A37: UAS Standards Tracking, Mapping, and Analysis

Final Report

August 9, 2022

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1. Report No.	**2. Government Accession No.**	**3. Recipient's Catalog No.**
A37-A11L.UAS.77		

4. Title and Subtitle	**5. Report Date**
A37: UAS Standards Tracking, Mapping, and Analysis Final Report	August 9, 2022
	6. Performing Organization Code

7. Author(s)	**8. Performing Organization Report No.**
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9. Performing Organization Name and Address		**10. Work Unit No.**
Embry-Riddle Aero Univ 1 Aerospace Blvd Daytona Beach, FL 32137	Univ. of North Dakota 3980 Campus Rd Stop 9007 Grand Forks ND 58202-9007	**11. Contract or Grant No.** ASSURE Grant A37

12. Sponsoring Agency Name and Address	**13. Type of Report and Period Covered**
U.S. Department of Transportation Federal Aviation Administration Washington, DC 20591	Final Report October 2020 – August 2022
	14. Sponsoring Agency Code 5401

15. Supplementary Notes

Conducted in cooperation with the U.S. Department of Transportation, Federal Highway Administration. This report can be found at Enter project URL.

16. Abstract

Development of consensus standards that can be used as acceptable means of compliance is critical to the successful integration of uncrewed aircraft systems into the National Airspace. However, timely development of standards requires tracking existing and in-development standards, and identifying gaps in research needed to develop future standards. This project sought to track existing and in-development standards, map them to the FAA's UAS Integration Research Plan, and identify research gaps that must be filled for standards to be developed that support the UIRP capabilities. Two software applications were developed to track standards and research gaps. A total of 180 research gaps were identified and/or tracked. Information about standards and research gaps should be centralized and made available to stakeholders.

17. Key Words	**18. Distribution Statement**
Unmanned aircraft systems, Uncrewed aircraft systems, UAS, standards development, SDO, package delivery, BVLOS, beyond visual line of sight.	No restrictions. This document is available through the National Technical Information Service, Springfield, VA 22161. Enter any other agency mandated distribution statements. Remove NTIS statement if it does not apply.

19. Security Classification (of this report)	**20. Security Classification (of this page)**	**21. No. of Pages**	**22. Price**
Unclassified	Unclassified	66	

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

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AASHTO	American Association of State Highway and Transportation Officials
AAM	Advanced Air Mobility
ACAS	Airborne Collision Avoidance Systems
AIA	Aerospace Industries Association
AMOC	Alternative Means of Compliance
AMPP	Association for Materials Protection and Performance
ANSI	American National Standards Institute
APSAC	Airborne Public Safety Accreditation Commission
ARINC IA	ARINC Industry Activities
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
ATC	Air Traffic Control
ATIS	Automatic Terminal Information System
ATM	Air Traffic Management
BSI	British Standards Institution
BVLOS	Beyond Visual Line of Sight
C2	Command and Control
CEN	European Committee for Standardisation
CFR	Code of Federal Regulations
CT	Core Network & Terminals
DAA	Detect and Avoid
DES	Directorate of Evaluations and Standardization
DHS	Department of Homeland Security
DoD	Department of Defense
EASA	European Union Aviation Safety Agency
EU	European Union
EUROCAE	European Organisation for Civil Aviation Equipment
EUSCG	European UAS Standards Coordination Group
FAA	Federal Aviation Administration
GA	General Aviation
GNSS	Global Navigation Satellite System
IA	Industry Activities
ICAO	International Civil Aviation Authority
IEC	International Electrotechnical Commission
IEEE	Institute for Electrical and Electronics Engineers
IETF	Internet Engineering Task Force
IFR	Instrument Flight Rules
ITC	Industry Technologies Consortia
ISO	International Organization for Standardization
JARUS	Joint Authorities for Rulemaking on Unmanned Systems
MASPS	Minimum Aviation System Performance Standards
MOPS	Minimum Operational Performance Standards
NACE	National Association of Corrosion Engineers

NAS	National Airspace System
NASA	National Aeronautics and Space Administration
NFPA	National Fire Protection Association
NIST	National Institute of Standards and Technology
NPUASTS	Northern Plains UAS Test Site
NTTAA	National Technology Transfer and Advancement Act
OEM	Original Equipment Manufacturer
OGC	Open Geospatial Consortium
OMB	Office of Management and Budget
OPV	Optionally Piloted Vehicle
POC	Point of Contact
RAN	Radio Access Networks
RDP	Rolling Development Plan
SA	Services & Systems Aspects
SAE	Society of Automotive Engineers
SATCOM	Satellite Communications
SDO	Standards Development Organization
SORA	Special Operations Risk Assessment
sUAS	small Unmanned Aircraft System
TC	Technical Committee
TCAS	Traffic Alert & Collision Avoidance Systems
TOR	Terms of Reference
TSG	Technical Specification Groups
UAM	Urban Air Mobility
UAS	Unmanned Aircraft System
UASSC	Unmanned Aircraft Systems Standardization Collaborative
UIRP	UAS Integration Research Plan
UN	United Nations
UTM	UAS Traffic Management
WG	Working Group
WP	Work Package
3GPP	3rd Generation Partnership Project

EXECUTIVE SUMMARY

Unmanned Aircraft Systems (UAS) research and applications have evolved to accommodate more missions with greater complexity. The Federal Aviation Administration's (FAA) UAS Integration Research Plan (UIRP) defines future UAS capabilities serving as a notional timeline for the future of UAS integration. Standards define the performance, operational, or training requirements for these future capabilities. Standards Development Organizations (SDOs) share the responsibility, often industry driven, to develop standards through the support of its membership. The FAA has supported research to help inform UAS standards development or validate newly published standards. To plan future research to support SDOs, the FAA must learn what standards are either planned or under development and the research gaps that the impact the SDOs ability to achieve new completed and validated standards. The A37 project collected existing and in-progress UAS standards, mapped these standards to the FAA's UIRP, identified research gaps to address, and established priorities for the research gaps.

Approach. To achieve the A37 project's research goals, the team first conducted a literature review of the "American National Standards Institute (ANSI) UAS Standardization Collaboration (UASSC) Standardization Roadmap," "European UAS Standardisation Rolling Development Plan," reports from AW Drones, and the work of several SDOs. The literature survey informed the research team of the current landscape of UAS standards development, contemporary approaches for tracking UAS standards, and finding standards and/or research gaps.

The team next used the standards tracked by ANSI as a starting point for identifying standards relevant to the FAA's UIRP capabilities. Direct engagement with SDOs permitted the team to decide if the collected set of standards for each SDO was complete and correct, or if revisions/additions were required. Through continued SDO engagement, the team, to varying degrees of success, identified research gaps impacting SDOs. Additional research gaps were identified from the ANSI UASSC Roadmap by identifying standards gaps where research was listed as required. The team prioritized the research gaps along a rough timeline based upon the UIRP capabilities they support.

To support future work such as this, the team also developed two software applications to track standards and research gaps, respectively. The application prototypes were implemented as desktop applications using the Python programming language, Python-built software libraries, and a PostgreSQL database.

Summary of Results. Through an analysis of the ANSI USSC Roadmap, engagement with representatives from several SDOs, and examination of recent publications by RTCA and AW Drones, the team identified new and under development standards and a variety of research gaps across a variety of subtopics including, but not limited to: administrative, regulatory, and miscellaneous; personnel; human factors; training; operations; design, construction, testing, certification, manufacturing, and maintenance; safety; avionics, sensors, artificial intelligence, and systems; software; networks and communications; navigation; and security and counter-UAS. A total of 180 research gaps were identified with RTCA (N=80), ASTM (N=49), and AW Drones (N=40) being the top-three sources for research gaps.

The full spreadsheet of research gaps has been provided as an addendum to this report. The FAA can leverage these findings to help guide resources toward supporting the impacted SDOs such as support to academia or government organizations to conduct the research identified by the gap. Such support could result in the successful development of new standards or validation of standards for adoption by the FAA.

Lessons Learned. Some of the lessons learned from this research include:

- Each SDO is unique with a variety of differences in organization, standards development methodologies, mechanisms to release standards, means for selecting standards to development, and mechanism for tracking research gaps / challenges faced.
- On a national level, research tracking must be centralized to prevent duplication of efforts and promote accountability in government spending.
- A methodology similar European UAS Standardisation Rolling Development Plan should be considered for adoption in the U.S. This plan's objectives include the joint planning of research activities, identification of gaps as well as direction on what standards need to be developed. Standards that are approved for development are then approved by the European Union Aviation Safety Agency (EASA) as an Alternate Means Of Compliance (AMOC) for which industry can use to meet governmental expectations.
- Research tracking should be updated and maintained for reference in the approval of future research.

Future Work. The process for which new standards are produced shall remain ongoing, and follow-up research is recommended. The team has recommendations for follow-on research. The team should leverage this technical report to understand each SDO. Rather than rely upon one-on-one conversations for all SDOs, the team should directly engage with the SDOs through membership and participation within their working groups and special committees. The FAA could choose to do this through research personnel, or through its existing liaisons with the SDOs. The team should also consider a kick-off symposium and annual meetings with all SDOs invited to provide a common overview of the project's status, goals, and deliverables, and to facilitate inter-SDO communication and coordination on the standards and gaps tracking efforts.

A key recommendation can be summarized as developing a method to centralize information about all standards development efforts in collaboration with all research efforts to ensure the efficient and effective use of taxpayer funded research, and to make this information available to stakeholders.

1 INTRODUCTION & BACKGROUND

Unmanned Aircraft Systems (UAS) research and its applications have evolved rapidly over the past decade. With the availability of low-cost hardware and easy-to-integrate design, UAS can be more affordable to run than manned aircraft. Worldwide, small UAS (sUAS) are increasingly used for a variety of applications such as package delivery, medical deliveries, critical infrastructure inspections, and precision agriculture to name a few. Other than industry applications, sUAS are an integral part of several government agencies such as public safety units, Department of Defense, etc. Medium and large UAS, while not routinely flown in the National Airspace System (NAS), have a wide variety of potential applications from advanced air mobility to cargo transport.

Safe integration of UAS in the NAS requires a combination of innovative technology, operational standards, policy, and knowledge of the operating environment. This includes knowledge on flight platforms, flight control systems (both hardware and software), ground control station (both hardware and software), on-board sensors integration, payload capacity and its integrations, command and control links, navigational support systems, etc.

Despite the increasing demand for UAS integration, current operations are limited by regulatory requirements for visual line of sight operations or special use waivers (beyond 14 Code of Federal Regulations (CFR) Part 107). Expansion of the regulatory environment to allow full integration of UAS requires the development of standards that ensure safe, efficient operations. This project collected existing and in-progress UAS standards, mapped these standards to the FAA's UAS Integration Research Plan, and identified gaps in standards as well as gaps in research, to focus on as future research priorities.

As the primary research/data-collection activity of this project, the team collected the published and in-progress standards on UAS from different SDOs. The team also collected data via interactions with SDOs actively developing UAS-enabling standards. Standards tracked for this study were gathered from national and international published standards, which are related to UAS, and SDO planned future standards. Many organizations around the world participate in developing standards for UAS. This includes International Organization for Standardization (ISO), Institute of Electrical and Electronics Engineers (IEEE), RTCA, American Society for Testing and Materials (ASTM) International,), 3rd Generation Partnership Project (3GPP), Society of Automotive Engineers (SAE), Open Geospatial Consortium (OGC), among others.

1.1 Motivation

The speed of development and rollout of UAS is simply outpacing the speed at which regulators can keep up. Standards serve as an efficient and effective way for industry and the public to establish a safe operating environment. Standards development also provides a means for safe integration of UAS with manned aircraft in the NAS. With different SDOs working towards developing standards for UAS and related systems, regulatory bodies must keep track of existing and in-progress standards, as well as identifying associated research gaps.

This research seeks to ensure that standards development is underway or planned to support future UAS capabilities as defined in the FAA's UAS Integration Research Plan (FAA, 2020). It also seeks to identify research gaps that impact the progress SDOs are making toward developing new UAS standards. Through an understanding of the UAS standards landscape and research gaps, this research shall enable the FAA to better prioritize its future research to support UAS integration in the NAS.

1.2 Background

The National Technology Transfer and Advancement Act (NTTAA) was signed into law on March 7, 1996. The Act amended existing legislation and mandated new directions for federal agencies with the purpose of bringing technological and industrial innovations to market more quickly. The legislation also encourages cooperative research and development between businesses and the federal government by providing access to federal laboratories and making it easier for businesses to obtain exclusive licenses and inventions that result from cooperative research with the federal government. NTTAA made an impact on the development of new industrial and technological standards by requiring all federal agencies to use cooperatively developed standards. It permits the federal agencies to adopt technical standards developed or adopted by voluntary consensus standards bodies if compliance would not be inconsistent with applicable laws or is found otherwise impracticable. The act also allows federal agencies to consult with voluntary, private sector, consensus-based standards bodies, and when such participant is in the public's interest and compatible with agency/departmental missions, authorities, priorities, and budget resources, to participate in the development of technical standards. As a part of revised Office of Management and Budget (OMB) Circular A-119, "Federal Participation in the Development and Use of Voluntary Consensus Standards and in Conformity Assessment Activities", the FAA has been working with ASTM and similar SDOs to develop consensus standards for aircraft and their operations. Instead of developing standards through the rulemaking process, the FAA participates as a member of the Committee in developing these standards.

The general rules published by FAA are in the Code of Federal Regulations Title 14. This contains the codified Federal regulations that are in effect as of the date of the publication pertaining to aeronautics, air transportation / aviation (including large and small aircraft, such as commercial airplanes, helicopters, balloons, UAVs and gliders), and space exploration, including areas overseen by the FAA and National Aeronautics and Space Administration (NASA). It contains the current, effective versions, as well as historical versions no longer in effect, but there are some gaps in the history.

The rule for operating UAS or drones under 55 pounds in the NAS is 14 CFR Part 107, referred to as the Small UAS Rule. Operational requirements while operating a small UAS include a) avoid manned aircraft, b) never operate in a careless or reckless manner, c) operate within sight and the operator must have a visual observer always keep the drone within unaided sight, d) operating more than one drone at a time is not advised, and e) do not fly a drone over people, unless they are participating in the operations etc. FAA on integrating UAS in NAS has categorized UAS research activities and the operational capabilities includes a) small UAS package delivery, b) expanded operations, c) integrated operations, d) routine scheduled operations, e) large carrier cargo operations, and f) passenger transport operations.

Standards development has an ability to impact the supply chain, benefiting the entire market when coordinated with all stakeholders. Often, accredited SDOs can ensure procedural resources are supported including balloting, conflict resolution, due process, appears, and communication services to increase awareness of its activities. Increasing awareness assists with early adoption of standards once they are readily available. The FAA and other organization reference standard as a means of compliance to aircraft certification rules and policies. The aerospace industry relies on standards for the entire supply chain including raw materials, nondestructive testing, individual parts and components, structure, systems, security, and continued airworthiness as well as guidance for assessments, inspections, installation, and ground support equipment.

1.3 Scope

The project's research plan held the following scope:

- Design and implement a standard tracking database to track and analyze UAS standards, research tasks, and the mapping of standards to UIRP capabilities.
- Identify existing and under development UAS standards addressing standards responsible for airworthiness, operations, and training.
- Map standards to future UIRP capabilities.
- Track ongoing/proposed ASSURE research activities relevant to future UAS capabilities.
- Generate a list of research gaps identified by SDOs, the American National Standards Institute (ANSI) Unmanned Aircraft Systems Standardization Collaborative (UASSC) Roadmap, and other relevant literature capturing information to guide future FAA research requirements.
- Prioritize research gaps based upon SDO priority, ANSI UASSC roadmap priority, and/or A37 team member evaluation.

1.4 Assumptions and Limitations

When writing the project's research task plan, the team considered the following assumptions and limitations.

- The project scope is inclusive of all future UAS capabilities as defined in the UIRP.
    - However, as per project sponsor, a deeper study of tracked standards and their relationship to future UIRP capabilities focused on three capabilities: expanded operations, small package delivery, and Advanced Air Mobility (AAM)/ Urban Air Mobility (UAM).[1]
    - AAM/UAM shall be conducted as a best effort and permit the research team to evaluate the impact of uncertainty in the definitions of UIRP capabilities later within its proposed timeline.
- The research team shall limit its standards analysis to SDO-based voluntary consensus standards as defined in OMB-119.
- Standard requirements shall be of one of three types identifying its primary function: airworthiness, operations, and training.

Research gap identification shall be prioritized for research to be performed by the FAA or FAA identified collaborators.

1.5 Research Tasks

The effort of this project was divided into six research tasks as shown in Figure 1.

[1] The reduction of scope from six capability areas to 2-3 capability areas was discussed at the March 2021 A37 TIM (03/24/2021) and approved by the sponsor to focus on higher urgency needs of more near-term capabilities. AAM/UAM was proposed by the sponsor as the 3rd capability with an understanding of higher uncertainty regarding the details of the capability at this time.

- Task A: Standards Tracking Database Preparation involved the development of a software tool for tracking UAS standards and identified research gaps.
- Task B: Mapping of UAS Standards to Future Capabilities identified published, new, and in-development standards and mapped their relationship to the FAA UIRP's defined future UAS capabilities.
- Task C Mapping Research to Future Capabilities produced a spreadsheet that captured all ASSURE projects to date, pertinent information about each project such as point-of-contact and mapped each ASSURE project to the UIRP capabilities it enables.
- Task D: Research Gap Identification identified research gaps from the ANSI UASSC's reports and directly from the SDOs.
- Task E: Research Gap Prioritization assigned a priority to each of the research gaps based upon the time horizon for which they must be addressed.
- Task F: Stakeholder Engagement, conducted in parallel throughout the project, involved the team reaching out to and meeting with SDOs to gain their inputs on standards to be tracked, research gaps impacting their efforts, and the prioritization of research gaps.

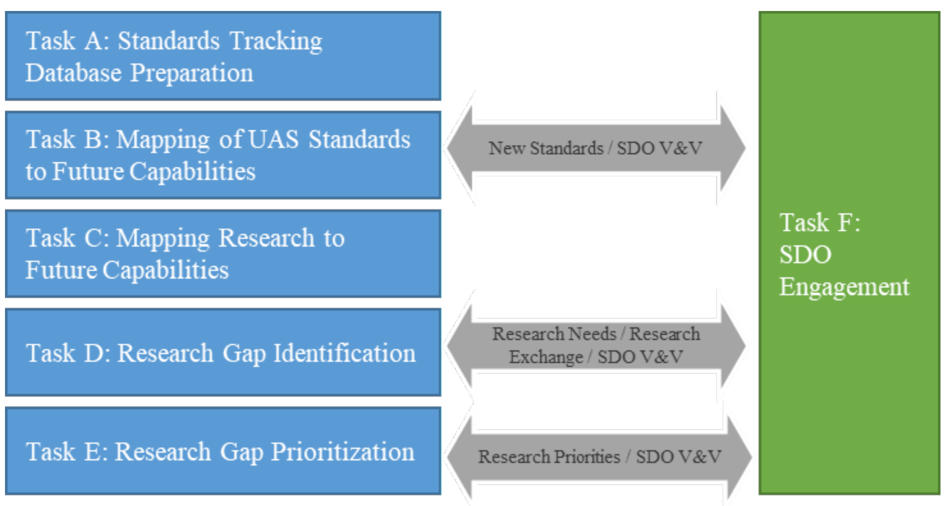

Figure 1. Project tasks and their relationship to stakeholder engagement.

1.6 Organization

This technical report has been organized to guide the reader through the team's methodologies, followed by results, and lastly lessons learned. Section 2 lists the research questions. Section 3 presents a literature review, which discusses similar studies completed by domestic and international SDOs and supporting organizations. Section 4 discusses the research team's strategies and approaches to SDO engagement. Section 5 and Section 6 discuss the approach, results, and analysis of UAS standards tracking and research gap identification, respectively. Section 7 surveys existing ASSURE literature, which can be shared with SDOs to improve their situational awareness about ASSURE. Section 8 presents an overview of the software applications that were implemented for the Standards Tracker and Research Gap Tracker software tools. Section 9 concludes the document with a summary of key lessons learned and recommendations for future work.

The body of the report is followed by a set of appendices:

- Appendix A: Tracked Standards
- Appendix B: Identified Research Gaps
- Appendix C: ASSURE research projects
- Appendix D: Software Application Source

2 RESEACH QUESTIONS

The team's research questions were as follows.

1. **Data Collection and Organization.** How should data be collected and organized to enable query, capture temporal dependencies, and enable funded and future research efforts?
2. **Identifying Standards.** What is the current state of published standards and standards development efforts by U.S. government, standards organization bodies, and industry stakeholder communities enabling UAS integration?
3. **Identifying ASSURE Research.** What ASSURE research activities are ongoing or planned to enable UAS standards development or validation for future UIRP capabilities?
4. **Mapping Standards to UIRP capabilities.** How do the identified standards (published or in-development) support specific UIRP capabilities?
5. **Mapping Research to UIRP capabilities.** How do the identified research activities enable the development or validation of identified UIRP capabilities?
6. **Classification of Standards Gaps.** What standard requirements are not fulfilled by published, in-development, or planned standards?
7. **Classification of Research Gaps.** What standard requirements require additional research to enable the development or validation of standards fulfilling the requirement?
8. **Research Prioritization.** What is the priority at which the FAA should address the research to achieve the capabilities within the timeline expressed in the UIRP?
9. **Engagement Strategies.** What are the best strategies to engage with SDOs to ensure a periodic update on standards in development, planned future standards, and known research gaps?

3 LITERATURE REVIEW

There are multiple SDOs developing standards for unmanned aviation. Though there are hundreds of standards identified, organizations involved in UAS standard development and/or oversight, the research team focused on the following organizations because they are the most critical in terms of establishing means of compliance in the United States, or in tracking standards:

- 3rd Generation Partnership Project (3GPP)
- American National Standards Institute (ANSI) - While ANSI is not an SDO, ANSI's work in the UASSC was examined extensively, greatly supplementing the team's situational awareness.
- ASTM International (ASTM)
- European Organisation for Civil Aviation Equipment (EUROCAE)
- Institute for Electrical and Electronics Engineers (IEEE)
- International Organization for Standardization (ISO)

- Open Geospatial Consortium (OGC)
- Radio Technical Commission for Aeronautics (RTCA)
- SAE International — previously known as the Society of Automotive Engineers — (SAE)
- SAE Industry Technologies Consortia (ITC)

Other relevant standards development-related organizations that were not examined during this study include, but are not limited to:

- Airborne Public Safety Accreditation Commission (APSAC)
- American Society of Mechanical Engineers (ASME)
- American Society of Safety Professionals (ASSP)
- British Standards Institution (BSI) — including ACE 20 committees
- European Air Traffic Management (ATM) Standards Coordination Group (EASCG)
- European Committee for Standardisation (CEN)
- European Cybersecurity Standards Coordination Group (ECSCG)
- European UAS Standards Coordination Group
- Japanese Standards Association (JSA)
- NACE International — National Association of Corrosion Engineers — (NACE)
- National Fire Protection Association (NFPA)
- Telecommunications Industry Association (TIA)

In addition to the SDOs contribution in UAS standard development and identifying research gap, there are multiple projects (including UASSC, European UAS Standards Coordination Group (EUSCG), and AW Drones) focused on collating existing standards, gaps analysis, and recommendations identified by the team as a part of this effort.

The literature review provided an overview of the current UAS-related standards development by different SDOs. The review aimed to identify the relevant UIRP capabilities enabled with each SDO standard development. The FAA has stated research is the foundation for UAS integration activities (FAA, 2020). Research into UAS operations enables the FAA to develop policies, procedures, regulations, and influence standards. The UIRP, developed by the FAA in partnership with industry, academia, and other federal agencies, is integral to informing priorities and initiatives of the FAA and its research partners (FAA, 2020). The UIRP summarizes continued research activities. Partnerships with the NASA, federal agencies, dedicated UAS Centers of Excellence, UAS Test Sites, Federally Funded Research and Development Centers, industry, academia, independent research organizations, and domestic and international standards groups play an essential role in the integration of UAS into the NAS and the development of standards. Topics such as UAS integration into the NAS, UAS research collaboration and partnerships, UAS research categories, key UAS research accomplishments, UAS research and needs, and budget planning are discussed in detail and highlight the FAA's goals to support the safe integration of UAS into the NAS. The plan's 2019 - 2024 timeline also supports standards development for UAS operations that may not be developed and in service by the end of 2024.

The following are operational capabilities outlined by the FAA in the UIRP. The operational capabilities, in order of growing complexity and planned integration, are (1) operations over people, (2) expanded operations, (3) sUAS package delivery operations, (4) integrated operations, (5) routine/scheduled operations, (6) large carrier cargo operations, and (7) passenger transport operations. Each of the operational capabilities drive future UAS research, thus spurring the requirement for new UAS standards.

Operations Over People. Research and subsequent standards development within this operational capability focus on expanding the 14 CFR Part 107 rule enabling sUAS to operate over persons not directly involved in the operation (FAA, 2020). Unlike larger aircraft, sUAS are more susceptible to weather conditions, terrain, and natural and human-made obstacles due to their small size, limited operational speeds, line of sight, and low-altitude operating areas.

The UIRP highlights the FAA's immediate need to streamline the approval process and implement risk-based decision-making for sUAS in operations over people. In December 2020, the FAA published the "Operation of sUAS Over People" final rule, allowing routine operations of sUAS over people with certain restrictions. The Operations Over People final rule represents an initial expansion of the Part 107 rule allowing certain operations that were subject to waiver under Part 107 (FAA, 2020). Mitigating risk and expanding the Part 107 rule to allow certain operations over people is instrumental for a safe, reliable, and expeditious process. Consistent with the FAA's proposed standards for allowing operations over people under Part 107 (FAA, 2020), the UIRP highlights the need for research activities to help the industry develop future standards to assist with risk mitigation.

Expanded Operations. As part of the FAA's phased approach, this operational capability builds upon Part 107 sUAS operations over people. It highlights activities such as Beyond Visual Line of Sight (BVLOS), multi-UAS operations, and on-airport operations. Expanded operations will evolve from current BVLOS operations (supported by visual observers) to operations supported by Detect and Avoid (DAA) and Command and Control (C2) solutions.

Research activities in expanded operations will help develop standards for safe and reliable DAA and C2 systems. The UIRP highlights the need for a standard protocol for publishing sUAS flight information to ensure others are aware of operations in their vicinity (FAA, 2020).

sUAS Package Delivery. sUAS package delivery builds on two previous capabilities and enables package delivery/retrieving operations and sUAS agricultural operations (FAA, 2020). sUAS package delivery will allow small cargo or the dispensing of agricultural loads to be carried internally or externally by sUAS.

Last-mile package delivery is an emerging worldwide sUAS market that falls within this operational capability. Defined by NASA (2018, p. 5) as a "rapid delivery of packages (less than 5 lb.) from local distribution hubs to a dedicated receiving vessel," this form of package delivery represents a paradigm shift in the shipping industry and may constitute a viable market by 2030.

sUAS package delivery operations will likely require FAA regulation changes to 14 CFR Part 135 (operating requirements for commuter and on-demand operations) as well as 14 CFR Part 137 (agricultural aircraft operations). sUAS package delivery will build upon operations over people and expanded operations. As safe and reliable package delivery operations are completed, duly proven, and validated, further expansion will likely be considered across different industries. Research in this area will address UAS traffic management for low altitude operations, reliable C2 networks, and human factors for control stations.

Integrated Operations. Building on the three previous operational capabilities' successes, the integrated operations phase will enable UAS operations to co-exist, with restrictions, in controlled airspace with crewed aircraft (FAA, 2020). This phase covers both civil and public UAS operations at varying altitudes, with Instrument Flight Rules (IFR) flight plans, and on or around airports.

The FAA will need to introduce new standards allowing risk-based certification processes to streamline decision-making and airworthiness approval processes (FAA, 2020). The integration of UAS Traffic Management (UTM) will likely constitute an enabler for the FAA management of future traffic in the NAS.

The FAA plans to leverage the experience of current UAS operations, advances in UAS technology, lessons learned, and research to integrate UAS over airports. In concert with technology, operational experience, and research, the FAA must adopt standards to ensure the safe and reliable integration of UAS into the NAS.

Routine/Scheduled Operations. The overarching purpose of research on routine and scheduled operations is to enable regularly scheduled UAS arrivals and departures at airports in Class B, C, and D airspace. For these operations, Air Traffic Control (ATC) services will be available for UAS operators to file IFR flight plans (FAA, 2020). The FAA believes that integration of routine UAS operations into Class B, C, and D airspace will require numerous changes to current policies, and the development of new standards (2020).

Optionally Piloted Vehicle (OPV) operations offer a considerable expansion into this operational capability due to their ability to carry passengers while retaining an onboard human operator providing back-up piloting capabilities (FAA, 2020). OPVs represent a possible stepping-stone of UAS into routine/scheduled operations. Due to this technology's nascent status, standards developed for OPV operations can likely be used to lay the foundation for future UAS operations in Class B, C, and D airspace.

Additional research is needed to determine acceptable thresholds for UAS and ATC routine/scheduled operations. Many challenges will drive the development of new standards. Challenges such as DAA capabilities, robust and resilient C2 links, and reliable automated functions are highlighted in the UIRP and form the basis for the development of new UAS standards (FAA, 2020).

Large Carrier Cargo Operations. Large carrier cargo operations facilitate cargo transportation conducted within the NAS and will ultimately be remotely piloted from departure to arrival. Remotely piloted cargo operations represent a further expansion of UAS operations to eliminate the need for an onboard human operator (FAA, 2020, p. 155). These operations will require updates to 14 CFR Part 110, Part 119, Part 121, Part 125, and Part 135 operations.

One research objective related to large carrier operators is to develop standards to encompass a multifaceted approach to their operations. For example, standards for C2 systems, integration of UAS operations into the NAS and controlled airspace, and aircraft certification must be explored to enable future large carrier cargo operations. Successive standards must be developed from future research surrounding cybersecurity requirements, ATC services, and airspace, as well as commercial operations impacting noise and emissions.

Passenger Transport Operations. The last phase of operational capabilities builds on the previous six phases of UAS integration into the NAS. Passenger transport operations enable personal transport and operations covered under small General Aviation (GA) and charter flights (FAA, 2020). Activities stemming from current and future UAS research will help develop new standards associated with passenger transport operations. NASA and the aerospace industry will explore passenger transport operations in UAM and AAM concepts. NASA (2018) projects air metro and taxi services will expand globally by 2030. Due to UAM and AAM implementation's short timeline, current and near-term research standards will be paramount in facilitating safe transport operations by 2030. By enabling passenger transport operations, the FAA can leverage research from NASA, industry, and academia to develop necessary standards.

3.1 The FAA's Methodology for Mapping UAS Standards.

Due to the significant market opportunities enabled by UAS activities, standards are needed to address all aspects of UAS production and operation, including UAS design and airworthiness, software assurance, operations and mission requirements, pilot training, and maintenance (FAA, 2020). The FAA has chosen a collaborative approach to develop UAS standards; moreover, they are working with numerous standards bodies for the certification and integration of UAS operations within the NAS. The FAA has concluded that a single standard will not sufficiently meet the needs of all UAS operations (FAA, 2020). Instead, a multi-tiered solution to the standards development process is in place that will hopefully act as a catalyst for future UAS research and development opportunities. The FAA (2020) collaborates with numerous domestic and international standards bodies on UAS-related technical and operational standards.

3.2 American National Standards Institute (ANSI)

In September 2017, ANSI convened the UASSC to collect all existing and planned standards work related to UAS, and to use this information to create a consensus of standards gaps, prioritize them, and identify which of them needed further research. This work was accomplished through volunteer participation from government, industry, and academia. Participation was open to all stakeholders who were involved in UAS operations and development in the United States.

Methodology for Identifying and Evaluating UAS Standards and Gaps. Functionally, the UASSC was organized into four working groups:

1. Airworthiness - addressing all aircraft systems, communication, and ground control stations.
2. Flight operations and personnel qualifications - addressing flight planning and operational issues, plus personnel training, qualification, and certification.
3. Critical infrastructure and environment - addressing use cases such as infrastructure inspection, precision agriculture, and package delivery.
4. Public safety - addressing use cases such as emergency and medical response, and law enforcement.

In an iterative process, working group members gathered existing and in-development standards and then classified them into one of the four working groups. Other types of documents, including best practices, white papers, and guidance materials were also collected and assigned to applicable working groups. ANSI also identified other areas in which no standards existed at all, but for which there was a potential perceived need. The initial UASSC Roadmap Version 1.0 was published in December 2018, with Version 2.0 published in June 2020. An updated Gaps Progress Report was published in June 2022. Standards and other documents were tracked using ANSI's UASSC spreadsheet addendum to Version 2.0 with hyperlinks to either the standard (if they were published), its working group, or the SDO. Gaps in standards development were also identified and tracked, then evaluated using a prioritization matrix. Each gap was then evaluated to determine if research was needed. The Gaps Progress Report was used to update the A37 standards tracking spreadsheet and associated gaps.

3.3 AW DRONES

A.W. Drones (2022) has been working the past two years to address the "lack of harmonized standards [that] is holding back the development of drone-related business, both at a global level and in Europe." Since the organization's implementation through a funding grant from European Union's Horizon 2020 Research and Innovation Program, this consortium of key European industry, academic, and government personnel assigned to the project have steadfastly worked toward their two sub-goals:

1. Gather and maintain an open repository of the technical standards and best practices to support EASA through their rulemaking process.
2. Propose and validate existing standards with relevant stakeholders to form a consensus on the most suitable technical standards for all applicable drone operations.

To meet these two sub-goals A.W. Drones (2022) envisioned and implemented a dual pronged simultaneous top-down and bottom-up approach.

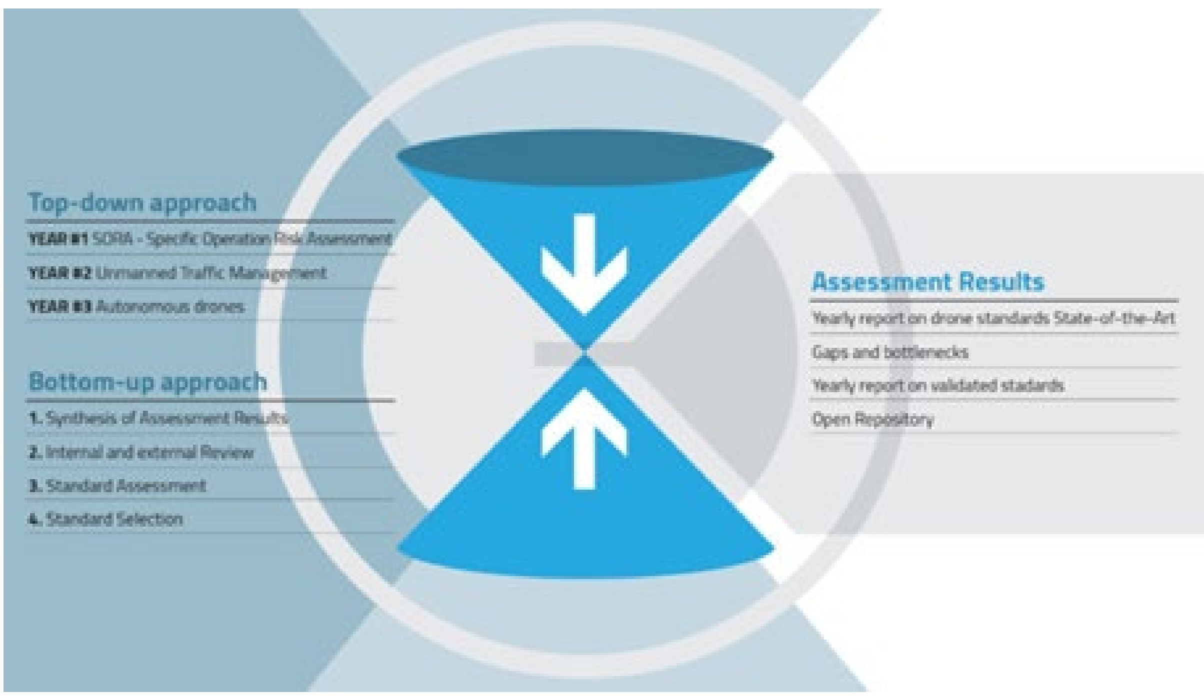

Figure 2. Model of A.W. Drones dual pronged research approach (A.W. Drones 2022).

The top-down component of the A.W. Drones (2022) objective involved the collection and assessment of rules, procedures and standards already developed worldwide while the bottom-up portion involved the consultation of key stakeholders to ensure that the collected standards are adequate and as agreed upon as possible before they would become regulatory requirements (see

Figure 2). The objective of this dual pronged approach was to ensure that, "AW-Drones identifies and highlights obstacles that could be missed if considering only one source of information" (A.W. Drones 2022). In other words, due to the changing nature of this emerging industry and the constant innovations being made, industry partners and stakeholders' input was actively sought out and applied to ensure they were getting the full picture of the future application of light UASs (i.e., UAS with a Mean Takeoff Mass of 600kg with no occupants or externally transported humans[2]) within Europe. This allowed the group to critically assess current standards while at the same time identifying gaps and bottlenecks that could potentially slow the integration of sUASs.

Over the past two years AW Drones has hosted several workshops and published technical reports that were part of an overall work plan formulated to collect and assess existing and planned standards. The efforts associated with this monumental task, were split into the following three Work Packages (WP):

- WP 2 – Development of a methodology for categorization and assessment.
- WP 3 – Collection and categorization of standards that might be applicable for UAS.
- WP 4 – Assessment of these standards to evaluate their feasibility to support this process to derive a set of standards that are validated and found applicable (Cain, 2019).

Each report amongst the numerous deliverables the organization has created is categorized and numbered based upon its work package applicability and iteration. Most work packages have three or more technical reports associated with them. The culmination of these reports and various works are focused on the EU and their applicability to agreed practices and future UAS integration plans for European airspace operations. Despite this fact, the works still could be used by U.S. stakeholders and regulators as a work model to follow for the creation of agreed upon standards that would hopefully lead to more expedient integration of sUASs within the United States NAS.

For example, the first published works of A.W. Drones were centered around adopting a common methodology for the assessment and collection of light UAS standards. The very first technical report of the organization published in April of 2019 focused on the methodology used to assess risk of various sUAS operations within the EU airspace (Bargemen et. al. 2019). That report was quickly followed by another that explained an adopted multi-criterion scoring methodology that was used to weight a particular drone standard's ability to serve as an acceptable means of compliance to existing or proposed regulations. At the same time, it was explained in the report how this same multi-criteria scoring would be used to identify and categorize potential standards gaps (Birgelen & Vreeken, 2019).

At the same time the methodologies for standard collection and assessment were being generated by members of WP2, individuals focused on WP3 began collecting and categorizing light UAS standards that could potentially meet current or proposed regulatory requirements within the EU. Due to sheer volume of standards that existed worldwide, the group purposely limited the scope of their collection to light UAS or drone standards that applied to specific category operations. Specific category operations are those within the EU that required a proposed Special Operations

[2] Definition from https://www.easa.europa.eu/downloads/116570/en

Risk Assessment (SORA) (JARUS, 2019) method and/or additional operator certification before being conducted (Cain, 2019).

The WP3 group initially used a set of standards from the most current EUSCG Rolling Development Plan and supplemented those with published standards information from organizations such as ANSI and ASTM. Cain and Torrens (2021) explain in the last iteration of the WP3 report how the final collection and categorization of the applicable drone standards was further limited based on regulatory framework and operations specific to current and proposed EU regulations for small UASs that fell into a specific role. This final group of standards were further categorized based upon their applicability to European U-space (SESAR, n.d.) and SORA requirements. Requirements the group gleaned from various published works by European aviation authorities envision how these agencies plan to integrate and certify small UAS operations within their borders.

The final and most compelling works from the AW Drones project were produced later in the work plan by the WP4 group which applied the methodologies created in WP2 to the standards collected and categorized by WP3. The ultimate goal of this work was to create and analyze a group of standards that could potentially be used to enable sUAS integration within the EU. In keeping with proposed EU certification requirements, standards analysis was accomplished by mapping standards to SORA, U-space, and Light UAS actual or proposed requirements the group identified. Throughout the span of the project, this analysis and subsequent report went through three iterations with the final iteration consisting of three different technical reports each focusing on one of these regulatory requirement categories. Since the work by A.W. Drones relates directly to EU UAS integration practices and proposed regulations, the applicability of their conclusions to U.S. sUAS integration appears to be limited. Despite this, some gap analysis and final recommendations from A.W. Drones to EASA in their final report may be used to drive FAA-sponsored UAS standards' research here in the United States (Birgelen, 2021). Individuals in charge of creating and dispersing funding for research to develop UAS standards could use the identified A.W. Drone gaps as supplementary information to inform their next actions.

In addition to this, a series of lessons learned can be gleaned from the A.W. Drones project before the spawning of similarly funded projects are deemed necessary in the United States. One of these lessons appears to be the limited scope that A.W. Drones took on their approach. The integration of light UAS was their primary focus and they subsequently narrowed that focus to certain operations and sUAS types. This indicates that a large-scale broad-based approach to standard assessment and gap analysis appears undesirable next to a narrow and more specific focus. Another major lesson is the fact that their standards were mapped to an existing and proposed regulatory adoptions within the EU for UAS integration. In other words, regulations were used to map and analyze the needed standards rather than letting existing unadopted industry created standards morph into a proposed set of future rules which appears to be the path the FAA has taken thus far with UAS standard integration in the light realm. Lastly, A.W. Drones was a well-funded large-scale project that included multiple stakeholders from industry and regulatory backgrounds with a timeline that was manageable for the desired deliverables. The individuals involved on the project were given a clear scope of work over which they had the necessary controls to produce a viable work that will hopefully meet their goals.

3.4 European UAS Standardization Rolling Development Plan

The EUSCG was established in 2017 as an advisory group responsible for coordinating and tracking European standards development activity relevant to UAS. Membership in the EUSCG includes SDOs such as ASTM and SAE, industry associations such as the Global Unmanned Aircraft Systems Traffic Management Association, and governmental agencies such as EASA. The EUSCG membership meets three to four times per year. The primary work product of the EUSCG is the European UAS standardization Rolling Development Plan (RDP), which identifies and tracks all relevant regulatory and standardization activities in Europe relevant to UAS.

EUSCG membership includes all major stakeholders in the European UAS standards development environment. Through the meetings held to date, members have been continually updating the RDP. The RDP divides all standardization activities into the following ten categories: general, UTM, Command Control and Communication, DAA, Remotely Piloted Aircraft System (RPAS) automation, Design and Airworthiness, Operations, Flight Crew Licensing, Environment, and Autonomous Operations. For each standardization activity, the RDP reports on the responsible SDO, the status of the activity, and the type of activity (standard, recommended practice, technical report, information report, guidance, or specification). The RDP does not include gap analysis or identification of research needs.

3.5 Standards Development Organizations

The standards activities tracked by the UASSC, AW Drones, and the EUSCG are undertaken by consensus-based groups including both governmental and private entities. A comprehensive description of the standards development organizations can be found in the UASSC Standardization Roadmap (ANSI, 2020). Examples of several major SDOs are provided here.

3.5.1 ASTM

Over 12,000 ASTM standards are in use around the world. ASTM endeavors to use an open and transparent process through an advanced information technology infrastructure that enables them to support industries and governments around the globe.

There are 150 technical standards-writing committees that apply efforts toward a plethora of industries. Examples of those industries are aerospace, infrastructure, public safety personnel, and consumer products. New industries like additive manufacturing, nanotech, and robotics utilize ASTM to help them enhance growth by the creation and application of standardization (ASTM, 2020).

ASTM UAS Portfolio: ASTM has one technical standards committee dedicated exclusively to UAS, and eight additional committees related to them (ASTM, 2018). Global regulatory bodies or volunteer programs use ASTM as a reference (ASTM, 2018). National organizations such as Air Navigation Service Providers and Civil Air Authorities rely on ASTM standards as a baseline (ASTM, 2018).

F38 UAS Unmanned Aircraft Systems: ASTM Committee F38 on Unmanned Aircraft Systems addresses issues related to the design, performance, quality acceptance tests, operational applications, personnel, and safety monitoring for UAS (Enright, 2017). F38 was formed in 2003 to develop UAS safety standards. This committee of 270 members has issued 17 UAS standards as of June 2020.

Three ASTM subcommittees focus their attention on UAS standards to support safe operations and integrations in three areas:

- Airworthiness (F38.01)
- Flight Operations (F38.02)
- Personnel Training, Qualification and Certification (F38.03)

UAS Original Equipment Manufacturers (OEMs), federal entities, design and engineering professionals, professional societies, maintenance professionals, trade associations, financial organizations, academia, and international regulatory authorities are all stakeholders in UAS industry efforts.

The ASTM F38 approach to develop the ANSI 2018 roadmap consisted of identifying requirements and review of the efforts already expended. Subsequently, the committee analyzed the roadmap and transformed it into a document to identify ANSI standardization gaps on which F38 would focus. In addition to these standardization gaps, the responsible body for closing them was also identified. F38 applied FAA strategies and guidance coupled with user demand signals. F38 developed a timeline based on priorities, available resources, and the standards' maturity or the level of complexity involved (ASTM, 2020).

The ASTM F38 UAS Standards Roadmap, issued in November 2020, highlights progress made on closing the gaps discussed above (Shegal, 2020). This document also identifies, prioritizes, and makes recommendations within the areas of airworthiness, flight operations, personnel training, qualification, and certification. A large amount of ASTM effort focused on requirements identification, efforts deployed to date, and remaining gaps based on FAA strategy and guidance, as well as user demands. The FAA's regulatory framework for current, near-term (12-18 month), intermediate (18-36 month), and long-term (> 36 month) timeframes served as a guide for the ASTM's roadmap to identify requirements for standards, map the standardization gaps identified by ANSI to the appropriate F38 subcommittee, identify ASTM efforts to date to meet the gaps/requirements, and plan action on any gaps remaining. F38 recommended action on 21 of 71 gaps discovered; 12 are in work, 5 would require collaboration, and 4 were added to the ASTM roadmap.

Notably, ASTM has included OPV within their scope. This will establish a link to a larger platform of UAS capabilities in the future. F38 is continuing to work with existing standards to complete the ANSI Roadmap mapping onto their work and subsequent F38 Roadmap update. Their priorities appear to be based on the regulator strategy, as well as resource availability (ASTM, 2020).

3.5.2 RTCA

RTCA is a private, not-for-profit SDO founded in 1935. RTCA develops industry consensus-based recommendations on aviation issues related to communications, navigation, surveillance, and air traffic management. The mission of RTCA is to "Inspire the creation and implementation of integrated performance standards that meet the changing global aviation environment and ensure the safety, security, and overall health of the aviation ecosystem" (RTCA, 2020d, p. 2).

RTCA produces minimum performance standards and guidance materials that are often considered by the FAA and become a partial basis of FAA policy, program, and regulations for aviation systems and equipage. They are produced by committees of volunteers representing the interested and relevant stakeholders. RTCA standards include:

- Operational Services and Environment Definition - provide the environment in which systems and equipment will operate, serving as the basis for assessing and establishing operational, safety, performance, and interoperability requirements.
- Minimum Aviation System Performance Standards (MASPS) - provide the characteristics of an overall system and the minimum test procedures needed to verify its performance. The MASPS describes the system and provides information needed to understand the rationale for system characteristics, operational goals, requirements, and typical applications.
- Minimum Operational Performance Standards (MOPS) – provide standards for specific equipment(s), including all components and units necessary for the system to properly perform its intended function. MOPS provide the information needed to understand the rationale for equipment characteristics and requirements.
- Operational, Safety and Performance Requirements – provide the safety, operational, and performance assessments regarding communication, navigation, and surveillance.
- Interoperability Requirements – provide specifications and requirements to assure all components of the Air Traffic Architecture (airborne and ground-based components; pilots and controllers; domestic and international) can work seamlessly in order to provide safe and efficient air travel services.

In October 2004, RTCA established Special Committee 203 (SC-203) to define overarching MASPS that will assure the safe operation of UAS within the NAS. SC-203 produced DO-304 Guidance Material and Considerations for Unmanned Aircraft Systems. Planned work for the committee was to establish working groups for "Detect, sense, and avoid," and "command, control, and communications," to address the considerations identified in DO-304 (Carey, 2013).

The work of SC-203 was discontinued with the establishment of Special Committee 228 in 2013. SC-228 was established to expedite the development of standards to enable UAS to fly in unrestricted airspace. A more refined scope and new Terms Of Reference (TOR) outlined the mission of SC-228. SC-228 has developed the MOPS for DAA and C2 equipment. Since 2013, there have been three phases to the SC-228 TOR (RTCA, 2020c).

To establish safe and seamless integration of UAS into non-segregated airspace, both DAA and secure C2 data link capabilities are required. Phase One of the SC-228 TOR focused standard development on civil UAS equipped to operate into Class A airspace under IFR. The operational environment for the MOPS in Phase One is the transitioning of a UAS to and from Class A or special use airspace, traversing Class D, E, and G airspace. MOPS for DAA equipment were established in accordance with this scope. C2 data link performance standards provided in Phase One utilized L-Band Terrestrial and C-Band Terrestrial data links (RTCA, 2020c).

Phase Two increased the scope and operational environment for SC-228 standards. Phase Two extended the operational environment to include extended UAS operations in Class D, E, and G airspace. The Phase Two operational environment also included takeoff and landing operations in Class C, D, E, and G airspace, and transit through Class B airspace. Regarding DAA standard development, ground operations remained out of scope. C2 standards during Phase Two provided material related to: service level agreements between UAS operators and satellite operators, UAS design and operational considerations for the use of Satellite Communications (SATCOM), and a unified methodology for a link budget to support applicants through certification and/or operational approval (RTCA, 2020c).

Phase Three of SC-228 TOR will expand on DAA equipment to address use cases applicable to smaller UAS, as well as to more specialized UAS. Use cases will include high altitude pseudo satellite (HAPS) launch and recovery operations, smaller UAS platforms with more limited performance and operations closer to terrain/obstacles, vertical takeoff and landing operations including AAM, and Part 135 cargo operations. Additionally, Phase Three will include updates to C2 standards to harmonize C-Band usage of SATCOM; and incorporate new use cases and new requirements on C2 link to support DAA standards. C2 work will consider new licensed band that are made available for C2 link use. This includes but is not limited to cellular networks. Phase Three also initiated new work in lost link and navigation standards. Lost link will establish guidance material that will harmonize the lost link behavior of UAS operating in controlled airspace. Navigation standards will establish standards to enable Global Navigation Satallite System (GNSS)-based, UAS operations to meet navigation requirements for all phases of flight without the use of legacy ground-based navigation aids, including precision approach capability with auto-takeoff and auto-land features. SC-228 will also revise DO-304 Guidance Material and Considerations for UAS, originally published by SC-203, as part of the Phase Three work (RTCA, 2020c).

Most notably, RTCA transitioned from being a Federal Advisory Committee to that of an SDO. As such, the FAA no longer provides the primary direct taskings for SC-228. Phase Three objectives were the result of several industry stakeholder meetings. The objective of these meetings was to establish a list of standards that may be leveraged by industry to enable operations (RTCA, 2020c).

UAS operations has influenced other RTCA special committees as well. Special Committee 147 has been long established, tasked with establishing and maintaining standards on Traffic Alert & Collision Avoidance Systems (TCAS). In 2018, SC-147 established DO-385 MOPS for Airborne Collision Avoidance Systems for NexGen (ACAS X). DO-385 specifies minimum requirements for collision avoidance system including surveillance, tracking, and threat resolution functionalities. The MOPS specify the optimized logic methodologies used by the collision avoidance logic and its performance, as well as providing testing of all requirements. SC-147 is in the preliminary development of an ACAS X variant for UAS, ACAS Xu. ACAS Xu will provide collision avoidance protection for UAS and will be compatible with TCAS II and ACAS X systems. In alignment with the standards established by SC-228, ACAS Xu provides the collision avoidance functionality for DAA systems. SC-147 will also establish additional standards for smaller UAS, which are outside the scope of SC-228 DAA MOPS, as ACAS sXu. ACAS sXu will be designed to be flexible in adapting to airspace beyond 14 CFR 107 operation restrictions. Moreover, it will be complimentary to the UTM concept, and even support operations outside of UTM if allowed (RTCA, 2020b). In December 2020, RTCA announced collaboration with ASTM International for the joint development of consensus standards for smaller unmanned aircraft systems. SC-147 will document ACAS sXu requirements in alignment with ASTM F3442 Standard Specification for Detect and Avoid System Performance Requirements (ASTM, 2020). Additionally, SC-147 will continue establishing other variants of ACAS X or new concepts for collision avoidance. ACAS Xr is a potential collision avoidance solution for AAM systems.

RTCA most recently established Special Committee 238 to address Counter UAS specifications. As UAS operations in the national and international airspace system continue to grow and UAS technology continues to mature, full integration into the aviation ecosystem highlights the need for industry and government to work together to develop standards around counter UAS technology. SC-238 will operate as a joint committee with EUROCAE Working Group (WG) 115. The efforts of the committee will be focused solely on developing a consensus standard that details detection and mitigation standards. The TOR for SC-238 were established in December 2020 (RTCA, 2020a).

3.5.3 Department of Defense

The U.S. Department of Defense (DoD) tracks and develops standards relevant to the military use of UAS. The Unmanned Systems Integrated Roadmap (DoD, 2017) outlines the DoD's strategic vision for the development of unmanned systems around four major themes: Interoperability, Autonomy, Secure Network, and Human-Machine Collaboration. Within each of these themes, the DoD identifies key enablers, including development of standards for system architecture; C2; modularity and interchangeability of software, firmware, and hardware; and test, evaluation, verification, and validation.

Although the civil and military roadmaps share some common challenges, the standards needed, and the processes used to identify and develop those standards are different. The DoD standards are not completely available to the research team. Each service establishes their own standardization management process. In some cases, a major command will own their standards development and process; and, in other cases, the discipline center (e.g., aviation), will own the responsibility for standards development. Flight and airspace regulations are different in the armed forces as each service publishes regulations covering manned/unmanned aircraft operations, crew requirements, and flight rules (U.S. Army, 2018a) and follow the FAA regulations for flights outside military airspace. However, there are some DoD activities that address common secure communications architecture that are relevant to commercial standards development efforts, including Small Unmanned Systems Autonomy Architecture, Joint Architecture for Unmanned Systems, UAS Control Segment Architecture, Joint Communications Architecture for Unmanned Systems, and UAS Ground Control Station Human-Machine Interface Development and Standardization Guide.

Acquisition processes also play a role in standards development as DoD has strict requirements for the level of platform/system standardization. This is evident in the requirement to deliver aircraft performance data for any configuration the aircraft may encounter in nearly all terrestrial environments.

U.S. Army example. An overarching Army Aviation standardization publication called Training Circular 3-04.11, Commander's Aviation Training and Standardization Program (U.S. Army, 2018b), offers insight into aviation standards. This document establishes training guidelines at all levels, accompanying standardization programs, and procedures. The development and integration of aviation standards in the U.S. Army appear to fall to the various centers of excellence (also known as schoolhouses). The Directorate of Evaluations and Standardization (DES) at Fort Rucker Alabama, is a part of the U.S. Army Aviation Center of Excellence. As the U.S. Army UAS SDO, they oversee the development of standards for crewmembers but may only coordinate support roles regarding aviation maintenance or equipment, since that falls under a different Army agency. With an increase in the integration of UAS, the directorate develops standards and oversees the implementation of UAS as an Army Aviation asset. They support the training and integration of users into complex airspace. DES manages all the UAS aircrew training in Army Aviation. Collaboration exists between DES and all applicable stakeholders for combat developments, training and doctrine, simulation, and future plans (U.S. Army, 2020).

The other branches in DoD appear to have similar pathways that involve OEMs, schoolhouses, major commands, and standards professionals from all these entities.

3.5.4 IEEE

The Institute of Electric and Electronics Engineers Standards Association (IEEE SA) is a unit in IEEE which focuses on developing global standards. Their standard development includes a broad range of industries including communication, consumer electronics, transportation, emerging technologies, and so on. IEEE SA has been an active unit of IEEE for over a century with technical experts from all over the world who participate in the IEEE standards development. The UAS related standard working group includes:

- Robotics Automation Society
- Vehicular Technology Society
- Electronics Packaging Society
- Control Systems Society
- Computer Society / Software Engineering
- Aerospace and Electronic Systems Society
- Communications Society
- Electromagnetic Compatibility Society
- Industry Applications Society
- Intelligent Transportation Systems Society
- Power Electronics Society
- Product Safety Engineering Society
- Reliability Society
- Systems, Man and Cybernetics Society

3.5.5 3GPP

The 3GPP is an organization that brings together seven telecommunications SDOs. They provide members/stakeholders an environment to create reports and specifications for 3GPP technologies. 3GPP was established in December 1998 with the goal of developing a specification for a 3G cellular system. The scope of 3GPP has grown to include continued maintenance and development of the Technical Specifications and Technical Reports for evolving 3GPP technologies, beyond 3G.

3GPP is organized into two groups: Technical Specification Groups (TSGs) and WGs. The direction of the research and development of specifications is very much driven by industry and their member companies. There are three Technical Specifications Groups, each of which consists of multiple WGs

The main TSGs includes

- Radio Access Networks (RAN)
- Service & System Aspects (SA)
- Core Network & Terminals (CT)

The TSGs work together to complete the work on the tasks or "Releases" at various stages throughout the time of performance. The RAN group works on defining functions, specifications and interfaces of the Universal Terrestrial Radio Access /Evolved Universal Terrestrial Radio Access network. The SA group looks at the architecture and service capabilities of the entities relying upon 3GPP specifications. The CT group works to specify terminal interfaces, capabilities, and Core network part of 3GPP systems.

3.5.6 SAE

The Society of Automotive Engineers (SAE) is a United States-based SDO. SAE standard development is related to transport related areas including automotive, aerospace, and commercial vehicles. SAE provides forums for companies, government agencies, research intuitions, and consultants to devise technical standards. SAE also publishes aerospace industry standards. This includes recommended practices for engineers and contains generally accepted engineering data and information. SAE has several committees that are specifically tasked with unmanned systems, for example E-39 Unmanned Aircraft Propulsion Systems Committee and G-10U Unmanned Aerospace Vehicle Committee, but many more committees work on vital interests to the UAS community such as G-34 Artificial Intelligence in Aviation and S-18A Autonomy. SAE is primarily involved with larger aircraft; hence, their standards relate to more distant UIRP capabilities such as large cargo and passenger transport. Because many larger aircraft will operate under existing certification standards, SAE's role in unmanned aircraft may not seem wide or deep. However, many new technologies or processes that will apply to all aircraft may have unique application in unmanned aircraft. For example, the G-34 committee on artificial intelligence in aviation is not exclusive to unmanned aircraft. However, particular aspects of artificial intelligence will be important in enabling autonomy that will underlie unmanned aircraft capabilities that may be distinct from manned aircraft capabilities.

3.5.7 SAE ITC

SAE Industry Technologies Consortia is an affiliate of SAE, made up of independent, industry-managed consortia. Member organizations determine the focus and scope of SAE ITC's work, which generally includes pre-standards support, or serve as a means for implementation for recommended practices and requirements defined by standards. The mission of SAE ITC is to provide a neutral legal framework for stakeholders to address key technical challenges in the transportation industry. As such, SAE ITC does not write standards, but rather provides a setting for identification of needed standards, needed research, and implementation of standards. SAE ITC does not have a specific committee dedicated to UAS, but rather several committees whose work affects UAS, including ARINC Flight Simulator Engineering and Maintenance Committee, and ARINC Avionics Maintenance Committee. The main impact on UAS of SAE ITC's work will be in the area of additive manufacturing. SAE ITC is focused on processes and functions that are broader than just unmanned aircraft, but which may involve particular topics unique to unmanned aircraft. For example, additive manufacturing of parts for unmanned, unoccupied aircraft may require different standards from a risk management and efficiency standpoint than parts for manned or occupied aircraft.

3.5.8 OGC
Open Geospatial Consortium (OGC) is an international consortium with members including government agencies, research organization, universities etc., to make geospatial information and services findable, accessible, interoperable, and reusable. The OGC standards comprises of more than thirty standards which includes:

- 3D tiles - a massive 3D geospatial content such as photogrammetry, 3d building etc.,
- Geopackage - An open standards-based platform for transferring geospatial information,
- SPS - Sensor planning services,
- WMS - Web Map services: provides map images, etc.

3.5.9 ISO
The International Organization for Standardization (ISO) is an international standard development organization composed of representatives from national standards organizations of member countries. ISO's work in unmanned systems is primarily through the ISO/TC20/SC16 committee on unmanned aircraft systems. This scope of this committee includes classification, design, manufacturing, operation, and safety management of UAS operation. The approval of ISO standards is a result of four years of collaboration involving ISO, BSI, and other national standards bodies from all over the world, supported with expert inputs from wide range of industry and public sectors stakeholders. ISO's portfolio of standards relating to UAS cover the spectrum from smaller aircraft to larger unmanned passenger carrying aircraft. However, ISO's focus is on testing methods for small and lightweight UAS, and operational procedures for UTM and UAS. ISO is also involved in some system requirements development, but only for small UAS in specific areas.

4 ENGAGEMENT WITH STANDARD DEVELOPMENT ORGANIZATIONS
As a major task for the project, the research team sought to engage with SDOs. Through direct engagement, the team worked with one or multiple representatives of SDOs or members of their committees, subcommittees, and/or working groups. The team identified additional standards that are under development or recently published. The team also learned of research gaps that could enable the SDO to succeed in developing new standards. Each SDO encountered was unique, requiring different engagement strategies with varying degrees of success. Lessons learned from the engagements are shared at the end of this section.

4.1 Approach
SDO contact did not begin until the team categorized each SDO's existing and in progress standards according to UIRP capability. While all standards included in the ANSI Roadmap V2 were included in the categorization, initial SDO contact was intentionally limited to the major SDOs, including 3GPP, ASTM, EUROCAE, IEEE, OGC, RTCA, SAE, and SAE ITC. A second round of contact also included ISO and UL. Each team member was assigned as the main point of contact for one or more SDOs. An initial letter was sent via email from the principle investigator to the SDO. Specifically, if UAS work was concentrated in a single committee (for example F-38 at ASTM) the team reached out to the chair of that committee. If UAS work was dispersed across several committees, the team reached out to the individual who was best positioned to have a wide perspective on the SDO's involvement in UAS (for example the Aerospace Initiatives manager at SAE). The emails were met with varying degrees of success, but nearly all required multiple

follow-up communications to secure a meeting with the SDO. Each team member tailored their interaction with their assigned SDO(s) to the needs of that organization, but a general pattern was followed. In the first meeting, the individual SDO liaison from the A37 team used a slide deck to briefly convey the scope and intent of the project. The A37 SDO liaison then sent a follow up email with a spreadsheet attached showing the team's categorization of the relevant SDO's standards according to the second UIRP capability (expanded operations). The intent was to run a pilot project, and then use the lessons learned to complete the validation of the rest of the UIRP capability categorizations. In practice, it often became easier to complete all the capabilities at once to keep the project moving. During this time, the emphasis shifted from validation and categorization to exploring research needs. In addition, the follow-on project was not funded, compressing the timeline to deliver useful information. Therefore, the team shifted the focus of subsequent meetings and communications with the SDOs to concentrate more on research needs and or gaps.

4.2 General Lessons Learned

The structure and processes for each SDO are different. In the pilot study, the team attempted to use the same approach for each SDO but learned that the particulars of each SDO required a tailored approach.

The intent of the project was not intuitive for the SDOs. Without access to the UIRP, the concept of the seven UIRP capabilities was not immediately well understood. Further, while the SDOs were uniformly appreciative of the opportunity to improve communication with the FAA, they did not immediately see what they could contribute in terms of identifying and elaborating upon research needs and or gaps. The SDOs understood that the FAA was trying to get ahead of research needs, but knowledge of the technical details required to flesh out the research requirements really resided at the individual subcommittee level, and would require contact with numerous separate individuals, who rarely work for the SDO, but rather are volunteers on the committees. Once the SDOs understood the project, they were generally on board and helpful, but developing the relationships with technical experts on individual subcommittees would take more time than the team has left. Asking the SDOs to do the work in reaching out to the individual subcommittees and sharing that information with the team is another option but would involve an uncompensated additional workload that would likely be met with varying degrees of success.

4.3 SDO-specific Lessons Learned

Each SDO provided its own lessons learned that the A37 team wishes to share to inform future investigators seeking to engage with these or similar SDOs. The workload started with over 1000 standards to review. These were extensively evaluated by the entire team, and standards that were not relevant or had resulted in rulemaking were culled from this project. SDO's may have recommended keeping a culled standard in the project and this was beneficial to the gap analysis.

3GPP. 3GPP has three TSG working groups (RAN, SA and CT) with work being conducted across the world. The A37 team was able to consult with two members of the working groups to get an understanding of the organization as well as the UAS related standards process. The working groups are guided by external company members or stakeholders and their specific needs and desires, and these are formatted into tasks or rather "Releases". Every year stakeholders get together with 3GPP, and new "Releases" are created. Meaning that work is being conducted on multiple Releases at the same time within the three different groups, RAN, SA and CT. Throughout this work various UAS specifications and standards were created. These standards were identified by communication with 3GPP as well as through their website. Further communication was initiated asking about potential research needs and gaps that 3GPP has identified. No response was received after multiple attempts.

ASTM. UAS related standards from ASTM are spread across eight separate committees. The A37 Team identified 82 ASTM relevant standards with gaps that needed further research. ASTM uses a central consultant (the Chair of F38 Committee) to consolidate and coordinate these UAS related standards for the organization. This consultant is well-versed and connected with each UAS standard across the eight different Committees and (initially) hundreds of standards. Each meeting with ASTM was productive. In this project, early contact was possible, and this enabled some flexibility as the ASTM interest in this project was very supportive from the outset. The work with ASTM helped formulate and test A37 positions and communications for the remaining SDO outreach. Additionally, ASTM's centralized Point of contact (POC) allowed for organized and responsive collaboration. Were it not for the ASTM application of the consultant, this would have taken far longer and have required numerous hours of coordination as evidenced by other SDO outreach experiences. ASTM has been very forthcoming and has fully participated. While the preponderance of standards relevant to this project came from F38, the collective input from E06, F15, F32, F44, and F46, only yielded 4 standards that needed research.

EUROCAE. UAS-related standards for EUROCAE impact both small and larger-than-small uncrewed aircraft. EUROCAE often collaborates with RTCA in many standards working groups. EUROCAE identifies several categories and definitions outlined in the EUROCAE documents (ED) that assist in the development of ED. Through the working groups established by the Council of EUROCAE forty-seven standards were identified that relate to UAS and potentially impact the ongoing FAA efforts to advance the seven capabilities identified within the UIRP. While EUROCAE's efforts are informed by industry and governmental stakeholders, much of the efforts of EUROCAE in development of standards is done by subject matter experts who are volunteering their time to advance previously identified gaps in industry/consensus standards. This made it difficult to collaborate between the various working groups to effectively identify future gaps and determine research needs. EUROCAE has demonstrated a close connection with governmental stakeholders which has resulted in standards being recognized by EASA as an AMOC benefitting industry commercialization and the integration of UAS into the European airspace system. Consequently, due to EUROCAE's focus on tasks directed by the EUROCAE Council, little effort appears to be placed on identifying future research needs for UAS. Research focus is done in conjunction with Single European Sky ATM Research, which seeks to update European airspace and related air traffic management functions including the development of a U-Space blueprint for drone commercialization.

IEEE. IEEE SA centrally organizes and coordinates standards working group activities but permits working groups to self-govern and organize research to support their activities. They do not have a broader awareness of their working group's planned activities or research needs. IEEE Industry Connection activities (ICs) can be used to bring together IEEE working group members to address cross-disciplinary challenges such as UAS standards tracking. ICs are supported by IEEE SA. For this study, an IEEE Industry Connection activity was established to track IEEE standards across its multitude of committees, and to identify research gaps that could help those committees. Despite attempts to recruit participants from across IEEE, only a handful participated in committee meetings resulting in validation of the tracked research gaps and the addition of several research gaps.

ISO. Contact with ISO was initiated later than with other SDOs, since ISO does not play as large a role in serving as a means of compliance in the United States as some of the other SDOs. However, the team did reach out and successfully meet with the manager of the ISO/TC20 committee on Aircraft and Space Vehicles, the chair of the ISO/TC20/SC16 committee on Unmanned Aircraft Systems, and representatives from the working groups within SC16. Since this contact was initiated later in the project, the focus shifted away from categorizing the standards according to the UIRP capabilities to identifying research needs. The research team sent a spreadsheet with all applicable ISO projects in progress to the manager of TC20 with instructions on how to add research needs. This sheet was then distributed to the working group representatives, who returned the documents with as much information as they were able to add.

OGC. OGC produces standards for cross-disciplinary applications including data format standards for geospatial information such as geofencing. OGC organizes its standards around "releases" which can incorporate new standards from a variety of working groups. Their UxS working group has coordinated standards development efforts to inform future OGC releases. For this study, the liaison worked with the OGC CEO to review and confirm the standards tracked. The liaison was invited to speak at an OGC Membership meeting during the UxS working group. During the presentation, a request was given for members to specify any research gaps that are impacting the success of developing future standards, but despite follow-up requests, no research gaps were identified.

RTCA. RTCA places a significant role in the development of aircraft and hence UAS standards. Interaction with RTCA was initially conducted through engagement by the Northern Plains UAS Test Site (NPUASTS). The NPUASTS was actively engaged with various applicable RTCA standards related to UAS. It was evident that the established relationships of the NPUASTS as a result of being actively engaged in the development of standards provided the NPUASTS the unique benefit of regular interaction and coordination with RTCA staff. Positive SDOs engagement requires in-depth understanding of the organizational processes in order to effectively navigate through the updates and changes of the standards. In addition to learning the value of active involvement in the standards process, mostly through voluntary efforts; the impact of change was also recognized. Change in personnel results in decrease in effectiveness. To maintain consistency, a standardized process, independent of personnel change, is needed update and manage relationships with all the SDOs on a regular basis.

SAE. Contact with SAE was established through a series of email requests. SAE validated the categorization of the standards by UIRP capability during two zoom meetings. Contact continued via email correspondence, although the departure of the main point of contact and the vacancy of the position at SAE added some challenges. Research needs were identified, recorded, and tracked. As noted above, SAE has several UAS-specific committees, but much of the work of relevance to UAS is conducted in other groups, as factors impacting the progress of UAS also impact traditional aviation sectors. For example, autonomy and AI are clearly critical committees for traditional crewed aviation, but also for UAS. Further, the application of autonomy and AI may differ in important ways between crewed and uncrewed aviation, to reflect the different risk profiles.

Therefore, research needs may appear to apply to a broader population than just UAS, but in reality, the specific application to UAS also requires research.

SAE ITC. Zoom meetings and email correspondence were also conducted with SAE ITC, However, SAE ITC's involvement with UAS was less comprehensive and impactful, and mainly centered on additive manufacturing for original equipment, maintenance and repair, or simulation and training.

UL. Contact with UL was exclusively through email, since their UAS portfolio is very limited. UL only has one draft document pertaining to UAS, which is focused on through-life assurance of aircraft systems not addressed by current standards and certification pathways. This draft includes, but is not limited to, UAS. The standard is intended to guide the integration of multiple sources of assurance into a coherent argument for confidence in the behavior of a given system. The novel configurations include capabilities such as vertical and horizontal lift, or control architecture such as autonomy and shared control.

5 UAS STANDARD TRACKING AND CLASSIFICATION

Leveraging the ANSI UASSC as a starting point, the research team sought to catalog recently published, under development, or planned standards for each SDO. The team mapped each of the tracked standards to the assigned UIRP capability(ies) which the standard will enable. Through SDO engagement the team validated our tracked standards and their mapping. This section shall first discuss in greater detail the approach taken. Next, the results shall show the extent of the standards tracked by SDO and UIRP capability. Appendix A presents a link to an Excel spreadsheet attachment containing the complete set of tracked standards.

5.1 Approach

One of the biggest challenges in this task was to organize information. Each UIRP capability covers a broad area of sub-capabilities. For example, expanded operations would involve standards related to C2, DAA, human factors, safety management, and automation, among others. The team first sought to define and clarify the necessary sub-capabilities for each UIRP category in order to give structure and consistency to the classification scheme (Task B.2). The focus areas defined in the UIRP were the starting place for outlining necessary sub-capabilities. These focus areas are command and control, communication, detect and avoid, environment, human factors, navigation, reliability, safety management, security, surveillance, and traffic management, and weather (UIRP p. 73). Within these focus areas, the team further defined specific sub-capabilities that applied to the UIRP categories, as shown in Table 1. The team then conducted a pilot program to outline what activity each major SDO was conducting in each sub-capability for the first UIRP category of expanded operations, and to categorize each sub-capability in terms of its applicability to airworthiness, operations, or training. (Task B.3). The raw data for this effort is found in Appendix A.

The results of the pilot program showed that the increased granularity of sub-capabilities was not worth the effort involved. The sponsor's emphasis shifted to research gaps rather than granular mapping of standards to capabilities. Therefore, the assignment of standards to sub-capabilities was only conducted for expanded operations.

5.2 Definition of sub-capabilities.

The sub-capabilities were listed and defined as follows in Table 1.

Table 1. Definition of sub-capabilities associated with future UAS capabilities.

Term	**Definition**
**** Denotes a common enabler/sub-capability term***	
Automated Systems*	Limited in scope to the implementation of systems that replace or augment direct human intervention regarding the flight or operation of a UAS. Does not include ATC, UTM, or other traffic management-like services.
C2 Interoperability*	Ability for multiple parties to harmonize C2 technology usage, e.g., multi UAS, multi-user, 3rd party network.
C2 Performance Requirements*	Requirements that establish minimum performance for C2 equipment.
C2 Operational Requirements*	Requirements that establish operational procedures for C2.
C2 Test Methods*	Definitive procedure(s) that produces results (with goal to prove compliance with operational or performance requirements) for C2 link systems and equipment applicable to UAS operations.
Cybersecurity*	Security of the datalinks, control stations, data, and UAs (including but not limited to C2), while not limiting the network-based architecture that is desired of future C2 link systems.
DAA Operational Requirements*	Requirements that establish operational procedures for DAA.
DAA Performance Requirements*	Requirements that establish minimum performance for DAA equipment.
DAA Test Methods*	Definitive procedure(s) that produces results (with goal to prove compliance with operational or performance requirements) for DAA systems and sensors applicable to UAS operations.
Meteorological Observations Tools and Methods*	An instrument or means of accessing weather information.

Noise and Emissions*	The control of sound or chemical(s) in an environment, including the measurement and determination of associated noise and emission levels.
Operational Approval*	Means by which the FAA can authorize a UAS operation. e.g., Waiver, authorization, exemption.
Pilot Training and Qualifications*	Additional training standards that must be met beyond that which is currently required under Part 107 and the FAA's current Remote Pilot ACS.
Risk-based Assessment*	Evaluation based on engineering and operational judgement and/or analysis methods in order to establish whether the achieved or perceived risk is acceptable or tolerable; and drives safety expectations or performance requirements.
Unmanned Traffic Management (UTM)*	Unmanned Aircraft Systems Traffic Management (UTM). A beyond visual line of sight system that safely and efficiently integrates UAS into air traffic already flying in low-altitude airspace. UTM is based on the digital sharing of planned/scheduled UAS flight details.

The research team collaboratively reviewed the standards spreadsheet and assigned each standard to applicable UIRP capability(ies). The standards mapping was validated with the relevant SDO by the research team in collaboration with each SDO. The results of that mapping process and validation are captured in the database.

5.3 Results and Analysis

This subsection presents the results and results analysis from UAS standards tracking and classification. Please view Appendix A for a table of tracked standards.

Figure 3 presents the number of tracked standards (recently published and/or in development) per SDO for all SDOs, which is divided by the number requiring research vs. the number not requiring research using stacked columns. From the chart, the team observes that ASTM has the most standards tracked (86) followed by EUROCAE (56) and SAE (51). ASTM and SAE have the most research needed at 30 and 27 standards, respectively.

Figure 4 to Figure 10 present the number of tracked standards for each of the FAA UIRP capabilities. For simplicity, the charts only show the eight SDOs that are the focus on the team's research analysis. For each SDO, the bar shows the total count of all standards for the SDO with the area in orange indicating the amount of those standards requiring research.

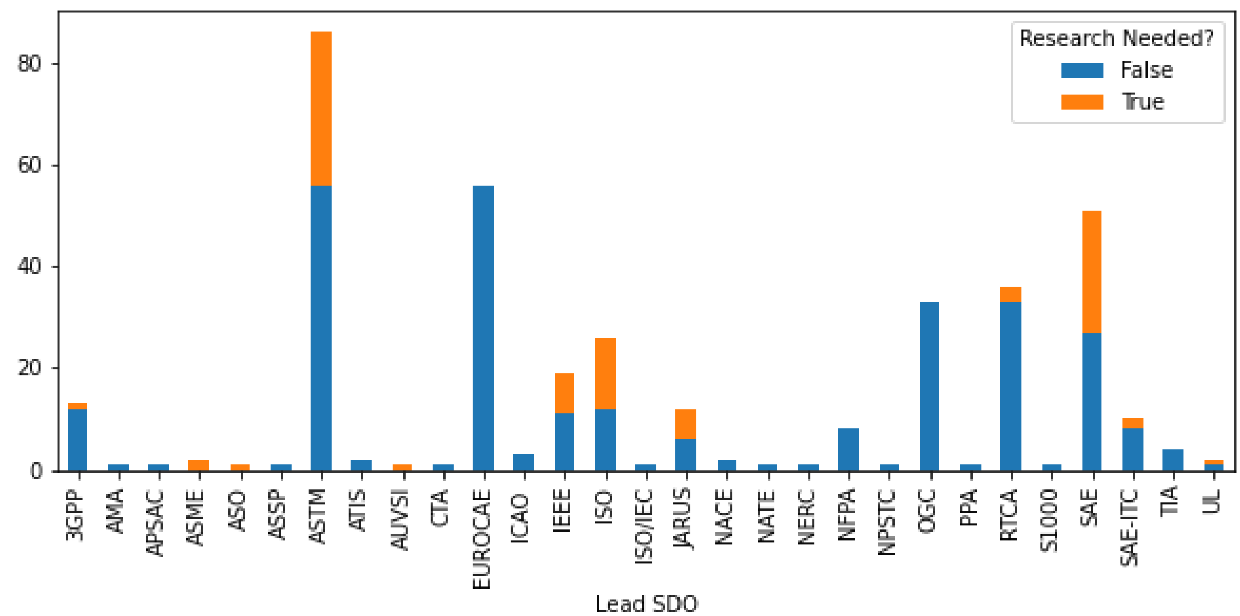

Figure 3. Number of tracked standards by all tracked organization.

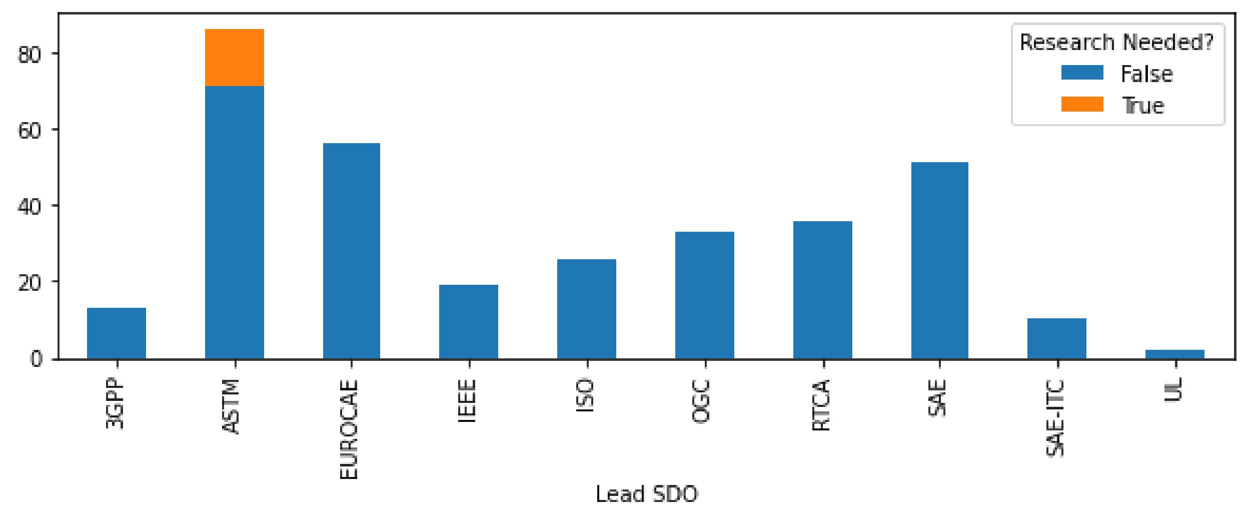

Figure 4. Number of standards related to operations over people for lead SDOs.

It can be observed that shorter-term capabilities such as operations over people (Figure 4) have fewer standards requiring research for ASTM (15 gaps).

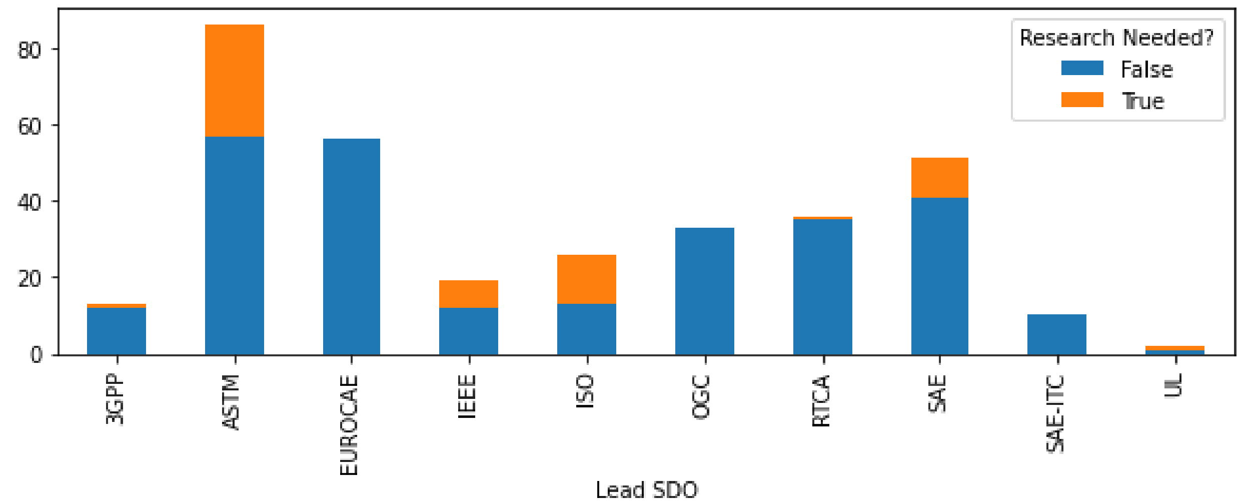

Figure 5. Number of standards related to expanded ops for lead SDOs.

For expanded operations, Figure 5, 62 standards require research with the majority from ASTM (29). For small package delivery, ASTM requires research for 28 standards and across all SDOs a total of 57 standards require research. ISO had the next highest number of standards requiring research at 13.

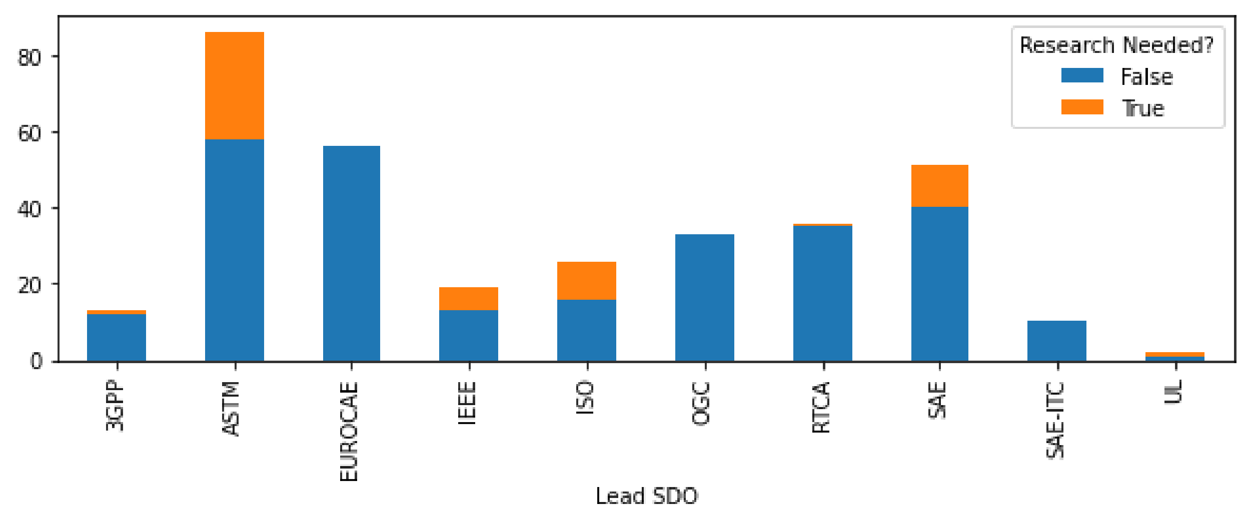

Figure 6. Number of tracked standards related to small package delivery.

Figure 6 shows the research requirement counts for small package delivery. A total of 58 standards required research including ASTM (28), SAE (11), ISO (10), IEEE (6), 3GPP (1), RTCA (1), and UL (1).

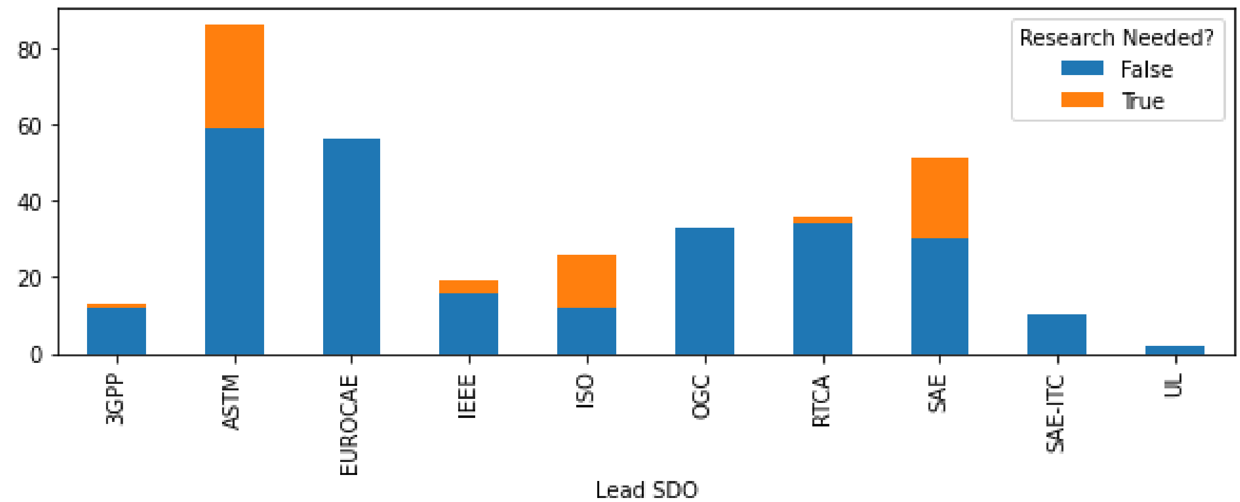

Figure 7. Number of tracked standards related to integrated operations.

For integrated operations, shown in Figure 7, 70 total standards require research with ASTM and SAE requiring the most. By SDO, the number of standards requiring research are ASTM (27), SAE (31), ISO (14), IEEE (3), RTCA (2), and 3GPP (1).

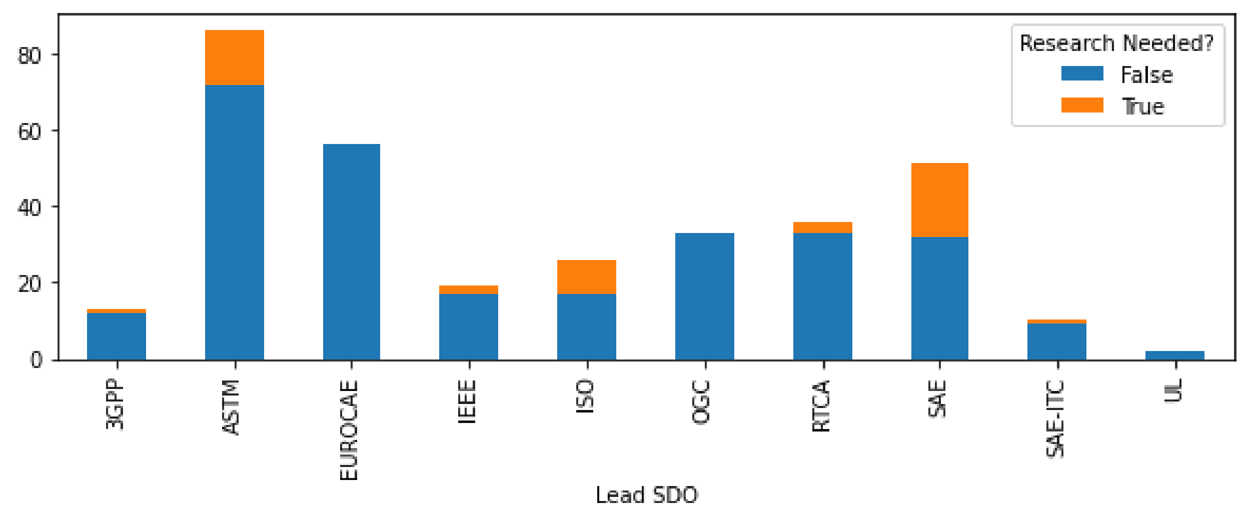

Figure 8. Number of tracked standards related to routine operations.

Figure 8 presents the count for research needed for routine operations in the NAS. A total of 49 standards require research, which is broken down into the following counts, SAE (19), ASTM (14), ISO (9), RTCA (3), IEEE (2), 3GPP (1), and SAE-ITC (1).

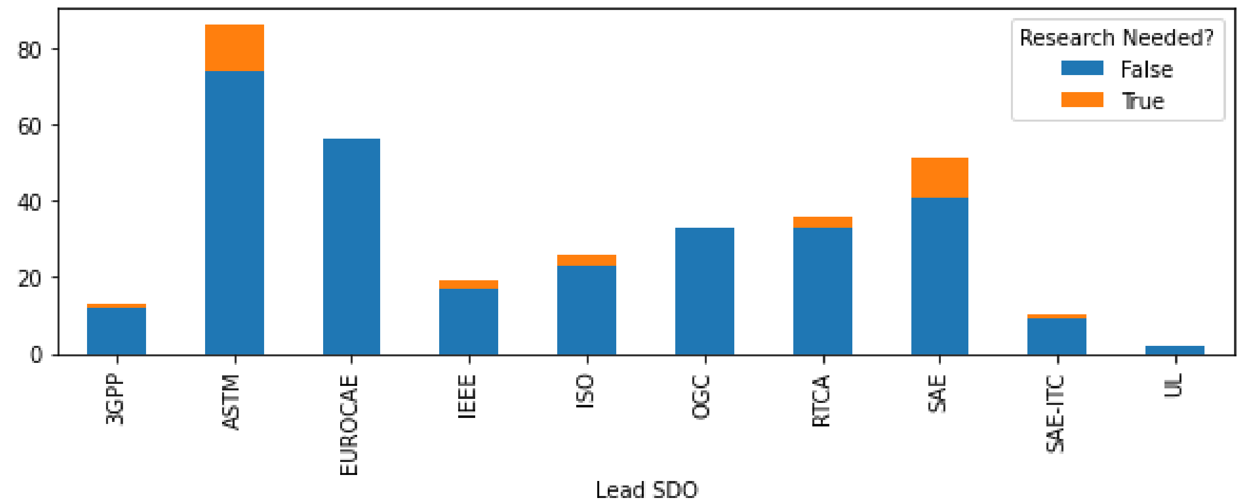

Figure 9. Number of tracked standards related to large cargo operations.

Figure 9 presents the research requirement counts for standards related to large cargo operations. There was a total of 32 standards requiring research including ASTM (12), SAE (10), ISO (3), RTCA (3), IEEE (2), 3GPP (1), and SAE-ITC (1).

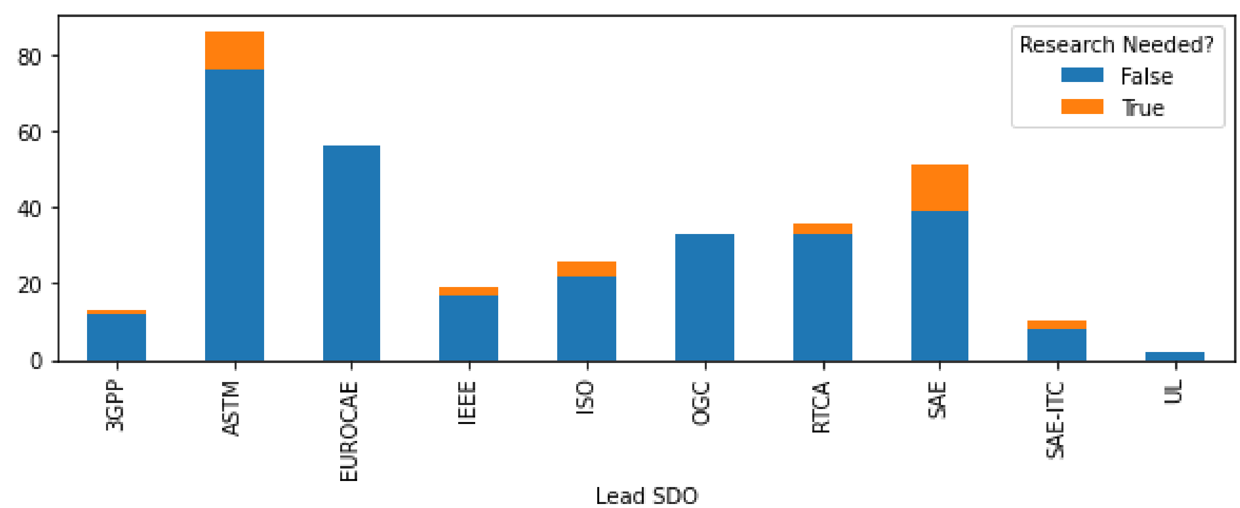

Figure 10. Number of tracked standards related to passenger transportation.

Finally, Figure 10 presents the count of standards requiring research for passenger transportation. A total of 24 standards required research for this capability including SAE (12), ISO (4), RTCA (3), IEEE (2), SAE-ITC (2), and 3GPP (1).

6 RESEARCH GAP IDENTIFICATION

This section summarizes the research gaps identified by the ANSI UASSC and this team's efforts in collaboration with the SDOs. The team began with a thorough analysis of the ANSI UASSC results and confirmed gaps that coincided with the UIRP. Then in collaboration with each SDO, the team further elicited existing gaps from within the SDO work. The result has been a best-case conglomeration of existing research gaps.

6.1 Research Gap Approach

As described in the stakeholder engagement in Section 4, the team's interface with assigned SDOs enabled an ability (in most cases, but not all) to identify gaps. In the final phases of contact with the SDOs (where possible), gaps were analyzed and thus summarized so as to further establish a problem statement, derive a background and scope, identify needs to overcome the gaps, establish potential benefits, and finally, to develop a high-level work breakdown (see Appendix B).

6.2 Analysis of ANSI UASSC Standard Gaps

The UASSC Roadmap Version 2.0 and the June 2022 Update were analyzed to validate the gap analysis. The gaps were categorized by SDO, and where possible, details were added including the parameters described in section 6.1.

6.3 Gap Elicitation from SDOs

This task consisted of a process whereby an extension of the previous validation task on each standard would have four sub-tasks to verify the following.

- Research gap summary (a few words on what issues still exist),
- Research problem statement (what needs to happen to resolve an issue that has been deemed to exist with this standard),
- Research background and scope (relevance), and
- Potential benefits (the objectives and aims of completing identified research needs).

6.4 Summary of Identified Gaps

The following is a list of research gaps derived from 181 total gaps that were identified from analyzing the ANSI UASSC gaps against stakeholder engagement. Many bullet comments below will span a number of standards across different SDOs on the same topic. Not all SDOs provided enough useful information for a thorough and development of the gap analysis. This list shows where current standards do not support clear elements required for continued UAS integration from a regulatory or standardization perspective. These bullet statements synthesize across related themes and identify SDOs or other non-SDO organizations that are focusing on the topics presented.

<u>Administrative, Regulatory, and Miscellaneous</u>

- Mapping standards to fit the type and size of UAS (SAE, EUROCAE, RTCA, IEEE, ASTM, SAE ITC ARINC IA)
- Applicability between UAS and manned standards that were converted (RTCA, EUROCAE, SAE, SAE ITC ARINC IA, IEEE, AIA, ASTM)
- Scalable manned aviation electrical systems standards addressing UAS. (ANSI, ASTM, SAE, RTCA, AIA, UL, International Electrotechnical Commission (IEC), IEEE, ISO, SAE ITC, ARINC Industry Activities (ARINC IA))
- Privacy regulation (ANSI, ISO, APSAC, International Association of Chiefs of Police, Internet Engineering Task Force (IETF))
- Methodology for approval and attainment of waiverless BVLOS operations (ANSI, ASTM, IETF, SAE ITC ARINC IA, IETF Drone Remote ID Protocol WG, RTCA)

- Addressing of UAS-only infrastructure [ANSI, ASTM, ISO, SAE, NFPA, American Association of State Highway and Transportation Officials (AASHTO)]
- Legal requirements for admissibility of digital media evidence (ANSI, OGC)
- Medical payload reporting for flight (IEEE)
- UAS Flight Rules (RTCA, FAA)
- Requirements for organizations in terms of structure, post-holders, etc. for categories of operations
- Integration of UAS into IFR rules (RTCA)

Personnel

- Determining task responsibilities (preflight/AW/WX/W&B) (SAE / ASTM)
- Personnel qualifications, certifications, single/multi-crew coordination requirements, and egocentric capabilities for UAS crewmembers (RTCA, SAE, International Council on Systems Engineering, ASTM, EUROCAE, International Civil Aviation Organization (ICAO), SAE ITC ARINIC IA, AWDrones)

Human Factors

- Platform-independent Human Machine Interface (HMI) capabilities (AWDrones)
- Human factors evaluation of the UAS to determine if the HMI is appropriate for the mission (AWDrones)
- Fatigue Risk Management and fitness condition standards (AWDrones),
- Integration of Human Factors-related issues (ANSI, RTCA, NFPA, MITRE, ICAO, SAE ITC ARINC IA)

Training

- Training for UAS RPICs, other crewmembers, and supporting personnel for VLOS and BVLOS operations (ASTM, AWDrones)
- Training for ground impact measures for remote crews (AWDrones)
- Validated inspection of training and crew competency by a competent third party (AWDrones)
- Standards for CRM training for all persons involved in the mission (AWDrones)

Operations

- Vertical structure (buildings and facades, bridges, towers) inspections (ANSI, AASHTO / ASTM / Association for Materials Protection and Performance (AMPP))
- Inspection of Power Transmission Lines, Structures, and Environs Using UAS (ANSI)
- Inspections of rail lines, rolling stock, and related HAZMAT (day, night, VLOS, BVLOS) (ANSI, SAE, OSHA, ASME, APTA, AREMA)
- Pilot operations near energized equipment or other elements of infrastructure transmission (telephone, gas, fiber, etc.) (SAE, IEEE, North American Electric Reliability Corporation (NERC), FERC, ORNL, ASTM, ASME)
- Pesticide applications (ANSI, ISO/TC 23/SC 6, CEN/TC 144, ASABE)
- Commercial package delivery and cargo transport (ANSI, ASTM, SAE, RTCA, EUROCAE, SAE ARINC)
- On-airport flight operations (SDO's publishing UAS standards and/or regulators)
- UAM/AAM short haul operations (SAE, RTCA, EUROCAE, SAE, ARINC, ASME, ASTM)

- Commercial passenger transportation (ANSI, ASTM, RTCA, SAE, EUROCAE)
- Provisions for commercial sensing services (ANSI, ASME, NACE, ASTM, AMPP (formerly NACE))
- Flight operations and meteorological considerations (RTCA, SAE, National Oceanic and Atmospheric Administration, WMO, universities, National Science Foundation (NSF) National Center for Atmospheric Research (NCAR), ASTM)
- Inclement weather operations (RTCA)
- HAZMAT transfer and transportation (ANSI, ASTM, NFPA, OSHA)
- Public safety UAS Payloads (ANSI, ASTM, NFPA, Department of Homeland Security (DHS), National Institute of Standards and Technology (NIST), IEEE, ISO)
- Tethered UAS operations (ANSI, ISO, NFPA, APSAC, ASTM)
- ATM CONOP requirements for navigation, contingencies, autonomy, surface taxi and operations, and emergency landings (RTCA)

<u>Design, Construction, Testing, Certification, Manufacturing, and Maintenance</u>

- Large and lightweight UAS design, construction, and verification (ASTM)
- Power source and propulsion standards (ANSI, ICAO, RTCA, SAE, AIA, ASTM, UL, IEC, IEEE, ISO)
- Standardized test methods and performance metrics (ANSI, NIST, ASTM E54.09, NFPA, DHS)
- Suite of displays, controls, and onboard sensors providing UAS crews with range of sensory cues for safe operations (ANSI)
- Human error detection and recovery with systems (AWDrones)
- UAS durability and reliability means of compliance (ASTM)
- UAS maintenance-related specifications and standards (ASTM)
- Automated termination system activation/documentation addressing techniques for recovery systems, reducing impact dynamics, and post-impact hazards (AWDrones)
- Measurement UA of noise near vertiports (RTCA)
- Materials and specifications for additive manufacturing of vehicle connectors, wear and tear and replacement (RTCA, SAE, SAE ITC)
- Through-life assurance of aircraft systems not accommodated by existing standards and certification pathways (UL, RTCA)
- Validated product inspection by a competent third party (AWDrones)

<u>Safety</u>

- Mitigations for hazards to UAS (bird strikes, ingestion, hail, lightning, electrical wiring, support towers etc.) (ANSI)
- Systems that mitigate airborne collisions with natural and manmade objects, as well as related occupational safety standards (ANSI, SAE)
- Unique differences in unmanned vs. manned safety and regulations not easily transferrable (ANSI, SAE, EUROCAE, SAE-ITC, RTCA, Joint Authorities for Rulemaking on Unmanned Systems (JARUS), ASTM, IEEE)
- Hazard detection (RTCA)
- Transportation of biohazard materials and post-crash tasks (UN, World Health Organization, ICAO, DHS, United States Department of Agriculture, NFPA, SAE, ANSI)

- No standards for contingency or emergency procedures containing means of reduction of ground impact (AWDrones)
- Defining how to evaluate number of people at risk (AWDrones)
- Post-pilot error protections to flight envelope (AWDrones)
- Contingency management for emergencies (RTCA, AWDrones)
- Procedures, training, and support for ground impact situations and related equipment (AWDrones)
- In-flight obstacle avoidance (RTCA)

<u>Avionics, Sensors, Artificial Intelligence, and Systems</u>

- Existing avionics standards are not all applicable to UAS (ANSI)
- Automated takeoff and automatic landing (RTCA)
- DAA systems for small/med UAS lack standards and prevent implementation, in regard to test methods, support, navigation, flight control, SWAP considerations, terminal environment capability (ANSI, RTCA, ASTM, IETF, SAE, AWDrones)
- Performance of UAS detection systems that might be used by operators of critical infrastructure or public safety agencies (ANSI)
- Design of UAS Command and Control systems (including deconfliction schemes) for VLOS and BVLOS (ASTM, AWDrones)
- Crash resistant voice/data recording capabilities (ANSI, SAE / RTCA / EUROCAE / IETF)
- Noise measurement, emissions, and fuel venting standards (ANSI, Environmental Protection Agency, RTCA, SAE, AIA, ASTM, ISO)
- Regulation and standards to enable fully autonomous flight (SAE, SAEITC ARINC, RTCA, AIA, ASTM, FCC, Aerospace Vehicle Systems Institute (AVSI), UL, ISO/IEC JTC1/SC42, SAE ITC ARINC IA)
- Lack of blockchain solutions for UAS (ANSI, SAE / ISO, IEEE, IETF)
- Minimum testing requirements to validate pipeline inspection sensors (ANSI, API, NACE, Pipeline Research Council International (R&D), California Energy Commission (R&D), ASME, AMPP (formerly NACE))
- Secure transmission of ID, authentication, and tracking data (ASTM, 3GPP, Automatic Terminal Information System (ATIS), IETF)
- Reliable control channel and protocols for autonomous UAV-Swarms (IEEE)
- Geo-fence data exchanges (ANSI, OGC, ISO/TC 20/SC 16, EUROCAE, ICANN, IETF)
- Geo-fence standards and practices (ANSI, OGC, RTCA, EUROCAE)
- Automated termination system activation and documents to address techniques for reduction of effects of impact dynamics and post impact hazards (AWDrones)
- IR Sensor capabilities (ANSI, NIST, NFPA, ASTM)
- AI: Lack of modeling for ATM/UTM simulation and validating AI systems (RTCA)
- Simulation environment maturing for characterizing, validating, and certifying AI-based algorithms (RTCA)
- Level of Automation/Autonomy and Artificial Intelligence (AI) (ANSI)
- Procedures for the monitoring of external services (AWDrones)

<u>Software</u>

- Software considerations outside Part 107 addressing the GCS, navigation, other equipment, and cloud services (ANSI, ASTM / SAE / RTCA)
- Dependability of UAS software (ASTM)
- Software and airborne electronic hardware (AEH) Development Assurance suitable for small UAS (AWDrones)

Networks and Communications

- Network development, functionalities, and equipment for UA, UAS operations, and crew communications (RTCA, 3GPP, IEEE, AWDrones)
- Alignment in Standards Between Aviation and Cellular SDO Communities (ANSI)
- Standard for remote identification, tracking, and functionality in unconnected environment (ANSI, ASTM)
- Performing in unlicensed spectrum bands or unlicensed interference predictability (American Radio Relay League, ANSI)
- TAWS, ADS-B out and transponder equipment support and use in all airspaces (RTCA)

Navigation

- Navigation standards lacking, especially in remote areas (ANSI, SAE, OGC, ASTM, RTCA)
- UTM services and supplemental data (ANSI, ASTM, ISO, IEEE, EUROCAE, JARUS)
- Transmission of ID & tracking data in an unconnected environment (ASTM, 3GPP, ATIS, IETF)
- Navigation equipment as a certifiable safety system (RTCA)_
- Support of non-navigation functions and APNT maturity (RTCA)
- More robust navigation support or baseline certification authority to specified UA operations (RTCA)
- Need for standardized certification for navigation system and GBAS signals-in-space (RTCA)
- GNSS robustness in implementation, operational and some environmental conditions, satellite downtime, validated multi-path model, operational testing, and for jamming/spoofing protection (ANSI, RTCA, AWDrones)
- GNSS and eGPS resiliency for performance, navigation, timing, and supporting taxonomies (RTCA, AWDrones)
- All weather/environmental standards for condition navigation system performance and coverage, third-party competence, support for flight planning, forecasting, and operating (RTCA, ANSI, AWDrones)
- Liability of responsibility for non-federal navigation system providers (RTCA)

Security / Counter UAS

- Considerations for cybersecurity that supports all phases of the UAS, from manufacturing, training, and operations (ANSI, RTCA / SAE / ASTM / IETF / AIA EUROCAE)
- Defense of counter-UAS (RTCA)
- Aircraft Systems Information Security Protection (ASTM)
- Addressing counter-UAS (ANSI, DHS, FCC, NTIA, EUROCAE, RTCA)

6.5 Analysis

From the research gap survey, the team was able to identify research needed to support SDOs to develop both develop the standards discussed in Section 5.3 that require research and additional research gaps identified by the SDOs.

The horizontal bar chart in Figure 11 presents the total number of gaps identified for each of the major SDOs. Note: "N/A" indicates research gaps that were not tied to a specific SDO, but AW Drones identified as a future research need for European airspace integration, which could also support US integration. The team found 181 gaps in total with some gaps being assigned to a single developing SDO and others from the ANSI roadmap assigned to multiple SDOs. The breakdown of the number of research gaps assigned to each SDO are as follows: RTCA (80), ASTM (49), AW Drones (40) SAE (36), EUROCAE (19), IEEE (19), SAE-ITC (17), 3GPP (4), UL (4), and OGC (3).

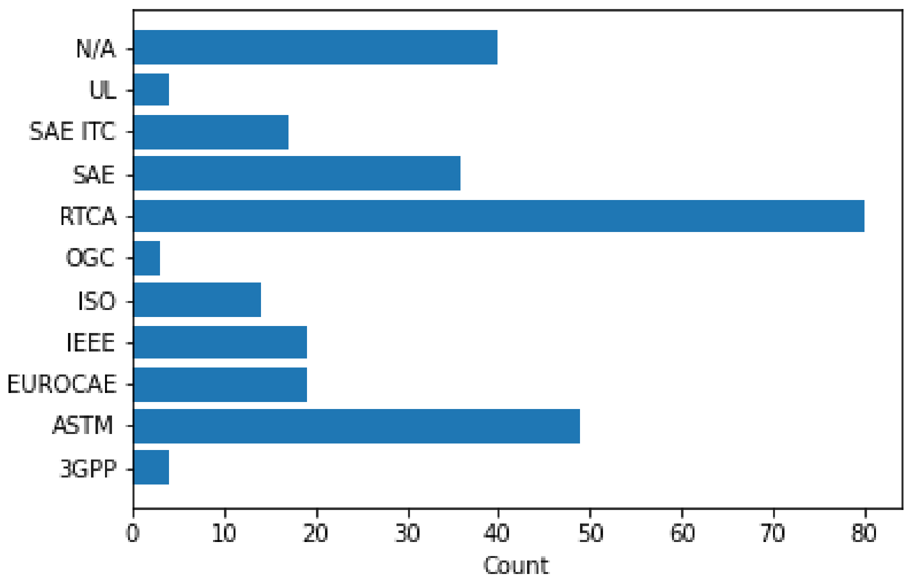

Figure 11. Number of Research Gaps by SDO.

For Figure 12, a word cloud was generated to capture the key words and their relative magnitude for the research gap titles. From the figure, "operation" and "navigation" were the top keywords. We can observe other keywords of note include, but are not limited to, alternative navigation, inspection, performance, cybersecurity, software, maintenance, automatic, control, etc.

Figure 12: Word Cloud for Research Gap “Titles.”

7 ASSURE RESEARCH TRACKING

7.1 Research Tracking Approach

In conjunction with standards tracking, it was determined that a comprehensive list of UAS research would need to be identified and tracked. By identifying and tracking all research efforts, the FAA would be able to more efficiently determine the remaining research gaps needed to meet the objectives listed in the UIRP as well as to cross reference with the research gaps identified in the Progress Report on ANSI UASSC Roadmap v2 Gaps – June 2022. The UAS research was to include UAS related research conducted by various branches of government referenced in the UIRP. Initial efforts were focused on documented research efforts that were linked to the research outcomes and objectives list in each of the seven UIRP capabilities. Much of the research identified did not have appropriate references needed to be obtained and it was further verified by the FAA that related research would not be accessed due to confidentiality of the UIRP document.

Through additional efforts to obtain the research conducted by the various government entities such as the DoD, DHS, and various lines of business in the FAA, it was determined that obtaining this information was not likely and continued efforts would result in little to no results due to the fragmented or siloed research efforts. These fragmented or siloed efforts often were a result of confidential information that could not be openly shared or easily accessed. Fortunately, due to the organized research efforts being conducted by ASSURE, research activities relevant to future UAS capabilities conducted by ASSURE could be identified and tracked. Research activities conducted by ASSURE were identified and tracked through assistance from ASSURE management, communication with ASSURE research leads, as well as follow-up during ASSURE Program Management Reviews. Research activities were tracked within a Microsoft excel spreadsheet allowing the research team to sort and filter the data as necessary to assist in identifying research gaps. The Microsoft Excel spreadsheet is in Appendix C: ASSURE Research Projects, which was last updated as of June 30, 2022. ASSURE research was tracked using the following categories:

- FAA UIRP Capability's primary Research Outcome title
- ASSURE Designation #
- Research Objective or Purpose
- Report Date
- Period of Performance Start and End
- UIRP Capabilities effected by research
- Research Lead and Contact Information
- FAA Sponsor and Contact Information
- Location of publication
- Additional notes and comments related to research activity

Lessons learned regarding the identification and tracking of research activities are as follows:

- On a national level, research must be centralized in order to prevent duplication of efforts and promote accountability in government spending.
- The European UAS Standardisation Rolling Development Plan, as earlier described, should be evaluated for adoption in the U.S. This plan's objectives include the joint planning of research activities, identification of gaps as well as direction on what standards need to be developed. Standards that are approved for development are then approved by EASA as an AMOC for which industry can use to meet governmental expectations.
- Using standards tracking format provided, research tracking should be updated and maintained for reference in the approval of future research.

8 SOFTWARE APPLICATION

To support this project and others, two software applications were implemented with Graphical User Interfaces to support the storage, query, and maintenance of tracked standards and research gaps. Section 8 presents an overview of the software application, summarizes the design of the application including its database backend, and lastly, presents recommendations of future work for the software application.

8.1 Application Overview

For follow-on research, the software applications shall serve as an alternative to spreadsheets as a mechanism for identifying, tracking, and reporting upon standards and research gaps. The three major components developed as part of the application are the user-facing tools "Standards Tracker" and "Research Gap Tracker" and the database backend. This section shall provide an overview of the user-facing tools.

8.2 Standards Tracker

The Standards Tracker application was written in Python with a PostgreSQL database backend. It enables users to enter standard information including its SDO, standard number, version number, title, relevance to UIRP capabilities, etc.

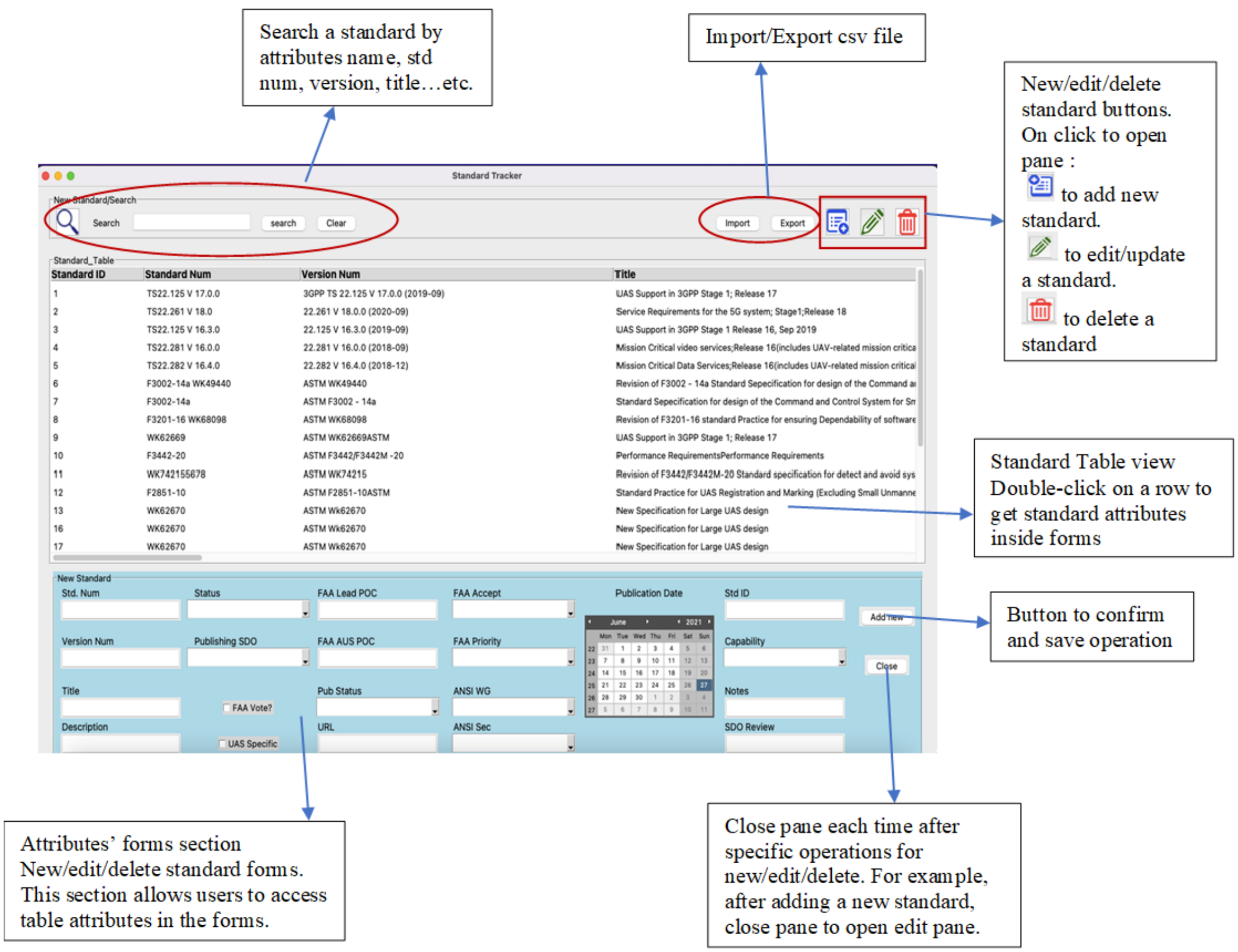

Figure 13. Screenshot of Standards Tracker application.

Figure 13 presents a screenshot of the Standards Tracker tool with labels for key features, which include:

- **Search:** The search field is designed to allow users to search any standard by adding search terms to the field and clicking on search button. The standard table section update and display the result of the search in the table view. After a search, the user can clear the query by clicking on the clear button to return to previous standard table state after a search operation.

- **Import/Export:** Users may import CSV directly from a local computer to the database and reflect the changes within the table view. An export is also possible to get all the current data from the standards table saved as a CSV formatted file on their computer's hard drive.
- **New/Edit/Delete buttons:** The buttons are designed to open an input pane to add, update or delete a standard.
  - **Add new standard**: To add a new standard, users may click on the blue icon button to open the blue pane add a new standard from the forms section. The user input data will be saved in the database after clicking on the add new button that appear in the blue pane. Click on close to close the blue pane.
  - **Edit standard**: To edit a standard, users can click on the green icon button to open the green pane that allow standards table rows editing. After opening the green pane, double click on any row from the standard table. The selection will appear in the pane's form and users may edit the selected row attributes within the form and click on update button to save the changes. Click on the Close button to close the edit pane and choose another operation.
  - **Delete standard:** To delete a standard, users may click on the red icon button to open the red pane that allows any standard to be deleted from the database. Users may delete the selected standard within the forms by clicking on delete button to perform the operation. Click on the Close button to close the delete pane.
  - **Duplicates handling:** The program is designed to handle duplicate standards. For this purpose, 'standard number' attribute was defined as unique so that there won't be duplicates data in the database. When adding a new standard, the standard number should be new and unique, it should not exist in the dataset.

8.3 Research Gap Tracker

The Research Gap Tracker shares many common design and layout elements with the Standards Tracker, but it is implemented to capture information relevant to a UAS gap, which can help inform future research requirements for the FAA. The data recorded includes title, source, the SDOs enabled by the research, gap priority, updates, problem statement, background and scope, high-level work breakdown, potential benefit to standards development, and see also fields.

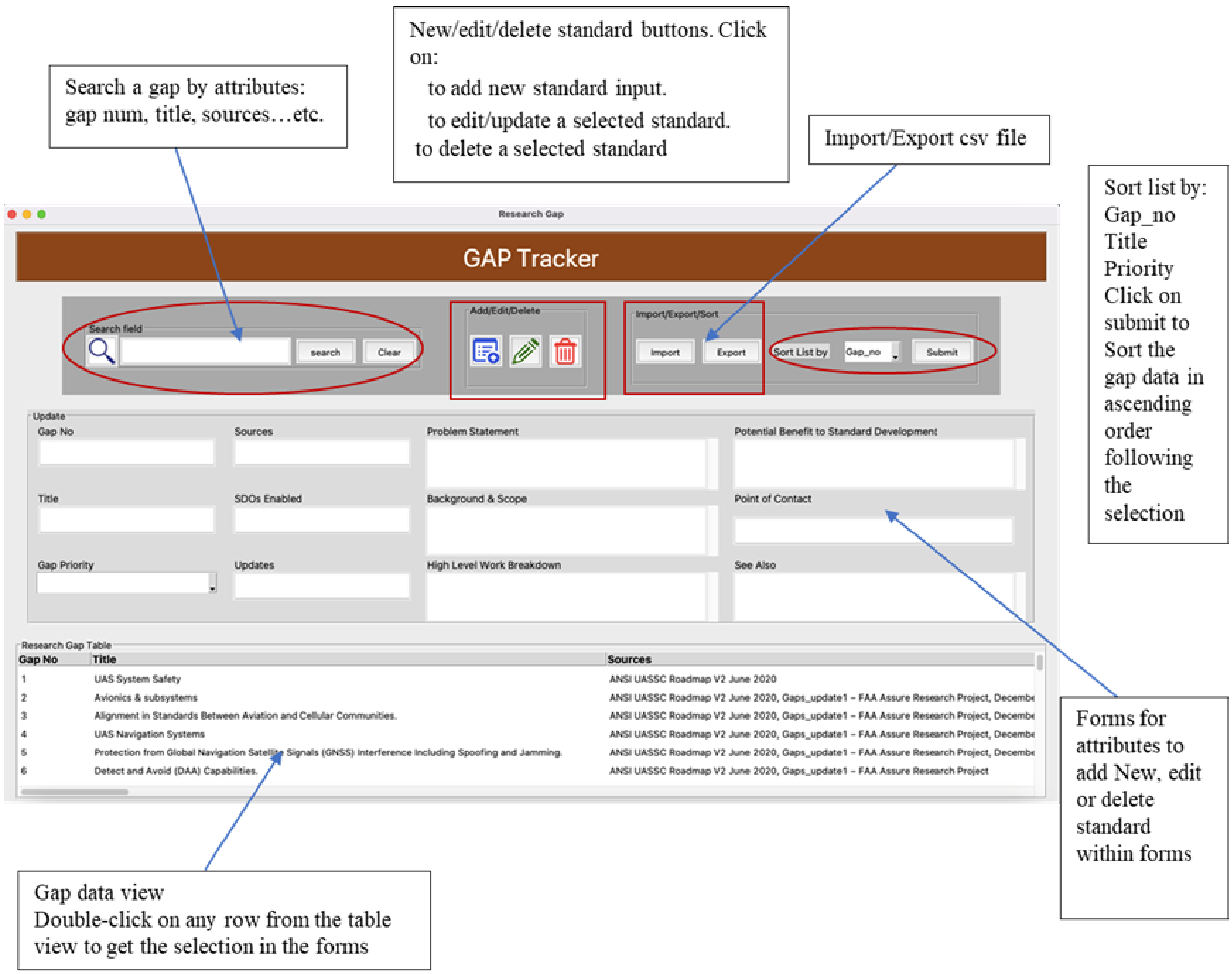

Figure 14. Screenshot of the Research Gap Tracker.

Figure 14 presents a screenshot of the Standards Tracker tool with labels for key features, which include:

- **Search.** The search field is designed to allow users to search any gap by inserting an attribute name in the search field and clicking on search button. The table section will be updated, and it will display the result of the search query in the table view. Users can clear the selection by clicking on the clear button to return to previous gap table state after search operation.
- **Import/Export.** Users may import csv directly from a local computer to the database and reflect the changes within the table view. The recommended file format is CSV UTF-8 (comma delimited).
  - An export is also possible to get all the current data from the gap table saved in a form of CSV within a local computer.
- New/Edit/Delete buttons. The buttons are designed to open an input pane to add, update or delete a research gap.
  - **Add new gap**: To add a new research gap, users will only need to access the forms section and insert new gap attributes. Then, click on the blue button icon to

perform add operation and save the change in the database. A pop-up will appear to confirm adding a new gap.

        - **Note**: To add a new gap, users do not need to insert a gap number in ‘gap_no’ cell. The number is a serial and auto incremented. The form was defined for references only. In case a gap number is inserted, the program will not process it while performing an add request.
    - **Edit gap**: To edit a gap, users will only need to double click on the desired gap/row in the gap table view, the selection will appear in the form and users may edit the selected row attributes within the forms. After editing a gap, to save the changes click on update button. Changes will be reflected in the table view.
        - **Note**: The only cell that may not be edited is the ‘gap_no’ cell. It will be updated automatically when an edit request is submitted.
    - **Delete gap:** To delete a research gap, double click on any row from the gap table view to get the data in the forms. Users may delete the selected gap within the forms by clicking on delete button to perform the operation.
- **Sort list by**. The “sort list by" button allows users to sort the gap table view by gap_no in ascending order, title in ascending order and priority in ascending order.
    - After selecting the attribute from the drop-down menu, click on submit to perform the sorting operation.
    - Sort list by operation can be reverted by clicking on clear button located near the search button.

8.4 Database Design

The design of an application's back-end services can in many cases be as important as the user-facing front-end elements. A well-designed database can not only support the functions of the application, but it should also be able to scale with an increase in users or application complexity. To meet such objectives, the team selected the PostgreSQL relational database management system.

Two database tables or relations were specified for the standards tracker and the research gap tracker, respectively. Figure 15 presents these schemas identifying the attributes and the attribute's datatype for each relation. The standard tracking relation's schema attributes were selected from two source spreadsheets from the ANSI UASSC's roadmap (2020) and Adam Hendrickson, AUS-300 (2020). The research gap tracking relation’s schema was inspired by FAA AUS-300 requests for proposal documents to essentially formatting the gap such that it can easily translate from gap to research requirement.

Standard	
standard_id	serial (primary key)
standard_num	character varying (255) unique
version_num	character varying (255)
title	character varying (255)
description	character varying (255)
status	enum
publishing sdo	character varying (255)
faa_lead_poc	character varying (255)
faa_aus_poc	character varying (255)
faa_vote	boolean
faa_accept	enum
faa_priority	enum
pub_date	date
pub_status	enum
uas_specific	boolean
url	character varying (255)
ansi_wg	enum
ansi_sec	character varying (255)
capabilty	enum
notes	character varying (255)
sdo_review	character varying (255)

Gap	
gap_no	serial (primary key)
title	text (unique)
sources	text
sdo_enabled	text
priority	text
problem_statement	text
Background_and_scope	text
high_level_work_breakdwon	text
potential_benefit_to_standard_development	text
point_of_contact	text
updates	text

Figure 15. Attributes and data types for Standards and Gap Tracker applications.

8.5 Recommended Future Work

So far, the work has focused on providing a platform for users to access and manage standards and gap data via a graphical user interface. Although the required software features are fairly-well optimized and developed, the software system presents many opportunities for improvement.

- The team recommends transitioning the database to a single online hosted platform before deployment. This will reduce the number of software dependencies that must be installed with the application.
- For deployment, it is recommended that a compiled version of the application is distributed to minimize the number of software dependencies necessary to build the application on individual workstations.
- Users' login interface may improve the security of the database and control the flow of authorized access. Users will provide a username and password to access the interface.
    - All known researchers must be pre-registered by an administrator prior to any login.
- An algorithm to keep track of all the changes made by users will be beneficial to help researchers access the latest changes within the dataset when they log in the interface.
- Rather than implementing the Standards and Gap trackers as separate applications, the team recommends merging the two into a single application with two sub-applications that use a common windows layout and permit the user to quickly return to the home screen by the click of a mouse.
- A Web version of the application may also be developed to allow easy access for researchers from everywhere by simply accessing the web interface and submitting request for operations.

    - For this recommendation, Python Flask provides useful tools and features that make creating web applications in Python easier.
- A ‘bug’ register can be created to keep track of any problems in the code release.

9 CONCLUSION

The research team concludes this report with a summary of key findings and recommendations for future work.

9.1 Key Findings

This section breaks down the key findings by research question.

Data Collection and Organization. How should data be collected and organized to enable query, capture temporal dependencies, and enable funded and future research efforts?

- To initiate interest and participation beyond the research team’s abilities, the team recommends the FAA convene a standards conference that could begin the effort of organizing the effort to collect data.
- A searchable online database should be produced to collect and track existing and in-development or planned standards, which is kept current by updates from FAA liaisons from each SDO. Protection of proprietary SDO data must be considered. Having a publicly available, searchable database would help break down silos and enhance efficiency.

Identifying Standards. What is the current state of published standards and standards development efforts by U.S. government, standards organization bodies, and industry stakeholder communities enabling UAS integration?

- Current approaches for identifying and tracking standards can be described as disheveled.
- Outside of the ANSI UASSC’s efforts there are no centralized efforts to consolidate UAS standards information in the United States.
- SDOs do not necessarily have an eye on industry developments, nor does the industry indicate that they are applying published standards to systems they design, develop, and/or test.

Identifying Standard Requirements. What standards are required to support the UAS operational capabilities proposed by the FAA UIRP? When are they needed?

- A spreadsheet of tracked standards is available in Appendix A of this study.
- Familiarity with the UIRP and its capabilities was not widespread among SDOs.
- Many of the needed standards and associated research gaps apply to UAS as well as traditional crewed aviation, for example artificial intelligence and autonomy. Critical research gaps cannot always be identified as UAS-specific.
- When communicating with SDOs, there was not a uniform approach toward planning or prioritizing the release of future standards.
    - Some organizations such as 3GPP rely upon annual releases to provide clear deadlines for new standards.

Identifying ASSURE Research. What research activities are ongoing or planned to enable UAS standards development or validation?

- Research conducted by the ASSURE UAS Center of Excellence seems dependent upon industry and SDO collaboration.
- Research findings for work done by OEMs were very limited within this study, which is largely expected due to proprietary technologies used and/or developed.
- A continued effort would be required of any organization to perform as a centralized clearinghouse for the identification of current, ongoing, and future research.
- Appendix C presents the ASSURE research projects tracked by this study.

Classification of Standards Gaps. What standard requirements are not fulfilled by published, in-development, or planned standards?

- The answer to this question remains elusive.
- Establishing the same level of detail from all SDOs whom the team has coordinated with could not be achieved.
- Industry and technological changes continue at an incredible pace.
    - e.g., During this project, two events occurred (BVLOS aviation rulemaking committee and remote ID ruling) that affect technology and regulation, as the standards in development or identified as planned, were sometimes paused until the rulemaking and regulatory environment settles.
- Beyond identifying future UAS capabilities and their high-level sub-capabilities within the UIRP, neither FAA, SDOs, or industry have provided detailed frameworks for the standardization requirements to enable these capabilities. As a result, it remains difficult to identify future standards and their research needs.

Research Prioritization. What is the priority at which the FAA should address the research to achieve the capabilities within the timeline expressed in the UIRP?

- Any research prioritization made by the FAA should center on enabling UAS integration into the NAS (such as establishing waiverless BVLOS rules). Research and standards development must support this effort. The UIRP can serve as a guide.
- There are examples that can support prioritization efforts.
    - The ASSURE A54 Right of Way study is one of many examples where results of the BVLOS ARC findings can be resolved through both concurrence and dissent.
        - OEMs working together to develop functional capabilities will support the updates to the regulations.
    - ASSURE A18 Detect and Avoid, which evaluated DAA systems test plans for future systems.
    - ASSURE A2 Small UAS Detect and Avoid Requirements Necessary for Limited BVLOS Operations.
- Prioritization of the research gaps for this study has been deferred to the FAA-based on its own criteria. The FAA monitor identified this task as low priority because the FAA has responsibility for reviewing the identified gaps and choosing what actions to take, when, and by whom.
    - However, this study provides the background, high-level work breakdown, and other relevant information to help guide research prioritization.

Engagement Strategies. What are the best strategies to engage with SDOs to ensure a periodic update on standards in development, planned future standards, and known research gaps?

- The team recommends direct engagement strategies that utilize a common set of questions and data collection tools to ensure consistent data collection.
- The team also recommend a centralized FAA office tasked with the collection of voluntary or mandated SDO-reporting of standards updates, standards planning, and research needs to ensure full situational awareness for policy makers.
- However, the fact remains that SDOs are not always well-positioned to identify research needs.

9.2 Recommendations for future work

At the conclusion of this study, the research team considered their recommendations for future work. The recommendations address improvements on SDO engagement and research gap elicitation.

SDO Engagement. SDOs exist and are successful due to the active involvement of industry volunteers who have a vested interest in the development of the standards to further the aviation industry as a whole. This elicits the need for an organized effort by the FAA to be actively involved in the development process. Active involvement must be significant, more in-depth than attending SDO meetings. Engagement by the FAA must correspond with the acceptance of the standards as an accepted means of compliance to satisfy key requirements to integrate UAS into the NAS. SDOs are overwhelmingly frustrated, in that, the standards developed are rarely accepted by the FAA as a means of compliance, which would validate the valiant efforts made over the years by SDOs.

It is recommended to develop an SDO engagement strategy:

1. The FAA must coordinate SDO efforts to identify what consensus standards are needed in order to advance the integration of UAS into the NAS. This could be done by developing annual working group(s) similar to FAA ARC meetings that identify the key needs of the FAA. For example, one working group could be established for each UIRP capability.
2. SDOs would then be empowered to develop the established standards outlined within the working groups and meet the requirements set forth in the NTTAA of 1995.
3. The FAA would be an active member of key standards working groups, which specifically address UIRP or other key objectives of UAS integration into the NAS, and would report to a centralized coordinator and/or annual working groups.
4. The FAA maintains active involvement and centralized reporting of standards development would result in swift acceptance by the FAA of various standards as an accepted means of compliance for specific areas, such as aircraft certification, DAA requirements, navigation requirements etc.

Future recommendations for follow-on to this project could include selecting mature consensus standards, developed with the FAA, industry, and academia, and walking through the process to both validate the process and specifically advance each selected consensus standard through the process to reach an acceptable means of compliance for the FAA.

Research Gap Elicitation. Unsurprisingly, it was clear that the SDO's purpose, overall, is to develop consensus standards. These standards are developed primarily with the direct involvement of volunteers from industry who are invested in the advancement of UAS integration. As volunteers, their time to engage in other activities is limited. During our study, SDO staff were often hesitant to further task their current volunteers. Furthermore, research gaps were outside most volunteers' area of expertise, having no knowledge of what research had been done in various areas over the last 10 years.

Therefore, the determination of research gaps should not primarily come from SDO engagement, but instead from a centralized organization or center of research excellence that has been given specific access to all government-funded research related to UAS.

The researchers' efforts were significantly hindered, in that neither the researchers nor FAA sponsors had the authority to obtain nor benefit from the publicly funded, government sponsored research conducted outside of ASSURE funding. Initial efforts were made to collect research efforts outlined in the FAA's UIRP as well as from other governmental agencies such as the DoD and NASA, but there was no clear pathway to obtain and analyze the research already conducted over the last 10 years. If such data had been available, the research team and FAA would have a greater success in identifying the true "gaps" in research.

Recommendations include establishing a research oversight group that catalogs research based on FAA objectives that tracks all UAS related research and provides a publicly accessible abstract of all government sponsored UAS-related research to enable the various governmental stakeholders to clearly identify the 'true' gaps in research and efficiently build on the knowledge of past research to inform new, future research.

It is the team's recommendation that ASSURE be tasked to be a repository of all UAS research giving them the ability, with ASSURE partners, to break down the barriers between governmental agencies and establish a complete representation of the UAS related research conducted.

Leaders of such a repository could then be directly engaged in the annual FAA standards working group(s) discussed, to link standards development more effectively with research gaps, which may also include research that validates or verifies developed consensus standards to allow those standards to be accepted as a means of compliance.

While these recommendations provide one possible strategy to propel the standards and research efforts within this research, the key recommendation can be summarized as developing a method to centralize information about all standards development efforts in collaboration with all research efforts to ensure the efficient and effective use of taxpayer funded research, and to make this information available to stakeholders.

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APPENDIX A: TRACKED STANDARDS

The team produced a spreadsheet of tracked UAS standards (new and under development). A copy of the spreadsheet can be found as **A37- Attachment-A- Tracked Standards.xlsx**.

APPENDIX B: IDENTIFIED RESEARCH GAPS SAMPLE

Table 1 presents an example of how the team has laid out the research gap analysis for Task D. The spreadsheet contains both research gaps identified by ANSI as well as those identified by the research team through SDO engagement and coordination. The table contains approximately 137 lines of gap data. Missing data comes as a result of limited feedback from SDOs, wherein months-long communications did not yield successful or complete analysis. In these cases, the research gaps are presented with as much information as provided and whenever possible the team's own expertise is used in substitute based on the other information provided by the SDO.

A copy of the full spreadsheet can be found as **A37- Attachment-B- Research Gaps.xlsx**.

Table 2. Sample from research gap tracking spreadsheet.

SDOs Enabled	Title	Problem Statement	Background and Scope	High-level work breakdown	Potential Benefits to Standards Development	Point of Contact	ASSURE Research Alignment with ANSI R&D needs and Overall Recommendations
These are the SDOs having connection to the ANSI Gap Analysis.	This title represents the most common theme represented with the associated SDOs	The problem statement identifies the most relevant …..	This will refer to the relevance of the theme of the standard gap discussed and the problem statement. Speaking to the level of importance of the problem that will assist the FAA and industry in applying a solution.	This will define the high-level tasks that would need to be followed to successfully address the research gap.	The objectives and aims of completing identified research needs.	Primary POC from the specific SDO authoring the titled Std. If relevant to multiple SDOs, several POCs may be present.	This field aligns the research gap with existing ASSURE R&D efforts.

ASTM, SAE, RTCA, EUROCAE, SAE ARINC	Commercial Package Delivery via UAS - GapI11	"Standards are needed to enable UAS commercial package delivery operations." There is a need to evolve the standards and regulatory framework supporting UAS capabilities for commercial package delivery operations.	There is a need to standardize concepts like: the way package will be carried in or on the aircraft the type of materials (hazardous and non-hazardous) that can be delivered Mechanisms and procedures for releasing the package at the delivery point and if human intervention is required. Determine the safety of the delivery point for both the drones to land and the package to be delivered Ways to test and evaluate safety features or algorithms and certify different operating conditions like weather or congested environments. How dynamic will the delivery zones be?	Recommendations include: "1) Complete work on ASTM WK62344 and SAE AIR7121. Review small UAS oriented standards for scaling into larger UAVs (those that exceed Part 107 and have Part 135 applicability). 2) Write new standards to address commercial package delivery UAS and its operations." Research is needed, but ANSI did not specify what R&D was needed.	Potential benefits to standards development would be to regulate the UAS commercial package delivery operations.	Phil Kenul , ASTM; Judith Ritchie, SAE; Phil Hall, Relmatech philip.kenul@gmail.com judith.ritchie@sae.org phall@relmatech.com	"1) A36 - Urban Air Mobility Studies 2) A38 - Cybersecurity Requirements for UAS Operations/Cybersecurity and Safety Literature review 3) A41 - Investigate and Identify the Key Differences Between Commercial Air Carrier Operations and Unmanned Transport Operations 4) A42 - UAS Cargo Operations-From Manned Cargo to UAS Cargo Operations: Future Trends, Performance, Reliability, and Safety characteristics 5) A?? - Risk-Based Assessments: Examine key factors of existing package delivery networks and commercial UAS activities to support a risk and hazard analysis to identify where and how UAS-related safety risks may appear."

APPENDIX C: ASSURE RESEARCH PROJECTS

The team produced a spreadsheet of ASSURE research tasks with a mapping of each project to the relevant UIRP capabilities. A copy of the spreadsheet can be found as **A37- Attachment-C-ASSURE Projects.xlsx**.

APPENDIX D: SOFTWARE DESIGN AND SOURCE CODE

The team produced a software design whitepaper for the Standards Tracker and Research Gap Tracker software applications. The whitepaper includes a printout of the source code used for the application and its database's configuration. A copy of the whitepaper can be found as **A37-Attachment-D- Software Design.pdf**.

The source code has been included as an attachment to this report as **"A37-Attachment-D2-Software Source.zip."**