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IEEE UAS STANDARDS TRACKING AND STANDARDS DEVELOPMENT RELATED RESEARCH NEEDS

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IEEE UAS STANDARDS TRACKING AND STANDARDS DEVELOPMENT RELATED RESEARCH NEEDS

ABSTRACT

The “IEEE UAS Standards Tracking and Standards Development Related Research Needs” team was formed by the IEEE Industry Connections (IC) Group to identify current IEEE unmanned aircraft systems (UAS) standards and possible research gaps. This new team comprised members of IEEE standards committees and members of the FAA Alliance for System Safety of UAS through Research Excellence (ASSURE) project “A37: UAS Standards Identification, Tracking, and Mapping.” The integrated team identified the list of standards published by the IEEE and validated whether the standards had been captured correctly. The team also identified research gaps in the current standards and, hence, possible future UAS standards development activities. As part of the effort, the team further identified multiple UAS standards developed for communications and networking, operations and applications, sensors, payload interfaces, and power research areas. The team could not identify any specific research gaps in the current standards development activities but did note a few IEEE standards development projects that need future research. Overall, participants found few general research gaps. In the future, the team should expand to include members from all unmanned aerial vehicle (UAV) working groups to better capture research gaps.

1. INTRODUCTION

Unmanned aircraft systems (UAS) and urban air mobility (UAM) are emergent aviation markets enabled by significant technological innovations. To achieve the integration of such systems into the U.S. National Airspace System (NAS) and similar air navigation service providers (ANSPs), standards must be developed regarding airworthiness, operations, and training to help guide developers, operators, regulators, and air traffic management. The Federal Aviation Administration (FAA)'s "Integration of Civil Unmanned Aircraft System (UAS) in National Airspace System Roadmap" helps set the tempo for standards development by articulating the sequence of future UAS capabilities [1]. Standards development organizations (SDOs) must work to keep pace to establish the standards needed for each capability based on inputs from industry experts and research.

The IEEE Industry Connections (IC) Group formed the "IEEE UAS Standards Tracking and Standards Development Related Research Needs" team to identify IEEE UAS standards and research gaps (i.e., opportunities for additional research that could aid the IEEE and its members in authoring new standards). The team serves as a collaboration between participating IEEE members and researchers on the FAA Alliance for System Safety of UAS through Research Excellence (ASSURE) project "A37: UAS Standards Identification, Tracking, and Mapping," which seeks to track UAS standards development activities.

The IC Group facilitates the coordination of members of the IEEE community across standards committees and working groups to identify current/ongoing/planned standards activities, locate research gaps, and trace those gaps to the UAS Integration Research Plan (UIRP) capabilities that would be enabled by new standards. Specifically, the IC Group's "IEEE UAS Standards Tracking and Standards Development Related Research Needs" team sought to meet twice to meet the following goals:

- Produce a committee-validated list of standards, confirming it completely and correctly captures the IEEE's UAS standards work.
- Discuss new and forthcoming UAS standards development activities within the IEEE.
- Identify and discuss research gaps impacting IEEE UAS standards committees' progress in developing new standards, which can potentially receive support through externally sponsored research efforts.
- Prioritize research gaps based on levels of importance to the IEEE's success in timely delivery of its supported standards activities.

This white paper presents a summary of the "IEEE UAS Standards Tracking and Standards Development Related Research Needs" team's efforts, results from its standards review and research gap analysis, and lessons learned from the experience. Section 2 provides a background summary regarding UAS standards tracking and research gaps. Section 3 summarizes IEEE's standards development progress in the domains of UAS and UAM. Section 4 presents research gaps identified by team members. Section 5 discusses opportunities for future IEEE/ASSURE/FAA collaboration opportunities.

2. BACKGROUND

This section provides some necessary background by addressing UAS standards tracking and UAS research gap identification and by providing an overview of the FAA ASSURE project "A37: UAS Standards Identification, Tracking, and Mapping."

The tracking of UAS standards involves the identification of standards published, under development, or planned. Information collected by a UAS standard may include the standard's identifier, name, description, publication status, publication date, SDO(s) and committee/working group(s) that prepared the standard, and adoption status with the FAA or other civil air authorities.

For example, the ANSI UASSC [2] has provided one of the more comprehensive surveys of UAS-related standards. The ANSI UASSC team leveraged domain-specific working groups, including those focused on airworthiness, flight operations and personnel qualifications, critical infrastructure and environment, and public safety. After the first ANSI UASSC Standards Roadmap [3], the working groups met periodically, releasing annual updates. The team has also tracked standards gaps, that is, when a standard is anticipated, but it has not been addressed by the SDOs.

SDOs might also internally track the standards they produce. Tracking standards provides internal situation awareness of what the organization produced, when, and by whom. Standards tracking can also help the SDO identify opportunities for future standards. For some organizations with one or a few working groups that develop UAS-relevant standards, the ability for the SDO to track its own UAS standards should be straightforward. For larger organizations, such as the IEEE, the role of UAS standards development is distributed across many working groups addressing standards that align with their committee's topic.

2.1. UAS RESEARCH GAPS IDENTIFICATION

Research supports the development of new standards. For instance, the development of minimum separation standards may require modeling and simulation research to derive those boundaries. Research also supports the verification and validation of standards. For example, a new standard for a ballistic recovery system will need to undergo testing to ensure that the safety needs of all stakeholders are met.

Researchers define a research gap as when new research has been identified but not addressed (i.e., it has not yet been planned or delegated to a research performer). The identification of research gaps helps to inform what work is necessary to support the standard. Once identified, the appropriate committee(s) or organization(s) can be delegated the research tasks.

2.2. FAA ASSURE A37: UAS STANDARDS IDENTIFICATION, TRACKING, AND MAPPING

To achieve its UAS integration roadmap, the FAA seeks under the A37 project to learn about standards that are planned, under development, or recently published. The FAA realizes the importance of SDO development of consensus-based standards and seems to identify opportunities when it can support research enabling standards development or standards validation. As such, the A37 team has conducted research gap analysis to identify specific opportunities for research support.

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 the 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 under 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, under 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 FAA priority level should be set for achieving 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 under development, planned future standards, and known research gaps?

The A37 team seeks to address these research questions through a set of six tasks as shown in Figure 1. Information exchange occurs regarding standards identification and mapping to the FAA's UIRP, research needs (gaps) of the SDO, and the SDO's priorities for its identified gaps.

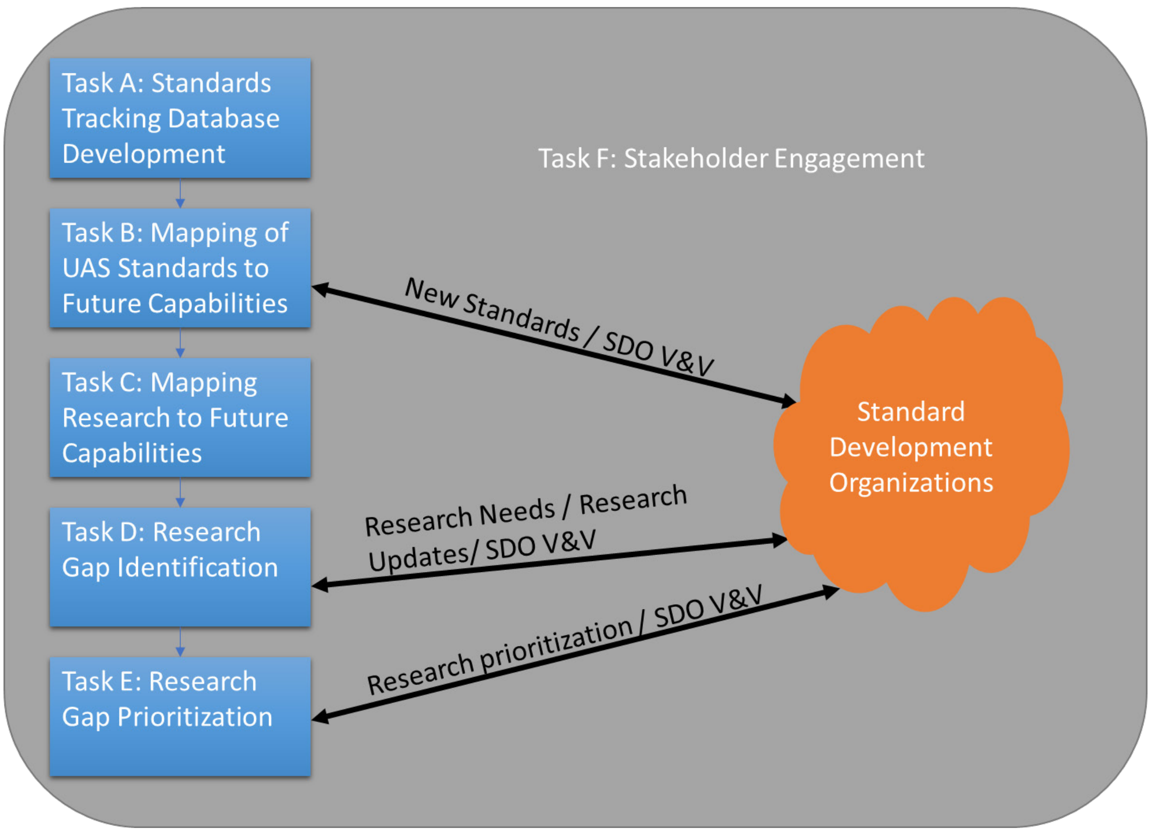

Figure 1. A37 project tasks and their relationship to SDO engagement

The IEEE IC Group sought to establish a small organization, the "IEEE UAS Standards Tracking and Standards Development Related Research Needs" team, to support these interactions between the IEEE and the A37 team. Through a pair of meetings, the newly formed integrated team identified new standards and research needs for the IEEE. The team did not prioritize these research gaps, however, due to the IC participating members not being representative of the IEEE overall.

3. IEEE STANDARDS DEVELOPMENT ACTIVITIES

A major objective of the "IEEE UAS Standards Tracking and Standards Development Related Research Needs" team was to produce a list of IEEE UAS standards. The team generated the initial list of standards by leveraging the ANSI UASSC Standardization Roadmap, which includes a spreadsheet of all surveyed standards by ANSI's UASSC working groups [2].

3.1. UAS STANDARDS

The following IEEE standards were developed according to UAS requirements:

- Communications and Networking
  - IEEE P1920.1
  - IEEE P1920.2
  - IEEE P1937.3
  - IEEE P1937.8
  - IEEE P1954
- UAS Operations and Applications
  - IEEE P1936.1
  - IEEE P1939.1
  - IEEE P2821
- Sensors
  - IEEE P1936.2
  - IEEE P1937.6
  - IEEE P1937.7
- Payload Interface
  - IEEE P1937.1
- Power/Electrical
  - IEEE P1937.9

Descriptions of each standard are provided below organized by ascending IEEE standard number.

IEEE P1920.1 focuses on aerial communications and networking standards. This draft standard defines air-to-air communications for self-organized ad hoc aerial networks [4]. The communications and networking standards apply to manned and unmanned, small and large, and civil and commercial aircraft systems. As UAS integrate into the NAS around the world, a need will arise for enhanced situational awareness of manned and unmanned aircraft systems. As of now, no standards exist for air-to-air communications and aerial networking. However, stakeholders agree on the need and benefits of aerial networks. The need for self-organized aerial networks in increasing the situational awareness of aircraft systems is also discussed in a working paper titled "Use of Self-organizing Airborne Networks to Monitor Commercial Aircraft Globally," which was presented at the International Civil Aviation Organization [5].

IEEE P1920.2 addresses the vehicle-to-vehicle (V2V) standard for UAS, which defines the protocol for exchanging information between two vehicles [6]. The information exchanged will facilitate beyond line of sight and beyond radio line of sight communications for the purpose of command, control, and navigation, as well as for any application-specific purpose.

IEEE P1936.1 focuses on supporting the drone application framework [7]. It specifies drone application classes and application scenarios, as well as the required application execution environments.

IEEE P1936.2 addresses the photogrammetric technical standard for civil light and small UAS for overhead transmission line engineering [8]. This draft standard specifies the operational methods and accuracy indicators. It also specifies the operational methods, accuracy indicators, and technical requirements for the photogrammetry of light-small civil drone applications in power grid engineering surveys and design. The light and small civil drones in this draft standard refer to fixed-wing UAV or multirotor UAV applied as the flying platform and powered by battery or fuel. The weight is between 0.25 kg and 25 kg without payload. The maximum active radius is 15 km, and the maximum operational altitude is 1 km.

IEEE P1937.1 focuses on the interface requirements and performance characteristics for payload devices in drones [9]. This draft standard establishes a framework for drone interface to payload. It defines the interfaces, performance metrics, provisioning, operation control, and management for drone payload devices.

IEEE P1937.3 addresses protocols for the flight data transmission of a civil UAV based on BeiDou short messages [10]. BeiDou is a satellite-based navigation system developed by the China Aerospace Science and Technology Corporation (CASC).

IEEE P1937.6 focuses on UAV Light Detection and Ranging (LiDar) remote sensing operations [11]. This draft standard specifies the operational methods and data management for UAV LiDAR remote sensing applications.

IEEE P1937.7 addresses the UAV Polarimetric Remote Sensing Method for Earth Observation Applications [12]. This draft standard specifies a UAV polarimetric remote sensing method for Earth objects observation applications.

IEEE P1937.8 focuses on functional and interface requirements for unmanned aerial systems UAV cellular communications terminals in UAVs [13]. It provides specification for hardware, signaling, data interfaces, environmental characteristics, performance, reliability, security, and configuration management.

IEEE P1937.9 addresses external power and power management interfaces for UAS [14]. This draft standard specifies the requirements for external power interfaces of UAV. It defines wireline and wireless power management interfaces for charging and in-flight operations.

IEEE P1939.1 focuses on a framework for structuring low-altitude airspace for UAV operations [15]. This draft standard defines a structure for low-altitude airspace that enables safe and efficient UAV traffic management. It defines UAV capabilities and related infrastructure for UAVs to operate in and comply with low-altitude airspace regulations.

IEEE P1954 addresses self-organizing spectrum-agile UAV communications [16]. This draft standard defines an architecture and protocols to enable self-organizing spectrum-agile communications among UAVs. It also enables UAVs to automatically build a network exploiting available spectrum resources and deploy connectivity to terrestrial users and devices. The draft standard focuses on enabling the usage of UAVs for fast network deployment. It does not cover specific communications technologies, but it will leverage existing communications standards while introducing additional functionalities at the system level.

IEEE P2821 focuses on a UAV patrol inspection system for transmission lines [17]. This draft guide addresses the composition, general technical requirements, testing method, and testing rules of UAV patrol inspection systems.

3.2. DISCUSSION

Appendix A, Table A1, provides a spreadsheet that breaks down the relationship of the tracked standards with future UAS capabilities. Research to enable expanded operations is needed for IEEE P1920.2 [6] and IEEE P2821 [17]. Research for IEEE P1920.2 [6] is also needed to enable small package delivery. The integrated operations capability has one draft standard, IEEE P1954 [16], deemed as applicable without research needed. For routine operations, IEEE P1937.8 [13] and IEEE P1954 [16] are applicable without research needed. IEEE P1937.8 [13], IEEE P1937.9 [14], and IEEE P1954 [16] are all applicable to large cargo operations. Lastly, for UAM operations, IEEE P1937.8 [13], IEEE P1937.9 [14], and IEEE P1954 [16] are all applicable.

4. IEEE RESEARCH GAPS IMPACTING STANDARDS

Multiple gaps were identified as a part of this effort. Appendix B provides a table summarizing all identified gaps.

4.1. GENERAL GAPS

Gap 1: One research gap identified by the team involves payload condition logging to ensure the acceptability of medical products transported by the drone. Currently, no common and systematic way exists to provide the necessary evidence that medical products are suitable for use after transport and can be transported without danger to the public, workers, and the environment, and with respect to privacy. When data are collected, it is not shared and not stored in a form that would allow sharing, so evidence cannot be accumulated, aggregated, or analyzed. Current progress and work breakdown is to (1) identify key flight and payload parameters (partly done); (2) define ontologies and data structures that organize the captured data in a way to allow sharing and reuse, including by humans and machines; (3) provide end-to-end frameworks from loading to unloading, including data sharing and reuse; and (4) provide examples.

Gap 2: The envisioned operation of UAV-Swarms for a multitude of applications requires a reliable communication channel and protocols. For mission guarantee, the system need for a reliable control channel and protocol for autonomous UAV swarms operations. Nowadays there are many proposals for UAV-Networks, but no reliable setting for control data exchange for autonomous UAV-Swarm operations. Standard-specific Gaps

During the two meetings of the "IEEE UAS Standards Tracking and Standards Development Related Research Needs" team, the researchers could not identify any specific research gaps for in-progress or planned standards development activities. However, the team did identify the following projects as likely needing further research:

- IEEE P1920.2 – Vehicle to vehicle UAS communications: Spectrum [6]
- IEEE P1920.2 – Vehicle to vehicle UAS communications: Use cases [6]
- IEEE P1920.2 – Vehicle to vehicle UAS communications: Cybersecurity [6]
- IEEE P2821 – Powerline inspection operations requires research to develop operational standards and Electromagnetic interference (EMI) mitigation/protection [17]

4.2. DISCUSSION

Participants in the IC team identified two general research gaps that could enable future standards development, but they could provide little information regarding gaps with the set of tracked UAS standards. The researchers presumed that with a greater number of participants from those initially invited to participate, the team would be better able to identify research gaps across a broader set of standards. Therefore, the team recommended that representatives from all UAS-relevant working groups be recruited to participate in future efforts.

5. OPPORTUNITIES FOR COLLABORATION

Based on observations made by the "IEEE UAS Standards Tracking and Standards Development Related Research Needs" team, this section presents recommended opportunities for collaboration within the IEEE and with the FAA.

5.1. IEEE

The IEEE coordinates standards and standards development under the IEEE Standards Association (SA). However, the decisions to develop new standards rest on the IEEE membership through the multitude of IEEE societies. For this IC, invitations were sent to relevant societies and working groups doing standards development relevant to UAS and UAM. Through the recruiting process, only a handful of these working groups were represented. As a result, when the IC met, the scope of UAS standards development and identification of research gaps were limited to those societies who participated.

Recommendation: The IEEE should form a long-term committee of its membership, coordinated by the IEEE SA, focused on UAS standards development. This committee would track UAS standards, provide opportunities for IEEE members across societies to give updates regarding their development progress and future plans, and maintain a prioritized list of research gaps to share with IEEE membership and external stakeholders such as the FAA.

5.2. FAA

This IC activity was initiated by researchers working on a sponsored grant from the FAA to track SDO standards and identify SDO research gaps the FAA could support with its resources. The recommendation in Section 5.1

could assist the IEEE in being prepared to share such information toward the FAA's future information requests. Additionally, the IEEE could coordinate with an FAA liaison to communicate this information periodically to the FAA.

Recommendation: The IEEE should identify an FAA liaison if none already exists. The IEEE should then establish a timetable for recurring meetings with the liaison to communicate standards development progress and share any research gaps inhibiting progress to develop new standards.

6. REFERENCES

The following sources have either been referenced within this paper or may be useful for additional reading:

[1] FAA 2020, Integration of Civil Unmanned Aircraft System (UAS) in National Airspace System Roadmap.[1]

[2] ANSI 2020, UASSC Standardization Roadmap for Unmanned Aircraft Systems, Version 2.0.[2]

[3] ANSI 2018, UASSC Standardization Roadmap for Unmanned Aircraft Systems, Version 1.0.[3]

[4] IEEE P1920.1, Draft Standard for Aerial Communications and Networking Standard.[4]

[5] ICAO 2014, Use of Self-organizing Airborne Networks to Monitor Commercial Aircraft Globally.[5]

[6] IEEE P1920.2, Draft Standard for Vehicle-to-Vehicle Communications for Unmanned Aircraft Systems.[6]

[7] IEEE P1936.1, Draft Standard for Drone Applications Framework.[7]

[8] IEEE P1936.2, Draft Standard for Photogrammetric Technical Standard of Civil Light and Small Unmanned Aircraft Systems for Overhead Transmission Line Engineering.[8]

[9] IEEE P1937.1, Draft Standard Interface Requirements and Performance Characteristics for Payload Devices in Drones.[9]

[10] IEEE P1937.3, Draft Protocol for the Flight Data Transmission of Civil Unmanned Aerial Vehicle Based on

[1] https://www.faa.gov/uas/resources/policy_library/media/2019_UAS_Civil_Integration_Roadmap_third_edition.pdf
[2] Kiernan, K., Joslin, R., & Robbins, J. (2020). Standardization Roadmap for Unmanned Aircraft Systems, Version 2.0.
[3] https://share.ansi.org/Shared%20Documents/Standards%20Activities/UASSC/ANSI_UASSC_Roadmap_December_2018.pdf
[4] https://sagroups.ieee.org/sagroups-1920-1/
[5] https://www.icao.int/Meetings/GTM/Documents/WP.10.Russian.Use%20of%20self%20organizing%20airborne%20networks.Revised.pdf
[6] https://standards.ieee.org/ieee/1920.2/7517/
[7] https://sagroups.ieee.org/1936-1/
[8] https://standards.ieee.org/ieee/1936.2/10521/
[9] https://sagroups.ieee.org/1937-1/

BeiDou Short Message.[10]

[11] IEEE P1937.6, Draft Standard for Unmanned Aerial Vehicle (UAV) Light Detection and Ranging (LiDAR) Remote Sensing Operation.[11]

[12] IEEE P1937.7, Draft Standard for the Unmanned Aerial Vehicle (UAV) Polarimetric Remote Sensing Method for Earth Observation Applications.[12]

[13] IEEE P1937.8, Draft Standard for Functional and Interface Requirements for Unmanned Aerial Vehicle (UAV) Cellular Communication Terminals.[13]

[14] IEEE P1937.9, Draft Requirements for External Power and Power Management Interfaces for Unmanned Aerial Vehicle.[14]

[15] IEEE P1939.1, Draft Standard for a Framework for Structuring Low Altitude Airspace for Unmanned Aerial Vehicle (UAV) Operations.[15]

[16] IEEE P1954, Draft Standard for Self-Organizing Spectrum-Agile Unmanned Aerial Vehicle Communications.[16]

[17] IEEE P2821, Draft Guide for Unmanned Aerial Vehicle-based Patrol Inspection Systems for Transmission Lines.[17]

[10] https://standards.ieee.org/ieee/1937.3/7591/
[11] https://standards.ieee.org/ieee/1937.6/10682/
[12] https://standards.ieee.org/ieee/1937.7/10683/
[13] https://standards.ieee.org/ieee/1937.8/10684/
[14] https://standards.ieee.org/ieee/1937.9/10685/
[15] https://sagroups.ieee.org/1939-1/
[16] https://standards.ieee.org/ieee/1954/10686/
[17] https://sagroups.ieee.org/2821/

APPENDIX A

IEEE UAS STANDARDS

The research team identified the 13 standards listed in Table A1 (RN – Research Needed; APP – Applicable).

Table A1. IEEE UAS Research Gaps

Standard No.	Designation/Title of Standard, Specification, Other Publication, or Program	Date of Publication of Latest Draft	Publication Status	UAS Specific?	ExOps	PkgDel	Integrated Ops	Routine	Large Cargo	UAM
P1920.1	IEEE P1920.1, Draft Standard for Aerial Communications and Networking Standard	Sept. 2020	Published	Yes						
P1920.2	IEEE P1920.2, Draft Standard for Vehicle-to-Vehicle Communications for Unmanned Aircraft Systems	PAR APPROVED	(New) In Development	Yes	RN	RN				
P1936.1	IEEE P1936.1, Draft Standard for Drone Applications Framework	Nov. 2020	(New) In Development	Yes						
P1936.2	IEEE P1936.2, Draft Standard for Photogrammetric Technical Standard of Civil Light and Small Unmanned Aircraft Systems for Overhead Transmission Line Engineering	Feb. 2021	(New) In Development	Yes						
P1937.1	IEEE P1937.1, Draft Standard Interface Requirements and Performance Characteristics for Payload Devices in Drones	June 2020	Published	Yes						
P1937.3	IEEE P1937.3, Draft Protocol for the Flight Data Transmission of Civil Unmanned Aerial Vehicle Based on BeiDou Short Message	May 2021	(New) In Development	Yes						

Standard No.	Designation/Title of Standard, Specification, Other Publication, or Program	Date of Publication of Latest Draft	Publication Status	UAS Specific?	ExOps	PkgDel	Integrated Ops	Routine	Large Cargo	UAM
P1937.6	IEEE P1937.6, Draft Standard for Unmanned Aerial Vehicle (UAV) Light Detection and Ranging (LiDAR) Remote Sensing Operation	PAR APPROVED	(New) In Development	Yes						
P1937.7	IEEE P1937.7, Draft Standard for the Unmanned Aerial Vehicle (UAV) Polarimetric Remote Sensing Method for Earth Observation Applications	PAR APPROVED	(New) In Development	Yes						
P1937.8	IEEE P1937.8, Draft Standard for Functional and Interface Requirements for Unmanned Aerial Vehicle (UAV) Cellular Communication Terminals	PAR APPROVED	(New) In Development	Yes				APP	APP	APP
P1937.9	IEEE P1937.9, Draft Requirements for External Power and Power Management Interfaces for Unmanned Aerial Vehicle	PAR APPROVED	(New) In Development	Yes					APP	APP
P1939.1	IEEE P1939.1, Draft Standard for a Framework for Structuring Low Altitude Airspace for Unmanned Aerial Vehicle (UAV) Operations	Oct. 2020	Published	Yes						
P1954	IEEE P1954, Draft Standard for Self-Organizing Spectrum-Agile Unmanned Aerial Vehicle Communications	PAR APPROVED	(New) In Development	Yes			APP	APP	APP	APP
P2821	IEEE P2821, Draft Guide for Unmanned Aerial Vehicle-based Patrol Inspection Systems for Transmission Lines	Sept. 2020	Published	Yes	RN					

APPENDIX B

IEEE UAS RESEARCH GAPS

The research team identified the six research gaps listed in Table B1.

Table B1. IEEE UAS Research Gaps

Source(s)	SDOs Enabled	Title	Problem Statement	Background and Scope	High-level Work Breakdown	Potential Benefits to Standards Development
IEEE	IEEE	Logging payload status to ensure acceptability of medical products transported by drone	No common, systematic means exists to provide evidence that medical products are suitable for use after transport and ensure the payload can be transported without danger to the public, workers, and the environment, while respecting privacy. Collected data are not shared, nor stored in a sharable format, which prevents evidence from being accumulated, aggregated, or analyzed.	Drone use for healthcare applications does not provide a means of demonstrating the acceptability of the delivered medical payload, and evidence is not being made available to regulators, users, suppliers, and researchers.	1. Identify key flight and payload parameters (partly done). 2. Define ontologies and data structures that organize the captured data in a way that allows sharing and reuse, including by humans and machines. 3. Provide end-to-end frameworks from loading to unloading, including data sharing and reuse (FAIR). 4. Provide examples.	A common basis would allow broader adoption and deployment at scale, to the benefit of society, healthcare workers, and the drone industry. May usefully sit above IEEE P1937.1 (Payload Interface and Control for Public Safety Operations) and include staff certification and training.
IEEE	IEEE	Reliable control channel and protocols for autonomous UAV swarms operations	Despite many proposals addressing UAV networks, no defined protocols exist for autonomous UAV swarm operations.	UAV swarms often require a reliable communications channel and protocols for UAV-to-UAV communications to guarantee the swarm's	1. Formal definition of an ontology for UAV swarms operations independent of the UAV model. 2. Standardized protocols for end-to-	Enables the autonomous operation of swarms, including heterogenous swarms made up of varying UAS platforms.

Source(s)	SDOs Enabled	Title	Problem Statement	Background and Scope	High-level Work Breakdown	Potential Benefits to Standards Development
				mission is followed and maintains integrity of communications for each member.	end data secure data exchange. 3. A common ground for secure and safe operation in the presence of communications failure (fault tolerance).	
IEEE	IEEE	IEEE P1920.2	Vehicle-to-vehicle UAS communications: Spectrum.	V2V UAS communications.	IEEE feedback and collaboration did not yield a clear work breakdown for this identified gap.	Benefits to standards development were not clearly enumerated in the collaboration and/or documentation provided.
IEEE	IEEE	IEEE P1920.2	Vehicle-to-vehicle UAS communications: Use cases.	V2V UAS communications.	IEEE feedback and collaboration did not yield a clear work breakdown for this identified gap.	Benefits to standards development were not clearly enumerated in the collaboration and/or documentation provided.
IEEE	IEEE	IEEE P1920.2	Vehicle-to-vehicle UAS communications: Cybersecurity.	V2V UAS communications.	IEEE feedback and collaboration did not yield a clear work breakdown for this identified gap.	Benefits to standards development were not clearly enumerated in the collaboration and/or documentation provided.
IEEE	IEEE	IEEE P2821	Powerline inspection operations require research to develop operational standards and EMI mitigation/protection.	Powerline linear infrastructure inspection.	IEEE feedback and collaboration did not yield a clear work breakdown for this identified gap.	Benefits to standards development were not clearly enumerated in the collaboration and/or documentation provided.

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