Government-University-Industry Research Roundtable
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Unmanned Aircraft Systems: Use & Regulation

The use and regulation of civil unmanned aircraft systems (UAS) has become a topic of interest, as governments and businesses have sought to use these aircraft for everything from law enforcement to movie making to package delivery. On June 23-24, 2015, the Government-University-Industry Research Roundtable held a meeting to explore potential applications of advances in UAS, privacy and security concerns that are unique to UAS, and existing and evolving regulations that govern their use.

The meeting's keynote speech on June 23rd was delivered by **Robert A. K. Mitchell**, retired vice president for advanced systems development at Northrop Grumman Aerospace Systems. "I believe we are in an exploding market, and it is revolutionary," said Mitchell in opening his presentation. He then offered an overview of the rules the Federal Aviation Administration (FAA) has proposed for unmanned aircraft. Although expressing doubts about the enforceability of the rules, he suggested that the FAA has done a very good job in trying to assemble a sensible set of regulations around this exploding industry.

The class of vehicles for which the FAA has established rules is 55 pounds or less and flies at 100 mph or less, Mitchell explained. According to the rules, the UAS needs to have markings consistent with manned aircraft, and the owner must register the vehicle and maintain it in a condition for safe operations, though there is no need for airworthiness certification. The operator must be at least 17 years old, vetted by the Transportation Security Administration (TSA), and mentally and physical capable. The operator must also get an unmanned aircraft operator's certificate with a small UAS rating. The UAS must be flown within visual line of sight, at or below 500 feet from ground level, and it cannot be flown above people uninvolved in the flight. The operator must yield the right-of-way to other aircraft, and there is a requirement for "see and avoid," which is notoriously difficult to accomplish even in some high-end military systems, according to Mitchell. UAS can be flown anywhere except in Class A airspace—18,000 to 60,000 feet in the United States—and must be flown in daylight and in weather that allows 3 miles of visibility. This is the proposed framework the FAA has published for feedback.

Mitchell offered a brief overview of the history of unmanned aircraft, starting with the 1849 Venice revolt, when Austria attacked Venice with unmanned balloons that dropped explosives, and continuing through the Southeast Asian conflict and the Cold War. The Air Force Global Hawk, a UAS currently used for surveillance, was developed and manufactured while Mitchell was at Northrop Grumman. He also described some of the technical glitches Northrop had to navigate while developing unmanned systems, such as an aircraft that refused to land and another that decided to take the long way around the earth

to its landing spot. "I offer this history in order to illustrate that the industry did not emerge quickly," said Mitchell. "Much of the experience and lessons learned by Northrop Grumman and hundreds of other companies have been folded into the development of current UAS."

Mitchell then reviewed the evolution of numerous technologies—such as nanocore modules, additive manufacturing, and batteries—that have driven the development of current unmanned aircraft vehicles (UAVs). "My hypothesis is that we have created a revolutionary capability with the potential for exponential growth," he said. "Software guidance and control has advanced so much that these aircraft can basically fly themselves, while the operator provides outer-loop control. Even software and mission planning has advanced; once a mission plan has been created, it can be loaded into an aircraft again and again, and transported to other craft. If we had an open architecture—an unmanned aircraft that was accessible to third party applications—the innovation would be unlimited."

Based on the number of pilots and aircraft in the United States, there are potentially between half a million and 3 million UAVs and operators, according to Mitchell. While applauding the FAA for taking a crack at formulating rules, he raised the question of whether they could be enforced with that number of aircraft. He also suggested that some of the FAA rules are subjective, and that it may be difficult to avoid flying over uninvolved people whose movements are beyond the operator's control.

Will the new FAA rules really address the core need? "My idea, which is very controversial, is to look hard at virtual presence," said Mitchell. "If we have a solid communications link, if we know where we are, if we have an accurate view of the terrain, if we know where all of the other aircraft are, and if we are fully aware of the weather and the vehicle's health, it would be equivalent to being in the aircraft. Combining all of this information would enable synthetic vision; the operator could both see the virtual view from the cockpit and get stand-off views, such as viewing the aircraft from above."

Mitchell concluded by suggesting that the United States is in a unique position to lead the world in this area in terms of technology, experience, mission understanding, and innovation. He indicated his faith in the opportunity the country has to create and benefit from smart legislation, which can enable additional exponential growth in the industry.

UAS APPLICATIONS

On June 24, the meeting opened with a series of presentations on various applications of UAS. First, **John Valasek** of Texas A&M University spoke about how UAS could support precision agriculture, which involves the precise application of nutrients, fertilizers, and other aerial and ground spraying. Precision agriculture is also used to continuously monitor crops, inventory animal herds, and manage irrigation.

"The value precision agriculture brings is not more data but actionable data," said Valasek. Information must be timely, because people need to act quickly; crop blight and insect infestations need a same-day response, for example. In the short term, UAS can contribute to precision agriculture by helping with research on better methods, better processes—in particular, automated data processing to provide actionable data faster—and better vehicles. Valasek suggested, "In the long term, the commercial aspects—crop dusting and spraying, irrigation, and handling risk management insurance claims—will ultimately be the most important."

Valasek noted three main types of operators that are likely to use UAS in precision agriculture. Some farmers will operate UAS themselves after some basic or self training. A second group will be crop consultants, who in the future will transition to operating UAS and using powerful processing tools for the data, enabling them to provide more information and advice to farmers. The third group is researchers, who are currently allowed to use UAS to do research on the aeronautical aspects of UAS, but not to do agricultural research.

Valasek prescribed three goals for UAS use in precision agriculture moving forward:

- Take existing UAS technology and help turn that into actionable information. Precision agriculture currently uses ground-based vehicles like autonomous tractors, but these vehicles lack the height advantage of UAS.
- Develop safe operational procedures and policies. This will allow the FAA to develop both a good database and some trust in the system.
- Address safety issues and competition concerns, given that there is a long history of manned aircraft and manned precision agriculture. Right now, there is uncertainty about how the unmanned vehicles will work with the manned ones, but likely both types of aircraft will be needed at certain times.

Paul Ferguson of CNN spoke about use of UAS for news gathering. He showed a video of President Obama speaking to a reporter after a UAV landed on the White House lawn; in the video the President explained that he had tasked the FAA and other agencies with talking to stakeholders and addressing the larger issue: the need for a regulatory structure for UAS that would allow beneficial uses of the systems while protecting people's safety and privacy. Ferguson offered examples of video footage CNN captured using UAS in disaster zones. "It makes for a more interesting and powerful story if news outlets can give people a visual of farmlands that have been destroyed by a tsunami and that are littered with small fishing boats, rather than just telling them about it," he said. "This is the reason CNN is active in the UAS space," said Ferguson, offering another sample video of a village in Nepal that was destroyed by an earthquake.

"We need to be integrated into the larger emergency response system," he continued. CNN and Georgia Institute of Technology are working on a research project that is examining the kind of craft needed to do so—which has not been developed by industry yet—and unhackable frequencies that can be used for transmission. CNN is also working with the FAA as part of an agency program called Pathfinder. As part of this program, FAA asked CNN to proceed with UAS use slowly and cautiously and to keep the agency apprised of activity so that the agency can observe how news gathering with UAS works. Ferguson also noted that CNN will be working with the National Aeronautics and Space Administration (NASA) on the issue of activity under 500 feet. In a disaster zone, it is necessary to distinguish quickly between UAS operators who are authorized to be there—such as infrastructure inspectors and emergency responders and media—and those who should not be there.

The next presentation was given by **Barry Milavetz** of the University of North Dakota (UND), who explained the university's efforts to address some of the ethical issues associated with UAS use by law enforcement. In 2012 UND formed a compliance committee to review proposals from the local sheriff's department, which wanted to begin using UAS. The committee includes representatives from the university, law enforcement, and aviation sectors, as well as a number of community members, including local farmers.

"One of the underlying principles used by the compliance committee is weighing the risks against the benefits to the public of a particular UAS use," said Milavetz. The committee began by approving proposals for uses where the benefit was tremendous and the risk was minimal—for example, the case of a person who had gone missing during a harsh North Dakota winter. The issues became more complex, as the proposed uses went from missing persons, to surveying disaster scenes, to suspect search, to crime and traffic accident scene analysis, to major event monitoring. The latter cases became more problematic because many people are present and affected by the UAS surveillance. "The committee has been fortunate because local law enforcement has been cooperative and has accepted the restrictions we have placed on UAS use," said Milavetz.

Milavetz discussed the results of a scientific survey the committee fielded in 16 counties of northeast North Dakota in order to learn about public perceptions of UAS use. Eighty to 90 percent of respondents considered search-and-rescue an acceptable use of UAS. A majority opposed UAS use for law enforcement against traffic violations and speeding, but 85 percent supported use in a hostage situation where people's lives were at risk. For commercial and agricultural use, there was 85 to 90 percent support for UAS use by a landowner but far less support for a large company surveying other people's land. The biggest concern for most people was not privacy but safety.

According to Milavetz, the committee does not consider some UAS uses acceptable; for example:

- Random persistent surveillance, such as putting up a UAS just to look at what is going on in the city.
- Maintaining data that is not required as evidence for longer than a maximum period. The committee puts specific requirements on data, and a UAS user cannot hold onto data indefinitely—usually 60 or 90 days.
- Use of a UAS without informing the public in the immediate vicinity. The committee requires law enforcement or other UAS users to notify those affected.
- UAS use outside of the specific area described in the proposed use.

Among the lessons the committee has learned, Milavetz noted, is that from a privacy standpoint UAS are simply a platform, and there is really no difference between using a helicopter or a fixed-wing aircraft and using UAS. Rather, the issues—ones the committee faces on a regular basis—are the data that is acquired, how it is managed, and who has access to it.

Patrick Meier of the Qatar Computing Research Institute spoke about UAS applications for disaster response and humanitarian assistance. After Cyclone Pam devastated the islands of Vanuatu, the World Bank activated the Humanitarian UAV Network, and Meier was recruited to coordinate two teams from the Network. The World Bank wanted aerial surveys in order to understand which houses were fully destroyed versus partially damaged versus largely intact. The UAVs used were preprogrammed and mostly autonomous, so much of Meier's teams' time was spent behind computers, programming flightpaths. The teams coordinated very closely with the government, with air traffic control, and with the Australian Defense Force.

"Humanitarian organizations are finding that aerial imagery is a big data challenge, because they did not have the tools or resources to make sense of 30 or 40 gigabytes of high-resolution aerial images they collect," said Meier. In Vanuatu, for example, the World Bank didn't have the resources to analyze the imagery quickly, so Meier's teams crowdsourced the analysis, pushing thousands of images to an open-source platform and inviting digital volunteers around the world to trace the houses that were fully destroyed versus partially damaged. Each image was shown to at least five different volunteers for quality-control purposes. The data was then shared with the World Bank and with the government of Vanuatu.

Meier also described his work liaising with 50 UAV teams at the request of the United Nations in post-earthquake Nepal. UAV teams worked with the government to do search and rescue, to recover bodies, to take high-resolution images of archaeological sites and World Heritage Sites, and to document landslides. Though the Humanitarian UAV Network has a code of conduct, the vast majority of UAV teams ignored it, which resulted in some arrests and approximately 16 UAV confiscation. As a result of those experiences, Meier put together a 15-page best practices document to raise awareness, drawing from his teams' experiences in Nepal, in Vanuatu, in Haiti, and in the Philippines. "Unless we raise awareness, behavior change is probably not going to happen," he said.

Meier explained that governments often go from no regulation of UAVs to overregulation of UAVs, and these swift changes rarely leave room for humanitarian considerations. For example, after Typhoon Hayan the Philippine government passed regulations that made it virtually impossible to use UAVs for disaster response for Typhoon Ruby a year later. After Typhoon Hayan, Meier founded the Humanitarian UAV Network to promote the safe, coordinated, and effective use of UAVs in a wide range of humanitarian settings. The network convenes expert meetings and recently offered the first formal humanitarian UAV training to established humanitarian organizations.

BRIDGING THE ACADEMIA - INDUSTRY GAP

A joint presentation on bridging the gap between academia and industry was offered by **Emanuel Manos Maragakis** and **Warren Rapp** of the Nevada Advanced Autonomous Systems Innovation Center (NAASIC) at the University of Nevada, Reno. Maragakis explained that Nevada recently went through an economic crisis in which the tourism industry was hit hard and the state faced high unemployment. It became obvious that if the state was to overcome the crisis and develop a sustainable economy, it had to diversify beyond tourism.

"In diversifying Nevada's economy, the two major drivers are the university and industry," Maragakis argued. "NAASIC is intended to bridge this gap between academia and industry in the area of advanced autonomous systems. The center wants to be recognized as a leader in technology and innovation in the area of advanced autonomous systems. In addition, it has a specific mission to spur innovation-based economic development in Nevada. The state has both a critical need for UAVs and the resources to develop them: space, operating base locations, and an excellent climate. It also has opportunities to test autonomous systems for precision agriculture, wildfire detection and protection, and mining."

NAASIC has a business side whose director has responsibility for talking to industry and learning about its needs. The center also has a technical side with its own director, who oversees three thrust areas: UAVs, advanced manufacturing, and sensors. In addition, NAASIC addressed a major industry need—workforce development—by reaching out to K-12 students about engineering and by creating a college-based minor program in Unmanned Autonomous Systems, which is available to those studying mechanical engineering, computer science, and electrical engineering.

Rapp, who directs the business side of NAASIC, began his remarks by noting that the problem of trust in UAVs is heightened by use of the term "drone" for civilian UAVs. "It is hard for people to hear on the news that a drone just killed two Al Qaeda

commanders and then hear that a drone just surveyed roofs in Boston after a heavy snowfall," he said. "People need to be educated about what is being done commercially and not on the military side." Rapp's job is to explain NAASIC's purpose to industry, to assess the research and development needs of industry, and to determine whether NAASIC can meet those needs. He offered examples of successes the university has had with UAV development, including its work with a package-delivery company called Flirtey. "NAASIC is selective about the ideas it invests resources in," said Rapp. "Many people have good ideas, but we look for people who also have done research and have a prototype and ideas for how to perfect it." Flirtey did that; the company had high commercialization potential as well as global partners. NAASIC had benefits to offer Flirtey—engineers, matching funds, and indoor and outdoor testing spaces—and in return Flirtey offered NAASIC the opportunity to build a reputation. Flirtey has had a successful product demonstration and now has almost $1 million in investments.

NAASIC has also been working with Drone America to perfect its UAS platform, which can stay airborne for almost 40 minutes, carry a payload of almost 5 pounds, and land and take off from water. They are working with the United States Geological Survey (USGS) on using the UAV to address algal blooms; other applications include search and rescue, support for lifeguards, and other first responder uses. Rapp added that Drone America is now the manufacturer for the university's UAVs. NAASIC is also working with the state of Nevada to standardize the UAVs that state agencies are using for emergency response, so that when collaboration is needed around a natural disaster or other incident, they already know which frequencies to use and how to capture the data.

PRIVACY

Harley Geiger of the Center for Democracy and Technology (CDT) spoke about privacy issues related to UAVs, focusing his remarks on three overarching points.

Unmanned Aircraft Systems are a promising technology but they have the potential to erode civil liberties by enabling new forms of pervasive surveillance. UAS are a valuable technology with many positive uses that pose little or no threat to privacy, and the potential economic and scientific benefits are substantial. CDT wants to see unmanned aircraft used for commerce, for journalism, for disaster relief, scientific research, and more. However, it s also widely recognized that UAS can be used to erode privacy and degrade civil liberties, and government and industry should not ignore that potential for abuse. Because UAS can operate at vantage points that other systems do not reach, their privacy impact can exceed those of older systems.

Current laws do not provide strong privacy protection from government or commercial use of unmanned aircraft. At present there are very few nationwide legal restrictions on law enforcement use of UAS to monitor Americans outside of their homes, and there is no federal statutory due process protection. Under the current law, the government has broad leeway to conduct aerial surveillance without a warrant. Americans have a bit more—but not much more—protection from private sector UAS observation. Geiger reasoned, "Because CDT is also a free speech organization, we believe that direct government regulation of UAS must not violate our First Amendment right to photography in public places." The perceived lack of privacy protection in the law has fed widespread public distrust of government and commercial UAS. A 2013 poll by Monmouth University found that three-fourths of Americans thought that government should get a warrant to use UAS, and a different poll the same year found that nearly half of Americans thought that they should have the right to shoot down UAS on their private property.

To earn public trust of UAS, both government and industry should fully address civil liberties issues through a combination of legislation and an industry code of conduct. CDT believes that the goal should be a light regulatory touch on UAS use for research and other uses that have a low impact on civil liberties. "Government UAS applicants for licensure should fill out a data-collection statement outlining the collection, retention, and use of the data, and the U.S. Department of Transportation should establish a public database that shows the licenses and data collection statements," Geiger suggested. He also argued there should be a restriction on use of law enforcement UAS to surveil private property, subject to exceptions such as if they have a search warrant or if they are in hot pursuit of a suspect. "When it comes to public property," Geiger noted, "the goal should be to prevent prolonged surveillance while still allowing for uses such as traffic accident scene photography." CDT also supports the Department of Commerce's upcoming effort to develop voluntary guidelines for UAS.

SECURITY

The next presentation was given by **Michael Francis** of United Technologies Research Center, who spoke about safety and security issues related to UAS use. He discussed some of the vulnerabilities of small UAS. Small UAS do not perform well in windy conditions, a vulnerability these systems must overcome if they are to become reliable, 24-hour/7-day mission systems. A bigger issue in the near term is the airframe pedigree: with the proliferation of UAVs, many companies are getting into the business of manufacturing small UAVs, and most lack aerospace knowledge or an understanding of the standards that have made aviation safe.

Small UAVs proposed for commercial and private uses also have limitations in the command-and-control area, he continued. One challenge is giving the operator the situational awareness needed to control the UAV, especially beyond the line of sight. Another challenge is the need for constant vigilance on the part of the operator, which limits the type and duration of the missions that can be conducted. Yet another concern related to pure security is the susceptibility to hostile disruption or even takeover of the system, whether accidental or intentional.

"However, the biggest Achilles heel that today's small UAVs have is communications—in particular latency or degraded communications", Francis said. "To improve UAS safety and security, one of the first strategies must be improving communications, especially in congested environments. There will be a need for connectivity on demand for all UAVs during operations—a capability important to operate a network of these aircraft delivering packages in an urban environment, for example. Finding ways to reduce or eliminate latency in transmitting flight-critical information is especially important."

Francis put forth another strategy to improve safety and security: reducing the level and the predictability of operator interactions. Francis purported that right now the biggest vulnerability is the wireless link that is used to control the aircraft. He stated, "We are attacking that problem by adding autonomous functionality—by making the vehicle more intelligent so that it can perform basic flight functions, like maneuvering, takeoff, and landing. This allows the operator to do other things such as increase situational awareness or manage payload operations." More recently UAVs have demonstrated damage-tolerant control—if something breaks, the system is able to reconfigure its controls to compensate for that damage. But in the area of contingency management—what the machine does when something goes wrong—technology is in the early stages.

"In the longer term, trust is a big issue," said Francis. "Certification processes today are built around hard-sciences-based systems that provide precise, repeatable, predictable results. Autonomous machines will likely exhibit nondeterministic features and even emergent behavior, attributes which cannot be certified with today's processes; the only analog we have is how we certify humans."

INTEGRATING UAS INTO THE NATIONAL AIRSPACE SYSTEM

The final two presentations examined issues surrounding the integration of UAS into the National Airspace System. **Robert Pappas** of the FAA focused his remarks on Section 333 and other agency initiatives to facilitate the integration of UAS.

"One of the first steps the FAA took to respond to the FAA Modernization Reform Act of 2012, which was the agency's reauthorization legislation, was to start some operations in the Arctic," said Pappas. The agency granted special airworthiness certificates to two UAVs that are flying over the Arctic today—nighttime operations, beyond line of sight, 24/7. The FAA was also required to set up six UAS test sites, and those are now operational and available to both the academic and private sectors.

Pappas discussed Section 333 of the FAA Modernization and Reform Act of 2012 (FMRA), which asks the Secretary of Transportation to identify if there are certain aircraft that can—as a function of their size, weight, speed, operating area, proximity to people, etc.—operate safely in the national airspace. The FAA makes recommendations to the Secretary of Transportation, who reviews the request and makes the determination if the system and operation meeting the requirements of Section 333. "What makes Section 333 so valuable is that it does not require that an aircraft approved under it to go through the difficult step of getting an airworthiness certificate," said Pappas.

A little more than a year ago, Pappas was tasked with implementing Section 333 within 90 days. He pulled a team together and they developed a structure for implementing it, and in September 2014 they granted their first exemption. Since then they have granted almost 600 exemptions. Applications have been received for UAS use for inspecting critical

infrastructure, movie making, agriculture, and real estate, among other uses. Based on experience with six key early exemptions, his team was able to develop a streamlined review process that can address 98-99 percent of the petitions they receive.

"Section 333 has been great in that it has opened up doors to more UAS operations," said Pappas, "but it is an extremely challenging project for the FAA, especially from a resource standpoint. In a typical year the FAA would get 400 to 500 total requests for all kinds of exemptions across the agency; in the past year they have gotten nearly 2,000 requests for exemptions for UAS alone."

Pappas explained that Section 333 is intended to be a bridge to the FAA, establishing a rule to regulate the use of UAS. He also spoke about the Pathfinder program (mentioned earlier in the meeting), which is working on some areas to aid the full integration of UAS into the national airspace. FAA has partners in three areas: CNN, with whom they are exploring UAS within visual line of sight in urban areas; Precision Hawk, with whom they are working on extended line of sight in rural areas; and BNSF Railways, with whom they are working on beyond line-of-sight use in rural areas. "Beyond line of sight is the Holy Grail," said Pappas, "and so the project with BNSF is helping the FAA think about standards development and potential regulatory development."

Lisa Ellman of the international law firm Hogan Lovells discussed federal efforts around UAS, including the FAA's proposed rules. She opened by acknowledging the considerable confusion about the rules governing UAS. One of the biggest challenges to regulation is evident in the fact that hobbyists have their own set of rules, and model aircraft use has been permitted for many years. Ellman explained, "Whether a UAS counts as a hobbyist use is an intent-based test rather than a safety- or risk-based test. Those who intend to use a small UAS for purely recreational purposes and who follow community guidelines, fly within line of sight, and stay 5 miles away from airports or notify air traffic control can pretty much do what they want," she said. "A lot of companies are trying to fit into that box, but it doesn't work."

The FAA released the notice of proposed rulemaking on small UAS on February 15, 2015, and soon after it was open for comment. "When the comment period closed, there had been far fewer comments than anticipated, which reflects well on what the FAA was able to do," said Ellman. She also noted that the general interpretation of the rule was very positive from industry, which perceived it as a strong step in the right direction; it was a lot more pro-innovation than many had expected.

Ellman offered some highlights of the proposed rule. For example, as drafted, UAS operator certificates would replace the current requirement of a 333 exemption approval for a private pilot's license. Those seeking an operator's license would go to a local center and take a knowledge test, and applicants would self-certify that they do not have a medical condition that could interfere with safe operation of a small UAS.

The FAA would verify compliance and accuracy of the application and provide information to the TSA for security vetting prior to certificate issuance. Realistically, the rule will come out sometime in 2016 or early 2017. The FAA gets many questions about privacy, Ellman noted, but the agency doesn't have jurisdiction over privacy issues. A White House Presidential Memorandum released February 15, 2015, crafted new restraints on the government's own use of UAS and set up a multi-stakeholder process that will be led by the Department of Commerce that will examine privacy, transparency, and accountability issues in the commercial context. "The current situation is rare and difficult in that policy-makers are being expected to come up with rules that work—that protect safety and privacy and promote innovation—in the absence of significant safety data," said Ellman. "That is a difficult task, and the FAA has done a remarkable job." ■

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DISCLAIMER: This Meeting in Brief has been prepared by **Sara Frueh** as a factual summary of what occurred at the meeting. The committee's role was limited to planning the meeting. The statements made are those of the author or individual meeting presenters and do not necessarily represent the views of all meeting participants, the planning committee, GUIRR, or the National Academies of Sciences, Engineering, and Medicine.

The document was reviewed in draft form by **Nora Ayanian**, University of Southern California and **Jack Hu**, University of Michigan to ensure that it meets institutional standards for quality and objectivity. The review comments and draft manuscript remain confidential to protect the integrity of the process.

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