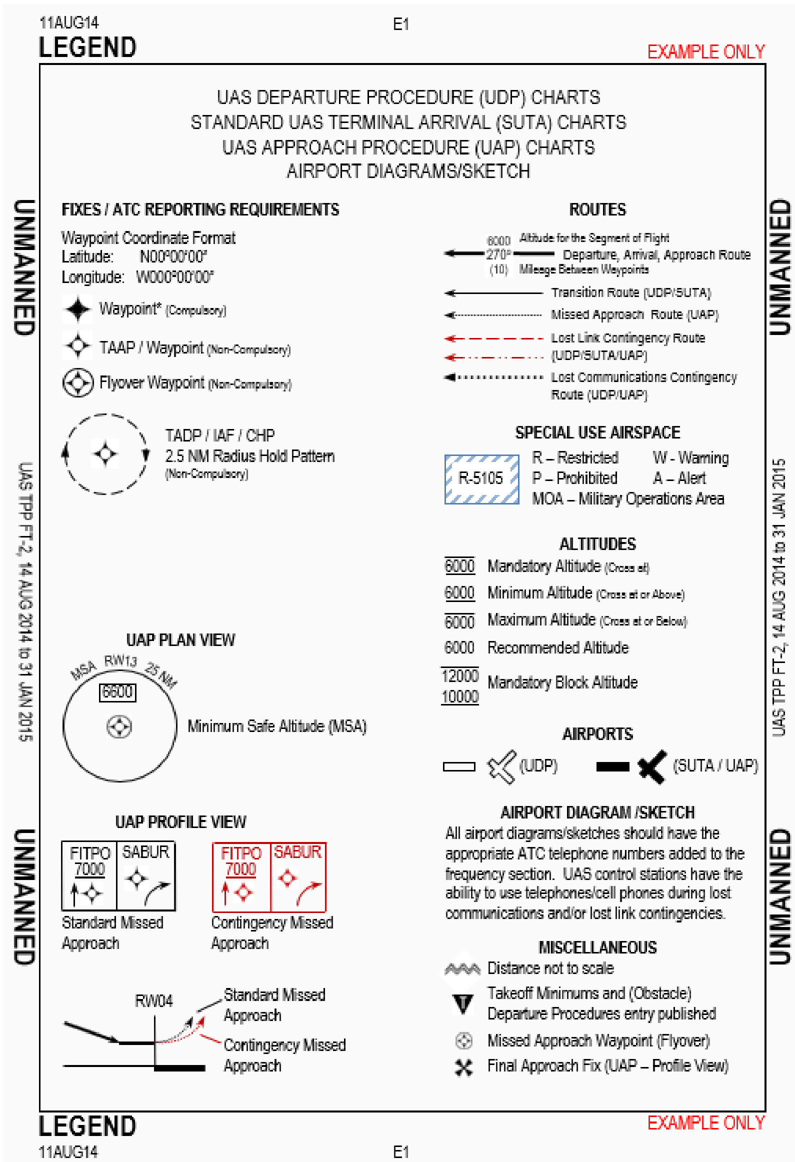

Figure 6: Example UAS Chart Legend page

E.1.2 UAS Departure Procedure

Figure 7 graphically depicts how a UAS might comply with standard manned departure procedures. An unmanned aircraft which experiences a contingency on departure, but prior to leaving departure control's airspace at the TADP, will follow the appropriate routing as depicted depending on the emergency encountered. The solid black line illustrates the UA's desired routing under normal conditions. The red (large dashed line) routing depicts UAS contingency procedure routing in the event of a lost link situation. If shown, the black small dashed line depicts desired routing in the event of a lost communications situation (see Figure 6 for what this would look like). In this case both contingency routes are the same, however other locations or procedures may dictate that they be different. Note that the TADP serves two purposes. First, as a point at which the remote pilot would switch lost link contingency logic from the terminal departure phase, to the logic of a subsequent phase of flight (see TADP definition listed above). Second, it also serves as a pre-programmed loiter point in the event of a lost link situation during departure. This would give ATC time to clear airspace and prepare for the UA's return via a pre-determined UAS arrival procedure. This arrival procedure could be specially made to pair with a specific departure or it can simply be one of the airport's standard arrivals (see next section for explanation of a terminal arrival).

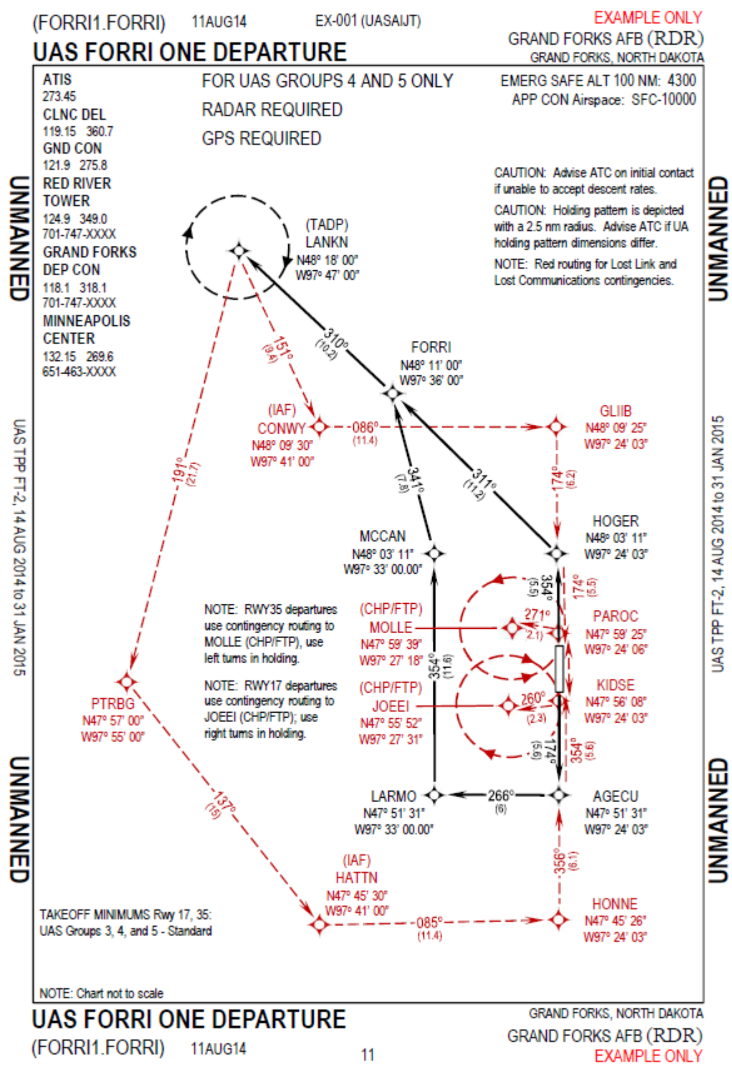

Figure 7: Example Departure Procedure

E.1.3 Standard UAS Terminal Arrival

As with UAS departures, Figure 8 graphically depicts how a UAS would comply with standard manned arrival procedures. The solid black and red large dashed lines once again depict UAS normal and contingency procedure routing upon entering terminal airspace. In this case, there are no special routes for lost communications. See the DoD UAS Airspace Integration Joint Test Final Report for further explanation on why it was determined that this is not necessary during arrivals. Note that the TAAP does not have a holding pattern depicted because ATC is expecting the UA to arrive in their airspace and land. However, as with the TADP, the TAAP also serves as a location at which the remote pilot would switch lost link contingency logic from the en-route phase, to terminal arrival lost link logic phase. Also note the existence of a CHP that is separate from holding pattern manned aircraft would use. This point, and routing leading to it, are de-conflicted from other traffic to give ATC and the UA's remote pilot time to clear airspace and troubleshoot lost link situations in a congested environment. In testing, non-autoland UAS were programmed to fly to this point during a lost link event and hold until the problem was resolved. Autoland capable aircraft were programmed to hold for a pre-determined amount of time before flying to the IAF of a pre-selected approach and executing the approach and landing autonomously.

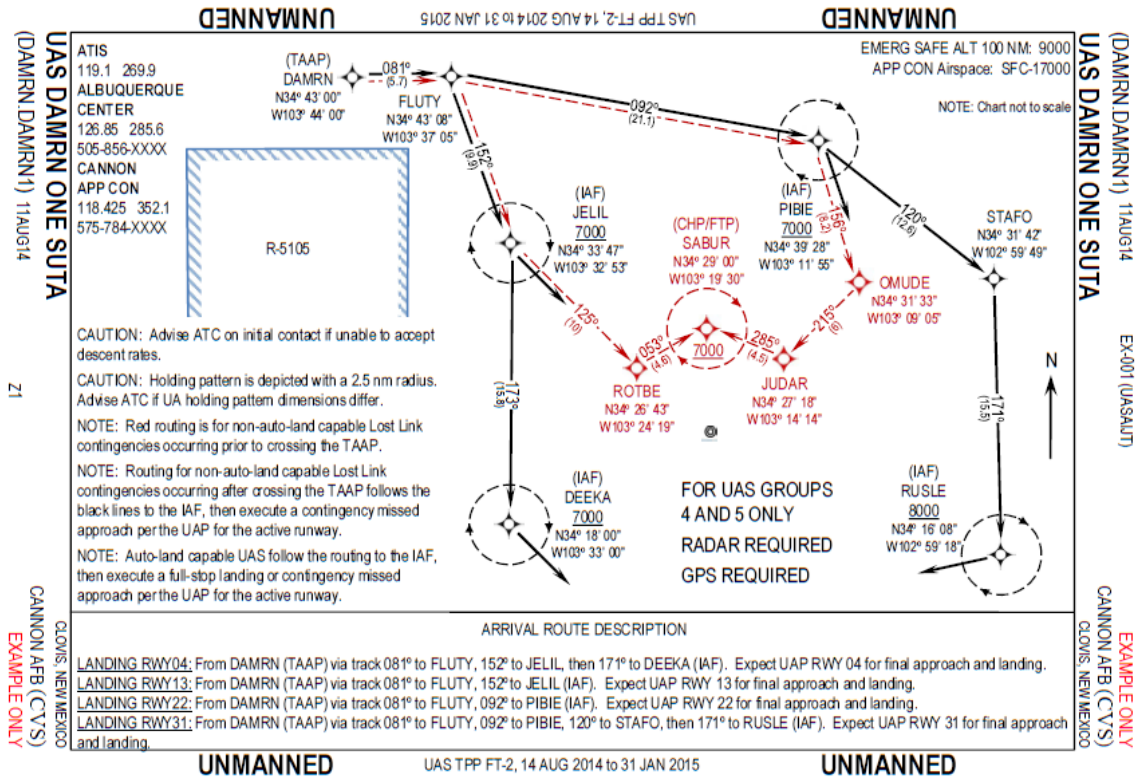

Figure 8: Example Arrival Procedure

E.1.4 UAS Approach Procedure

Like departure and arrivals, as shown in Figure 9, UAS approaches were designed to mirror manned standards with a few notable acceptations. Because aircraft congestion and proximity to the runway environment were elevated in the approach phase, special considerations were given to UAS contingency operations. In testing, the UA was expected to fly its normal approach, even during a lost link event, up until the missed approach point. Here an autoland UAS could continue with the approach and landing (after being cleared by ATC), whereas a non-autoland UAS would follow lost link contingency logic which leads it to the CHP via depicted routing. At the CHP it would hold just as in the terminal arrival phase example. It should be noted that unlike manned charts, here there are two different missed approach procedures. This was desired by the community of interest to differentiate between the flight path taken due to a normal missed approach (e.g. revoked clearance) versus a lost link situation. Although the routes are depicted together here, in some cases they may be completely separate due to the desire for a CHP to be away from the normal flow of traffic. Also note that Lat/Long coordinates are included until such time that UAS possess NAS certified flight data systems and their specific points (CHPs) are registered as a NAS airspace fix.

Approaches designed to serve aircraft with differing capabilities (autoland vs non-autoland) should be published on separate procedures to avoid confusion. Autoland aircraft have many types of systems that possess different capabilities and limitations. Establishing categories or tailored procedures for these different systems would ensure each is performing within expected standards.

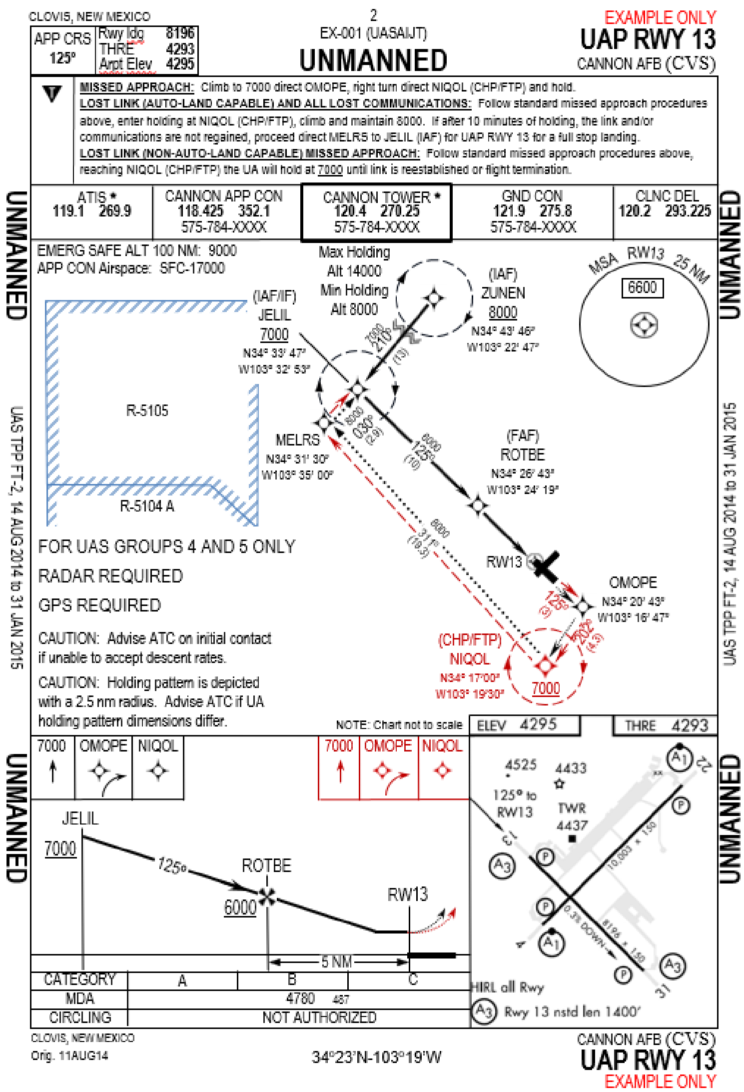

Figure 9: Example Approach Chart

E.2 Contingencies

Many emergencies or contingencies can occur in flight, but it is suggested that only the ones unique to UAS be explored here. In order from most to least significant they are; Loss of C2 Link, Loss of Voice Communications, and Loss of DAA. Charts and procedures should be standardized in such a manner that they lay the groundwork for standardizing the basic design criteria that must be adhered to. The goal is to enable ATM facilities or regions to individually tailor local procedures to their specific needs (such as routing, location of CHP, missed approach procedures, etc.) while providing them the building blocks to do so.

Appendix F Definitions

Acronym	Terminology	Definition	Source
	Airworthiness Certification	A repeatable process that results in a documented decision by the System Manager (SM) that an aircraft system has been judged to be airworthy. It is intended to verify that the aircraft system can be safely maintained and safely operated by fleet pilots within its described and documented operational envelope.	FAA 14 CFR, CHAPTER 1, PART 21 https://www.govinfo.gov/app/details/CFR-2011-title14-vol1/CFR-2011-title14-vol1-part21
	Autoland Approach	An autoland system aids by providing control of aircraft systems during a precision instrument approach to at least decision altitude and possibly all the way to touchdown, as well as in some cases, through the landing rollout. The autoland system is a sub-system of the autopilot system from which control surface management occurs. The aircraft autopilot sends instructions to the autoland system and monitors the autoland system performance and integrity during its execution.	FAA Order JO 7110.65X Pilot/Controller Glossary, February 2019: https://www.faa.gov/documentLibrary/media/Order/7110.65X_w_CHG1_CHG2_and_CHG_3.pdf
	Automated	The automatic performance of scripted actions.	ASTM International: F2395 -07
	Automatic	The execution of a predefined process without human intervention.	Guidance Material and Considerations for UAS. [RTCA DO-304. March 22, 2007] https://standards.globalspec.com/std/1012614/RTCA%20DO-304
COA	Certificate of Authorization or Waiver	An authorization issued by the Air Traffic Organization to a public operator for a specific UA activity.	FAA INTERIM OPERATIONAL APPROVAL GUIDANCE 08-01 - FAA Order JO 7210.3 https://www.faa.gov/regulations_policies/orders_notices/index.cfm/go/document.information/documentID/1029468

Acronym	Terminology	Definition	Source
	Chase Aircraft	A manned aircraft flying in close proximity to UA that carries a qualified observer and/or UA pilot for the purpose of seeing and avoiding other aircraft and obstacles.	FAA UAS ARC Terminology and Classification Action Team
	Class A airspace	Generally, that airspace from 18,000 feet Mean Sea Level (MSL) up to and including FL 600, including the airspace overlying the waters within 12 nautical miles of the coast of the 48 contiguous States and Alaska; and designated international airspace beyond 12 nautical miles of the coast of the 48 contiguous States and Alaska within areas of domestic radio navigational signal or ATC radar coverage, and within which domestic procedures are applied.	AIM, Chapter 3, Section 2. 3-2-2. Class A Airspace: https://www.faa.gov/air_traffic/publications/atpubs/aim_html/chap3_section_2.html
	Class B airspace	Generally, that airspace from the surface to 10,000 feet MSL surrounding the nation's busiest airports in terms of IFR operations or passenger enplanements. The configuration of each Class B airspace area is individually tailored and consists of a surface area and two or more layers (some Class B airspace areas resemble upside-down wedding cakes) and is designed to contain all published instrument procedures once an aircraft enters the airspace. An ATC clearance is required for all aircraft to operate in the area, and all aircraft that are so cleared receive separation services within the airspace. The cloud clearance requirement for VFR operations is "clear of clouds."	AIM, Chapter 3, Section 2. 3-2-3. Class B Airspace: https://www.faa.gov/air_traffic/publications/atpubs/aim_html/chap3_section_2.html
	Class C airspace	Generally, that airspace from the surface to 4,000 feet above the airport elevation (charted in MSL) surrounding those airports that have an operational control tower, are serviced by a radar approach control, and that have a certain number of IFR operations or passenger enplanements. Although the configuration of each Class C airspace area is individually tailored,	AIM, Chapter 3, Section 2. 3-2-4. Class C Airspace: https://www.faa.gov/air_traffic/publications/atpubs/aim_html/chap3_section_2.html

Acronym	Terminology	Definition	Source
		the airspace usually consists of a 5 NM radius core surface area that extends from the surface up to 4,000 feet above the airport elevation, and a 10 NM radius shelf area that extends no lower than 1,200 feet up to 4,000 feet above the airport elevation.	
	Class D airspace	Generally, that airspace from the surface to 2,500 feet above the airport elevation (charted in MSL) surrounding those airports that have an operational control tower. The configuration of each Class D airspace area is individually tailored and when instrument procedures are published, the airspace will normally be designed to contain the procedures.	AIM, Chapter 3, Section 2. 3-2-5. Class D Airspace: https://www.faa.gov/air_traffic/publications/atpubs/aim_html/chap3_section_2.html
	Class E airspace	Generally, if the airspace is not Class A, Class B, Class C, or Class D, and it is controlled airspace, it is Class E airspace.	AIM, Chapter 3, Section 2. 3-2-6. Class E Airspace: https://www.faa.gov/air_traffic/publications/atpubs/aim_html/chap3_section_2.html
	Class G airspace	Class G airspace (uncontrolled) is that portion of airspace that has not been designated as Class A, Class B, Class C, Class D, or Class E airspace.	AIM, Chapter 3, Section 3. 3-3-1. General: https://www.faa.gov/air_traffic/publications/atpubs/aim_html/chap3_section_2.html
C2	Command & Control Link	The datalink between the remotely-piloted aircraft and the remote pilot station for the purposes of managing the flight.	ICAO Cir. 328 – Unmanned Aircraft Systems (UAS), 2011 http://www.icao.int/Meetings/UAS/Documents/Circular%20328_en.pdf
	Nominal C2 Link State	The RPAS state when the C2 Link performance is sufficient to allow the pilot to actively manage the flight in a safe and timely manner appropriate to the airspace and operational conditions [16].	ICAO, "RPAS Meeting #7, Working Paper #4, ICAO, March 2017.

Acronym	Terminology	Definition	Source
	Lost C2 Link State	The RPAS state in which the remote pilot is no longer able to actively manage the flight in a safe and timely manner, appropriate to the airspace and operational conditions, and the RPA is performing pre-programmed, pre-coordinated and predictable manoeuvers [16].	ICAO, "RPAS Meeting #7, Working Paper #4, ICAO, March 2017.
	Lost C2 Link Decision State	The RPAS state in which the C2 Link performance is not sufficient to allow the pilot to actively intervene in the management of the flight in a safe and timely manner appropriate to the airspace and operational conditions but the remote pilot and/or RPAS have not initiated the Lost C2 Link state because not enough time (the amount of time is dependent on the operating scenario) has elapsed [16].	ICAO, "RPAS Meeting #7, Working Paper #4, ICAO, March 2017.
	Lost C2 Link Decision Time	The maximum length of time, pre-coordinated with ATS, that the pilot and/or RPAS is allowed to wait while the C2 Link performance is not sufficient to allow the remote pilot to actively intervene in the management of the flight in a safe and timely manner appropriate to the airspace and operational conditions before declaring a Lost C2 Link [16].	ICAO, "RPAS Meeting #7, Working Paper #4, ICAO, March 2017.
	C2 Link Interruptions	Temporary situations where the C2 Link is either unavailable, discontinuous, too slow, or lacks integrity; but where the Lost C2 Link Decision Time has not been exceeded such as to require the RPAS to enter the Lost C2 Link State [16]. Figure 9 illustrates the Loss of C2 Link definitions in a flowchart.	ICAO, "RPAS Meeting #7, Working Paper #4, ICAO, March 2017.
	Commercial Operation	An aircraft operation conducted for business purposes (mapping, security surveillance, wildlife survey, aerial application, etc.) other than commercial air transport, for remuneration or hire.	ICAO Cir. 328 – Unmanned Aircraft Systems (UAS), 2011 http://www.icao.int/Meetings/UAS/Documents/Circular%20328_en.pdf

Acronym	Terminology	Definition	Source
CNPC	Control and Non-Payload Communications Link	The combination of a Control Link and a Communications Link into one link used by some UAS. This does not include communication from payloads.	RTCA SC-203 Workgroup (2011) DRAFT
	Controlled Airspace	A generic term that covers the different classification of airspace (Class A, Class B, Class C, Class D, and Class E airspace) and defined dimensions within which air traffic control service is provided to IFR flights and to VFR flights in accordance with the airspace classification.	Aeronautical Information Manual (AIM), Chapter 3, Section 3. 3-2-1. General: https://www.faa.gov/air_traffic/publications/atpubs/aim_html/chap3_section_2.html
	Detect and avoid	The capability to see, sense or detect conflicting traffic or other hazards and take the appropriate action to comply with the acceptable rules of flight.	ICAO Cir. 328 – Unmanned Aircraft Systems (UAS), 2011 http://www.icao.int/Meetings/UAS/Documents/Circular%20328_en.pdf
	Flight Plan	Specified information relating to the intended flight of an aircraft that is filed orally or in writing with a Flight Service Station or an ATC facility.	FAA Order JO 7110.65X Pilot/Controller Glossary, February 2019: https://www.faa.gov/documentLibrary/media/Order/7110.65X_w_CHG1_CHG2_and_CHG_3.pdf
GNSS	Global Navigation Satellite System	The GNSS is a generic term for satellite-based navigation, including GPS, SBAS, GBAS, GLONASS, and any other satellite navigation system.	AC 20-138A "AIRWORTHINESS APPROVAL OF GLOBAL NAVIGATION SATELLITE SYSTEM (GNSS) EQUIPMENT"
GPS	Global Positioning System	The Global Positioning System is a space-based radio-navigation system consisting of a constellation of satellites and a network of ground stations used for monitoring and control.	FAA http://www.faa.gov/about/office_org/headquarters_offices/ato/service_units/techops/navservices/gnss/gps/
LOS	Line-of-Sight	Radio communication over distances where the path between the transmitter and receiver is not obstructed by the curvature of the	FAA UAS ARC Terminology and Classification Action Team

Acronym	Terminology	Definition	Source
		earth or other obstructions such as terrain or structures.	
PIC	Pilot in Command	The person who: (1) Has final authority and responsibility for the operation and safety of the flight; (2) Has been designated as pilot in command before or during the flight; and (3) Holds the appropriate category, class, and type	FAA 14 CFR, PART 1, Definitions and Abbreviations https://www.govinfo.gov/app/details/CFR-2012-title14-vol1/CFR-2012-title14-vol1-part1
	Remote Pilot	The person who manipulates the flight controls of a remotely piloted aircraft during flight time.	ICAO Cir. 328 – Unmanned Aircraft Systems (UAS), 2011 http://www.icao.int/Meetings/UAS/Documents/Circular%20328_en.pdf
	Remotely Piloted	Control of an aircraft from a pilot station which is not on board the aircraft.	ICAO Cir. 328 – Unmanned Aircraft Systems (UAS), 2011 http://www.icao.int/Meetings/UAS/Documents/Circular%20328_en.pdf
	Remotely Piloted Aircraft	An aircraft where the flying pilot is not on board the aircraft. Note: This is a subcategory of unmanned aircraft.	ICAO Cir. 328 – Unmanned Aircraft Systems (UAS), 2011 http://www.icao.int/Meetings/UAS/Documents/Circular%20328_en.pdf
RNAV	Area Navigation	A method of navigation which permits aircraft operation on any desired flight path within the coverage of ground- or space-based navigation aids or within the limits of the capability of self-contained aids, or a combination of these. Note: Area navigation includes performance-based navigation as well as other operations that do not meet the definition of performance-based navigation.	FAA Order JO 7110.65X Pilot/Controller Glossary, February 2019: https://www.faa.gov/documentLibrary/media/Order/7110.65X_w_CHG1_CHG2_and_CHG_3.pdf
RPAS	Remotely Piloted Aircraft System	A set of configurable elements consisting of a remotely-piloted aircraft, its associated remote pilot station(s), the required command and control links and any other system	ICAO Cir. 328 – Unmanned Aircraft Systems (UAS), 2011

Acronym	Terminology	Definition	Source
		elements as may be required, at any point during flight operation.	http://www.icao.int/Meetings/UAS/Documents/Circular%20328_en.pdf
RNP	Required Navigation Performance	(1) RNP is RNAV with the addition of an onboard performance monitoring and alerting capability. A defining characteristic of RNP operations is the ability of the aircraft navigation system to monitor the navigation performance it achieves and inform the crew if the requirement is not met during an operation. This onboard monitoring and alerting capability enhances the pilot's situation awareness and can enable reduced obstacle clearance. (2) Required Navigation Performance is a statement of the navigation performance necessary for operation within a defined airspace.	FAA PBN Brochure FAA, Advisory Circular No: 90-101 https://www.faa.gov/documentLibrary/media/Advisory_Circular/AC_90-101A_CHG_1.pdf
	See & Avoid	The ability of a pilot to see traffic which may be a conflict, evaluate flight paths, determine traffic right-of-way, and maneuver to avoid the traffic.	RTCA DO-320 Operational Services and Environmental Definition (OSED) for Unmanned Aircraft Systems https://standards.globalspec.com/std/1271720/rtca-do-320
TSO	Technical Standard Order	A minimum performance standard (MPS) issued by the Administrator for specified materials, parts, processes, and appliances used on civil aircraft.	FAA 14 CFR 21.601 (b)(1) https://www.govinfo.gov/content/pkg/CFR-2018-title14-vol1/xml/CFR-2018-title14-vol1-part21.xml#seqnum21.601
	Type Certificate	A document issued by a Contracting State to define the design of an aircraft type and to certify that this design meets the appropriate airworthiness requirements of that State.	ICAO Annex https://store.icao.int/annexes.html
UA	Unmanned Aircraft	An aircraft which is intended to operate with no pilot on board. Note: RPA is considered a subset of UA.	ICAO Cir. 328 – Unmanned Aircraft Systems (UAS), 2011

Acronym	Terminology	Definition	Source
			http://www.icao.int/Meetings/UAS/Documents/Circular%20328_en.pdf
UAS	Unmanned Aircraft System	An unmanned aircraft and its associated elements required for operation.	RTCA Operational Services and Environmental Definition (OSED) DO-304 https://standards.globalspec.com/std/1012614/rtca-do-304 Operational Services and Environmental Definition (OSED) DO-320 https://standards.globalspec.com/std/1271720/rtca-do-320
	Waypoint	A specified geographical location used to define an area navigation route or the flight path of an aircraft employing area navigation. Waypoints are identified as either: Fly-by waypoint: A waypoint which requires turn anticipation to allow tangential interception of the next segment of a route or procedure; or Flyover waypoint: A waypoint at which a turn is initiated in order to join the next Flyover waypoint: A waypoint at which a turn is initiated in order to join the next	ICAO Annex https://store.icao.int/annexes.html

Figure 10 illustrates the Loss of C2 Link definitions in a flowchart as described in the ICAO RPAS Meeting #7, Working Paper #4, March 2017.

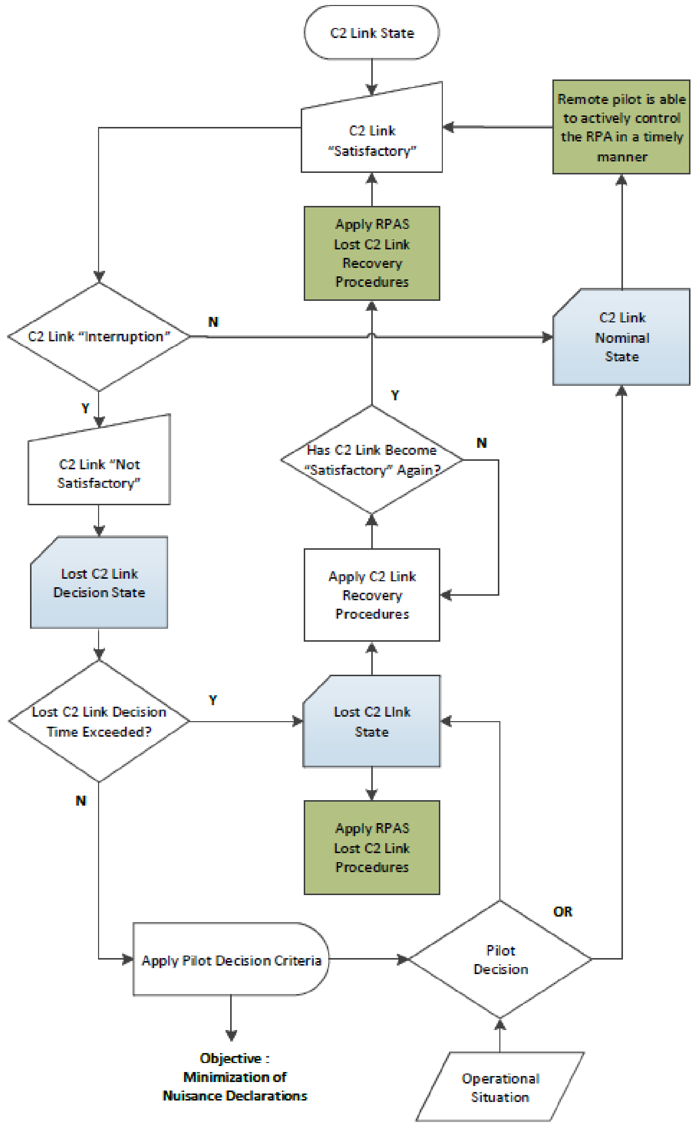

Figure 10: Loss of C2 Link Flowchart [16]

Appendix G Acronyms

Acronym	Definition
AC	Advisory Circular
AJV-1	Airspace Services (FAA)
AMRS	Aeronautical Mobile-Satellite Service
ANG	Air National Guard
ARC	Aviation Rulemaking Committee
ARFF	Aircraft Rescue and Firefighting
ATC	Air Traffic Control
ATM	Air Traffic Management
BRLOS	Beyond Radio Line of Sight
BVLOS	Beyond Visual Line of Sight
C2	Command and Control
CAT III	Category III
CDM	Collaborative Decision Making
CFR	Code of Federal Regulations
CHP	Contingency Hold Point
CNPC	Non-Payload Communications
CNS	Communication, Navigation, and Surveillance
COA	Certificate of Waiver or Authorization
CS	Control Station
CVS	Combined Vision Systems
DAA	Detect and Avoid
Datacomm	Data Communications
DH	Decision Height
DHS	Department of Homeland Security
DME	Distance Measuring Equipment
DoD	Department of Defense
DOT OIG	Department of Transportation Office of Inspector General
EIP	Early Implementation Plan
ERAM	En Route Automation Modernization
EVS	Enhanced Vision Systems

Acronym	**Definition**
FAA	Federal Aviation Administration
FCC	Federal Communications Commission
FL	Flight Level
GCS	Ground Control Station
GIISST	GNSS Intentional Interference and Spoofing Study Team
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
IAF	Initial Approach Fix
IAP	Instrument Approach Procedure
ICAO	International Civil Aviation Organization
IFE	In-Flight Emergency
IFR	Instrument Flight Rules
ILS	Instrument Landing System
IMC	Instrument Meteorological Conditions
IMU	Inertial Measurement Units
INS	Inertial Navigation System
IRU	Inertial Reference Units
ITU	International Telecommunications Union
JCAB	Japan Civil Aviation Bureau
JT	Joint Test
LAHSO	Land and Hold Short Operations
LOA	Letters of Agreement
LPV	Localizer Performance with Vertical Guidance
MOPS	Minimum Operational Performance Standards
MPS	Minimum Performance Standard
MSL	Mean Sea Level
NAS	National Airspace System
NASA	National Aeronautics and Space Administration
NATCA	National Air Traffic Controllers Association
NAVAID	Navigational Aid
NBAA	National Business Aviation Association

Acronym	Definition
NTIA	National Telecommunications and Information Administration
NVS	National Airspace System Voice Switch
PANS	Procedures for Air Navigation Services
PBN	Performance Based Navigation
PIC	Pilot in Command
RLOS	Radio Line of Sight
RNAV	Area Navigation
RNP	Required Navigation Performance
RPA/RPAS	Remotely Piloted Aircraft/System
RVSM	Reduced Vertical Separation Minimum
SARPS	Standards and Recommended Practices
SBAS	Satellite-Based Augmentation Systems
SID	Standard Instrument Departure
AM	System Manager
SME	Subject Matter Expert
SMS	Safety Management System
SOP	Standardized Operating Procedure
SRM	Safety Risk Management
SRMD	Safety Risk Management Document
SRMP	Safety Risk Management Panel
STAR	Standard Terminal Arrival
SUTA	Standard UAS Terminal Arrival
TAAP	Terminal Area Arrival Point
TADP	Terminal Area Departure Point
TARGETS	Terminal Area Route Generation and Traffic Simulation
TCAS	Traffic Alert and Collision Avoidance System
TERPS	Terminal Instrument Procedures
TET	Transaction Expiration Time
TFR	Traffic Flow Restriction
TRSA	Terminal Radar Service Area
TSO	Technical Standards Order

Acronym	**Definition**
U.S.	United States
UA	Unmanned Aircraft/System
UAP	UAS Approach Procedure
UAS	Unmanned Aircraft
UASCA	UASCA
UDP	UAS Departure Procedure
VFR	Visual Flight Rules
VOIP	Voice over Internet Protocol
VOR	Very High Frequency (VHF) Omnidirectional Range
WAAS	Wide Area Augmentation System
WJHTC	William J. Hughes Technical Center