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on

Unmanned Aircraft Systems Integration: Emerging Uses in a Changing National Airspace

before the Subcommittee on Aviation
Committee on Transportation and Infrastructure
U.S. House of Representatives

November 29, 2017

Chairman LoBiondo, Ranking Member Larsen, and Members of the Subcommittee:

Thank you for the invitation to appear before you to discuss my thoughts, opinions, and ideas to ensure that the United States remains the worldwide leader in Unmanned Aircraft Systems (UASs, also referred to as "drones" in this testimony) R&D, operations, and integration. Our ability to solve the complex problems that UASs face today depends heavily on a carefully-balanced combination of technology development, pilot programs, data collection, and on the use of probabilistic risk-based approaches for the right amount of regulation, while meeting privacy concerns.

I am a professor in the Department of Aeronautics and Astronautics at Stanford University and a current member of the FAA Drone Advisory Council (DAC). In this testimony, I am appearing in a personal capacity and speaking solely for myself. I am therefore not representing the views of either Stanford University or the FAA DAC.

Since I became a professor at Stanford University over 20 years ago, I have worked on the development of computational analysis and design methods to enable the creation and development of realizable and efficient aerospace systems. My research has involved advanced low-speed, transonic, and supersonic aircraft, launch and re-entry vehicles, jet engines, and drones. I began teaching drone courses at Stanford in 2001, long before they were perceived as the next new thing, and have designed a variety of drone vehicles under the sponsorship of both industry and the federal government (NASA and NSF). Together with my students and research staff in the Aerospace Design Laboratory, we are responsible for open-source tools such as SUAVE (http://suave.stanford.edu) and SU2 (http://su2.stanford.edu) that are being used around the world for many new aircraft developments, including drones and electric Vertical Take-Off and Landing (VTOL) aircraft for personal air transportation.

I have served in the FAA Management Advisory Council (2011-14), the Secretary of Transportation's Future of Aviation Advisory Committee (2010-11), and the NASA Advisory Council (2005-06). I am currently a member of the FAA DAC and an Independent Expert in the ICAO/CAEP Integrated Review for Technology Goals in aviation noise, fuel burn, and emissions. I have received a number of awards and recognitions, including the NASA Exceptional Public Service Medal (2009) for my role as the Director of the Fundamental Aeronautics Program at

NASA (2006-09), where I was responsible for all of the agency's vehicle technology R&D programs.

Just as with many advanced technologies in aerospace engineering in the past 100 years, UASs find their origins in military technology investments and requirements. But a remarkable technology convergence that began in the early 2000s with the advent of miniaturized sensors, more powerful real-time computing capabilities, and a strong interest in research in perception, automatic control, and autonomy, has opened up the possibilities for the use of drones to a very large number of applications that have the potential to generate new capabilities and open new markets. Precision agriculture and infrastructure monitoring, fire-fighting, disaster recovery, package and medical supply delivery, law enforcement and border patrol, mapping and surveying, search and rescue, even journalism and aerial photography are but a few of the possible uses of this incredible new technology.

Retaining US Leadership in UAS Technology and Integration

Arguably, the United States has been at the forefront of R&D of the very capabilities that are enabling such a bright future for UASs. But this is just the beginning: much work remains to continue to nurture these new capabilities and to allow them to develop into the systems that will impact our society in many profound and beneficial ways. The rest of the world has not been sitting in the sidelines: multiple countries have recognized the potential civilian and military value of drone technologies and companies that produce small and medium-sized drones have been created and are thriving. These foreign companies are laying the foundation for more complex vehicles and uses and have come to dominate this market. The question I try to address in this written testimony is "what must the US do to retain leadership in a field that we had originally developed?"

There are many technical obstacles that prevent more widespread development, integration, and acceptance of UASs in the United States and abroad. These can all be resolved through diligent and inspired technical breakthroughs that our engineering and scientific base is used to pursuing and accomplishing. With this comment, I do not intend to minimize the magnitude of these endeavors, but I will not focus on them in this testimony, given that the Subcommittee has already heard from my colleagues Prof. Mykel Kochenderfer (Department of Aeronautics & Astronautics, Stanford University) and Prof. Nicholas Roy (Department of Aeronautics & Astronautics, MIT) and they have made a compelling case for technology development to enhance the reliability, safety, communication, navigation, air traffic control, and manufacturing cost of future drone systems.

Instead, in this testimony, I would like to focus on three separate areas of the regulatory environment that can further enhance capabilities and attempt to solve the policy-technology dilemmas that we are currently facing. First, during these early days in the development of UAS capabilities, we will need more flight testing experiences, not fewer; we will need more opportunities, with low barriers to entry, to try out new ideas, fail, try again, and eventually succeed: such is the iterative nature of most technology development programs and, in this case, these iterations will necessarily involve interactions with other stakeholders beyond the technology-based ones. The FAA UAS Test Sites, the FAA Pathfinder programs, and the recently-announced UAS Integration Pilot Program are all steps in the right direction. Second, it is critical that all tests result in data of sufficient quality and in the appropriate amount so that they can be used to inform requirements / regulations for different levels of service in the NAS. Moreover, it is critical that this data be made openly available to the community for better insights and understanding. Third, we must setup a regulatory environment that provides a reasonable expectation of periodic and timely updates to the levels of service available to UAS operators for those who can demonstrate compliance with stricter requirements, as appropriate, to ensure safe operation in the NAS.

There is ample evidence that multiple US companies are seeking a more predictable regulatory environment to conduct the testing of their UAS prototypes (see for example, WSJ, May 17, 2017 “Welcome to the Jungle: Amazon’s Australian Expedition to Rattle Retailers”, and NYT, Oct 25, 2017, “Trump to Open Skies to More Drone Testing”.) How do we make sure that the situation in the United States encourages both US and foreign companies to develop and test here and not abroad? How do we setup the proper regulatory environment so that companies can plan for both the testing and deployment of their systems? How do we train and retain the technical talent that will be needed to realize this vision? How, above all, do we ensure that the jobs created by this new field stay here in the US?

A Nimbler and More Rational Regulatory Process for UASs

On the topic or regulation, and more importantly the predictability of upcoming regulatory requirements, it would be beneficial to ensure that the FAA embarks on a yearly cycle of updates to the existing rules. It would be useful to ensure that the FAA views updates to the UAS regulations like the standard software development cycle with periodic releases that update the regulatory framework. Take Part 107 - Small Unmanned Aircraft Regulations, for example. Part 107 covers commercial uses of drones weighing less than 55 lbs for non-hobbyists and provides a certain level of service (daylight and twilight operations, under 400 ft of altitude, within visual line of sight, with a pilot certificate) with a minimum level of requirements: the safety implications of operations in compliance with this rule are virtually non-existent. This level of safety is achieved by directly avoiding circumstances that may expose the uninvolved public to any level of risk.

There are several small steps forward that will be required to realize the full potential of UASs that many organizations are clamoring for today. In particular, flights over people, operations beyond visual line of sight (BVLOS) and/or at night, and flights in the proximity of buildings and structures all require the operators to follow a waiver process that is neither scalable nor conducive to understanding what might be possible (from the regulatory point of view) in the future. In the future, I would prefer to see a steady rhythm of updates to Part 107 that enable operators to receive a higher level of service by complying with a clearly articulated set of increasingly stricter requirements to guarantee the desired level of safety. Such a process could begin with the increased services that have smaller safety impacts and progress towards scenarios where safety does become a major concern. The FAA is already conducting a series of Pathfinder Programs that have these precise objectives in mind. I would recommend that (a) these kinds of programs are significantly enhanced (perhaps through the UAS Pilot Integration Program or by enlisting additional participants into the existing programs), and that (b) a more concerted effort to learn from such experiences and disseminate the results is pursued.

Note that I mention "required level of safety" in my comments above. The truth of the matter is that, at present, no technologist knows what this required level of safety ought to be for different kinds of vehicles and operations in the airspace. The "required level of safety" must be arrived at from direct involvement of policy makers such as yourselves, in consultation with experts in government, industry, and academia, as well as local governments and the public at large. The FAA has a key role to play in this area and has been able to navigate complex regulatory matters such as these ones in the past.

Risk-based Probabilistic Safety Analyses and the Availability of High-quality Data

The focus on a "required level of safety" that we must arrive at as a community, begs the question of how we measure the level of safety that a UAS / operator combination can achieve given the equipment that is available on board the vehicle and the amount of training that the operator has completed. This is truly a hard question and there are no easy answers. I personally believe (and given recent briefings I have received from the FAA in the context of the DAC, it appears that the FAA is in full agreement) that the only way to assess whether the combination of a given UAS and operator meets a "required level of safety" for a particular mission is by using a probabilistic risk-based analysis approach. Such an approach would control for the main variables of the problem and provide confidence intervals based on significant amounts of data collected during extensive flight trials. Let me state that again more clearly: we can only reach conclusions about levels of safety attained and the level of requirements in new regulations with significant amounts of high-quality data. Notice that, in addition, we must focus not only on the risk but also the consequences of accidents/incidents that occur. With a combination of risk and consequence we can truly make progress in setting regulations that make sense.

This discussion begs two fundamental questions: how much data are needed and where will these data come from? The simple answer is that we will need lots of data and that we should collect these data (and should have been collecting them for some time) from every opportunity we have. This includes the recently-announced UAS Integration Pilot Program, the FAA Focus Area Pathfinder Program, and many other flight tests being conducted within the seven FAA UAS Test Sites. My colleagues from AirMap (and from other companies developing similar infrastructure) will probably tell you that we have the software system prototypes that can help collect, catalogue, classify, and mine the data for useful information that can influence regulations. I believe this to be the case. But we are far behind in setting up the proper data collection plans: what data should be collected? How do we make it easy for every operator to provide these data for further analysis? How do we maintain the anonymity of the operators to encourage truthful reporting of accidents and incidents?

As far as data are concerned, I believe we are missing out on two key opportunities that should be addressed in the very near term:

1. With the establishment of new UAS flight test programs we must require, as a condition for approval, that the operator share all data about all flights, and that this data-sharing process be an integral part of the learning from these flight test activities, and

2. We must commit to ensure that all data (appropriately de-identified) are open to the UAS community at large: the value of data is not in the data per se but, rather, in the interpretation of patterns and values contained in the datasets. By opening the data to a larger number of interested parties, new methods and ideas will be applied that will lead to better safety estimates and to identifying situations that are precursors to unsafe outcomes, thus improving the quality of the regulatory requirements that are eventually imposed. We cannot underestimate the importance of open data sources and crowd-sourcing the data analysis process.

The FAA jointly with NASA have a rich history, in the commercial aviation context, of collecting and cataloguing data about incidents and accidents in the Aviation Safety Information Analysis and Sharing (ASIAS) system and it seems that many of the lessons learned there could be directly applicable to the UAS context.

The Potential Role of the FAA DAC

As a member of the FAA DAC that has observed its discussions and interactions since the first meeting, I would like to make some comments about the very positive impact that a well-balanced and diverse consensus body such as DAC can have in improving the eventual integration of UASs in the NAS. It is my opinion that we face some complex interdisciplinary problems that will only be solved by timely action on the part of the FAA if proper advice from all participating stakeholders is provided. Since the DAC is at a point where some of its early efforts are being completed and new directions for its work are being discussed, it would be beneficial for the FAA to task the DAC with specific issues (e.g. definition of datasets to be collected, architecture of database to be used, probabilistic risk-based analyses to be pursued, etc.) and let it come back to the FAA with recommendations on these and other subjects within a reasonable time period.

Note that the DAC can be helpful in also recommending what not to pursue. Where should we invest and where should we not? Finally, it is also important to understand that a deliberative body such as the DAC may not be well positioned to pursue certain tasks that are of a highly political nature.

Final Comments / Thoughts

As I was writing this testimony, I read about six laws written by a technology historian, the late Prof. Melvin Kranzberg, to better understand the interactions between technology and society and the significant consequences that misuse of technology can bring about (*WSJ, "The 6 Laws of Technology Everyone Should Know", Nov. 26, 2017*). Two of these laws are particularly relevant to our discussion. Firstly, he stated that *technology is neither good, nor bad; nor is it neutral*. Rather, new technology must be viewed in context: although UAS technology has the potential to improve our lives in many ways, we have a responsibility to anticipate unintended consequences and preempt them as much as possible through both knowledge/data generation and an appropriate regulatory framework. Secondly, he stated that although *technology might be a prime element in many public issues, nontechnical factors take precedence in technology-policy decisions*. The benefits of technology cannot be considered independently of issues of safety, privacy, public perception, local regulations, and noise. Better sources of information lead to better decision making and, ultimately, to more coherent regulations that responsibly minimize the burden on UASs and their operators.

Although I am directing my comments to small UASs in this testimony (as the most urgent need at this very moment) I would like to note that the requirement for a similar regulatory framework for larger vehicles is just as pressing: electric VTOL aircraft are being developed today that could enable large-scale personal air transportation in congested urban areas. In some senses, these larger vehicles are easier to regulate and integrate into the NAS since the FAA and NASA have been conducting research on this topic for a number of years, and these larger vehicles can carry the necessary equipment to satisfy stricter requirements. In other senses, though, these vehicles are harder to integrate into the NAS as they will pose significant challenges in air traffic control (regardless of how it is achieved) and the safety implications will be vastly more significant. If we lump all UASs under a single category, we will fail to understand the profound differences between vehicles at the larger and smaller ends of the spectrum.