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Abstract
It is estimated that there are over one million unmanned aircraft systems (UAS) that, if operated incorrectly, can pose a significant threat to individuals, property, and other aircraft. Many of these systems are now finding their ways into universities, where they are operated by non-aviation professionals with an overall objective of exploring new research opportunities. While these initiatives hold significant promise for technical advancements, some employ relatively primitive operational and safety protocols. This article reviews FAA rules and reports on a university effort that has developed a formal partnership between an established aviation center utilizing licensed pilots and an engineering center that is focused on using UAS for infrastructure research. The fundamental concept of this partnership is a division between UAS operational and research activities. The article describes a structure that clearly segregates the research activities from flight operations. The framework described in this paper can serve as a model for universities seeking to initiate UAS research in a manner that conforms to FAA rules and accepted aviation best practices.

Keywords
Unmanned aircraft systems, Certificate of Waiver or Authorization, sUAS, 14 CFR 107, JTRP, A^{3}IR-CORE.

Introduction
Unmanned aircraft systems are increasingly used by a broad cross section of academic researchers, many of whom have no formal aviation training. The most expeditious means for a public higher education research institution to receive permission from the Federal Aviation

Administration to operate in the national airspace system is through the establishment of special-use airspace granted through the COA, or Certificate of Waiver or Authorization, process.

Once a COA has been established to allow research-based operations of unmanned aircraft systems at a state institution, with that certificate presumably encompassing a broad potential research mission involving multiple organizations and stakeholders across the institution, questions related to COA administration and the provision of qualified operators naturally arise. This article describes a model that is being implemented at a large Midwestern research university in an effort to define clear boundaries between research and flight operations. The model is intended not only to provide broad flexibility in the types of remote sensing research conducted, but also to house the flight operations in a dedicated center with personnel trained in the administrative, safety, and operational procedures required by the FAA. This model is consistent with longstanding military and flight test practices that establish a crew complement with clearly defined roles where duties for safely piloting the aircraft are segregated from those related to collecting scientific data or operating electronic warfare devices. This segregation of responsibilities is critical to ensure safe aircraft operation.

The organizational structure described within this article provides an example of the need for engagement between those conducting the research and those managing the operational aspects of an unmanned aircraft systems program at a major higher education research institution. The article demonstrates how the natural separation that exists between researchers and operators can be used to provide an appropriate division of responsibility between those groups best suited to accomplish these different functions. This division of responsibility has resulted in an efficiently-run organization that is permeated by a positive and proactive safety culture, two goals that were explicitly stated from the inception of the concept.

Certificates of Waiver or Authorization (COA): Background

The FAA has the authority to issue a COA for the public operation of unmanned aircraft systems. A Certificate of Waiver or Authorization is simply a document by which the FAA approves a particular operator to engage in a specific aviation activity. This type of approval has historically been granted to accommodate air shows and other types of activities, which might constitute a hazard to the normal operation of air traffic, and is issued by the FAA's Air Traffic Organization and reviewed by the FAA's Flight Standards Service. Currently, operations of unmanned aircraft systems require a Certificate of Waiver or Authorization because these systems do not comply with administrative law pertaining to regulation of operations in the national airspace system. For example, 14 CFR 91.113 requires the pilot of an aircraft to "see and avoid" other aircraft; UAS are unable to comply with this regulation due to the absence of an onboard pilot.

In 2007, the FAA promulgated a notice (FAA, 2007) announcing that its UAS policy is based on whether an aircraft is operated as a model aircraft, civil aircraft, or public aircraft. This notice also includes guidance for entities seeking to operate unmanned aircraft systems as public aircraft. It should be noted that public aircraft operations differ from civil aircraft operations in

that "the FAA has no regulatory authority over public aircraft operations other than those requirements that apply to all aircraft operating in the national airspace system" (FAA, 2014, p. 3). According to Jacobs and Jawed (2015), the question of whether an operation qualifies for public aircraft operation status must first be answered. The applicable statutes that may be used to determine the answer to this question are found in 49 U.S.C. 40102(a)(4l) and 40125. In general, the only aircraft operations that may qualify for public status are those of a government entity; however, once it is determined that an operation has that status, the government entity responsible for the operation may contract with a third party (itself not necessarily a government entity) to perform the operation, thereby giving public status to the particular aircraft operation. This would allow, for example, the contracting of search and rescue operations using an unmanned aircraft system by a state or local government as long as certain conditions on the leasing of the aircraft are met.

More recently, the FAA released a legal interpretation (Bury, 2014a) addressing the proposed use of public aircraft for educational purposes. The interpretation states that the FAA has "determined that education is not a valid governmental function under the public aircraft statute," and continues, "if Congress had intended the list to [include] any [governmental] activity, it would have used the term 'any activity'" (Bury, 2014a, p. 1). For example, a number of public universities have applied for certificates of authorization to allow the operation of unmanned aircraft systems for purposes of training students. The interpretation creates a delineation between the public entity conducting the operation and the nature of the operation itself, and indicates that training operations such as these do not constitute public aircraft operations. The interpretation points out that all flight schools, including those owned by state institutions, conduct operations that are civil in nature and that are subject to FAA regulations, as they do not use public aircraft operated by flight instructors who are not FAA-certified to train students.

It is clear, however, that certain research conducted by state institutions of higher education is not subject to the same restrictions as flight training operations, and that operations of unmanned aircraft systems for particular research purposes is indeed a valid governmental function under the public aircraft statute. For example, a separate legal interpretation (Bury, 2014b) states that aeronautical research is a specifically-allowable research function under the public aircraft statute, and is therefore one which may be performed by a state institution of higher education, provided that the research is not performed for commercial purposes. The memo detailing the interpretation explicitly states that "such aeronautical research may be funded by a grant (without being a commercial purpose) provided that the results of the research belong to the state (university) and the research does not carry the property of another (including the entity funding the grant)" (Bury, 2014b, p.3).

In June, 2016, the FAA announced new regulations, promulgated as 14 CFR 107, that provide for the commercial operation of small UAS (sUAS), those aircraft between 0.55 and 55 pounds. While these regulations allow the operation of sUAS in Class G airspace below 400 feet above ground level, they do not permit the same degree of freedom as a COA that has been established for the operation of public aircraft as described above. Specifically, the ability to self-certify

operators and self-determine required maintenance procedures does not exist under 14 CFR 107, while it does for public aircraft operated under a COA.

Certificates of Waiver or Authorization (COA): The Application Process

It is the responsibility of the Federal Aviation Administration to ensure the safe and efficient operation of the United States National Airspace System (NAS); the NAS includes all navigable airspace, regardless of altitude. A common misconception among UAS operators stems from the unfortunate labelling of Uncontrolled (Class G) Airspace. It is this label that leads UAS operators to assume incorrectly that they may fly unrestricted below 500 feet above ground level. Class G airspace is regulated, and it does not require specific aircraft equipage and communication. It does, however, require all aircraft to comply with applicable Federal Aviation Regulations.

When submitting a COA request, the operator must either meet the requirements of all applicable portions of the CFR or provide a possible alternate means of compliance for the FAA to consider. The time and effort to develop a COA can be significantly reduced by using certificated aircraft pilots, mechanics, and other support personnel in order to comply with these regulations. This allows the FAA to concentrate on the other regulations that the UAS cannot inherently comply with, such as 14 CFR 91.113 (known as “see and avoid”), as noted previously.

Although a number of interested parties at the institution in question had been engaged in discussion regarding unmanned aircraft systems research and related operating areas for several years, little progress toward establishing a COA of significant impact had been made. A Certificate of Waiver or Authorization for limited airspace usage was awarded to the university’s College of Agriculture, but the airspace boundaries of this COA are restrictive and specifically exclude the Class D airspace surrounding the university’s airport, further limiting the usefulness of that COA. It became clear that broader airspace boundaries would be required to meet the institution’s expanding research needs, as described below. To expedite the application process, an outside consultant was hired to secure a new COA with greater geographic coverage.

Using Research Centers to Separate Research and Operational Functions

The Joint Transportation Research Program (JTRP) facilitates collaboration between the Indiana Department of Transportation, higher education institutions, and industry to implement innovations that result in continuous improvement in the planning, design, construction, operation, management and economic efficiency of the Indiana transportation infrastructure (Newton, Bullock, Watkinson, Bracke, & Horton, 2012).

As civil infrastructure in the United States ages and deteriorates, it is critical to leverage technology that can be used to collect quantitative data for long term asset management. In 2015, JTRP recognized a need for research on UAS-based platforms that could be utilized to deploy high-resolution cameras for a variety of applications, including collection of traffic movement data, site assessments, and bridge inspections. While bridges can be inspected manually, that process requires lane closures, and the resulting vehicle queues can lead to an

increase in the potential for back-of-queue accidents by a factor of 24 (Mekker, Remias, McNamara, & Bullock, 2015). Unmanned aircraft systems could potentially allow a much greater margin of safety during these inspections. Initial tests were very promising (Hainen et al., 2015), but upon review of FAA regulations and accepted practices, subsequent UAS research was suspended until a formal protocol could be developed.

It is clear that research into applications of unmanned aircraft systems to facilitate inspection of highway bridges and other types of civil infrastructure is congruent with JTRP's stated mission. However, the operation of aircraft lies outside this mission and the program's capabilities. Because of this constraint, JTRP turned to the School of Aviation and Transportation Technology (SATT). SATT houses a professional flight major and manages a training fleet of 26 aircraft, including 16 Cirrus SR20 single-engine trainers and two jets. The school also houses a relatively new major in unmanned aircraft systems. A partnership between JTRP and SATT provided a natural delineation between responsibilities, with the JTRP team conducting the research and an entity within SATT selecting, training, and managing unmanned aircraft systems operators, pilots, and observers. SATT also was identified to manage administrative functions, including oversight of the COA application process, recordkeeping and reporting, and safety responsibilities. SATT currently has approximately 150 licensed pilots enrolled as students at the university.

Housed within the school, the Advanced Aviation Analytics Institute for Research (A³IR-CORE), a university-level center of research excellence, is "focused on the dual mission of addressing operational challenges within the aviation industry and facilitating positive educational outcomes for students by actively involving both graduate and undergraduate student researchers working closely with faculty mentors in a highly-collaborative multidisciplinary environment" (Mott, 2014, p. 27). A principal objective of this center is the enhancement of the employability of graduates of the school in which it resides, an objective that aligns closely with the strategic goals of the university. A³IR-CORE is partially sponsored by industry partners, and a portion of the research performed is consistent with needs suggested by those partners. The resulting research agenda of the center is focused primarily on the assessment and data-driven improvement of aviation operational processes.

A³IR-CORE is structured in such a manner that it facilitates the mentoring and guiding of graduate students by associated faculty as those students in turn supervise teams of undergraduate student researchers engaged in projects. This structure is designed to promote the fulfillment of outcomes related to both problem-based and project-based guided inquiry learning, leading to the development of positive educational achievements on the part of the participating students.

Given the needs for a division of responsibility between the research functions and the operational and administrative functions as noted previously, and for engagement between the respective entities, it is readily apparent that the A³IR-CORE center can both facilitate the engagement aspect and handle the operational and administrative requirements of the UAS

research program while, in addition, accomplishing its goal of enhancing the employability of participating students by providing them with real-world operational experience in the UAS discipline.

Structuring the Respective Research and Operations Components

The goal to be accomplished with the division of responsibilities between research centers is the safe operation of the related unmanned aircraft systems. The Certificate of Waiver or Authorization was specifically developed to ensure the predominance of the safety theme; for example, operator/pilot qualifications were established so that both a private pilot certificate and training on the specific UAS are required, which exceeds the baseline operator requirement in 14 CFR 107. Lost link procedures were developed to require the unmanned aircraft system to return to base by means of a preset pattern that ensures that object and personnel clearance is maintained, as opposed to simply flying the most direct route to base.

The operations personnel in A^3IR-CORE are students who either major in unmanned aircraft systems, or who have experience working in this discipline. The three distinct focus areas related to this initiative, operators, administration, and the prevailing safety culture, are described below.

Operators are chosen to meet the requirements described above. The school with which A^3IR-CORE is associated, or its precursors, has conducted flight training since the 1930s and has substantial experience training students to operate all manner of aircraft. The operation of unmanned aircraft systems is a natural outgrowth of the institutional training experience that exists at the university in manned flight programs.

The administrative personnel responsible for maintaining the operations database and generating required FAA reports are also students selected for their understanding of data collection and analysis, areas of emphasis in the school's aviation management program. Both the student operators and administrative personnel are expected to develop valuable skills in their respective areas that will readily translate to job skills when the students graduate from the institution.

The safety culture that does and must encompass all of the school's training operations is, again, a result of the collective institutional experience that is present. This culture is fostered by faculty and staff and embraced by students as they matriculate into and graduate from the academic programs offered by the institution. The safety culture and assessment and continuous improvement thereof is a requirement for accreditation by the Aviation Accreditation Board International, the organization that accredits multiple programs within the school.

The key point to understand is that the operations and administrative expertise, as well as the associated safety culture, resides within the School of Aviation and Transportation Technology, and it is that school which has been tasked with the responsibility of ensuring that those functions are executed properly.

In the near term, virtually all of the JTRP-related research is focused on collecting aerial images of construction sites, hard-to-access infrastructure, major vehicle crash scenes, and detours (Figure 1). Currently, much of this imagery is collected by photographers using fixed-wing aircraft. However, due to time constraints, cost, and aircraft scheduling, it is anticipated that there will be a substantial increase in demand for research imagery with low cost UAS following the establishment of a COA.

a) Work Zone Schematic Drawing

b) Aerial Image Before Construction

c) Aerial Image During Construction

Figure 1: I-65 & US 231 bridge construction and work zone configuration (White Co., IN). (Photo credit Bullock 2016)

Conclusion

The expectation is that A^{3}IR-CORE and JTRP will continue to collaborate within the partnership structure described herein, and that students participating in the related sponsored projects will continue to benefit from the positive outcomes that have been anecdotally noted. Quantification of those outcomes, however, will be necessary to facilitate a detailed analysis, thereby allowing the researchers to formally conclude that the missions of the respective organizations are being accomplished. That dual mission, the successful collaboration to achieve research goals in the area of unmanned aircraft systems and the facilitation of positive educational outcomes for students with respect to increased acquisition of systemic competencies and improved employability, is critical for graduates of academic programs at higher education institutions. It is a mission that suggests that educators should continue to remain dedicated to the fulfillment of their related responsibilities. Such dedication will facilitate the effective preparation of graduates from both of the programs discussed in this article for employment within the rapidly-evolving unmanned aircraft systems industry workforce.

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Biographies

John H. Mott is an Associate Professor of Practice in the School of Aviation and Transportation Technology at Purdue University, at which he has held various instructional and administrative positions since 2006. A summa cum laude graduate of the University of Alabama with Bachelor's and Master's Degrees in Electrical Engineering, he also possesses an FAA Commercial Pilot Certificate with Instrument and Multiengine ratings, an FAA Flight Instructor Certificate with Airplane Single- and Multiengine and Instrument ratings, and an FAA Ground Instructor Certificate with Advanced and Instrument ratings. He holds type ratings in the Hawker Beech King Air 300, Hawker HS-125, and Canadair Challenger 600. Professor Mott serves as the Director of the Advanced Aviation Analytics Center of Research Excellence at Purdue University, the Executive Editor of the Journal of Aviation Technology & Engineering, and as the Interim Head of the Purdue School of Aviation and Transportation Technology. His research interests are in the areas of statistical modeling of transportation operations and aerospace applications of Bayesian inference.

Mrs. Ardyth (Ardy) Williams is the President of AJ Panorama, LLC, a company specializing in working with public and civil Unmanned Aircraft System (UAS) operators. Ardy is a retired Federal Aviation Administration (FAA) air traffic controller and pilot. During her 30+ year career with the FAA she held numerous management positions, concluding with her award winning work in expanding the safe use of UAS in the National Airspace System. Ardy is an Aviation Records Board member with the National Aeronautics Association, an active Officer in the Civil Air Patrol, and has a Bachelor of Science Degree from Purdue University.

Dr. Darcy Bullock is a Professor of Civil Engineering at Purdue University and serves as the director of the Joint Transportation Research Program. Bullock is a Registered Professional Engineer in Indiana and has 30 years of experience in the industry working closely with vendors, highway agencies, airport authorities and USDOT. Bullock’s teaching, research, and consulting interests have been in the general area of intelligent transportation systems.