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on

Ensuring Aviation Safety in the Era of Unmanned Aircraft Systems

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

October 7, 2015

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

Thank you for the invitation to appear before you to discuss the risks associated with unmanned aircraft, also commonly called drones, in the United States.

I am a professor in the Department of Aeronautics and Astronautics at Stanford University and a third-generation pilot. In this testimony, I am speaking solely for myself.

My research for nearly ten years has involved statistical estimation of risk and the development of technology for enhancing aviation safety. While at MIT Lincoln Laboratory, I helped develop a collection of airspace models, jointly funded by the FAA, DHS, and the Air Force. These models have since been used to estimate collision risk for manned and unmanned aircraft by government, academic, and commercial organizations around the world. My work has also led, in part, to the technology underlying the FAA's next generation collision avoidance system called ACAS X that is currently undergoing international standardization. The FAA is developing a version for unmanned aircraft. My students at Stanford have been supporting this effort and the effort of NASA to build a UAS Traffic Management (or UTM) system.

Personally, I find the rapid acceleration of unmanned aircraft technology to be the most exciting recent development in the field of aeronautics. As we heard in previous panels, this wave of technology has the potential to save lives and create jobs. Few things are as beautiful as flight, and the proliferation of unmanned aircraft has made aviation accessible and inspired a generation of eager university students in a way we have not seen for a long time. It is no surprise that the growing popularity of these vehicles has also raised concern about the safety to other aircraft and the potential for interference with such operations as firefighting and air ambulances. There has been tremendous media coverage of these risks.

I hope to inform the discussion with my thoughts with respect to two questions. First, how do we measure and analyze these risks? Second, what are the best technologies and policies to mitigate these risks?

There is tremendous diversity in unmanned aircraft. We have very small aircraft such as the robot bee developed at Harvard University that weighs about the same as the average honey bee. We also have very large aircraft that are used primarily by the military. I do not believe that this hearing is especially concerned with the risks posed by the extreme ends of this spectrum. Rather, I believe we are concerned with and should be concerned with consumer drones that weigh a couple pounds or more. Drones much lighter than this do not represent true aviation safety hazards due to their physical inability to enter their airspace.

To answer the first question of how to measure and analyze the safety risk of consumer drones, we must have the understanding that risk is determined by both the likelihood and the severity of different hazards.

First, let us consider severity. A sufficiently large drone can cause damage to any part of an aircraft, but one of the most severe hazards is engine ingestion. We all recall the US Airways flight in 2009 that was struck by multiple Canada geese, leading to failure in both engines at takeoff and an emergency landing on the Hudson river. Of course, a flock of sufficiently large drones could cause similar damage. However, flocks of drones are rare; they are typically operated individually. In addition, most consumer drones, such as the DJI Phantom, are only one-third the weight of an average Canada goose. I am not aware of any engine ingestion testing of the Phantom, but it is certainly conceivable that it could cause some degree of damage to an engine but likely not of the severity of what occurred with the US Airways flight.

What is the likelihood of a mid-air collision involving a drone? In order for a collision to occur, the drone needs to be at the same altitude and in the same location as another aircraft. An analysis of radar data indicates that there are large portions of the United States where the risk of encountering another aircraft is negligible at the altitudes a small drone is capable of flying. However, there are portions of our airspace where the likelihood of a collision is orders of magnitude more significant.

Since it is in their interest to prevent accidents, some drone manufacturers, but not all, have been implementing altitude limits and geofencing. Geofencing uses GPS location to help prevent drones from flying in certain geographic areas, such as near airports and over national parks. For some drones, altitude limits and geofencing may be hard constraints representing areas where the drone will not function. For other drones, these constraints are presented as warnings and can be overridden by the operator. In addition to integrating altitude limitations and geofencing into drones, the drone industry has been working with the FAA to educate the public on the safe operation of drones.

In assessing the likelihood of collision with these mitigations in place, it is helpful to break the risk down into four categories of user: the conscientious user, the naïve user, the reckless user, and the bad actor. I will not discuss the bad actor here because this category is unlikely to be significantly impacted by legislation, though I do appreciate that there is a threat it could provide in the future.

First, the conscientious user is one who strives to operate within the altitude limits and geofences and diligently follows FAA guidance and regulation. For this category of user, the likelihood of collision can be quite low. The altitude is measured by a barometer. Failures in the barometer are exceptionally rare. Errors in the estimation of the geographic location are much more common. However, the system can be engineered in a way to help prevent unexpected “fly aways” where the aircraft departs the operating region. For example, in the event of loss of or errors in GPS or the radio control system, the system can be programed to either return to base or to land slowly. In the drones I am aware of, they are designed to only decrease altitude, never increase altitude, in the case of a fault. The likelihood of different failure modes might be estimated to some extent from service call data from vendors.

Second, the naïve user is one who may not be aware of the FAA guidance and regulations. They may receive their drone as a gift and may have noticed something about “know before you fly” packaged up with their drone, but they have no clue on how to estimate an altitude of 400 feet and they might not be aware that they are within a couple miles of a small general aviation airport. If their drone does not have at least a default altitude limit or geofencing, this can result in a safety risk far beyond that posed by the conscientious user. For decades, aircraft modelers and enthusiasts have maintained an exceptional safety record and the community has largely consisted of conscientious users. However, with the mass production of prebuilt consumer drones, many believe that the composition of the community is likely to change and will include a greater proportion of naïve users. The risk presented by these users may be mitigated by education and technology features that provide pertinent information at the time of operation.

Third, the reckless user is one who is aware of regulations but, for example, cares more about capturing a photograph or video than the safety of others. They are not bad actors who are acting primarily to harm others, but they can still pose significant risk. They might ignore or disable altitude-limits or geofences if made easy by the manufacturer, but they generally would not have the capability to reprogram the firmware or modify the hardware to override safety features.

It may be tempting to use the FAA database of alleged pilot sightings of drones to arrive at a quantitative measure of risk. However, as the Academy of Model Aeronautics has observed, many of the sightings are likely military aircraft or recreational aircraft operated legally and safely. It is also possible that some of the sightings were birds. I suspect that some of the pilot sightings involve drones flown by reckless users, but it is difficult to tell since the database does not include details of follow-up investigation. In addition to the potential for the database to lead to an overestimate of risk, there is also the potential to underestimate risk. Many drones are very difficult to see. As a pilot, I know that even conventional manned aircraft can be difficult to see, and so it is possible that there have been potential incidents that went unreported. Although the database of reports is helpful in drawing attention to potential hazards, it does not allow us to precisely measure risk.

Now, the second question: what are the best technologies and policies to mitigate these risks?

There are several technologies to help mitigate risk. I have already mentioned altitude limitations and geofencing. Altitude limits can be implemented fairly reliably and only require a barometric altimeter. A barometric altimeter measures pressure altitude at takeoff and the drone's software can make sure that the altitude of the vehicle not exceed some threshold above that. Of course, if you take off at the top of a mountain, you may be able to go to an area where you are well over 400 feet above the ground. There is not much you can do about this unless your drone is equipped with a terrain database or a laser altimeter. Implementing geofencing is even more difficult because it requires an up-to-date database of geofenced locations and accurate GPS position information, but the safety risk can be significantly reduced with such technology.

Altitude limitation and geofencing technologies are available today and implemented on many of the commercial drones, but should they be mandated? If so, in what form? I am not a policymaker, but I believe it would be wise to establish default altitude limits for non-toy drones capable of flying above 400 feet. The cost to add this safety feature if it does not already exist is fairly negligible. Most drones capable of flying above 400 feet already have an altimeter. One of the first things a new user might be tempted to do after opening the box is see how high the drone can go. A default altitude limit will not ensure safety or prevent interference with firefighting on its own, but it will certainly help naïve users and discourage reckless users. However, prohibiting a conscientious user from overriding the altitude limit is problematic. For example, authorized users such as firefighters might need to go above 400 feet in order to collect imagery of the wildfire they are fighting. The exact approach for overriding limits is still being thought through by industry, and I believe it is too early to mandate a particular mechanism. You do not want it to be especially easy for a casual user to dismiss altitude limits. An altitude limit for an appropriate category of aircraft that can be overridden in some way by a competent operator can go a long way in reducing risk.

Geofencing is more complicated and there are many cases where you may want it disabled. For example, some of my students were authorized to fly drones within a netted cage right next to Moffett Federal Airfield during a convention at NASA Ames on unmanned aircraft. If a geofence were strictly mandated, they would not be able to perform their demonstration. Similarly, fire fighters within an emergency temporary flight restriction should have access to drone technology. Appropriate users need the ability to override geofences. How to determine whether a user should be permitted to override a geofence is unclear and raises complicated questions. A basic geofencing capability implemented by drone manufacturers with the capability of user overrides would help prevent unintentional airspace violations.

Altitude limitations and geofences are near-term risk mitigation measures, but it is becoming clear that some kind of infrastructure will be needed to facilitate the integration of commercial drones into the airspace to support applications such as goods delivery and agricultural monitoring. NASA Ames, in collaboration with industry and academia, has been pursuing the development of the UAS Traffic Management System. I believe this is a strong path forward in bringing together many of the features of air traffic control to ensure safe and efficient drone operation. However, there is still tremendous research to be done in terms of security, resource allocation, and contingency management.

When flying in the same airspace as manned aircraft, a "sense and avoid" system is likely to be necessary to help prevent collision. The FAA has successfully flight tested a version of ACAS X on a Predator B aircraft. The Predator B is equipped with much more sophisticated surveillance systems and avionics than can be placed on smaller, far less expensive drones. It is likely, however, that much of the technology can be adapted for sensor systems that are appropriate for smaller drones. I anticipate that sense and avoid technology will progress significantly over the next few years. Estimating the reduction of risk with such sense and avoid systems can be done through modeling and simulation.

In conclusion, I offer the following: The growing popularity of commercially available drones presents a risk that should not be ignored. Education should play a major role in risk reduction. In addition, there are technologies that can be easily implemented by drone manufacturers on the relevant categories of drones to help prevent inadvertent altitude or geographic airspace violations. It is in the interest of the drone industry as a whole to implement these safety measures. It is in the interest of our nation to support the research needed to ensure aviation safety as our technology evolves. The future of unmanned aviation is bright and has the potential to flourish into an entirely new industry with applications yet to be imagined.

Thank you for this opportunity, and I am happy to be a resource to this subcommittee.