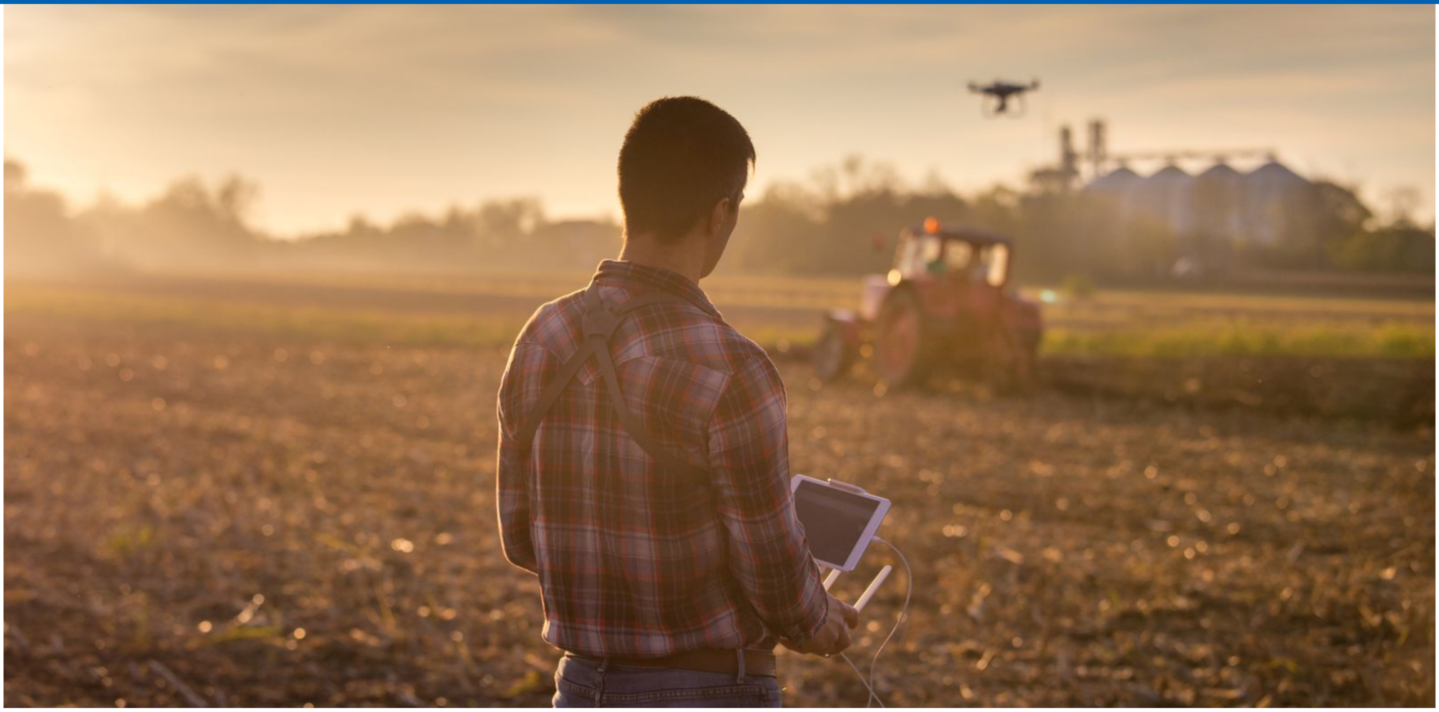
Guiding the New UAS Industry to Safety Excellence

SEPTEMBER 2021



Author

Ken Dunlap, Managing Partner, Catalyst-Go, Autonomous Vehicle Group

Acknowledgements

Long-established industry standards and advisory committees have made immeasurable contributions to key aspects of promoting safety within the UAS industry. Guiding the New UAS Industry to Safety Excellence recognizes these and complements their body of work. Key insights have been gained from:

- FAA Drone Advisory Committee (DAC) Task Group 8, Safety Culture
- SAE S-18 / EUROCAE WG-63, Aircraft and Systems Development and Safety Assessment Committee
- SAE S-18 UAS Autonomy WG / EUROCAE WG-63, SG-1
- SAE G-34 / EUROCAE WG-114, Artificial Intelligence (AI) in Aviation Ecosystem
- UAS Safety Team (UAST)
- ASTM Committee F38 on Unmanned Aircraft Systems

About the Aviation Working Group

The Aviation Working Group is an advisory group on all matters related to aviation policy and practice. The group is made up of diverse experts and stakeholders. It provides Eno with insights, knowledge, feedback, and guidance on how to continue to lead the world in aviation safety, modernization, and innovation. The group is co-chaired by former Secretary of Transportation Jim Burnley and former United States Senator Byron Dorgan.

About the Eno Center for Transportation

The Eno Center for Transportation is an independent, nonpartisan think tank whose vision is for a transportation system that fosters economic vitality, advances social equity, and improves the quality of life for all. The mission of Eno is to shape public debate on critical multimodal transportation issues and build an innovative network of transportation professionals.

Table of Contents

Executive Summary

Industry and regulators are achieving many notable successes in creating effective policies to facilitate the integration of Unmanned Aircraft Systems (Uncrewed Aircraft Systems, or UAS) into the National Airspace System (NAS). This report addresses two of the most urgent gaps that have yet to be resolved. Theseare establishing a safety culture among all users and using this as a stepping stone to Safety Management Systems (SMS) among commercial users.

Both safety culture and SMS enjoy a rich heritage in many sectors including transportation, healthcare, and power generation where they are routinely used to promote systemic industry safety and safe day-to-day operations. But this research found that they are not yet established in the nascent UAS industry except for large UAS manufacturers and certificate holders. Further, current Federal Aviation Administration (FAA) UAS pilot testing and licensure are not tied to a larger safety culture framework and pilot safety responsibilities are not tied to the complexity of an aircraft or flight operation. Compounding matters, most UAS manufacturers supply little information to recreational and commercial users on basic legal requirements they must meet.

There are two important reasons to set in motion now the establishment of safety culture and SMS policies for UAS users. First, because the UAS industry is relatively young, regulators will not be fighting established culture and traditions that often fuel resistance to these safety frameworks. Second, should the introduction of safety culture and SMS be delayed, the American public will view any future catastrophic accident involving UAS through the same lens used for traditional aviation. This risks Congress and the U.S. Department of Transportation (DOT) creating reflexive and possibly irreversible expectations and rules around safety.

It is incumbent upon the industry and regulators to proactively establish smart and effective UAS safety culture and SMS policies now that can work for both recreational and commercial UAS users. This report lays out how Congress and DOT can harness the resources already in place to establish safety culture and SMS. Much has been achieved and little needs to be done from scratch. Such proactive measures will create a sustainable and rich safety culture and safety tradition for the UAS industry.

However, the research demonstrates the importance of recognizing and separating low-risk and high-risk UAS activities while building safety culture and SMS frameworks. This involves few changes to the existing regime for hobbyist and recreational UAS pilots flying within the confines of a FAA-Recognized Identification Area (FRIA). Such activities have been conducted safely for decades and keeping barriers to entry reasonable for non-commercial pilots can ensure that they participate in the important safety culture steps outlined in this work.

Commercial operators, on the other hand, present a higher level of risk and are more likely to conduct operations in metropolitan areas, near airports, or within airspace that is adjacent to that utilized by air carriers. For this segment and pilots wishing to operate UAS in controlled airspace or use highly complex aircraft this report proposes new testing and licensure requirements tied to a larger safety culture framework.

Similarly, the report presents recommendations on matching elements of SMS on a continuum from novice UAS pilot to UAS professional and manufacturer. This involves a light touch in low-risk, non-commercial circumstances, but nonetheless provides building blocks to support career and organizational development, illustrated in the graphic below. It aligns needed safety skills and understandings with the increasing complexity of an aircraft. For example, ab initio operators need to understand the importance of operating in accordance with documented safety policies, while manufacturing and commercial operations need to use elements of a formally recognized SMS program. This research found that voluntary measures are effective at creating safety culture and traditions, but wide-spread adoption may require mandates.

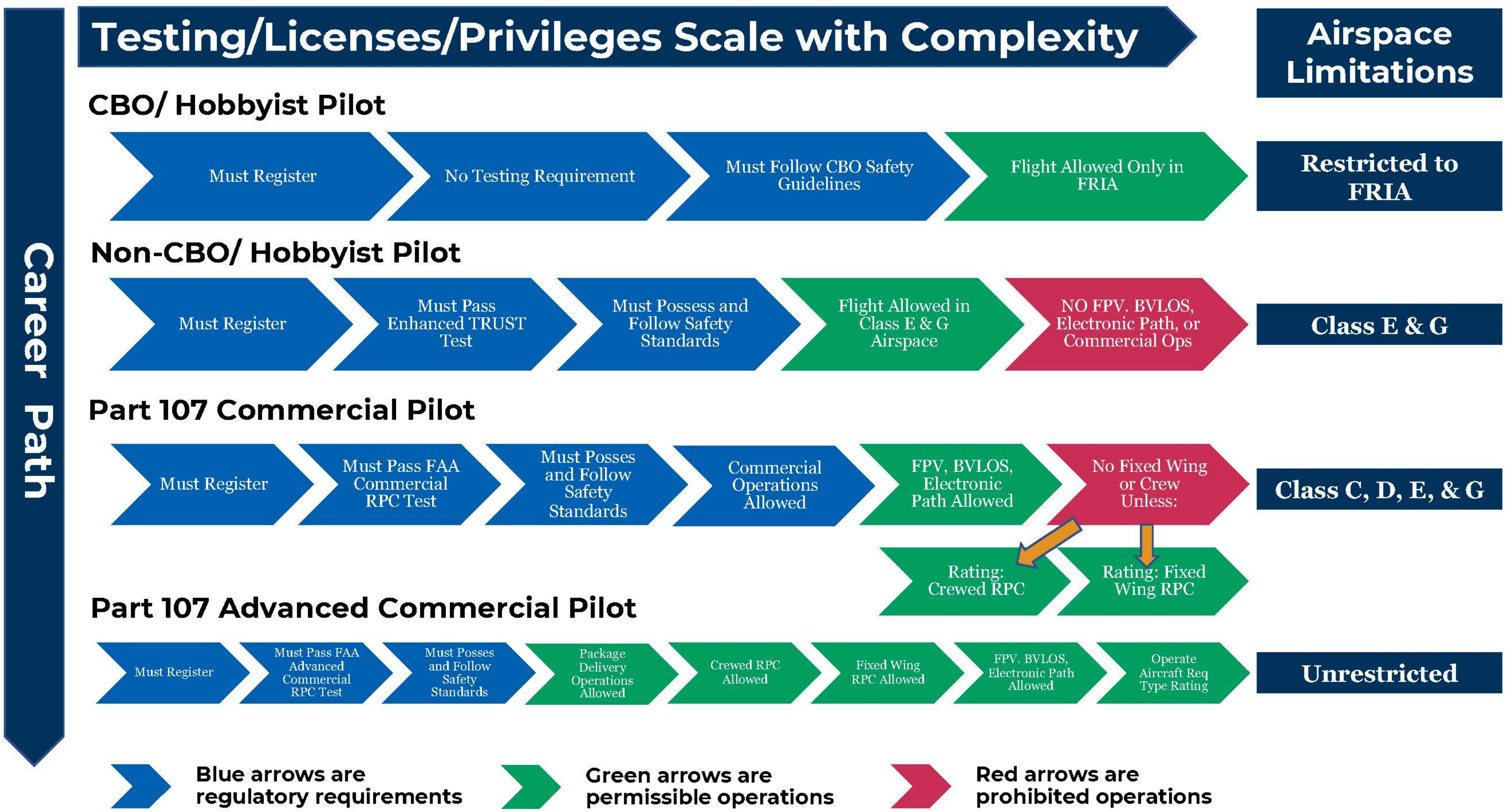
Both the licensure and SMS frameworks work together to promote the safety knowledge and required skills upon which an aspiring aviator can build skills on a career path from hobbyist to professional UAS pilot. They also advance the mission of the Federal Aviation Administration (FAA) by providing checkpoints through which companies and individuals can be measured against well accepted safety practices.

Finally, the report presents research findings within the boundaries of voluntary and compulsory measures to inform Congress, the FAA, and industry of policy needs and resulting trade-offs that implementation options may present.

The research and analysis presented here builds on previous work and recommendations by the Eno Center for Transportation.[1] It provides historical insights into transportation policy, complements the work of industry standards and advisory committees, and presents recommendations to senior policymakers. In all these areas, the report strives to address substantial, yet unique, areas of public safety policy not fully addressed in other forums.

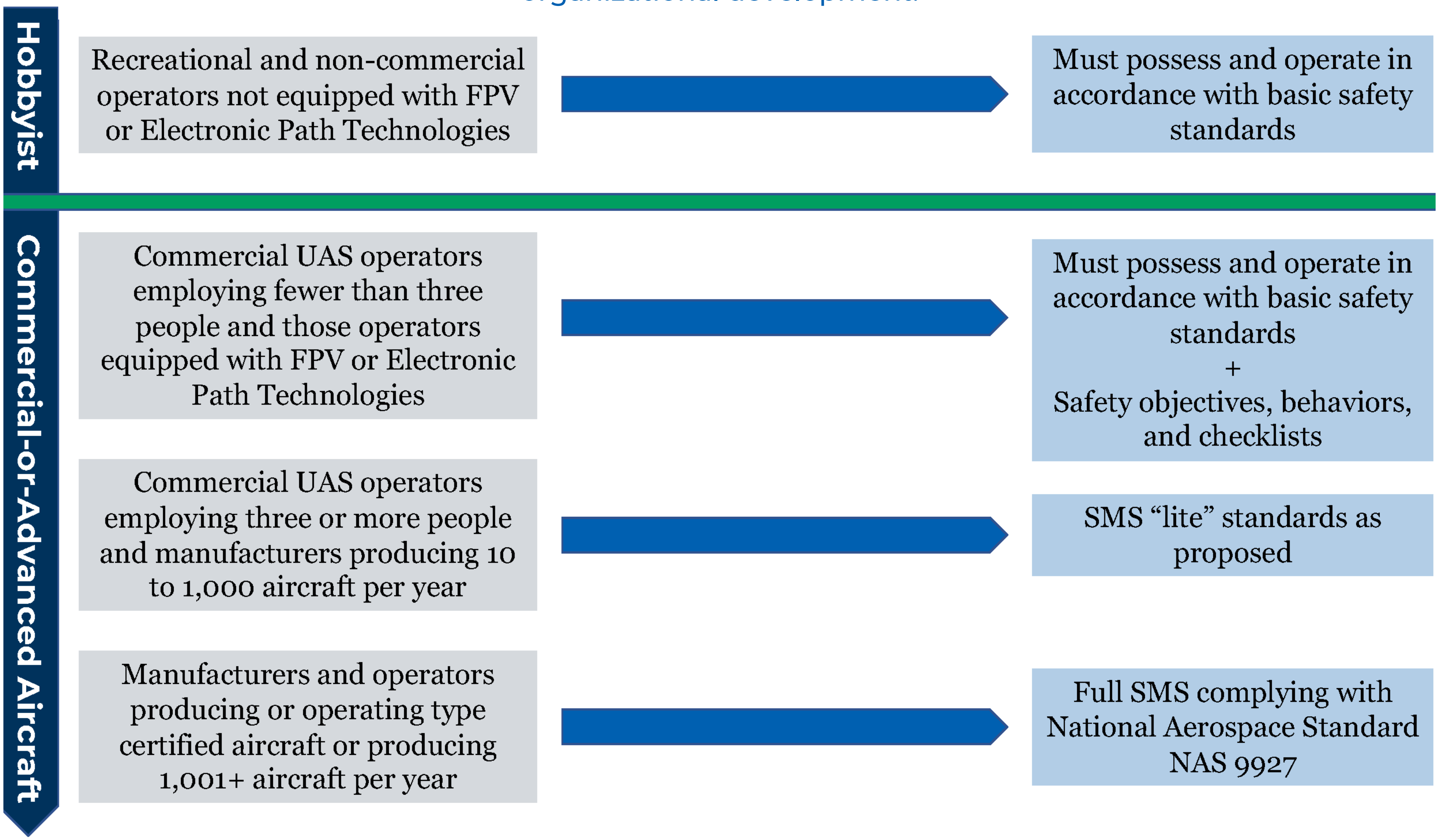
This report proposes recommendations to expand adoption of key principles of safety culture and Safety Management Systems (SMS) based on analysis of public expectations, the composition of the UAS industry, traditional aviation safety tools, and prior DOT experience in promulgating these in new transportation industries. These leverage the positive impact of Congress in setting a direction for an industry and agency, the need for a trigger to spark broader regulatory reform, segmentation of user groups by level of experience, type of operational use and the capabilities of the aircraft. Specific recommendations are summarized the report and in Appendix A.

Recommended Testing and Licensing Schema tied to a larger safety culture framework:



From top to bottom the graphic displays career progression. From left to right it displays operating and airspace privileges.
Note: For more information on airspace classifications, see Federal Aviation Administration, "ENR 1.4 ATS Airspace Classification"

Recommended elements of SMS presented on a continuum from novice UAS pilot to UAS professional and manufacturer to support a building block approach to career and organizational development:



1.0 Introduction: Key Concepts and Public Policy Issues

This section summarizes key concepts and public policy issues needing to be addressed to build a sustainable system of safety for UAS manufactures and operators. It relates safety to the expectations of the American public, other stakeholders in the National Airspace System, and regulators. Finally, key national policy issues are introduced and placed in context.

1.1 Key Concepts

The FAA Serves as both a Regulator and Partner in Aviation Safety

Two commercial aviation tragedies led to the passage of PL 85-726, the Federal Aviation Act of 1958, which created the Federal Aviation Administration (FAA).[2] On June 30, 1956, a United Airlines DC-7 aircraft collided with a TWA Lockheed Super Constellation over the Grand Canyon resulting in the loss of 128 lives.[3] Less than two years later, Capital Airlines Flight 300 was struck by a United States Air Force T-33 over Brunswick, Maryland.[4] Both accidents prompted Congressional review of the basic tenants of aviation safety and the regulatory structures necessary for oversight. The intent of Congress and authorities granted to FAA are captured several places in the law, most notably in Section 307 (c):

> *"The Administrator is further authorized and directed to prescribe air traffic rules and regulations governing the flight of aircraft, for the navigation, protection, and identification of aircraft, for the protection of persons and property on the ground, and for the efficient utilization of the navigable airspace, including rules as to safe altitudes of flight and rules for the prevention of collision between aircraft, between aircraft and land or water vehicles, and between aircraft and airborne objects.[5]"*

The Federal Aviation Act of 1958 also provided the FAA Administrator the authority to convene advisory committees and retain consultants to advise the agency.[6] Today, these public-private partnerships include the Commercial Aviation Safety Team (CAST), General Aviation Joint Steering Committee (GAJSC), and the UAS Safety Team (UAST). These forums bring together aviation experts to collaboratively identify risks to aviation and develop mitigations before accidents or serious incidents occur.[7]

What Do We Mean by Aviation Safety?

Cabinet agency guidance, Congressional intent, and industry standards provide formal definitions for the concept of "safety" in transportation. Yet, the most powerful definition rests in the collective conscience of the American public as it expresses expectations of the level of risk it is willing to accept and the level it cannot in aviation.

Such expressions are found in the media, public hearings, regulatory comments, and even protests that accompany fatal transportation accidents, serious incidents, or proposed regulatory changes.

On February 12, 2009, Continental Connection flight 3407 operated by Colgan Air, Inc. crashed on approach to Buffalo-Niagara International Airport in Buffalo, NY resulting in the loss of 45 passengers and 4 crew members.[8] In the final Aircraft Accident Report, the National Transportation Safety Board (NTSB) issued 46 Findings and 25 New Recommendations to the FAA. [9]

Following the release of the NTSB Accident Report, the families of the victims of Flight 3407 pushed for improvements in aviation safety. As a result, Congress passed PL 111-216, The Airline Safety and Federal Aviation Administration Extension Act of 2010.[10] This law established new requirements for crew member training, duty time limits, SMS, and crewmember qualifications.

The American public provided the FAA with thousands of comments expressing individual and collective concerns as the agency began to propose new safety regulations. The FAA reported that the Advanced Notice of Proposed Rulemaking (ANPRM) generated 8,227 comments from 1,299 commenters.[11] The subsequent Notice of Proposed Rulemaking (NPRM) generated an additional 517 comments.[12] An analysis of these comments performed in July 2013 revealed that 83 percent of the comments came from individuals, and of this group, 65 percent did not have any level of flight experience.[13,14] Further, 52 percent of the commenters on the NPRM disagreed with the FAAs proposed rules on safety.[15]

How then should we define aviation safety from the view of the American public?

On the 10th anniversary of the Airline Safety Act (PL 111-216) being signed into law, the Families of Continental Flight 3407 released a statement which concluded,

> *"Let this occasion serve as a powerful reminder to our government and all industry stakeholders that the flying public is counting on them each and every day to avoid the temptation to cut corners, and to do the right thing when it comes to safety."*[16]

Understanding UAS Safety

While we often speak of uncrewed aircraft within the context of a "new" or "fledgling" industry, these vehicles have a rich history in the United States dating back to the 1930s with the development of the Curtis N2C-2 drone by the Navy Research Lab. For the next several decades uncrewed aircraft were largely focused on and developed within military programs. As a result, operational concepts and manufacturing processes relied heavily on experience gained from developing larger crewed aircraft.

Around the early 2000s, several technologies emerged that allowed for the development of UAS outside military programs. Compact stabilization systems, autopilots, high-speed electric motor controllers, and high-density batteries drove miniaturization to enable small UAS. In addition, the ability to link a UAS to the growing constellation of GPS satellites provided information which the aircraft could use to navigate precisely. These new aircraft not only looked different but could be produced at comparatively large volumes with basic knowledge of electronics and access to a commercial supply chain.

By the middle of the decade of the 2000s, these systems commonly referred to as "drones," dominated the marketplace and public imagination. We see this effect present today. So, while today's drones borrow from their military origins, they represent a new and divergent branch in the family tree of UAS. Compared to preceding systems they represent a different heritage, industry, design philosophy, acceptance of risk, and understanding of accessing airspace. In many ways UAS come from two completely different industries.

Understanding this evolutionary split, its implications for aircraft safety, and the associated regulatory challenges remain key to successfully addressing industry safety. Yet, as we have seen, the public will not accept fatalities nor dangerous incidents and will expect that the "right thing" will be done, regardless of industry evolution. Just how the UAS industry and regulators accomplish this remains largely unwritten, but baseline expectations have been set.

A UAS is an Aircraft that Must Comply with Safety Requirements

Within the past several years, Congress and the FAA through various laws and regulations have begun to establish a regulatory framework that provides for safety oversight and accountability over this bifurcated industry. Key to this was defining UAS as aircraft and linking regulatory activity to two main legal authorities granted to the FAA. These authorities allow for the FAA to regulate the production, operation, and integration into the NAS of Unmanned Aircraft Systems.[17]

Specifically, 49 U.S.C.§ 4013 establishes FAA's safety mandate to regulate the operation of aircraft in the National Airspace System. In addition, 49 U.S.C.§ 44701(a) requires the agency to prescribe regulations and standards the Administrator finds necessary for safety in air commerce and national security.

The FAA solidified the position that a UAS is an aircraft in the Final Rule for Registration and Marking Requirements for Small Unmanned Aircraft.[18] The rule, published in 2015, was written to cover the full range of systems including uncrewed aircraft, model aircraft, and small uncrewed aircraft systems. It reads in portion,

> *"The Secretary and the Administrator recently affirmed that all unmanned aircraft, including model aircraft, are aircraft consistent with Congressional direction in Title III, Subtitle B of Public Law 112–95 and the existing definition of aircraft in title 49 of the United States Code. 49 U.S.C. 40102."*[19]

Since then, FAA has exclusive oversight of the uncrewed industry.

The FAA Has Set a High Bar for UAS Safety

Determining that all UAS should be defined as aircraft was a necessary legal mechanism to assert FAA authority over their manufacture, operation, and integration into the NAS. It places safety oversight and monitoring on portions of the industry not previously covered by aviation regulations. It also enables the agency to employ many existing regulatory frameworks for compliance purposes. However, through this action DOT either wittingly or unwittingly set for the American public a higher expectation for UAS safety.

As we have seen, public expectations exponentially increase the closer one gets to commercial aviation matters. At face value, defining UAS as aircraft implies the FAA will exert a level of scrutiny and demand a level of safety somewhere in the continuum between general and commercial aviation.

In practice, industry and regulators understand that near equivalency in equipment, procedures, and performance between traditional and uncrewed regulations should only be reserved for the most complex and high risk UAS operations. For example, those conducted in airspace shared with traditional aircraft and/or those that subject people nearby to greater dangers. For the remaining, equivalency is viewed through the lens of achieving outcomes that mirror the intent of existing regulations. Eno has previously discussed how today's regulations function largely on a "by-exception" basis as policy makers and the industry work toward a permanent framework.[20]

Now that the bar has been set by FAA declaring UAS as aircraft, regulators and industry face the continuing task of understanding and collaborating with one another on safety to position UAS within regulatory context and public expectation. Some parties bring to the table a bias toward traditional regulation, others few connections to established aviation safety paradigms, and all bring differing perspectives on how risk is to be understood. Yet this nuance and interplay will remain inside baseball to the American public. When a catastrophic accident occurs involving a UAS and a commercial airliner, the lens will be the one they use for traditional aviation. The industry needs to understand this above all.

Public Attention to UAS Safety is Growing

Outside of responding to accidents and incidents, the public is also reviewing routine regulatory filings and letting their opinions be heard. On August 18, 2019, Amazon Prime Air filed for an exemption to allow it to conduct operations under a part 135 air carrier operating certificate with a UAS, to enable its commercial delivery operations.[21] Forty-seven parties filed comments and 68 percent were from private citizens.[22] Concerns included: environmental impact, privacy, noise pollution, hazards to other aircraft, safety of people on the ground, and compliance with existing regulations.

In another example, Uber Elevate on May 21, 2019, sought permission to conduct small UAS air carrier operations for commercial food package delivery in the United States, initially in the City of San Diego.[23] A similar number of parties commented with 85 percent from private citizens reflecting the same concerns.[24]

Rulemaking activity on UAS operations and safety draws a high degree of public interest as well. The following table summarizes the breakdown of the nearly sixty-seven thousand public comments received by the FAA during recent rule promulgation.

Table 1: Number of Public Comments per UAS Rulemaking

Rulemaking	Number of Public Comments
Operation of Small Unmanned Aircraft Systems over People[25]	966
Remote Identification of Unmanned Aircraft Systems[26]	53,224
External Marking Requirements for Small Unmanned Aircraft[27]	418
Safe and Secure Operations of Small Unmanned Aircraft Systems[28]	1,842
Operation and Certification of Small Unmanned Aircraft Systems[29]	4,671
Registration and Marking Requirements for Small Unmanned Aircraft[30]	5,594

A common thread in all the comments reviewed is that as UAS operations become more complex and maneuver closer to structures, terrain, and people, the level of public concern increases. Yet, complex operations and those in proximity of infrastructure tend to be those with the highest commercial value for UAS operators. These include long distance inspections beyond the visual line of sight of the operator such as those done for bridges and buildings and those contemplated for door-to-door delivery.

An Overview of the Traditional Tools of Aviation Safety

The practice of aviation safety relies on four interrelated tools available to industry and the FAA. These core tools include:

- Regulation
- Education
- Data
- Tradition and Culture

Regulation represents the outward facing aspect of the FAA and enables it to set high-level performance expectations of industry, hold individuals accountable for their actions, and facilitate the efficient interconnection of the National Airspace System.

For example, from 1998 to 2008, industry and government operational data analysis sponsored by the CAST, along with new aircraft, regulations, and other activities, resulted in the fatality risk for commercial aviation in the United States falling by 83 percent.[31] This historic achievement can be attributed to the FAA promulgating new data driven regulations and industry sharing lessons gleaned from the CAST analysis.

Education encompasses the core knowledge required of an individual or organization to understand regulatory obligations, considerations to ensure continued safe operations of an aircraft, and frameworks needed to evaluate existing risks and future risks.

Fundamentally, individuals advance and maintain safety based on the knowledge and experiences they bring to the workplace. Especially in traditional aviation, workers exist within a broader aviation safety culture which allows them immediate access to knowledge and experiences from other colleagues.

Data: Aircraft, employees, training events, flight operations, and simulation all generate large volumes of data for regulators and industry to evaluate. These contribute to informing future actions and developing procedures to control risks. Yet, data is only valuable when effectively shared.

A complex web of international, federal and state regulations apply to data. Some of which may penalize stakeholders based on information that may be disclosed in the collection process. To remedy this, federal regulators have embraced non-punitive sharing of data protected by immunity provisions in many cases. The challenge for regulators in a new industry, such as UAS, is extending these protections and identifying the type of data that should be shared.

Tradition and Culture came into being with the drafting of the first aircraft design and operation of the first flight. This represents the proverbial "way we have always done things." In aviation more often than not, these ways of doing things came into practice as the result of previous lessons learned from accidents or incidents.

Equally important, *Tradition and Culture* exist within an organization based on their hiring practices. Aviation companies, and in fact most companies (including regulators), have a personality profile they hire to, either overtly or unconsciously. *Tradition and Culture* therefore have a tremendous impact on education as they place emphasis on the information perceived to be most important.

Day to Day Outcomes in Safety Are Linked to a Company's Safety Culture

This report focuses on two fundamental aspects of safety as they impact the UAS industry: culture and Safety Management Systems (SMS). We use "safety culture" to refer to the fundamental attitudes and approach to resolving risks used by an organization, whether an individual or a group of people.

As we will discuss later, safety culture guides and supports continuous improvement processes extending from the company leadership to field staff to identify and address safety issues. It should be viewed as foundational in the life cycle of an organization. If a purposeful safety culture is not developed by an organization, an ineffective ad hoc one will likely fill the void.

Organizations with robust safety cultures address unexpected events during normal operations far more effectively than those with none. This means the safety of day-to-day operations is inextricably linked to an organization's culture.

Safety Management Systems (SMS) Operationalize an Organization's Safety Culture

While safety culture exits within an organization in many intangible ways, such as attitudes, values, feelings, and how people communicate among themselves, SMS exists in concrete ways. This includes repeatable, persistent, transparent, and auditable processes in operations from the field to the boardroom. Organizations can point to their SMS manual and be held accountable under SMS since it measures organizational performance on safety.

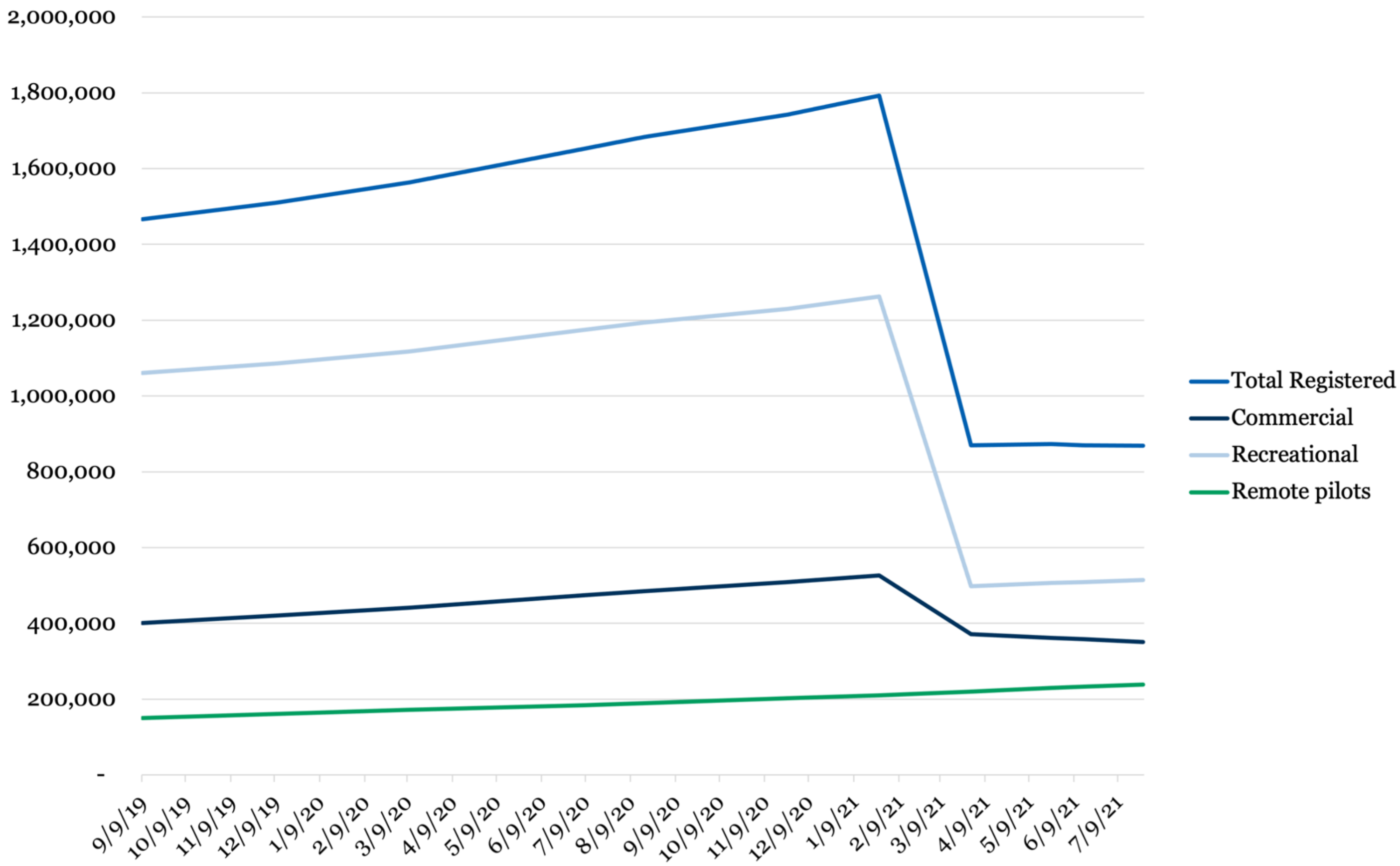
SMS enjoys a rich heritage in many sectors of commercial and general aviation. For some organizations such as Part 121 air carriers, SMS is mandatory.[32] SMS requirements for airports and Design and Manufacturing (D&M) organizations are forthcoming. The FAA has also integrated SMS throughout its Air Traffic Organization (ATO).[33] Other aviation stakeholders, such as operators of large business aircraft fleets, have also voluntarily adopted SMS.

Key to SMS is the creation of safety structures, goals, policies, and procedures for the organization. SMS encourages these to be tailored to the organization and avoids a one size fits all approach. Within this process, an organization enables and exercises its safety values in daily operations.

Characteristics of the UAS Industry

In the year since Eno released, "*Bridging the Gap*" FAA statistics show remarkable changes to the composition of the industry. [34] Still, many of these are not yet fully understood at the time of writing. For example, in our previous research we noted that FAA reported 1,683,266 UAS systems were registered by the agency.[35] As of July 26, 2021, the number of registered UAS systems has fallen 52 percent to 868,838.[36] At the same time, the number of remote pilots increased 19 percent to 238,571.[37] The following table reflects data from the preceding 22 months.[38] Further research will be required to determine if these declines in registration remain permanent.

Figure 1: Pilot and UAS Registrations



"*Bridging the Gap*," also looked at the composition of the UAS industry based on surveys and analysis of 14 CFR Part 107 (Part 107) Waiver applicants, 49 U.S.C. Section 44807 exemption petitioners, and organizations producing unmanned systems under the FAA certification rules. This data reflects an industry composed of small companies with fewer than 3 years of operating experience.

Eno found that 75 percent of applicants for Part 107 waivers identify themselves a small business either by annual revenue or by number of employees under the standard US Government definition.[39] Respondents reported income ranging from $0 to $100+M annually, with the majority reporting $1M or less in revenue.[40] Complementary data reviewed from the FAA Drone Advisory Committee (DAC) analysis showed that 61 percent of applicant companies have been in business 3 years or fewer and employ 1-4 remote operators.[41]

Commercial UAS aircraft and production certification was identified as largely a specialized activity conducted by only a small number of organizations in the United States.[42] Many of these organizations are established aerospace companies that participate in the development of military and civilian crewed aircraft. Aircraft and production certification remain expensive undertakings that require long term commitment and capital expenditures.

Yet, many smaller subgroups characterize the variety of stakeholders in the UAS industry, and it is useful to identify these for the safety discussions. The FAA Drone Advisory Committee developed a grouping of operators in their report, "Task Group 8: Safety Culture – Discussions and Recommendations.[43] These groups include:

- Traditional Aviation
- Recreational/Community Users
- Small Commercial Operators
- National UAS Operators

FAA's NextGen organization offers a further informative breakdown of industry participants based on the technological capabilities of the aircraft and qualifications of the operator.[44]

- **Visual Line of Sight (VLOS) Operators**: The term VLOS describes operations where the pilot of the UAS flies the vehicle so that it always remains within their direct visual contact. FAA notes, "VLOS is not predicated upon data exchanges with other UTM (unmanned air traffic management for UAS) participants."[45]
- **Beyond Visual Line of Sight (BVLOS) Operators**: The term BVLOS describes operations where the pilot of the UAS flies the vehicle along a route of flight where it cannot be seen directly by the pilot. "As such, they are reliant on various technologies to safely operate in the NAS. "[46] BVLOS can be further broken down to reflect two distinct aircraft capabilities enabled by new technologies:
    - **Electronic Path Enabled:** This technology allows for routes of flight to be uploaded to the aircraft enabling it to follow a predetermined path set by the pilot without the need for active control from the ground.
    - **First Person View (FPV):** This technology consists of a live streaming camera on the aircraft which provides a picture to either a monitor on the ground, such as the screen on a mobile device, or goggles that the operator may wear. This allows the pilot on the ground to remotely control the aircraft from the same perspective as would a pilot onboard.

Although the FAA is currently evaluating ways to enable more BVLOS operations in different classes of airspace, using different technological means to promote greater access to the NAS, there is still significant research and testing that needs to take place in this area.

Stakeholder Collaboration

Our research paints a very rich portrait of an industry with many internal and external interdependencies. As users of the NAS, the UAS industry is inextricably linked to traditional NAS participants such as general and commercial aviation, air traffic controllers, and pilots. A new twist is the addition of local communities as key stakeholders on matters such as privacy and land use within areas under their jurisdiction.

These groups of stakeholders share a common need for safe and secure operations with the UAS industry and are key partners in dialog on safety. Creating a common frame of reference and language for approaching safety issues remains a work in progress. But these are necessary to establish goals and set priorities to provide confidence to the American public.

1.2 Public Policy Issues

While much more needs to be understood on the applicability of specific aviation safety measures to the industry, several key public policy questions have been identified during this research on high-level matters. These are:

How Do We Incentivize Stakeholders to Stay at the Table to Have Safety Conversations?

Our research shows that message fatigue may be affecting the UAS industry. Interviews with industry experts reveal concerns that too often the message from traditional aviation stakeholders, "sounds too much like 'be more like us.'"[47] This they fear may lead to loss of acceptance of any safety messages from traditional aviation.

How Widely Should Outcome and Performance-Based Regulation Be Employed by FAA for UAS?

In 2018 the FAA included in their Strategic Plan several transformation initiatives emphasizing the need to shift to performance-based regulations for safety.[48] This type of regulation evaluates outcomes, rather than compliance with written procedures.[49] Yet, an industry may need a certain level of maturity and experience with traditional regulations to properly employ performance-based measures. Formally assessing the maturity of the UAS industry may be necessary by the FAA to determine the extent, if any, performance-based regulation is used.

What Is the Appropriate Mix Between Voluntary and Compulsory Measures?

The industry executives we spoke to link the success of voluntary safety measures to an understanding of "knowing the right thing to do." Whereas they viewed compulsory measures necessary in situations where information was lacking or intense competition clouds judgment.[50]

Eno's previous research revealed that UAS operators under Part 107 reported the need for a larger general knowledge base in many areas.[51] Combined with perspectives from several of the experts we spoke to noting the highly competitive nature of UAS industry, regulators may wish assess the current regulatory mix."[52]

Another aspect of this question is how to avoid a regulatory model that becomes overly prescriptive? Under SMS, regulated parties are granted the flexibility to determine their pathway to attaining safety outcomes in this framework. Such strict models may work against the purpose of and incentive for Safety Management Systems.

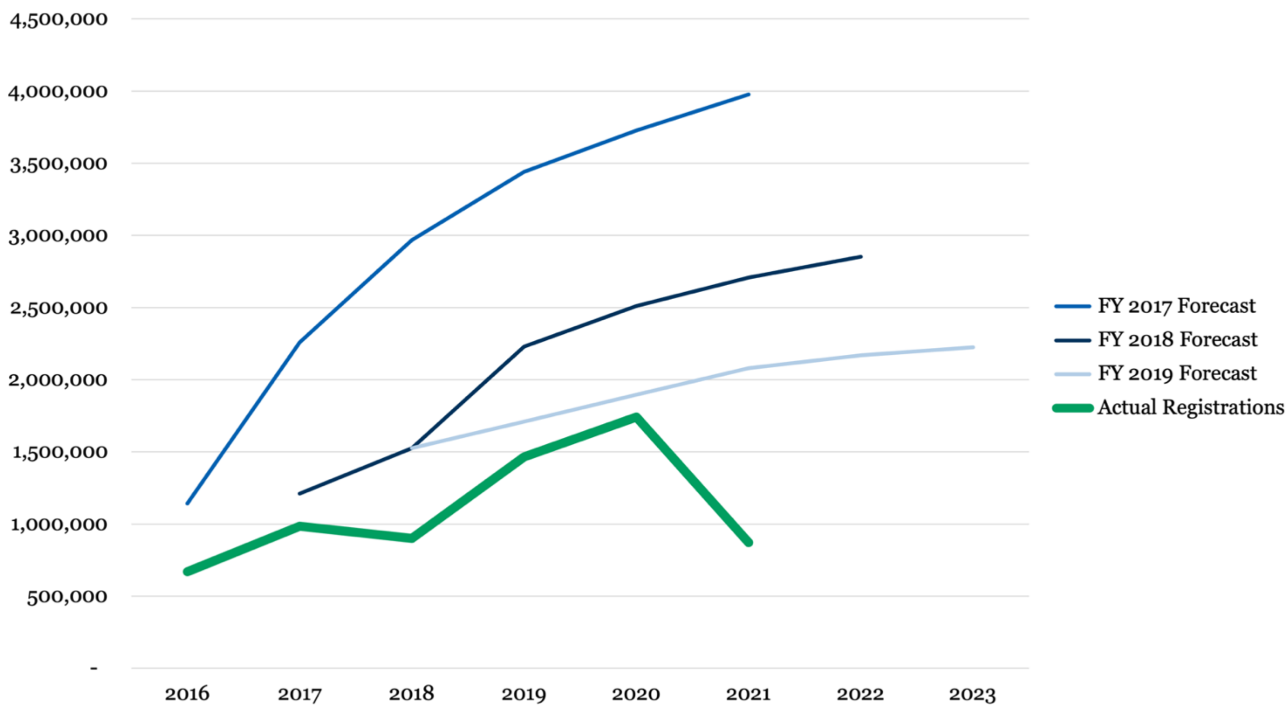
What Resources Does the FAA Need to Support Consistent Oversight of the UAS Industry?

The roughly 800,000 to 1,600,000 registered, and unknown number of unregistered UAS systems, present the FAA with an enormous regulatory challenge in the areas of oversight and enforcing accountability. The explosive growth of this technology was never fully anticipated or forecast by either Congress or the FAA. The chart below compares forecast UAS aircraft sales data from 10 years of FAA Strategic Plans against the number of UAS aircraft registered by the FAA.[53]

With most of this growth occurring between 5-year FAA reauthorization cycles (2012, 2018) few opportunities existed to match funding to growth. With many foundational regulatory processes in place covering registration, remote identification, flying over people, and light at night, Congress has a stabilized industry to evaluate for future funding.

This funding may need to address several areas: FAA staffing for administrative and enforcement personnel, industry training and educational efforts, expansion of safety programs such as CAST, Aviation Safety Information Analysis and Sharing System (ASIAS), and the Aviation Safety and Reporting System (ASRS). Further, separately funded entities devoted to UAS safety research, could be created to provide the capabilities found in other DOT initiatives, such as the Volpe National Transportation Systems Center.

Figure 2: Forecast sUAS Systems vs. Registration Data



Can Safety be Enhanced Through a Licensing Frameworks?

Part 107 governs the operation of UAS weighing under 55 pounds in the United States. It requires users operating UAS for business, commercial operations, non-profit work, or flying for educational purposes to obtain a Remote Pilot Certificate (RPC) with a small UAS rating.[54] (Pilots with existing Part 61 certificates may apply to the FAA for the addition of remote pilot privileges to their license.) Users who engage in recreational flying of UAS do not require an RPC but must follow safety guidelines in Part 107 and those of an FAA recognized Community Based Organization (CBO).[55]

Both RPC and recreational pilots may operate highly automated and complex UAS systems. These can include aircraft with the capability to follow electronically created paths, navigate by means of First Person View (FPV), and possess jet engine technology. The lack of linkage between an aircraft's technology and pilot licensing contrasts with traditional Part 61 licensing for traditional aviation. Under Part 61, increasing the complexity of an aircraft's systems and/or its type of operation may require the pilot to obtain additional certificates, ratings, and authorizations. For example, pilots wishing to fly in clouds must obtain the training and demonstrate competency for an Instrument Flight Rules (IFR) rating. Similarly, pilots wishing to operate aircraft with multiple engines must obtain a multi-engine rating.

Another aspect of the Part 107 licensing regime is that it is not associated with a skills path. For example, a private pilot can train to become a commercial pilot. That commercial pilot can then train to become an Airline Transport Pilot. Each of these transitions builds on previous training and demonstrations of competency. Such skill building does not exist within Part 107.

How Do We Know if Regulated Parties Comply?

Currently, few mechanisms exist for the FAA to monitor and assess whether users comply with Part 107 rules. A key finding in Eno's 2020 report was that applicants use the Part 107 waiver process only for straightforward waivers. More complex operations are either not performed at all or most likely done without the required regulatory approval.[56] A cursory glance at various YouTube channels supports the idea that fear of encountering representatives of the FAA may not have a deterrent value in various parts of the UAS community.

Which leads us to solutions that either involve increasing the size of the agency and expanding its footprint and/or delegating certain enforcement authorities to local government. Congress certainly can provide additional budgetary resources to FAA if it believes a larger organization is necessary. However, as FAA has defined UAS as aircraft, delegation of authority to state, tribal, and local jurisdictions may be difficult or impossible under current law.

2.0 The Framework of Aviation Safety

This section covers in greater detail the framework of aviation safety and its applications to UAS. It explains how traditional safety tools used by industry and regulator interact and how each contributes to safe day to day UAS operations. Also discussed is the link between the effectiveness of safety measures and an organization's "safety culture." Finally, we explore the tie between safety culture and the use of Safety Management Systems (SMS).

2.1 The Traditional Tools of Aviation Safety in Detail

The previous section introduced the four traditional tools of aviation safety: regulation, education, data, and tradition and culture. This section provides greater detail on how they work and many of the challenges the UAS industry faces in each. These tools contribute to the safety framework of the UAS industry and contributes to minimizing risk to the public and operator but do not guarantee a successful or safe outcome.

Regulation

Regulations provide the framework for safely operating UAS in the NAS and set a base level of expectations of the UAS industry.[57] They prescribe, in certain cases, how UAS systems or components should be manufactured, the base knowledge and certification required of operators, and operational procedures that contribute to safe flight. Regulation also allows for a framework of oversight and compliance through which FAA can review actions of individuals or even that of an entire industry's integration into the NAS.

The FAA regulates UAS under authorities granted to it by Congress. These most notably include Public Law 112-95 (The FAA Modernization and Reform Act of 2012), Public Law 114-190 (The FAA Extension, Safety, and Security Act of 2016) and Public Law 115-254 (FAA Reauthorization Act of 2018).[58,59,60] Rules prescribed by the FAA governing UAS systems are found in the Federal Air Regulations (FARs). These include: 14 CFR Part 107, Small Unmanned Aircraft Systems, the main body of regulations for UAS systems under 55 lb and 14 CFR part 21, Certification and Production Certification.

The FAA Administrator has the authority to use waiver, exemption, and certification processes to address situations where applicants seek to operate outside of existing regulatory standards or where none exist. In *Bridging the Gap*, the report noted that these mechanisms dominate and, "oversight currently functions largely on a 'by-exception' basis."[61]

Larger and/or more complex UAS must be approved through the traditional aircraft certification process. Certification is required for UAS to participate in highly controlled airspace, carry people or products for hire, and execute all operations defined as high risk by the FAA. UAS aircraft entering these processes are evaluated much in the same way as their traditional aircraft analogs.

For some functions, the FAA employs a regulatory strategy based on performance-based outcomes. Rather than prescribing a set of rules or operational procedures, desired safety objectives are issued by the FAA. Then it is up to each regulated party to choose the way they intend to achieve the outcome and submit a Means of Compliance (MoC) letter to the FAA for approval. In many cases, standards organizations or the FAA publishes means to comply with safety objectives and the regulated party may choose one of these or develop their own. In cases of aircraft modifications required by the FAA through Airworthiness Directives (AD), a similar process called Alternative Means of Compliance (AMOC) exists.

The FAA also uses non-regulatory instruments to provide guidance to the UAS industry on critical safety topics. These documents are called Advisory Circulars (AC) which provide means, but not the only means, that the FAA finds acceptable to comply with certain requirements. The agency also promulgates approved best practices. These are not mandatory, and parties are not obligated to use ACs. Yet, our research noted that the industry views these documents as anything but optional and feels pressure to use them, especially in those cases where certification activities are tied to continued federal funding.[62]

The FARs also specify licensure, testing, and required training for various categories of aviation stakeholders. For instance, certain aviation professional who construct or repair aircraft systems may need to hold an Aircraft and Powerplant Certificate (A&P). Similarly, UAS pilots require a Remote Pilot Certificate (RPC). These and other certificates are awarded after completion of required testing, training, and in some cases demonstration of skills.

The agency also convenes advisory committees under authorities granted to it under The Federal Aviation Act of 1958.[63] These bodies tend to be at the forefront of collecting industry perspectives that the FAA may use to evaluate critical issues. For instance, the FAA convened the Unmanned Aircraft Systems (UAS) Identification and Tracking Aviation Rulemaking Committee (ARC), Unmanned Aircraft Systems (UAS) ARC, and UAS in Controlled Airspace ARC in anticipation of rulemaking activity in these areas. Perspectives typically cover topics ranging from technical considerations, policy implications, to cost estimates.

Other FAA sponsored or supported advisory committees include the Drone Advisory Committee (DAC), Commercial Aviation Safety Team (CAST), General Aviation Joint Steering Committee (GAJSC), UAS Safety Team (UAST), and the Safety Oversight and Certification Advisory Committee (SOCAC). These and other collaborative bodies collect and analyze data critical to safe operation, manufacture, and equipage.

Internal policies also guide FAA as it provides oversight to the UAS industry. On October 4, 2019, the agency published Order 8040.6 established the methodology for assessing and identifying risks and evaluating the effectiveness of the proposed risk mitigations in support of UAS requests for operation.[64] These policies assign roles and responsibilities across the agency, as well as procedures to allow a consistent approach to risk evaluation in Part 107 waivers or Section 44809 petitions.

Education

Education represents the exchange of the body of knowledge required of individuals and organizations to operate UAS systems. Going far beyond the technical aspects of how an aircraft functions, it also includes proper ways to analyze risks and develop plans to mitigate threats. In aviation, this body of knowledge grows with each new data point regarding the technical capabilities of aircraft and the how humans interface with it.

In crewed aviation, the knowledge required of an operator or manufacturer scales with the complexity of the aircraft, component, or airspace operation. For example, a holder of an Airline Transport Pilot certificate requires a broader and more detailed knowledge base than that of a Private Pilot certificate holder. The FAA uses both written and oral tests of applicants for initial issuance and in cases, recurring certification.

The issuance of an FAA Remote Pilot Certificate (RPC) depends on successful completion of a knowledge test. This covers areas such as regulations, airspace, weather, emergency procedures, performance, and human factors.[65] In addition, a recurrent test on aeronautical knowledge must be taken every 24 months. Beginning by 1Q 2022, operators of recreational UAS will need to take The Recreational UAS Safety Test (TRUST) as mandated by Congress.[66]

The FAA also supports Part 107 RPC applicants through resources such as the "*Pilot's Handbook of Aeronautical Knowledge,"* test study guides, and practice exams. The FAA provides continuing UAS educational resources through several different fora, including the annual FAA UAS Symposium, National Drone safety Awareness Week, webinars, online community engagement toolkits, and operational best practice manuals.

Industry standards organizations and their international partners are closely linked to both regulation and education. Of note, ASTM, formerly the American Society for Testing and Materials and the Society of Automotive Engineers (SAE) are working on establishing levels of knowledge and best practices in core disciplines within the UAS industry. ASTM Committee F38 on Unmanned Aircraft Systems plays a leading role in identifying and developing needed technical and operational standards for UAS. Similarly, SAE S-18 / EUROCAE WG-63, Aircraft and Systems Development and Safety Assessment Committee and SAE S-18A UAS Autonomy WG / EUROCAE WG-63, SG-1 have been focusing on safety through the lens of risk management and systems engineering. Additionally, the Association for Unmanned Vehicle Systems International (AUVSI) sponsors the Trusted Operator Program (TOP) which certifies applicants demonstrate conformance with over 300 established standards, policies and procedures.

Yet, despite these initiatives, Eno found in 2020 a need for more education opportunities and more resources expressed by respondents.[67] Specifically, respondents of the survey requested greater support from the FAA in the areas of best practices, approved procedures to demonstrate compliance, risk management frameworks, and hazard identification.[68] Eno found that lack of knowledge manifested itself in a Part 107 waiver process that appeared to be dominated by filling out applications based on publicly available templates from the internet and not knowledge.[69]

Data

The manufacture and operation of aircraft generate enormous amounts of data. Key uses include calculating the failure potential of components down to the supplier level and logging inflight aircraft performance. Further, trends and associations within data sets previously unable to be inferred by other technologies can be identified using machine learning (ML) technology and artificial intelligence (AI). The uses of data appear endless.

Popular culture largely associates data with accident reconstruction. Certainly, investigators can and do recover information from “black boxes,” more properly referred to as flight recorders, to build a picture of the moments leading up to an incident or accident. Often, the number of data channels captured by a “black box” allow this to be accomplished to a high degree of fidelity. Yet, as valuable as data is for accident reconstruction it is even more valuable in the field of accident prevention.

Accident prevention begins with the construction of aircraft with well tested and understood parts. Then as aircraft accumulate flight hours, data on component performance may be used to validate construction techniques and establish durability and reliability (D&R) benchmarks. The FAA uses analyses such as these to inform development of new regulations on aircraft and production certifications, which in turn may result in changes in training, manufacture, and revised operational limitations.

Aircraft also collect inflight data from pilot flight control movements, flight path, irregular occurrences, and system performance. For example, flight data may contain event information leading up to and immediately after an aircraft warning system provides the pilot with an alert. Thereby painting a picture consisting of action and reaction which may be used to assess the performance of the pilot and aircraft during an event. A series of identical events and reactions can be compared to assess whether larger matters such as pilot training or aircraft systems need modification.

The most dramatic example of using data to enhance aviation safety can be found in the achievements of the Commercial Aviation Safety Team (CAST). Using data from voluntary programs such as the Aviation Safety Action Program (ASAP), Flight Operational Quality Assurance (FOQA) program, National General Aviation Flight Information Database (NGAFID), and Air Traffic Safety Action Program (ATSAP), CAST contributed to the reduction of the fatality risk for commercial aviation by 83 percent from 1998-2008.[70] For this work CAST received the prestigious 2008 Robert J. Collier Trophy.

CAST demonstrates effective sharing of data provides the most value to aviation. Data sharing would not be possible without a series of federal protections granted to the data provided and analyzed by certain industry and government partnerships. Section 49 U.S.C. 40123 specifically protects voluntarily provided safety information from disclosure to encourage persons to provide the information to the FAA.[71] Further, in this same section, the FAA extended protections to CAST information from disclosure.

Mutual trust among participants plays a key role in contributing to CAST's success. Commercial aviation remains a highly competitive and highly regulated global industry. Prior to CAST, airlines were reluctant to share information among themselves. On one hand, anti-trust laws regulating the airline industry made sharing of any competitive information illegal and subject to serious penalties. On the other, formal sharing safety of information was done largely in smaller controlled forums such as trade association safety committees. CAST represented a new paradigm of industry-wide sharing of information among highly competitive partners. This meant building trust and viewing safety as a collaborative issue and not a competitive one.

The UAS industry faces the same challenge today as CAST did prior to starting up. It is highly competitive, uses technologies protected as trade secrets, and does not enjoy immunity for information sharing. In fact, a complex web of international, federal, and state regulations discourages sharing and analyzing data collected by uncrewed aircraft. Some laws require full disclosure of any data obtained by the collection process. Others err to the side of privacy if collected information contains personally identifiable data.

The challenge for regulators with a new industry, such as UAS, is extending protections and building trust among industry participants. The former may be achieved by extending those same data protection provisions for bodies like CAST to the UAST and similar partnerships. The later remains a challenge for industry participants to overcome. Underlying all of this, the FAA needs to identify the type of data that should be shared by and among the UAS industry, starting with regulations that specify the data the FAA needs.

Tradition and Culture

Tradition and culture serve as the common language and set of values that drive individual and organizational behaviors related to safety. These are rooted in history, shared practices, organizational values, and hiring practices. At the most fundamental level, they represent the proverbial "way we do things." In aviation, often these "ways of doing things" came into practice as the result of powerful lessons emerging from analysis of terrible tragedies or from the continued successful use of existing policies and procedures.

Tradition and culture remain some of the most potent and influential forces in aviation. They are difficult to "train out" once established and in some cases may take years to revise. Yet, established repetitive practices contribute immeasurably to enhancing safety. For example, the use of checklists by maintenance professionals and pilots dates to the early days of aviation. In 1935, an Army Air Corps Boeing Model 299 aircraft crashed on takeoff from Wright Field as the result of a control locking mechanism being left attached to the aircraft flight controls. This lock prevented the pilots from moving the flight controls and made the aircraft uncontrollable.[72] As a result of the accident, the Army Air Corps developed and mandated the use of checklists, which remain in use to this day.[73]

Individuals absorb tradition and culture through training and education but also through interactions with other professionals. The UAS industry faces steep challenges in developing its own unique culture and traditions. First, education and training remain fragmented and relatively sparse. This arises partially from regulations with few educational requirements, the relative immaturity of certain sectors of the industry, and highly automated aircraft which minimize the need for specialized training. Second, most uncrewed aircraft operators come from small organizations employing between 1-3 employees operating in relative isolation from the greater UAS industry. These factors are more fully discussed in *"Bridging the Gap."*

Equally important, organizations develop and promote their own tradition and culture. Companies hire either overtly or unconsciously to an ideal personality profile. From the words they use in employment ads to the screening of applicants through personality tests, each establishes the profile of the ideal candidate they believe will fit. Organizations also convey to employees the ideals important to them through documented goals, policies, application of financial resources, and the way they incentivize performance. In heavily regulated industries such as aviation, how a company responds to government mandates and best practices further shapes employee attitudes and values.

Organizations involved in unmanned aviation often face a twofold problem. First, they likely come from industries having established traditions and cultures they may not favorably align with those of general and commercial aviation. For instance, the tech industry's famous "move fast and break things ethic" likely does not have any analogs in aviation.[74] Certainly, as unmanned organizations evolve, they understand this fundamental misalignment, but the real question is do they have the tools, resources, and time to break from this tradition? Another hurdle for the UAS industry is that regulators and other stakeholders will over analyze and perhaps penalize it for once being associated with this ethic.

Second, tradition and culture evolve over time, and these remain a work in progress for this relatively new industry. Often tools such as industry standards, data analysis, and education can fill in the gaps. In uncrewed aviation, the existing body of standards could be considered the most mature tools. However, progress and adoption appear to have reached a plateau in that very few standards are being recognized by the FAA. If the FAA wants to accelerate creation of a unique uncrewed tradition and culture, one strong tool would be widespread acceptance of industry standards. That in turn will drive educational resources to support their understanding and use. Finally, as discussed in the previous paragraphs, support for data analysis programs will not only enhance safety but in this case contribute to the building of culture and tradition.

2.2 The Mechanics of Day-to-Day Safety

The previous sections discussed the conceptual underpinnings of the traditional tools contributing to aviation safety. Together and individually, they point people and organizations in a direction, but do not provide guaranteed outcomes. They remain theoretical until they are used to build policies and procedures that direct day to day actions. The translation of theory to practice depends almost entirely on the perspective through which an organization views regulation, education, data, and tradition and culture. We call this perspective "safety culture."

The FAA defines safety culture as "a collection of beliefs, perceptions, and values that all employees share in relation to the risks that exist while conducting operations within an organization. It is what each person believes about the importance of safety and how he or she contributes in light of that belief."[75] In effect, safety culture drives how an organization understands and react to risks.

As common in any industry, UAS operators and manufacturers face a seemingly endless range of risks on any given day. Common categories of risk identified by the FAA facing UAS operators include, but are not limited to:[76]

- **Pilot:** An individual needs to possesses the knowledge, skills, and training required for the mission to be flown. Additionally, physiological factors such as health, fatigue, use of medication or alcohol, and stress contribute to risk.
- **Aircraft:** The equipment selected for a given mission must be capable of performing all required tasks. This includes proper maintenance, preflight inspections, and endurance.
- **Environment:** Factors such as weather, terrain, and airspace must all be suitable for the intended duration of a flight. These must also be evaluated for any potential emergency situations that may arise.
- **External pressures:** These include pressures internally generated within the pilot reflecting an "I must get the job done" attitude as well as pressure caused by clients or end users of the data to be collected by the UAS.

The FAA outlined categories of risk faced by UAS manufacturers.[77] These include, but are not limited to:

- **Workplace conditions**: Typically consist of risks associated with equipment, human-machine interfaces, quality of information contained in procedures and guidance material, physical environment of the workplace, and the relationship between the company and the regulator.
- **Human error:** Time pressures, quality of teamwork, group norms, shift schedules, and availability of instruction all factor into this category.
- **System processes:** This category covers the organizational structure which allocates responsibilities and authorities in the workforce, procedures used by the organization to conduct business, and the ways in which performance is measured.

None of these areas are all inclusive, nor do they apply to all organizations, as risks will vary from organization to organization. However, each needs to be identified and addressed so activity can be conducted safely.

Formally Managing Risk

The process of identifying and addressing risks within a flight operation or an organization is commonly referred to as Safety Risk Management (SRM).[78] Using SRM, an organization builds a formal enterprise-wide, disciplined, and documented decision-making process to address safety risks. This consists of five components: system design/task analysis, hazard identification, risk analysis, risk assessment, and risk control/mitigation. SRM educates an organization on available courses of action once a risk has been identified.

Safety Risk Assessment (SRA) is a core component of SRM which identifies hazards and quantifies the degree of risk posed to individuals, populations, or resources.[79] This is a scientific evaluation of adverse consequences and potential to cause harm. SRA serves as the foundation for all subsequent target risk analysis process including Safety Program Planning (SPP), Operational Risk Assessments (ORA), Functional Hazard Assessments (FHA), and Preliminary Safety System Assessments (PSSA).

These processes typically educate "go/no go" decisions, training programs, operational restrictions, standard operating procedures, manufacturing processes, and personnel development, to name a few. They affect the whole of the enterprise daily. How well these processes are developed, executed, and revised reflect largely on an organization's safety culture or lack thereof.

Safety Management Systems (SMS) Tie Everything Together

The FAA defines Safety Management Systems (SMS) as a "formal, top-down, organization-wide approach to managing safety risk and assuring the effectiveness of safety risk controls. It includes systematic procedures, practices, and policies for the management of safety risk."[80] More broadly, it integrates safety awareness into business processes. It does this by aligning company leadership, management, and employee attitudes around safety. A well-functioning SMS provides decision making tools consisting of highly documented processes for day-to-day use. SMS will be covered in more detail in Section 5.

Whereas safety culture exits in the realm of individual and organizational attitudes, SMS resides at the functional level, or proverbially, "where the rubber hits the road." Fundamentally, safety culture can either support or erode SMS. But SMS can be used to reinforce an organizations safety culture.

3.0 Strengthening the Safety Culture of the UAS industry

This section presents an analysis of possible approaches to promote adoption of safety culture and recommendations based on these for the UAS industry. The analysis includes a review of how critical industries place importance on safety culture, descriptions of historical triggers leading to regulation, and specific approaches used by DOT. Recognizing that industry participants come from varied backgrounds and organizations of different sizes, these recommendations are formulated to scale.

3.1 Safety Culture Perspectives Within Transportation & Other Critical Industries

In 1966 Public Law 89-670 created the US Department of Transportation (DOT) and established authorities for it to develop programs and policies to promote safe and efficient transportation in the U.S.[81] It established the Federal Highway Administration, Federal Railroad Administration, and the Federal Aviation Administration.[82] Subsequently, Congress authorized under DOT the creation of the National Highway Traffic Safety Administration (NHTSA), Pipeline and Hazardous Materials Safety Administration (PHMSA), Federal Motor Carrier Safety Administration (FMCSA), Saint Lawrence Seaway Development Corporation (SLSDC), Federal Transit Administration (FTA), and Maritime Administration (MARAD). Each of these DOT components share a common focus on safety culture.

DOT has provided its agencies a common definition of safety culture and directed them to promote programs and initiatives to their specific sector. DOT formally defines it as the "shared values and behaviors that demonstrate a top-down commitment to safety over competing goals."[83] For example, the Federal Railroad Administration (FRA) in 2020 issued the System Safety Program and Risk Reduction Program rule.[84] One of the requirements is a passenger railroad must have a system safety program "designed so that it promotes and supports a positive railroad safety culture."[85] The Federal Highway Administration through its Zero Death initiative promotes the Safe System approach which requires a supporting safety culture.[86] Also, in 2020 the Pipeline and Hazardous Materials Safety Administration (PHMSA) conducted a series of meeting with industry to discuss the benefits of an effective safety culture in response to the gas transmission final rule 84 FR 52180 and the pipeline final rule 84 FR 52260.[87]

Industries and regulators outside of transportation have taken similar steps. The US Nuclear Regulatory Commission in 2011 issued a Safety Culture Policy Statement which set forth the Commission's expectation that individuals and organizations establish and maintain a positive safety culture.[88] The Bureau of Safety and Environmental Enforcement of the Department of the Interior which overseas portions of the oil and gas industries published their Final Safety Culture Policy Statement in 2013.[89]

These agencies used a mixture of mandates, voluntary compliance, and published expectations to set industry set industry baselines for safety culture develop. Yet, more often than not, serious incidents or accidents served as the catalyst for these actions. The next section discusses triggers that have promoted regulatory action.

3.2 Tragedies Often Trigger Legislation and Regulation on Safety Culture

In late 2018 and early 2019, two accidents involving B737 MAX aircraft resulted in the loss of 346 passengers and crew members.[90] As part of the investigation, the FAA chartered the Joint Authorities Technical Review (JATR) to review the type certification of the flight control system of the B737 MAX. The JATR published 12 recommendations which primarily focused on aircraft certification, a holistic, airplane level approach to airplane design, and the impact of design changes on pilot training and operations. Congress later passed the Aircraft Certification, Safety, and Accountability Act. These provisions were included in Public Law 116-260 and signed by the President on December 27, 2020. The Act mandates the FAA to require manufacturers that hold both a type certificate and a production certificate issued pursuant to Section 44704 of Title 49 have in place a Safety Management System (SMS) consistent with ICAO Annex 19.[91]

Accidents involving rotorcraft also have set regulatory focus on safety culture. On January 29, 2019, a medical helicopter crashed into terrain near Zaleski, OH. The NTSB determined that the probable cause of the accident was the operator's "inadequate management of safety, which normalizes pilots' and operations control specialists' noncompliance with risk analysis procedures."[92] Specifically, NTSB noted, "the lack of a positive safety culture endorsed by management and the lack of a comprehensive safety management system."[93] The Board in its final report reiterated its previous recommendation to revise laws such that, "all Title 14 *Code of Federal Regulations* Part 135 operators to establish safety management system programs (A-16-36)."[94]

Over the road and light rail accidents have also spurred Congressional intervention. From 2000-2009, the NHTSA recorded 87 fatal crashes with 209 occupant fatalities by over the road buses.[95] In 2009, a Red Line train crashed on Washington D.C.'s Metro rail system killing nine passengers and injuring fifty-two. The NTSB cited Washington Metropolitan Area Transit Authority's (WMATA) lack of a safety culture as one of the contributing factors.[96] An outside analysis performed by the US Nuclear Regulatory Commission further detailed three contributing factors to a lack of safety culture at WMATA. These include senior management not demonstrating leadership in safety values and actions, problem identification and resolution, and lack of personal accountability.[97]

In response to these and other trends in highway, roadway, and public transportation safety, Congress passed safety-related provisions in the Moving Ahead for Progress in the 21st Century Act ("MAP-21"; P.L. 112-141) This law mandated public transportation agencies to establish, "comprehensive safety plans, thus encouraging a culture of safety."[98,99]

Tragedies like these trigger safety agencies to respond with a mixture of voluntary and compelled measures. But there is also a larger framework of continuing goals and policies set by the Department in their pursuit of national transportation safety objectives. Both steer the course of the DOT as it pursues advances in safety culture.

3.3 DOT's Approach to Drive Adoption of Safety Culture Across Transportation Modes

This section examines methods DOT and component agencies historically have used to promote adoption of safety culture. These have been applied to industries ranging from those never subject to safety culture regulation, such as the 15-passenger motor coach industry, to long-standing ones, such as commercial aviation, where safety culture concepts were first developed. The examples demonstrate that tools and regulatory models exist within DOT that may be useful in promulgating safety culture within unmanned aviation. While this industry externally appears different, DOT has successfully worked with industries in similar circumstances. In fact, there may be little need to think too far outside of the box for solutions.

Historically, DOT has been proactive and consistent in setting annual goals and targets for safety culture and implementation of safety management programs. A review of DOT

Strategic Plans for the period 2006-2022 shows targets in all-mode strategies, mode specific strategies, safety outcomes and performance measures, and internal DOT policies.[100] Promulgation is generally through a mixture of voluntary programs and compliance mandates. Voluntary approaches include education, targeted research, industry engagement, and professional publications. Compliance mandates include rules, fines, and best practice advisories that have an unwritten compliance expectation.

Voluntary Measures

Educational and reference resources*:* FHWA provides educational resources for stakeholders in support of the agency's Zero Deaths and Safe System Visions. These provide tools to promote organizational and community adoption of safety culture. Resources include outreach materials, reports, compilations of success stories, and support of research conducted by the National Cooperative Highway Research Program and assisted by the FHWA.

The FMCSA offers businesses educational resources consisting of research and technology fora, training reports, sponsored publications, multimedia messaging campaigns, and analysis of safety data. Additionally, the agency promulgates industry best practices, information on noncompliance, and sponsors research projects.

Along with activities like those of FHWA and FMCSA, FTA developed requirements for a safety certification training program mandated by Congress in MAP-21. The agency established a uniform curriculum of safety certification training to enhance the technical proficiency of individuals who are directly responsible for safety oversight of public transportation systems not subject to the safety oversight requirements of another Federal agency.[101] The course has requirements for knowledge of both safety culture and SMS.[102] The DOT also sponsors transportation institutes and primary research under different funding models.

Sponsored by DOT, Self-Funded: The John A. Volpe National Transportation Systems Center (Volpe Center) was chartered in 1970 to "serve as a federal resource positioned to provide world-renowned, multidisciplinary, multimodal transportation expertise on behalf of U.S. DOT's operating administrations, the Office of the Secretary, and other federal agencies, state and local governments, academia, and industry."[103] Unlike other federally sponsored organizations, Congress allocates no funds for the operation of Volpe, instead sponsored projects fund 100 percent of the Center's $220M budget, 85 percent of which come from US DOT and partner agencies.[104] In aviation, Volpe specializes in air traffic systems and operations.[105]

Sponsored by DOT, Funded by DOT*:* FHWA sponsors the National Highway Institute (NHI) which serves as its training and education arm.[106] DOT funds 100 percent of its budget. NHI offers instructor led courses, accredited training to fulfill continuing education needs for certification or licensure, reference manuals, workbooks, and training curriculums.

DOT Sponsored and Funded Partner NGO: The Transportation Research Board (TRB) of the National Academies of Science, provides research and analytical support of key issues facing both state highway and transportation departments and the federal government. In 2019, TRB cooperative research activities totaled $94.5M, of which $21.9M were funded directly by the DOT.[107]

Advisory Committees: DOT has established several safety advisory committees to provide advice on matters ranging from rulemaking, R&D investment priorities, exercise of safety oversight authorities, and safety standards.[108] Experts appointed by the Secretary gather to engage in targeted research, public outreach, and establish consensus on major issues facing the industry and government. These bodies severe all stakeholders as educational forums and "early warning mechanisms" for critical safety issues that may face enhanced regulatory scrutiny and rulemaking activity.

Properly used, these mechanisms provide an industry the ability and opportunity to understand, anticipate, and react to critical safety issues. Yet, voluntary measures remain just that, regardless of the goodwill and enthusiasm brought by stakeholders. Several reasons may contribute to the lack of engagement.

Change is expensive: Whether measured by training expense, changes to operational procedures, new raw materials necessitated by new standards, or capital investment, application of voluntary federal measures create new costs for an organization. As a result, many companies avoid pursuing these as they will incur a cost but not receive any regulatory credit or relief for doing so.

Product development cycles are extremely short. For high-tech industries, the ability to compete among peers by turning out successive generations of a product providing new functionality is tied to profitability. So, regulatory requirements that are common among competitors, effectively placing each at a similar disadvantage, are seen as part of a level playing field. Adoption of voluntary measures may be seen as placing additional disadvantages on an organization and in turn affecting your competitiveness.

Concerns such as these metaphorically date back to the first time a government demanded an organization change its business practices. As a result, the lack of application of voluntary measures by industry stakeholders often necessitates the need for compliance mandates, especially on time critical issues.

Compulsory Measures

Compulsory measures can either be initiated by Congress or the Executive Branch. The resulting regulations usually involve urgent or wide-ranging national reforms. An analysis of how the FTA established the Public Transportation Safety Program (PTSP) to promote the culture of safety envisioned in MAP-21 illustrates the complexities, timelines, and mechanics of this process.

In MAP-21 Congress authorized and appropriated more than $440M per year to administer provisions of law by the Federal Highway Administration and Federal Transit Administration. This wide-ranging legislation required and funded each agency to plan and execute oversight activities in areas covering infrastructure, environment, planning and realty, safety, operations, program delivery, federal lands, and research.[109]

As a first step toward implementing the culture of safety mandate, on October 3, 2013, FTA published an Advance Notice of Proposed Rulemaking (ANPRM) establishing its authority and outlining a vision for a Public Transportation Safety Certification Training Program (PTSCTP). [110] This program would be critical foundational component of the full PTSP.

To create the PTSCTP, the FTA then published requirements for an interim safety certification training program in May of 2015 FTA.[111] In Dec 2015, FTA published a Notice of Proposed Rulemaking (NPRM) seeking to have this interim safety certification adopted as the PTSCPT.[112] Finally, on June 29, 2018, the FTA published the final rule (FR) which formally created the PTSCPT and incorporated the interim certification.[113] The effective date of the rule was August 20, 2018.

The creation of the Public Transportation Safety Program (PTSP) illustrates the long road from law to regulation and the challenges regulators face. Six years lapsed from the passage of MAP-21 to the effective date of the program, which is not atypical for regulation.

Mandates in Context

Regulation ensures all industry participants have a recognized set of goals, behaviors, and procedures to direct activities toward. Similarly, they also provide the boundaries, which if exceeded, will trigger civil or criminal action against the violator. Regulations are powerful tools. Yet, they don't come quickly.

One of the challenges all regulators face is developing rules that don't become one size fits all solutions resulting in market distortions or enforceability issues. The other is turning regulation into a laundry list of procedures whose meaning to an individual and organization becomes lost over time. The most powerful regulations are those built with an implicit understanding of the ends to which you are compelled to perform certain activities.

To that end, the DOT has started adopting performance-based regulation. These types of regulations propose desired end states and leave it up to the regulated party to devise the manner in which the outcome is achieved. That manner must be approved by the regulator and that regulator may also publish suggested means of compliance.

Whether the regulatory framework aligns with prescriptive means or outcome-based performance, both demand a high degree of auditing and oversight for compliance purposes. Without these, even the most well-informed regulations risk being ignored by stakeholders.

3.4 Approaches to Support Adoption of a UAS Safety Culture

Voluntary Measures

DOT has developed many tools and supported industry activities to promote safety culture across the various modes of transportation it has oversight authority. These include encouraging standard making organizations, providing educational and reference resources, and supporting research and education institutes. The remainder of this section compares these Department-wide activities against those currently being used by FAA in support of the UAS industry to develop a baseline for subsequent recommendations in this report.

Supporting Standards-Making Organizations

Standards can build habits and inform people and organizations of better ways of doing things. The FAA has immediately available to them critical standards covering key aspects of safety such as required knowledge, training, use of artificial intelligence, aircraft performance, and design criteria. But these will remain peripheral to safe day-to-day UAS operations unless more fully embraced by the FAA.

Certainly, the FAA widely supports and participates in key international and domestic standards creation activities for uncrewed aircraft systems. Working with organizations such as, the International Civil Aviation Organization (ICAO), the European Organization for Civil Aviation Equipment (EUROCAE), the Society of Automotive Engineers (SAE), ASTM International,[114] RTCA, and the International Organization for Standards (ISO), FAA has been a key partner in helping to capture the collective expertise of the industry.

This report has identified the collaborative environment and work products of the following groups as critical to moving the UAS industry forward in the areas of safety culture and safety management systems:

- ICAO, Remotely Piloted Aircraft Systems Panel (RPASP)
- SAE/ EUROCAE, S-18 / EUROCAE WG-63, Aircraft and Systems Development and Safety Assessment Committee
- SAE/ EUROCAE, S-18A UAS Autonomy WG / EUROCAE WG-63, SG-1
- SAE/ EUROCAE, G-34 / EUROCAE WG-114, Artificial Intelligence (AI) in Aviation Ecosystem
- ASTM, Committee F38 on Unmanned Aircraft Systems
- ISO, TC 20 / SC 16 Unmanned Aircraft Systems
- RTCA Special Committee 228

Despite a seemingly robust body of standards having been developed by these organizations for aviation, very few have been formally recognized and incorporated into regulation by the FAA. Through August 16, 2016, as reported by the National Institute of Standards and Technology, *Standards Incorporated by Reference Database (SIBR)*,[115] only seven industry standards have been fully incorporated by FAA into regulation. These include two developed by SAE on evaluating aircraft noise and seven from RTCA on navigation technology. While critical to aviation safety, they were not developed specifically to support UAS operations. In contrast, the NHTSA and the FMCSA have incorporated 428 consensus standards into federal regulations. Many of these are contained in the body of auto safety regulation known as the Federal Motor Vehicle Safety Standards (FMVSS).

In the future this may change as FAA more fully incorporates performance-based regulations into their oversight programs. For example, the recent Remote ID Final Rule, "encourages consensus standards bodies to develop means of compliance and submit them to FAA for acceptance."[116] Further, FAA Advisory Circular 107-2A which provides guidance for conducting small uncrewed aircraft systems in the NAS recognizes the role of consensus standards bodies and introduces a role for these organization in developing a broader range of Means of Compliance solutions for Part 107.[117]

Yet, Means of Compliance (MoC) are used to support edge case operations that don't easily fit within the existing body of Federal Aviation Regulations (FARs). These are the exceptions to the rules. Why does that matter? As a relatively new industry, operators and manufacturers would benefit from access to best practices and learnings for even the most basic elements of safe operations. This should be the perspective from which FAA views standards: *tools to build that foundation.*

These tools come with a cost, though. Many are behind paywalls and come with a price tag, which can be high for individuals. The following table contains examples for various standards products.

Table 2: Prices for UAS-Related Standards Documents

Standard	Price
ASTM Standard F3411 Standard Specification for Remote ID and Tracking[118]	$88
SAE ARP 5707-2010 Pilot Training Recommendations for Unmanned Aircraft Systems (UAS) Civil Operations[119]	$85
ICAO Manual on Remotely Piloted Aircraft Systems (RPAS) (Doc 10019)[120]	$198

FAA has the authority to make standards accessible and make them impactful in the realm of safety education. These can be incorporated into regulation as a stand-alone set of foundational best practices and standards, as done by other DOT Agencies.

Recommendations for Standards

Congress should mandate the FAA to create Federal UAS Safety Standards.

The FAA should charter an ARC and authorize it to identify processes whereby industry standards on safety and SMS become incorporated into Federal UAS Safety Standards.

The FAA should identify and promulgate a body of foundational safety standards and SMS for UAS through AC and SAFO processes.

Educational and Reference Resources

The FAA has accelerated development of educational resources for operators. The agency has created a webpage devoted to the various activities and publications available to the UAS industry. Content includes the Code of Federal Regulations, Advisory Circulars, Policies, Orders, and educational publication. The FAA also produces conferences and events for stakeholder education.

However, this information has a few shortcomings. First, it is presented as a simple list of materials and events. Individuals and organizations from novice UAS operators to commercial enterprises currently have few ways to identify the specific educational or training material that applies to their needs. Nor is it easy to understand the information FAA has identified as of value to various types of possible UAS operations. Second, the materials may be outdated or not focused on the UAS industry.

For example, it will not be until the end of 2021 when the foundational Aeronautical Information Manual (AIM) used by traditional aviation, will include chapters specifically on uncrewed operations. Further, the Pilot's Handbook of Aeronautical Knowledge is five years out of date and its one reference to uncrewed aviation notes, "Regulations regarding unmanned aircraft systems (UAS) are currently being developed and are expected to be published by summer 2016 as 14 CFR part 107."[121]

As noted earlier in this paper and in *Bridging the Gap*, a chief concern in the UAS industry is that more information on safety and best practices needs to be made available to them. The current body of resources would benefit from greater accessibility and applicability.

Recommendation for Education and Reference Resources

The FAA should organize the educational materials it is providing to industry according to testing, pilot certification, and Part 107 waiver submission needs.

Another foundational issue related to education is that a new UAS user rarely receives guidance from systems manufacture on the education necessary on how to operate a vehicle safely in the NAS, the type of licensure required, or best practices. On one hand, vehicles with advanced technologies for collision avoidance and detection of manned aircraft offer a high degree of inherent safety capabilities. Yet, without education, the human element remains a weak point.

The most common UAS operated by recreational and commercial operators is usually Commercial Off the Shelf technology (COTS) purchased from a big box retailer. Essentially, you either walk out of the store or have a box delivered to you with a UAS system. Open the box and you become a UAS pilot.

Eighty six percent of all UAS operating in the US are manufactured by just four companies.[122] The following table lists the type of information typically supplied to the purchaser at time of purchase for current UAS products. Information has been gathered from manufacturer websites and purchase of UAS from a national retailer.

Table 3: Information Included with Purchase of Select Small UAS Systems

	User Manual	Quick Start Guide	General Safety Guidelines	License Requirements* (Country Sold)	Regulatory Requirements** (Country Sold)
DJI Air 2S	Y	Y	Y	N	N
DJI Mavic Air 2	Y	Y	Y	N	N
DJI Mavic Mini	Y	Y	Y	N	N
DJI Mavic Pro	Y	Y	Y	N	N
DJI Phantom 4 Pro V2.0	Y	Y	Y	N	N
DJI FPV	Y	Y	Y	N	N
Intel*** Falcon 8+	Y	Unknown	Y	N	N
Yuneec H20	Y	Unknown	Y	N	N
Yuneec Typhoon H Plus	Y	Y	Y	N	N
Yuneec Typhoon H3	Unknown	Y	Unknown	N	N
Parrot Anafi	Y	Y	Y	N	N

**Commonly regulated areas in Part 107: Maximum flight altitude, maximum speed, rules for flight over people, observer requirements, and weather minimums.*
***Remote Pilot in Command Certificate requirements*
**** This systems is still sold, but the manufacturer no longer produces it.*

The information in the table illustrates manufacturers expect the purchaser to be responsible for obtaining the required knowledge about FAA regulations governing the use of the uncrewed system. For new users unfamiliar with aviation or the FAA, this expectation represents a monumental hurdle both in gaining the information necessary to operate safely and operate within the bounds of national legislation. How can we expect a new user to guess if they need this information or where to find it.

Recommendation for Commercial Sales of UAS Components

The FAA should mandate manufacturers of UAS aircraft and radio control transmitting systems inform the purchaser of regulatory requirements for registration, safe operations, and licensure at the time of purchase.

Lacking manufacturer guidance, some users may encounter FAA resources such as the Drone Zone or the Unmanned Aircraft Systems webpage. A cursory review of these tools would naturally direct the novice user to Part 107 and perhaps the RPC certificate. It's instructional for this discussion to look at the economics of what happens next.

In the FAA Aerospace Forecast Fiscal Years 2021-41 the agency determined that the average price of a UAS system was around $750 or less.[123] If the new user desires training on Part 107 and to receive a RPC certificate the follow expenses would be incurred:[124]

The following table shows a representative sample of Part 107 academic instructional fees.

Table 4: Sample of Part 107 Academic Instructional Fees.

Course	Price
Drone Launch Academy	$149
Drone Pilot Ground School	$299
Clemson University	$1,500
John Peltier Part 107 Prep	$129
King Schools	$129
Montgomery Community College	$181
Pilot Institute	$149
SkyOp Online	$395
Wake Technical Community College	$500

The median price of these typically advertised courses: $331
The average price of these typically advertised courses: $530

Costs are also associated with taking the Part 107 test:

- FAA testing Fee: $65.00 + Testing Center Fee: $109 = Total: $174.00

This would total:

- Low: $129 + $174 + $5 registration= $308 or 41 percent of the purchase price of the UAS
- Median: $331 + $174 + $5 registration=$510 or 68 percent of the purchase price of the UAS
- High: $1,500 + $174 + $5 registration= $1,679 or 224 percent of the purchase price of the UAS

The data suggests that even the most basic training to become a Remote Pilot in Command (RPIC) would be proportionately expensive compared to the purchase price of the UAS. If the applicant chose to only receive the least expensive online training it would still represent 17 percent of the cost of the UAS system. Expense, accessibility, and understanding of the required knowledge that must be gained by a US operator remain disincentives to safer operations.

Another perspective worth mentioning is that this educational gap does not exist across the entire industry. UAS subject to certification processes usually come with educational requirements and operational procedures mandated by the FAA. But those systems represent the smallest share of the domestic UAS market.

Recommendation for Cost of Educational Testing

To broaden adoption of safety culture principals by the UAS community, the FAA should provide low cost or no cost basic testing through the Basic Part 107 RPC license proposed in this paper.

Cost Recovery

In December of 2019, the GAO reported that the FAA's $110M per year budget for UAS integration has not been associated with long-term funding mechanisms by either Congress or the Agency.[125] Further, items such as the UAS registration fee, currently set at $5, did not reflect the true costs to FAA to administer this program. As integration activity increases, future Agency funding needs must be taken into consideration. While it is outside the scope of this research to evaluate ways in which the UAS industry can cover their administrative costs, the issue is undoubtedly tied to balancing the costs of training and ensuring that the UAS industry supports its associated costs at the FAA.

Recommendation for Cost Recovery

Similar to recommendations in the GAO-20-136 report, the Federal Aviation Administration should further review the recovery of UAS-related costs and establish criteria for future fee designs.

Centers of Excellence

Congress mandated the establishment of FAA Air Transportation Centers of Excellence in the Omnibus Budget Reconciliation Act of 1990 Public Law (P.L.) 101-508, Title IX – Aviation Safety and Capacity Expansion Act. Thirteen Centers were designated and six remain in operation at the time this report was prepared. This includes the Unmanned Aircraft Systems Center of Excellence, also known as the Alliance for System Safety of UAS through Research Excellence (ASSURE).

In FY 2020, the FAA provided $13.4M in cost sharing or matching to ASSURE. Of that amount, $2.48M funded research in pilot proficiency, safety case development, and risk-based training.[126] In comparison, the Volpe Center receives $187M/year from DOT and the TRB, $21.9M/year. Certainly, funding of ASSURE represents a significant investment by FAA in areas critical to safety. However, fundamental questions arise. Does research from ASSURE convert into easily accessible education resources for the industry? Can ASSURE provide training resources to a broader community of UAS operators and manufacturers? Does the FAA adequately fund ASSURE?

Recommendations for Centers of Excellence

Congress should fund and the FAA should develop a national institute of UAS safety modeled after the National Highway Institute.

FAA should increase funding of ASSURE programs and prioritize expanding the body of foundational knowledge required by pilot and industry applicants to understand the application of safety culture and SMS.

FAA should fund ASSURE programs which develop Means of Compliance (MoC) that UAS operators may use, and the agency will accept for common Part 107 waiver operations.

Unmanned Aircraft Safety Team (UAST)

UAST is the uncrewed analog of CAST. As previously noted, CAST collaboration and work product has demonstrably increased the safety of commercial aviation. UAST appears to be perfectly positioned to provide data gathering, analysis, and sharing of data to promote the overall safety of the UAS industry.

Several hurdles remain. UAST needs funding to expand its footprint in data analysis and industry outreach. Despite pioneering work in safety culture and safety management systems, few products have achieved critical mass as widely used tools by industry. UAST remains largely removed from the greater unmanned community.

UAST needs federal protections for the data which it analyzes and the collaborative mechanisms it uses. Such protections would support the FAA's use of data to determine the effectiveness of safety enhancements, encourage voluntary participation by industry in sharing programs, and provide information to mitigate underlying safety hazards. This needs to be one of the highest priorities for Congress and the agency if UAST is to achieve the same level of success as CAST. Further, the FAA must define the data it needs from industry more tightly to make regulation and oversight effective.

Finally, just as CAST relies on the Aviation Safety Information Analysis and Sharing (ASIAS) program, UAST needs its own dedicated information processing resource. It also needs programs to collect and share data from industry that are analogs to the Aviation Safety Action Program (ASAP), Flight Operational Quality Assurance (FOQA) program, and Air Traffic Safety Action Program (ATSAP). Each of these programs rely on data sources and governance structures derived from manned aviation and converting them for use by UAST may be prohibitive or perhaps impossible.

Recommendations for Unmanned Aircraft Safety Team (UAST)

The FAA Administrator should issue a Notice of Order which designates information provided to the UAST as protected from public disclosure.

The FAA Administrator should direct the Drone Advisory Committee (DAC) to identify specific data generated during UAS operations that can be aggregated and used to identify and reduce safety risks. These data fields should be published for use in a subsequent Advisory Circular.

Congress should fund programs similar to ASAP, FOQA, and ATSAP for collection and analysis of UAS data by the UAST.

Congress should program additional FAA resources to support the ongoing operations and expansion of the UAST.

Non-Regulatory Guidance

The FAA also has available to it opportunities to produce quasi-regulatory guidance for the UAS industry. While not binding or having the force of law, they can convey recommended actions that the agency believes are effective in addressing safety issues. Chief among these are Advisory Circulars (AC) and the Safety Alert for Operators (SAFO). Historically, these have not been used to address unmanned safety issues, but the FAA may want to revisit if this mechanism may be appropriate for assisting the industry.

Specific Operations Risk Assessment (SORA) and 'standard scenarios' are tools provided by Member States of the European Union and the European Safety Agency (EASA) to UAS operators to assist them in establishing whether an operation can be conducted with an acceptable level of risk. SORA helps operators systematically evaluate ground and airborne risks. To avoid repetitive SORA approvals, EASA provides industry with 'standard scenarios,' more easily understood as predefined risk assessments and risk mitigation procedures around which an operator may conduct a UAS operation.

The process starts with the operator comparing the SORA assessment matrix against the specific operation intended for the UAS and using it to calculate a Specific Assurance and Integrity Levels (SAIL) score. This score educates both the user and regulator as to the level of risk associated with the proposed operation and areas where risk mitigations are necessary. The operator then develops a revised concept of operations that employs new or predefined risk mitigations. For many common UAS operations, users may select one of the 'standard scenarios' most closely resembling their proposed operation and use the pre-defined risk assessments, operational practices, and limitations it contains.

Certain domestic UAS operations may benefit from standard scenarios and SORA frameworks. As a regulatory tool, most of the burden is upfront for the agency in the SORA and standard scenario development process. Such tools may assist the FAA in promulgating safe operations by identifying for UAS operators specific ways to understand risk and acceptable procedures to use. These could be MoCs under FAA approval.

Robust voluntary programs do not guarantee adoption by an industry. Yet, our analysis has showed that many voluntary programs for the UAS industry remain works in progress and have not yet reached their full potential. The challenge for the FAA is to recognize the need to support both financially and in regulation a maturation process for these resources, only then can their effectiveness be fully assessed.

Recommendation for Use of AC, SAFO and SORA Frameworks for Safety Culture

The FAA should issue a series of Advisory Circulars and SAFOs establishing best practices on promoting safety culture and SMS.

The FAA should charter an ARC to provide advice on developing a SORA framework and standard scenarios for commonly sought operations in Part 107 Waivers or Section 44807 Petitions.

Compulsory Measures

The FAA has a variety of tools it may use to mandate adoption of the principles of safety culture by industry. These include licensure, recurrent educational requirements, testing, inspection and auditing, levying of civil fines, and promulgating new rules. The delineation of how these are applied to the various segments of the industry remain the biggest challenge facing FAA. The balance of this section analyzes these tools.

Testing

FAA specifies three testing regimes for UAS operators. In late 2021, the FAA will introduce the Recreational UAS Safety Test (TRUST) required by the FAA's 2018

Reauthorization Bill. Individuals operating UAS for recreational purposes must pass this aeronautical knowledge and safety test and carry proof of passing when flying. Next, RPC applicants must pass an initial aeronautical knowledge exam to obtain a remote pilot certificate under Part 107. Every two years the RPC must take the Part 107 Small UAS Recurrent online training course. Lastly, Part 61 certified pilots have their own tailored test to become an RPC.

However, these testing schemas do not tie required knowledge to a larger safety culture framework, nor align safety awareness skills with the increasing complexity of an aircraft. Further, these tests do not contain a safety knowledge continuum from novice UAS pilot to UAS professional. For example, even RPC holders must take a recreational TRUST test, even though they have demonstrated a higher level of knowledge.

In manned aviation there are six types of certificates pilots may obtain: Sport Pilot, Recreational Pilot, Private Pilot, Commercial Pilot, Flight Instructor, and Airline Transport Pilot. As the pilot seeks more operating privileges, the FAA requires a demonstration of a greater depth of safety understanding and aeronautical knowledge. As the pilot demonstrates greater knowledge and competency, operational privileges increase to include flying further than 50 miles away from home airport, access to controlled airspace, flying heavier weight aircraft, flying at night, operating aircraft for revenue, and flying in an airline environment.

One possible solution for the FAA to consider for UAS may be a revised testing framework whereby an applicant must demonstrate increasing competence in applying the principals of safety culture and SMS in operations. In parallel these would align with demonstrating safety knowledge aligned with increasing complexity of aircraft. For example, testing the UAS operator ab initio would be introduced to demonstrate knowledge of the basic concepts in aviation safety. A new Part 107 RPC would be expected to know the theories and practical considerations in safety that would scale to enterprise SMS. Operators of complex UAS following a professional path would need to demonstrate knowledge of SMS in large organizations.

In this scheme, the FAA would be supporting an end-to-end safety culture through embedding it in professional testing and licensure. Notionally, such a framework would have gates that would trigger greater levels of testing and demonstrated knowledge.

No Testing

Users of very small UAS under .55 lbs. or those flying within the boundaries of FAA Recognized Identification Areas (FRIA) under community-based organization guidelines (CBO).

Rationale:

- Operating in a FRIA requires rudimentary safety knowledge as contained in the CBO's code of conduct.
- Knowledge of and operations within a recognized code of conduct would be sufficient to limit risk. The FAA recognizes that aircraft under .55 lbs. present limited risk to the public and are not required to be registered.
- Education and demonstration of knowledge of safety culture would not appreciably decrease an already limited risk.
- Enforcement of testing for this group would be extremely problematic.

The Recreational UAS Safety Test (TRUST)

1. Users of UAS more than .55 lbs. who do not do not perform operations requiring a Part 107 waiver.
2. Users operating UAS outside of recognized FRIAs.

Testing Objectives:

- Demonstration of understanding of basic safety concepts and the need to identify situations where operational risk is increased.
- Test completion required. No minimum passing score, but must be corrected to 100 percent
- Provide users with a professional development path to Advanced RPC.

Rationale:

- The FAA recognizes that aircraft above .55 lbs. present a greater risk to the public.
- Aircraft operated outside of FRIA do so without a requirement to operate according to CBO safety guidelines.

Part 107 Basic RPC

1. Commercial operations under Part 107, not requiring additional crewmembers.
2. Individuals possessing UAS that can operate via first person viewing (FPV) equipment or via the use of electronic paths.

Testing Objectives:

- Understanding and demonstration of the application of basic safety concepts, including risk to the public from commercial operations.
- Understanding and demonstration of risks associated with advanced navigation capabilities such as FPV and electronic paths.
- Test completion required. Minimum passing score 70 percent

Rationale:

- Commercial operations involve higher risk and necessitate a demonstration of a higher degree of competence.
- FPV and electronic paths can be used to perform beyond visual sight operations.
- Users with these capabilities may be enticed to use them without adequate knowledge of the increased risks.
- Current Part 107 testing does not provide safety education around these technologies.

Part 107 Fixed Wing RPC

Part 107 RPC intending to operate traditional fixed wing aircraft

Testing Objectives:

- Understanding and demonstration of the application of basic safety concepts in the operation of fixed wing aircraft.
- Understanding and demonstration of the application of how weather affects fixed wing aircraft safety.
- Test completion required. Minimum passing score 70 percent.

Rationale:

- Fixed wing aircraft introduce added risks in the form of longer flight endurance, higher speeds, and use of internal combustion engines.
- Current Part 107 testing does not provide safety education which delineates the safety differences and risks between rotary and fixed wing aircraft.

Part 107 Crewed RPC

UAS that require a Remote Pilot in Command (RPIC) and supporting team members.

Testing Objectives:

- Understanding and demonstration of the application of basic safety concepts of working in a team environment.
- Understanding and demonstration of the application of human factor risks associated with multiple crew members.
- Understanding and demonstration of the application of basic principles of safety culture and tie with crew resources management.
- Test completion required. Minimum passing score 70 percent

Rationale:

- The attitudes and behaviors of an RPIC are central to how a flight crew operates.

- UAS necessitating the need for supporting team members likely perform many of the highest risk activities.
- Current Part 107 testing does not provide safety education around crew performance and establishing a safety culture.

Part 107 Advanced RPC

Individuals employed in commercial delivery operations.

Testing Objectives:

- Mastery and demonstration of understanding the fundamentals of safety culture and SMS.
- Mastery of demonstration of understanding risks associated with highly advanced aircraft operated in high stress and dynamic environments.
- Mastery of interpersonal conflict resolution as part of crew resource management (CRM).
- Test completion required. Minimum passing score 70 percent

Rationale:

- The Advanced RPC test is an analog to the FAA Airline Transport Pilot (ATP) test. ATP holders are expected to have a mastery of key safety concepts.
- Advanced Part 107 operators would be expected to be responsible for the most advanced, complex, risky, and NAS integrated operations.

Recommendations for Knowledge Testing

The FAA should revise UAS knowledge testing to require applicants demonstrate understanding and the ability to apply the principals of safety culture and SMS to common situations they might encounter.

The FAA should align UAS knowledge testing to support a professional development path from ab initio UAS user to professional UAS RPC.

The FAA should develop an Advanced RPC testing framework for commercial delivery operations focusing on demonstrating mastery and application of the fundamentals of safety culture and SMS.

The FAA should align UAS knowledge testing with complexity of aircraft systems and operations. A suggested testing framework is:

- TRUST
- Part 107 Basic RPC
- Part 107 Fixed Wing RPC
- Part 107 Crewed RPC
- Part 107 Advanced RPC

Licensure, Ratings, and Privileges

During this research the authors have reviewed in detail Part 107 educational materials, testing procedures, and certificate processes. The near totality of the material reviewed reflects a transference of knowledge from manned aviation and a resulting bias toward it. Often, this framework reflects a different operational reality and safety culture need than that confronting a pilot in a common Part 107 environment.

Licensure, ratings, and privileges should be used to create safety culture and provide a professional development path that scales knowledge with increasing complexities. The following frame may facilitate such professional develop, risk reductions, and greater public confidence. It relies on the rationale found in the testing examples above.

- **Part 107 Advanced Commercial Pilot:** *With type ratings for specific unmanned platforms.*
  Description: Holders of this license demonstrate the highest levels of aeronautical knowledge and proper use of safety culture and SMS tools in a complex organization. Pilots would be authorized to perform highly complex commercial operations in all categories of airspace. Written, oral, and practical testing would be required.

- **Part 107 Commercial Pilot:** Ratings: Crewed RPC, Fixed Wing RPC
  Description: Holders of this license demonstrate professional knowledge of UAS operations and proper use of safety culture and SMS tools. Pilots would be authorized to perform commercial flights using BVLOS and FPV technologies.
  - Crewed RPC: Holders of this privilege demonstrate professional knowledge of safe operations requiring crew member support.
  - Fixed wing RPC: Holders of this privilege demonstrate professional knowledge of safe operations of fixed-wing aircraft.

Recommendations for Licensure, Ratings, and Privileges

The FAA should revise UAS pilot Licensure, Ratings, and Privileges to create a safety culture and professional development path that scales with increasing complexities of aircraft and operations.

The FAA should create a Part 107 Advanced Commercial pilot license with type ratings for specific uncrewed aircraft.

The FAA should revise the Part 107 RPC pilot license requirements to include understanding of BVLOS and FPV technologies. It shall include ratings and privileges for UAS operations and fixed winged aircraft.

Continuing Professional Education

The FAA developed the WINGS Pilot Proficiency Program to address the primary accident causal factors in general aviation. The program provides pilots "ongoing, targeted flying tasks and learning activities keyed to identified risks and which are designed to mitigate those risks."[127] Knowledge and flight takes are central to this training. Of note, as it collects information on new risks FAA updates the WINGS curriculum. The FAA has incentivized pilots to enroll in WINGS and satisfactorily meet requirements by eliminating the flight review requirements of 14 CFR Part 61.

Currently, Part 107 RPC pilots must take online recurrent training every 24 months. The successful WINGS program suggests that the unmanned community might benefit as well from a continuing professional education program focusing on safety tools and aeronautical skills. RPCs in the rapidly changing UAS industry might benefit from exposure to understanding updated risks and being educated in new mitigation tools. An RPC-WINGS program could help develop a safety culture and safety community for the UAS industry.

Recommendation for WINGS

Congress should fund, and the FAA develop WINGS for UAS operators.

Safety Culture Mandates

As discussed in the earlier sections of this report, Congressional action has moved DOT to mandate various forms of safety culture and safety management systems reforms to sectors of the transportation industry. In aviation, Part 121 commercial air carrier reforms were driven by the Colgan Air Tragedy and the accidents involving B737 MAX spurred new requirements for holders of type and production certificates. Metro rail and a series of bus accidents triggered reforms in these industries. Absent Congressional action broad industry initiatives in safety culture and SMS often languish. Safety culture and SMS mandates for airports has been discussed for at least a decade and reforms for Part 135 commercial operators remain voluntary despite calls from the NTSB.

This broad review of DOT initiatives suggests that voluntary measures will continue to be the predominant paradigm absent Congressional action. This is understandable in the context of well-established industries where culture and tradition provide strong resistance to change. For a relatively new industry, such as with uncrewed aircraft, Congressional action can be needed before tradition and culture establish themselves and contribute the same inertia to change. In fact, at this early stage of industry evolution, mandates to incorporate safety culture and SMS could set a solid foundation for creating the safety framework that will serve this industry in the years ahead.

Recommendation for Promoting Safety Culture and SMS

Congress should incorporate the following provision into 49 CFR Part 107.15, Condition for Safe Operation:

"No person may operate or manufacture a civil unmanned aircraft system unless there is in place a safety management system that is consistent with the standards and recommended practices established by ICAO and contained in annex 19 to the Convention on International Civil Aviation and approved by the FAA Administrator."

Civil Fines

Should goodwill, voluntary measures, and mandates not convince pilots to operate in a lawful safe manner, civil fines may provide such incentive. In the FAA Extension, Safety, and Security Act of 2016 49 U.S.C. 46320, Congress authorized the FAA to impose civil penalties up to $20,000 against operators who interfere with wildfire suppression, law enforcement, or emergency response efforts. In 2018 FAA Order 8000.373A created a compliance program which incorporated these authorities from 2016 and included intentional or reckless deviations from regulatory standards.

We found in our previous report, *Bridging the Gap,* civil penalties offer little in the way of disincentivizing breaking Part 107 rules. Further, fines have only been occasionally used by the FAA and only in the most egregious circumstances. The GAO reports that from October 2015 to October 2018, 158 enforcement actions were opened and of these 51 involved the assessment of civil penalties ranging from $250 to $55,000.[128] The question of "who should be fined how much and for what?" lies outside the scope of this report. There is a role for fines as a deterrent and punishment for reckless behavior. Nonetheless, these fines occur after the fact. What we note in this report and our previous one is that fines by themselves do not establish a safety culture.

Commentary on Challenges Posed by Mandates and Relying on Voluntary Measures

Safety culture and safety management systems (SMS) are well understood and documented by the Department of Transportation. The challenge is how best to use them to instill knowledge and good habits in a continuum starting with before a box with a new drone is opened by an aspiring unmanned pilot and extending throughout their career as a professional UAS pilot.

Before a box is opened, ideally the aspiring pilot already has knowledge of their safety responsibilities once the wrapper comes off the box. This knowledge needs to come from a combination of freely available educational tools from the FAA and instructions supplied by the manufacture relevant to the jurisdiction in which the aircraft is purchased. If left to chance or placed solely on the aspiring pilot, there is little hope of success.

As a pilot wishes to fly more complex aircraft, engage in commercial operations, or fly as a professional member of a delivery or inspection organization, required testing, licensure, education, and corporate structure must be in place to support their development as an aviator. This framework suggests that voluntary measures have a place early on in career progression and mandates have a role as aircraft become complex and commercial operations that may present hazards to people on the ground.

Regarding safety culture, the preceding analysis of accidents, Congressional mandates, and Department responses suggest that unless it is mandated it will be lost in any fast paced and highly competitive industry. Further, it is far easier to implement principles of safety culture at the birth or an industry rather than in middle age. The imperative then is for a safety culture mandate to be established and support it through voluntary measures, education, and licensure.

3.5 Recommendations on Promoting Safety Culture Within the UAS Industry

The preceding analysis of public expectations, the composition of the UAS industry, traditional safety tools, and DOT experience in promulgating safety culture in new transportation industries highlighted several key themes:

- Major accidents can force cultural changes on industry in a one-size-fits all manner.
- Proactive measures will better align with the differing needs of segments in an industry.
- Molding an industry close to inception is easier than changing it once its tradition and culture have been established.
- Voluntary measures are effective at creating safety culture and traditions, but wide-spread adoption may require mandates.

Cognizant of these themes, this research proposes recommendations to promote the adoption of safety culture by manufacturers and unmanned operators. These leverage the positive impact of Congress in setting a direction for an industry and agency, the need for a trigger to spark broader regulatory reform, segmentation of user groups by level of experience, type of operational use and the capabilities of the aircraft. Further, these recommendations propose the use of voluntary measures as widely as possible and regulatory mandates in targeted circumstances.

4.0 Using Safety Management Systems (SMS) to Sustain Excellence

This section presents an analysis of possible approaches to promote adoption of safety management systems (SMS) by the UAS industry. The analysis includes a review of basic SMS principles, historical approaches used by DOT to drive adoption, elements of SMS applicable to the UAS industry, and recommendations. Recognizing industry participants come from varied backgrounds and organizations of different sizes, these recommendations are formulated to scale and build on those proposed earlier for adoption of safety culture.

4.1 Fundamentals of SMS

Either as the result of necessity or regulation, many industries have come to employ SMS as a tool for promoting safety. Domestic and international industries such as nuclear power, healthcare, spaceflight, and transportation use SMS. Regulatory agencies, such as the FAA, have also internally adopted SMS as a framework within their own organizations.[129] SMS is well understood and well documented.

SMS allows for an organization's safety culture to be reflected day-to-day from operations in the field to decisions in the board room. In its 2009 report on the derailment of a Canadian National Railway Company (CN) freight train in Cherry Valley, Illinois involving a fatality, injuries, and $7.9M of damage, the NTSB defined SMS as,

> *"a systematic approach to managing safety, including the necessary organizational structures, accountabilities, policies, and procedures. An effective safety management system program can help companies reduce and prevent accidents and accident-related loss of lives, time, and resources."*[130]

Regardless of the industry, definitions of SMS remain largely consistent with that put forward nearly a decade ago by NTSB.

SMS normally exists within the context of performance-based regulation. This type of regulation defines desired outcomes instead of specifying prescriptive procedures to follow. How these outcomes are achieved is left to the regulated party to determine. For example, Federal Motor Vehicle Safety Standard (FMVSS) No. 208, requires a vehicle shall have "a seatbelt warning system." Rather than specifying how it should be designed, the law "permits vehicle manufacturers to choose different compliance options for different performance tests and is technology neutral with regard to how a vehicle complies."[131]

Performance-based regulations do not provide regulated parties unlimited discretionary power in the pursuit of compliance. Rather, regulators monitor compliance through collection and analysis of data provided by the regulated party, auditing sample business processes, and requiring submittal of methods that will be employed as a means of compliance. SMS and performance-based regulation are linked in that SMS is often relied on to create and sustain the business processes tied to compliance. Normally, performance-based regulations place a higher administrative burden on the regulated party.

Beyond being useful for compliance, SMS serves as a decision-making tool to enhance organizational performance around safety. It does so by providing an organization with insights from past events, understandings of hazards it may encounter, and predictive identifications of future problems.

Key characteristics of SMS:

- **Enterprise-wide applicability:** SMS aligns attitudes about safety across senior executives, managers, and employees. Each level of an organization has specific duties and accountabilities under an SMS program.
- **Repeatable and proactive practices:** By integrating risk management and safety assurance into a unified framework, organizations can continuously examine operations and decisions to predict future risks. This in turn increases confidence in risk controls used for safety assurance.
- **Business processes integrated with safety:** Managing human and employee resources and producing products is shaped and viewed through the lens of safety.

The FAA recognizes four major components of SMS.[132] These have become key features across regulatory efforts for Part 121 air carriers, airports, manufacturers, and voluntary programs for industry.

Safety Policy: Fully documented methods, processes, and organizational structures supported by senior management. This includes values and commitments to safety recognized by the organization.

Safety Risk Management (SRM): A formal process whereby an organization assesses risk controls, identifies hazards, and revises these controls on a regular basis. These may be embedded in the production and delivery of goods and services.

Safety Assurance: Continuous evaluation of the effectiveness of risk control strategies, compliance with FAA requirements, and collecting and analyzing data for opportunities to improve safety and minimize risk.

Safety Promotion: Training, communication, and organizational support of a positive and proactive safety culture. Promotes everyone’s role in safety.

4.2 DOT’s Approach to Drive Adoption of SMS

The Department of Transportation uses many of the same voluntary approaches and resources described in the preceding section on safety culture to promote adoption of SMS. The DOT and its components consistently treat safety culture and SMS proverbially as *two sides of the same coin*. Therefore, the balance of this section will focus on FAA mandates and initiatives for aviation.

SMS for Part 121 Air Carriers

Section 215 of the Airline Safety and Federal Aviation Administration Extension Act of 2010 required all Part 121 air carriers to implement a safety management system.[133] This airline focused requirement arose out of the circumstances leading up to the Colgan Air tragedy. Congress directed the FAA to initiate a rulemaking process and enact a final rule mandating SMS no later than July 30, 2012, 24 months after passage of the Act.

To comply with the Congressional mandate, on February 12, 2009, the FAA chartered a Safety Management System (SMS) Aviation Rulemaking Committee (ARC).[134] Its purpose was to provide expert stakeholder advice to FAA on SMS regarding implementation and policy. On July 3, 2009, FAA posted the Safety Management System ANPRM. This was followed on November 5, 2010, by the Safety Management Systems for Part 121 Certificate Holders NPRM. Six years after the creation of the SMS ARC, and four years past the Congressional deadline, in 2015 the FAA issued a final rule mandating SMS for all Part 121 certificate holders.[135]

In the rule, the FAA laid out the framework for SMS and specified compulsory items the SMS program must include:

- Each SMS program must include the four major components. (*See above*)
- Each air carrier must have a safety policy, safety objectives, and a commitment to achieving these.
- An accountable executive must be designated for operations and integration of SMS.

In the SMS Final Rule, the FAA stated that one of its aims was to craft the SMS framework and requirements in such a way as to establish, "a uniform standard that could be extended to apply to 14 CFR Part 135 (Part 135) certificate holders, part 145 repair stations, and design and manufacturing entities."[136] Final rules for these industry segments have not yet been released.

SMS for Design and Manufacturing (D&M) Entities

Most recently, provisions for SMS for design and manufacturing entities were included in Public Law 116-260 in the aftermath of the B737 MAX tragedies. As noted in the previous section, this Act mandates the FAA to require manufacturers that hold both a type certificate and a production certificate and to have in place a Safety Management System (SMS) consistent with ICAO Annex 19. This law comes at a time when foundational regulatory and standards activity has been in place for several years for D&M organizations.

In October 2009, the FAA created a Manufacturers SMS (MSMS) Pilot Project to encourage voluntary adoption of SMS by D&M. In 2012, the Part 21/SMS Aviation

Rulemaking Committee (ARC) was established and released recommendations to the FAA. In September of 2014, the agency's Aircraft Certification Service (AIR) launched a Part 21 SMS rulemaking project to identify ways to incorporate ICAO Annex 19 requirements. In 2015, the SMS Final Rule for Part 121 was crafted to include a framework that could be expanded to design and manufacturing entities. In June of 2016, the FAA accepted National Aerospace Standard (NAS) 9927 titled, "Safety Management Systems and Practices for Design and Manufacturing" and accepted "as a basis for SMS recognition."[137] Despite all of this activity, the NPRM for D&M has been put on hold and subject to reconsideration.

SMS for Airports

SMS for airport operators follows nearly the same regulatory path as described for air carriers and D&M. Like D&M, it is characterized by a flurry of voluntary activity followed by temporary holds and inertia in regulation. In 2006, the FAA funded research activities on the notional framework for SMS for airports through the TRB.[138] In February 2007, the FAA published voluntary guidance on SMS in an Advisory Circular entitled, "Introduction to Safety Management Systems (SMS) for Airport Operators."[139] Next, in 2010, the FAA published Order 5200.11 which provided the basis for implementing SMS within the FAA's Office of Airports (ARP). Throughout 2011, the FAA convened a series of educational roundtables to support airport adoption. In 2012, the FAA funded a TRB research report to gather lessons learned from airport SMS pilot programs.[140]

Concurrently with many voluntary activities, the FAA initiated a rulemaking process. In October 2010, the FAA issued a Notice of Proposed Rulemaking on Safety Management Systems for Certificated Airports.[141] The NPRM proposed requiring each certificate holder to establish a safety management system (SMS) for its entire airfield environment (including movement and non-movement areas) to improve safety at airports hosting air carrier operations.[142] The FAA issued a Supplemental Notice of Proposed Rulemaking (SNPRM) on July 14, 2016. The Office of Information and Regulatory Affairs (OIRA) latest tracking information suggests that a final rule could be expected by October of 2021.[143]

SMS for Non-Part 121 Operators, MROs, and Training Organizations

As detailed earlier in this report, various safety agencies and Congress have called for greater adoption of SMS within the aviation industry. Presently, Part 135 air carriers, business aviation, general aviation, maintenance, repair, and overhaul (MRO) organizations, and training providers have not received any SMS mandates. However, FAA has been proactive in organizing information on SMS and making it accessible to these organizations.

Industry as well, has also been proactive in encouraging voluntary adoption of SMS. The International Air Transport Association (IATA) has adopted many of the concepts and practices embedded in SMS and promulgated them through the IATA Operational Safety Audit (IOSA). This program encourages global airlines to achieve standardization in safety management and has been adopted by all 290 IATA members and an additional 129 aviation operators. In the US, organizations such as the Flight Safety Foundation (FSF) and the National Business Aircraft Association (NBAA) have been active in providing encouragement and SMS resources to their members.

4.3 Elements of Safety Management Systems (SMS) for the UAS Industry

This section proposes a model and recommends certain common SMS standards along a continuum from novice UAS pilot to UAS professional and from small commercial operator to manufacturer. The aim is to provide tools to establish organizational frameworks and professional paths for lessening risks and proactively identify hazards. This involves a light touch in low-risk, non-commercial circumstances and gradually scales with the size of entity and assumption of risk. It focuses on what needs to be done and not how to do it.

The goals are twofold:

- Provide confidence to the American public that the industry has a commitment to their safety.
- Create a compliance framework for regulators that scales and moves at the speed of industry.

The cited standards below are used in traditional aviation and the language in the report has been adapted to the UAS industry, where appropriate. To the maximum extent possible, the report uses language found in National Aerospace Standard NAS 9927, Safety Management Systems and Practices for Design and Manufacturing. NAS 9927 has been approved by the FAA for use in aviation. Those standards taken from ICAO Annex 19, FAA SMS, IOSA, and UAST are footnoted accordingly.

The composition of the UAS industry suggests that requirements for SMS be applied along a continuum across four easily identifiable categories of operator, operation, and manufacture.

- Recreational and non-commercial operators not equipped with FPV or electronic path technologies
- Commercial UAS operators employing fewer than three people and those operators equipped with FPV or electronic path technologies

- Commercial UAS operators employing three or more people and manufacturers producing 10-1000 aircraft per year
- Manufacturers and operators producing or operating type certified aircraft or producing 1001 or more aircraft per year

These standards align with the testing and licensure requirements of the preceding chapters and are taken to the maximum extent possible from National Aerospace Standard NAS 9927, Safety Management Systems and Practices for Design and Manufacturing. Many of these have been previously approved in writing by the FAA for aviation.

Recreational and Non-Commercial Operators Not Equipped with FPV or Electronic Path Technologies

Proposed Pathway UAS Safety Standard

An operator of any uncrewed aircraft weighing more than .55 lbs. must operate in accordance with and have in her of his possession documented UAS safety standards applicable to their operation and level of risk. [Basis: ICAO SMS 1.1, NAS 9927 5.3]

Rationale: Operators of recreational and non-commercial UAS systems are likely too small for a full SMS program. Operations without FPV or electronic path technologies enabled represent line of sight operations with understood risk. Safety guidelines from Community Based Organizations (CBO) or other similar organizations would fulfill this requirement. Note that this introductory standard is designed to introduce and teach small entities about safety frameworks and eventual obligations that they may incur as organizational size and risks increase.

Commercial UAS Operators Employing Fewer Than Three People and Those Operators Equipped with FPV or Electronic Path Technologies

Proposed UAS SMS Standard

A commercial operator of any uncrewed aircraft weighing more than .55 lbs. and employing three or more people or operating aircraft enabled with FPV or electronic path technologies must operate in accordance with and have in her of his possession documented UAS safety standards applicable to their operation and level of risk. These must include at least the following components: [Basis: ICAO SMS 1.1.5, NAS 9927 5.21]

- Safety objectives
- Acceptable and unacceptable behaviors in the promotion of safety
- Process checklist to help identify risks and hazards

Rationale: Operations employing three people or more require a formal collaborative process to build safety habits. Operations involving FPV and electronic path finding involve higher levels of risk. Both categories of operators are likely too small for a full SMS program. In these cases, safety guidelines used to set expectations of crew behavior, identify risks, and over safety objects should be sufficient.

Commercial UAS Operators Employing Three Or More People and Manufacturers Producing 10-1000 Aircraft Per Year

General Requirements

Proposed UAS SMS Standard

Any organization operating uncrewed aircraft under Part 107 employing three or more people and manufacturers producing ten or more aircraft, but fewer than one thousand aircraft annually, must have a documented Safety Management System and submit to the Administrator for approval. The SMS must be appropriate to the size and complexity of organization's operations. It must include as a minimum: [Basis: ICAO SMS 1.1, NAS 9927 5.3]

- Safety policy
- Safety risk management
- Safety assurance
- Safety promotion

Rationale: These are fundamental components of all SMS programs. These align with the FAA SMS Voluntary Program for Non-Part 121 Operators, MROs, and Training Organizations

FAA Recognized SMS Component: Safety Policy

Proposed SMS Standard

The organization must have processes to document safety policies and these policies must address: [Basis: ICAO SMS 1.1, NAS 9927 5.21]

- Safety objectives of the organization
- Commitment of the organization to the safety objectives
- Promotion of a just safety culture throughout the organization
- Statement of acceptable behaviors to promote safety
- Defined accountabilities and authorities
- Policy to inform personnel of applicable laws, regulations, and procedures

Rationale: These are fundamental elements of all SMS programs.

Proposed SMS Standard

The organization must have processes to document and formally define safety objectives and these must address: [Basis: ICAO SMS 1.1.6, NAS 9927 5.21]

- Scope: Formally defined safety objective
- Timescale in which the objective is assessed for achievement
- Measurement of performance in relationship to objective

Rationale: These are fundamental elements of all SMS programs.

Proposed SMS Standard

The organization must designate an executive accountable and assign responsibilities for safety objectives, assigning accountability, and resourcing. [Basis: ICAO SMS 1.2.1, NAS 9927 5.23, 5.25]
Rationale: These are fundamental elements of all SMS programs.

Proposed SMS Standard

The organization must have emergency response plans scaled to the size of their organization and anticipated hazards. [Basis: ICAO SMS 1.4, NAS 9927 5.27]
Rationale: These are fundamental elements of all SMS programs.

FAA Recognized SMS Component: Safety Risk Management

Proposed SMS Standard

The organization must have a documented safety risk management process and programs which at a minimum cover. [Basis: ICAO SMS 2.1.2, 2.2, 6.2.2, NAS 9927 5.51]

- Proactive and reactively identification of hazards
- Process to analyze and implement risk mitigations in decision making

Rationale: These are fundamental elements of all SMS programs.

Proposed SMS Standard

The organization must have a hazard identification process which documents severity and likelihood of risks to personnel, equipment, and facilities. [Basis: ICAO SMS 2.2, NAS 9927 5.53]
Rationale: These are fundamental elements of all SMS programs.
Note: This recommendation proposes a strategic organizational process in contrast to the operational standard proposed by UAST for hazard identification.

Proposed SMS Standard

An organization must have a Management System for flight operations that ensures proper control and achievement of safety outcomes. This must include: [Basis: UAST, IOSA FLT 1.1]

- Defined management structure for flight operations and control
- Organization must issue policies, procedures, checklists, and compliance information to flight crews
- Organization must have a training and evaluation program for flight crew
- Organization must have a program to ensure flight crews are qualified

FAA Recognized SMS Component: Safety Assurance

Proposed SMS Standard

The organization must have a safety assurance program which provides continuous monitoring, evaluation, and measuring safety performance and effectiveness. [Basis: ICAO SMS 3.1.1, NAS 9927 5.55]

Rationale: These are fundamental elements of all SMS programs.

Proposed SMS Standard

The organization must have a Safety Analysis Program which: [Basis: ICAO SMS 3.1.1, NAS 9927 5.51]

- Assesses whether the appropriate risk controls are applied and effective.

Rationale: These are fundamental elements of all SMS programs.

Proposed SMS Standard

The organization must have a flight data analysis program which as a minimum: [Basis: ICAO, IOSA ORG 3.7.1]

- Records routine flights for review
- Provide data for accident investigation
- Support airworthiness requirements

Rationale: These are fundamental elements of all SMS programs.

Proposed SMS Standard

The organization must have a Product Quality Control program to ensure: [Basis: IOSA ORG 3.6]

- Purchased or manufactured equipment meets safety and technical requirements

Rationale: These are fundamental elements of all SMS programs.

FAA Recognized SMS Component: Safety Promotion

Proposed SMS Standard

The organization must have a Safety Promotion Program which ensures personnel are competent to perform their SMS duties. [Basis: ICAO SMS 4.1.1, NAS 9927 5.91]

- Communicated throughout the organization [IOSA]
- Shared in employee training [FAA SMS]

Rationale: These are fundamental elements of all SMS programs.

Manufacturers and operators producing or operating type certified aircraft or producing 1001 or more aircraft per year

Proposed SMS Standards

The organization must have a Full SMS Program Approved by the Administrator. National Aerospace Standard NAS 9927 complies with this requirement

Rationale: Organizations of this size can be expected to produce complex unmanned systems with the highest market penetration, thereby having the highest probability of the public encountering them. This category does not include manufacturers of traditional model aircraft, unless those are equipped with FPV or electronic path finding capabilities. For these organizations, National Aerospace Standard NAS 9927 provides a robust SMS framework. As previously noted, it has been approved by the FAA for use by aircraft manufacturers.

4.4 Overview of Possible Approaches to Support Adoption of SMS by the UAS Industry

Voluntary Measures

Various industries and their regulators have developed an expansive body of reference material on the tenets of SMS. Proverbially, all of the hard work has been accomplished. The challenge as described by former Flight Safety Foundation President and former US Ambassador to ICAO, William (Bill) Voss is to not treat SMS as a process exercise and "reduce the concept to a series of checklists."[144] Clearly, the adoption case for SMS as a tool to reduce risk and prioritize safety spending is more attractive to industry than as process framework which places new administrative burdens.

The airport industry tackled the presumed arrival of SMS with the help of pilot studies and research from the FAA and TRB. Beginning in 2008, over twenty-five airports volunteered to share their experience with the challenges and benefits of implementing SMS.[145] Information collected included workload impact, gap analyses, benefits, and sufficiency of guidance material. Along with organizational benefits, airports reported that SMS helped establish a common language among stakeholders who shared safety responsibilities. Industry executives during this research noted that Atlanta (ATL), Seattle (SEA) and San Francisco (SFO) airports were especially proactive in sharing the benefits they accrued. These and other pathfinders influenced numerous other airports to trial SMS.

In addition to sponsoring pilots and targeted research, the FAA provides tool kits and targeted funding for organizations to assess their state of readiness for SMS adoption. Central to the agency's efforts is the SMS - Gap Analysis Tool and Implementation Planning Document. This resource allows an organization to establish benchmarks and identify gaps in existing processes against those needed for SMS. It does so by guiding an organization through many aspects of SMS including safety policy, accountability and authority, delegation of responsibilities, safety risk management. With regard to funding, in 2014 the FAA allowed the Airport Improvement Program (AIP) to fund SMS implementation plans.[146]

Despite robust tools, educational resources, and AIP funding availability, voluntary uptake of SMS remains inconsistent throughout the airport and airline industries. This strongly suggests that compulsory measures may be required by the regulator.

Compulsory Measures

The case for regulating an organization's business processes rests in filling the gaps where individual licensure, ratings, and educational testing do not provide an adequate margin for safety. The regulatory path for mandating SMS is well traveled by the FAA and it does not have to start from scratch. The processes, working groups, and consensus building exercises in support of SMS for Part 121 airlines, D&M, and airports can be duplicated. Any one of these industries could serve as the model for the UAS industry. In terms of time, the average journey is well understood, from trigger to final rule it consistently takes about six years. But the question for policymakers will be: is it worth it?

Recommendation for SMS Standards

The FAA should publish a Notice of Proposed Rulemaking containing a notional framework for SMS for the UAS industry based on previous work done for airlines, airports, and D&M.

The FAA should charter an advisory ARC to identify industry segments and specific SMS standards that may apply to each industry segment.

The FAA may wish to incorporate the SMS framework proposed in this report in future regulations on safety culture and SMS.

4.5 Recommendations on Promoting SMS for the UAS Industry

The preceding analysis of safety culture, key components, and regulatory activity surrounding SMS highlighted several key considerations around which next steps should be framed.

- Individual licensure, ratings, and educational testing do not provide an adequate progression of understanding and implementing the basic concepts of safety culture and SMS.
- Major regulatory gaps exist in defining organizational accountabilities for safety.
- Industry-wide adoption of SMS usually does not occur without Congressional mandate.
- SMS must scale from small operators to large organizations.

Cognizant of these themes, this research proposes recommendations to promote the adoption of SMS by manufacturers and unmanned operators. These leverage the positive impact of Congress in setting a direction for an industry and agency, the need for a trigger to spark broader regulatory reform, segmentation of user groups by level of experience, type of operational use and the capabilities of the aircraft. Further, these recommendations propose the use of voluntary measures as widely as possible and regulatory mandates in targeted circumstances.

5.0 Conclusion

When a catastrophic accident occurs involving UAS the American public will view it through the same lens they use for manned aviation. This perspective was set in place when DOT defined all UAS as aircraft and created irreversible expectations around unmanned safety. The UAS industry needs to understand this above all else.

Stakeholders would be well served by acknowledging this high bar and approaching unmanned safety challenges from this perspective. Ultimately, the American public will more broadly accept UAS within communities and the national airspace system if the industry can demonstrate positive achievements in safety.

Many achievements have already been captured in the volumes of data produced by the industry. Yet, these remain unspoken success stories because of the lack of data protections, over reliance on trade secrecy, and lack of regulatory acceptance. The data also contains elements which point to failures by operators, manufacturers, and organizations. Little is being learned and shared from these events. This needs to change.

Safety culture and SMS lead to one well tested path for the industry to change. More precisely, they could be foundational and transformational as it develops and matures. The key advantage to setting safety culture and SMS in motion now is that regulators won't be fighting established culture and traditions that often fuel resistance to these safety systems. The UAS industry represents a blank sheet in this regard.

Safety culture and SMS certainly will take five to six years of regulatory work to implement, but during those years, the industry can work on implementing these well-established frameworks. No one will need to wait for the safety culture and SMS manuals to be written. They just need to be pulled off the shelves and maybe dusted off.

Appendix A: List of Recommendations

Recommendations for Standards

- Congress should mandate the FAA to create Federal UAS Safety Standards.
  The FAA should charter an ARC and authorize it to identify processes whereby industry standards on safety and SMS become incorporated into Federal UAS Safety Standards.
- The FAA should identify and promulgate a body of foundational safety standards and SMS for UAS through AC and SAFO processes.

Recommendation for Education and Reference Resources

- The FAA should organize the educational materials it is providing to industry according to testing, pilot certification, and Part 107 waiver submission needs.

Recommendation for Commercial Sales of UAS Components

- The FAA should mandate manufacturers of UAS aircraft and radio control transmitting systems inform the purchaser of regulatory requirements for registration, safe operations, and licensure at the time of purchase.

Recommendation for Cost of Education Testing

- To broaden adoption of safety culture and principals by the UAS community, the FAA should provide low cost or no cost basic testing through the Basic Part 107 RPC license proposed in this paper.

Recommendation for Cost Recovery

- Similar to recommendations in the GAO-20-136 report, the FAA should further review the recovery of UAS-related costs and establish criteria for future fee designs.

Recommendations for Centers of Excellence

- Congress should fund and the FAA should develop a national institute of UAS safety modeled after the National Highway Institute.
- FAA should increase funding of ASSURE programs and prioritize expanding the body of foundational knowledge required by pilot and industry applicants to understand the application of safety culture and SMS.
- FAA should fund ASSURE programs which develop Means of Compliance (MoC) that UAS operators may use, and the agency will accept for common Part 107 waiver operations.

Recommendations for Unmanned Aircraft Safety Team (UAST)

- The FAA Administrator should issue a Notice of Order which designates information provided to the UAST as protected from public disclosure.
- The FAA Administrator should direct the Drone Advisory Committee (DAC) to identify specific data generated during UAS operations that can be aggregated and

used to identify and reduce safety risks. These data fields should be published for use in a subsequent Advisory Circular.
- Congress should fund programs similar to ASAP, FOQA, and ATSAP for collection and analysis of UAS data by the UAST.
- Congress should program additional FAA resources to support the ongoing operations and expansion of the UAST.

Recommendation for Use of AC, SAFO, and SORA Frameworks for Safety Culture
- The FAA should issue a series of Advisory Circulars and SAFOs establishing best practices on promoting safety culture and SMS.
- The FAA should charter an ARC to provide advice on developing a SORA framework and standard scenarios for commonly sought operations in Part 107 Waivers or Section 44807 Petitions.

Recommendations for Knowledge Testing
- The FAA should revise UAS knowledge testing to require applicants demonstrate understanding and the ability to apply the principals of safety culture and SMS to common situations they might encounter.
- The FAA should align UAS knowledge testing to support a professional development path from ab initio UAS user to professional UAS RPC.
- The FAA should develop an Advanced RPC testing framework for commercial delivery operations focusing on demonstrating mastery and application of the fundamentals of safety culture and SMS.
- The FAA should align UAS knowledge testing with complexity of aircraft systems and operations. A suggested testing framework is:
  - TRUST
  - Part 107 Basic RPC
  - Part 107 Fixed Wing RPC
  - Part 107 Crewed RPC
  - Part 107 Advanced RPC

Recommendations for Licensure, Ratings, and Privileges
- The FAA should revise UAS pilot Licensure, Ratings, and Privileges to create a safety culture and professional development path that scales with increasing complexities of aircraft and operations.
- The FAA should create a Part 107 Advanced Commercial pilot license with type ratings for specific uncrewed aircraft.

- The FAA should revise the Part 107 RPC pilot license requirements to include understanding of BVLOS and FPV technologies. It shall include ratings and privileges for UAS operations and fixed winged aircraft.

Recommendation for WINGS

- Congress should fund, and the FAA develop WINGS for UAS operators.

Recommendation for Promoting Safety Culture and SMS

- Congress should incorporate the following provision into 49 CFR Part 107.15, Condition for Safe Operation:
- The FAA should align UAS knowledge testing with complexity of aircraft systems and operations. A suggested testing framework is:
  - "No person may operate or manufacture a civil unmanned aircraft system unless there is in place a safety management system that is consistent with the standards and recommended practices established by ICAO and contained in annex 19 to the Convention on International Civil Aviation and approved by the FAA Administrator."

Recommendations for SMS Standards

- The FAA should publish a Notice of Proposed Rulemaking containing a notional framework for SMS for the UAS industry based on previous work done for airlines, airports, and D&M.
- The FAA should charter an advisory ARC to identify industry segments and specific SMS standards that may apply to each industry segment.

  The FAA may wish to incorporate the SMS framework proposed in this report in future regulations on safety culture and SMS.

Appendix B: Acronyms

A&P	Aircraft and Powerplant Certificate
AC	Advisory Circulars
AD	Airworthiness Directives
AI	Artificial Intelligence
AIM	Aeronautical Information Manual
AIP	Airport Improvement Program
AIR	Aircraft Certification Service
AMOC	Alternative Means of Compliance
ANPRM	Advanced Notice of Proposed Rulemaking
ARC	Aviation Rulemaking Committees
ASAP	Aviation Safety Action Program
ASIAS	Aviation Safety Information Analysis and Sharing System
ASRS	Aviation Safety and Reporting System
ASSURE	Alliance for System Safety of UAS through Research Excellence
ASTM	American Society for Testing and Materials
ATO	Air Traffic Organization
ATP	Airline Transport Pilot
ATSAP	Air Traffic Safety Action Program
AUVSI	Association for Unmanned Vehicles International
BVLOS	Beyond Visual Line of Sight
CAST	Commercial Aviation Safety Team
CBO	Community Based Organization
COTS	Commercial off the Shelf
CRM	Crew Resource Management
D&M	Design and Manufacturing
D&R	Durability and Reliability
DAC	FAA Drone Advisory Committee
DOT	Department of Transportation
EASA	European Aviation Safety Agency
Eno	Eno Center for Transportation
EUROCAE	European Organization for Civil Aviation Equipment
FAA	Federal Aviation Administration
FAR	Federal Air Regulations
FHA	Functional Hazard Assessments
FMCSA	Federal Motor Carrier Safety Administration
FMVSS	Federal Motor Vehicle Safety Standards

FOQA	Flight Operational Quality Assurance
FPV	First Person View
FR	Final Rule
FRA	Federal Railroad Administration
FRIA	FAA-Recognized Identification Area
FSF	Flight Safety Foundation
FTA	Federal Transit Administration
GAJSC	General Aviation Joint Steering Committee
IATA	International Air Transport Association
ICAO	International Civil Aviation Organization
IFR	Instrument Flight Rules
IOSA	IATA Operational Safety Audit
ISO	International Organization for Standards
JARUS	Joint Authorities for Rule-making on Unmanned Systems
JATR	Joint Authorities Technical Review
MARAD	Maritime Administration
ML	Machine Learning
MoC	Means of Compliance
MRO	Maintenance, Repair, and Overhaul
MSMS	Manufacturers SMS
NAS	National Airspace System
NBAA	National Business Aircraft Association
NHI	National Highway Institute
NHTSA	National Highway Traffic Safety Administration
NPRM	Notice of Proposed Rulemaking
NTSB	National Transportation Safety Board
OIRA	Office of Information and Regulatory Affairs
ORA	Operational Risk Assessments
PHMSA	Pipeline and Hazardous Materials Safety Administration
PSSA	Preliminary Safety System Assessments
PTSCTP	Public Transportation Safety Certification Training Program
PTSP	Public Transportation Safety Program
RPC	Remote Pilot Certificate
RPIC	Remote Pilot in Command
SAE	Society of Automotive Engineers
SAFO	Safety Alert for Operators
SIBR	Standards Incorporated by Reference Database
SAIL	Specific Assurance and Integrity Levels
SLSDC	Saint Lawrence Seaway Development Corporation

SMS	Safety Management Systems
SORA	Specific Operations Risk Assessment
SPP	Safety Program Planning
SRA	Safety Risk Assessment
SRM	Safety Risk Management
TOP	AUVSI Trusted Operator Program
TRB	Transportation Research Board
TRUST	The Recreational UAS Safety Test
UAS	Unmanned Aircraft Systems or Uncrewed Aircraft Systems
UAST	Unmanned Aircraft Safety Team
VLOS	Visual Line of Sight
WMATA	Washington Metropolitan Area Transit Authority

Endnotes

[1] Paul Lewis and Ken Dunlap, "Bridging the Gap: Sustaining the UAS Revolution While Pursuing a Permanent Regulatory Framework." (Eno Center for Transportation, August 24, 2020): Herein referred to as "*Bridging the Gap*"; Lewis and Dunlap, "Bridging the Gap," 31.
[2] Public Law 85-726 Aug 23, 1958, Federal Aviation Act of 1958 [72 Stat.]
[3] Civil Aeronautical Board, Accident Investigation Report SA 320 File No. 1 0090, April 15, 1957
[4] Civil Aeronautical Board, Accident Investigation Report SA 333 File No. 1 0074, January 9, 1959
[5] Public Law 85-726 Aug 23, 1958, Federal Aviation Act of 1958 [72 Stat.] 750
[6] Public Law 85-726 Aug 23, 1958, Federal Aviation Act of 1958 [72 Stat.] 747
[7] CAST, "Goal, Mission, Vision." 2020
[8] National Transportation Safety Board, "Loss of Control on Approach, Colgan Air, Inc. Accident Report NTSB/AAR-10/01, PB2010-910401." (NTSB, February 2, 2010)
[9] Ibid 151, 156.
[10] Public Law 111-216, Aug. 1, 2020; 124 STAT. 2349
[11] Babbitt, Randall, "ARC Order" 1
[12] FAA-2010-0100-1340, FR 2012-04627
[13] Chaffee Doolittle, Amy, "A Descriptive Analysis of Public Comments Submitted in Response to Notice of Proposed Rules on Air Carrier Pilot Qualification" (Embry-Riddle Aeronautical University Scholarly Commons, Dissertations and Theses, July 2013) Herein, "Descriptive Analysis of Public Comments"
[14] Doolittle, "Descriptive Analysis of Public Comments." 29
[15] Doolittle, "Descriptive Analysis of Public Comments." 51
[16] http://3407memorial.com/flight-3407-families-commemorate-10th-anniversary-of-airline-safety-act-being-signed-into-law
[17] "Law Enforcement Guidance for Suspected Unauthorized UAS Operations," (FAA, December 18, 2015)
[18] FAA-2015-7396, RIN 2120-AK82, (80 Fed. Reg. 78594, December 16, 2015)
[19] Ibid 78596
[20] Lewis and Dunlap, "Bridging the Gap," 1.
[21] FAA-2019-0573-0003
[22] Ibid
[23] FAA-2019-0346
[24] Ibid
[25] FAA, "Operation of Small Unmanned Aircraft Systems over People, FAA-2018-1087-0001." February 13, 2019
[26] FAA, "Remote Identification of Unmanned Aircraft Systems, FAA-2019-1100-0001." December 31, 2019
[27] FAA, "External Marking Requirement for Small Unmanned Aircraft, FAA-2018-1084-001." February 13, 2019
[28] FAA, "Safe and Secure Operations of Small Unmanned Aircraft Systems, FAA-2018-1086-001." February 13, 2019
[29] FAA, "Operation and Certification of Small Unmanned Aircraft Systems, FAA-2015-0150." February 23, 2015
[30] FAA, "Registration and Marking Requirements for Small Unmanned Aircraft, FAA-2015-7396." (FAA, December 16, 2015)
[31] FAA, "Fact Sheet-Commercial Aviation Safety Team." (FAA, July 2, 2020)
[32] FAA-2009-067-0180, "Safety Management Systems for Part 121 Certificate Holders." (FAA Jan 8, 2015)
[33] FAA, "SMS for Air Traffic Service Providers." (FAA April 27, 2021)
[34] Lewis and Dunlap, "Bridging the Gap," 2; FAA, "UAS by the Numbers." (FAA May 24, 2021)
[35] Lewis and Dunlap, "Bridging the Gap," 2.
[36] FAA, "UAS by the Numbers." (FAA May 24, 2021)
[37] Ibid
[38] Source: FAA, "UAS by the Numbers." (FAA, see data label for date)
[39] Lewis and Dunlap, "Bridging the Gap," 10.
[40] Ibid 11.
[41] Ibid
[42] Ibid 26.
[43] FAA, "Drone Advisory Committee Public eBook." (FAA, October 22, 2020)
[44] FAA, "Concept of Operations V2.0, Unmanned Aircraft System (UAS) Traffic Management (UTM)" (FAA, March 2, 2020)
[45] Ibid 13.
[46] Ibid.
[47] Comment from Executive H
[48] FAA, "FAA Strategic Plan FY 2019-2022." 9. (FAA, February 2018)
[49] Note that performance-based only works if there is some objective way to measure performance
[50] Comment from Executive D
[51] Lewis and Dunlap, "Bridging the Gap," 16.
[52] Comment from Executive H

[53] FAA, FAA Aerospace Forecasts for each year FY2010-FY2019
[54] 14 CFR Part 107.12
[55] FAA, "UAS – Recreational Fliers," 2019. 49 USC 44809
[56] Lewis and Dunlap, "Bridging the Gap," 14.
[57] Please see Lewis and Dunlap, "Bridging the Gap" for a complete discussion
[58] Public Law 112–95—Feb. 14, 2012, 126 Stat. 11
[59] Public Law 114–190—July 15, 2016, 130 Stat. 628
[60] Public Law 115–254—Oct. 5, 2018, 132 Stat. 3186
[61] Lewis and Dunlap, "Bridging the Gap," 1.
[62] Comments from Executives E, F
[63] Public Law 85-726 Aug 23, 1958, Federal Aviation Act of 1958 [72 Stat.]
[64] FAA, "Unmanned Aircraft Systems Safety Risk Management Policy." October 4, 2019
[65] FAA, "FAA-G-8082-22 Remote Pilot – Small Unmanned Aircraft Systems Study Guide." (FAA, August 2016)
[66] Public Law 115–254—Oct. 5, 2018, 132 Stat. 3186, Sec. 349
[67] Lewis and Dunlap, "Bridging the Gap," 16.
[68] Ibid.
[69] Ibid.
[70] FAA, "Fact Sheet – Commercial Aviation Safety Team." (FAA, July 2, 2020)
[71] FAA, "Commercial Aviation Safety Team Safety Enhancements." (Docket No. FAA-2004-19400, February 2, 2005)
[72] Boyne, Walter J., "The Checklist." (Air Force Magazine, August 1, 2013)
[73] Ibid.
[74] Taneja, Hemant. "The Era of Move Fast and Break Things is Over." (Harvard Business Review, January 22, 2019)
[75] Woods, Sabrina. "How to Do a Safety Culture of Just You." (FAA Safety Briefing, July/August 2019)
[76] FAA, "Pilot's Handbook of Aeronautical Knowledge FAA-H-8083-25B." (FAA, 2016) 22-8
[77] FAA, "Voluntary Implementation of SMS for Non-Part 121 Operators, MROs, and Training Organizations." (FAA, May 2020)
[78] FAA, "Safety Risk Management Order 8040.4." (FAA, June 26, 1998)
[79] Ibid. 2
[80] FAA, "Safety Management System Order 8000.369B." (FAA, March 18, 2016)
[81] Public Law 89-670 – October 15, 1966, Sec. 2. (a)
[82] Ibid. Sec. 3. (e) (1)
[83] US Department of Transportation, "Safety | U.S. DOT Strategic Plan | FY 2018-2022." (DOT, February 2018) 15
[84] FRA, "System Safety Program and Risk Reduction Program FRA-2020-04424." (FRA, March 4, 2020)
[85] Ibid. Sec. 270.101 – System Safety Program; General
[86] FHA, "Zero Death - Saving Lives through a Safety Culture and Safe System." (FHA, updated February 16, 2021)
[87] FHA, "Pipeline Safety: Public Meeting on Implementing the Recently Published Gas Transmission and Hazardous Liquid Final Rules PHMSA-2019-0255." (FHA, February 18, 2020)
[88] NRC, "Final Safety Culture Policy Statement [NRC-20010-0282]." (NRC, June 14, 2011)
[89] BSEE, "Final Safety Culture Policy Statement [78 FR 27419]." (BSEE, May 10, 2014)
[90] NTSB, "Safety Recommendation Report, Accident Number DCA19RA017 / DCA19RA101." (NTSB, September 19, 2019)
[91] Law 116-26, TITLE I--AIRCRAFT CERTIFICATION, SAFETY, AND ACCOUNTABILITY, Sec. 103
[92] NTSB, "Aircraft Accident Report AAR-20-01, PB2020-101001." (NTSB, May 19, 2020) vii.
[93] Ibid.
[94] Ibid xi
[95] NHTSA, "National Highway Traffic Safety Administration Docket No. NHTSA-2014-0085, Federal Motor Vehicle Safety Standards." (NHTSA, August 6, 2014)
[96] NTSB, "Collision of Two WMATA Metrorail Trains Near Fort Totten Station. Accident Report NTSB/RAR-10/02, PB2010-916302." (NTSB, June 22, 2009) xiii.
[97] USNRC, "June 2009 Collision of Two Washington Metropolitan Area Transit Authority Metrorail Trains Near Fort Totten Station, Washington, DC." (Safety Culture Communicator, July 2011)
[98] 49 U.S. Code § 5329. Public Transportation Safety Program
[99] 112th Congress, 2nd Session, House of Representatives and Senate Conference Report H.R. 4348." 603.
[100] DOT, "Strategic Plan FY 2006 – FY 2011, FY 2012 – FY 2016, FY 2014- FY 2018, FY 2018 – FY 2022"
[101] FTA, "Public Transportation Safety Certification Training Program, FTA–2015–0014." (FTA, July 19, 2018)
[102] Ibid 34054.
[103] DOT, "Website: https://www.volpe.dot.gov/our-sponsors."
[104] Ibid.
[105] DOT, "Air Traffic Systems and Operations." https://www.volpe.dot.gov/our-work/air-traffic-systems-and-operations
[106] DOT, "About NHI website: https://www.nhi.fhwa.dot.gov/about-nhi."
[107] TRB, "2020 Annual Report, Appendix A: Statement of Activities." (National Academies, 2021)
[108] GSA, FACADatabase.Gov, "All Agency Counts." (GSA, June 2021)

[109] The 113th Congress extended funding through FY2020 in Public Law 113-159, the Highway and Transportation Funding Act of 2014.
[110] 78 FR 61251
[111] 80 FR 10619
[112] 80 FR 75639
[113] FTA 49 CFR Part 672 Final Rule, "Public Transportation Safety Certification Training Program."
[114] ASTM International is formerly known as American Society for Testing and Materials
[115] National Institute of Standards and Technology, Standards *Incorporated by Reference Database (SIBR)*
[116] Remote Identification of Unmanned Aircraft, FAA-2019-1100. 13
[117] FAA, "Advisory Circular Small Unmanned Aircraft Systems, 107-2A." (FAA, February 1, 2021)
[118] ASTM price published in the Standards Products Store, valid as of June 11, 2021
[119] SAE price published in the Webstore, valid as of June 11, 2021
[120] ICAO price published in the ICAO Store, valid as of June 11, 2021
[121] FAA, "Pilot's Handbook of Aeronautical Knowledge, FAA-H-8083-25B." (FAA, 2016)
[122] Drone Industry Insights, "Top 10 Drone Manufacturers Market Shares in the US." (March 2, 2021)
[123] FAA, "FAA Aerospace Forecast Fiscal Years 2021-2041." 47
[124] Prices published by organization as of June 11, 2021
[125] GAO, "Unmanned Aircraft Systems: FAA Should Improve Drone-Related Cost Information And Consider Options To Recover Costs, GAO-20-136." (GAO, December 2019)
[126] FAA, "FAA Centers of Excellence Grant Awards FY 2020." (FAA, October 15, 2020)
[127] FAA, "Advisory Circular: WINGS Pilot Proficiency Program AC 61-91J." (FAA. February 16, 2011)
[128] GAO, "Unmanned Aircraft Systems FAA's Compliance and Enforcement Approach for Drones Could Benefit from Improved Communication and Data GAO-20-29." 21 (GAO, October 2019)
[129] FAA, "Safety Management System, Order 8000.369C." (FAA, June 24, 2020)
[130] NTSB, "Railroad Accident Report, NTSB/RAR-12/01." (NTSB, February 14, 2012)
[131] NHTSA, "Federal Motor Vehicle Safety Standards; Occupant Crash Protection, A Proposed Rule." (DOT, October 29, 2020; Additional information on this topic as it applies to aviation is contained in AC-120-92B published by the FAA.
[132] FAA, "SMS Explained, Safety Management System Components." (FAA website, September 11, 2017)
[133] Public Law 111-216, Aug. 1, 2020; 124 STAT. 2349
[134] FAA, "Safety Management Systems (SMS) Aviation Rulemaking Committee, Order 1110.152." (FAA February 12, 2009)
[135] 80 FR 1308, 1313 (January 8, 2015)
[136] Ibid. 1313
[137] Baker, Dorenda D. "Letter to Ali Brahrami and Walter Desrosier." (FAA, Jun 9, 2016)
[138] ACRP, "Safety Management Systems for Airports." (TRB, 2007)
[139] FAA, "Introduction to Safety Management Systems (SMS) for Airport Operators AC 150/5200-37."
[140] ACRP, "Lessons Learned from Airport Safety Management Systems Pilot Studies" (TRB, 2012)
[141] 14 CFR Part 139, Safety Management Systems for Certificated airports, FAA-2010-0997
[142] Ibid 62008.
[143] Executive Office of the President, "Airport Safety Management System RIN 2120-AJ38." (OIRA, Spring 2021)
[144] Voss, William R., "President's Message, SMS Reconsidered." (Aerosafety World, May 17, 2012)
[145] FAA, "FAA SMS Pilot Studies Technical Report." (FAA, May 2011) 3.
[146] FAA, "Minimum Requirements for AIP-funded SMS Implementation Plans." (FAA, August 11, 2014)

Eno
Center for Transportation
www.enotrans.org

@EnoTrans

/EnoCenterForTransportation

bit.ly/EnoLinkedIn

/EnoTransportation

@EnoTrans

1629 K Street, NW
Suite 200
Washington, DC 20006

CONTACT US:
publicaffairs@enotrans.org