A42 Lit Review

Goal:
Finding articles in each area and drafting verbiage about a pertinent particular area stressing information for the FAA. We must document the references in a bibliography. You will investigate NASA Advanced Air Mobility, Cargo UAS development, UAS Certification, Part 135, etc. In some cases, interviews with SCI and JetRight may be in order. Also note that Ground Operations for Cargo doesn't exist and should be searched for papers and presentations, etc. Your lit research is due Draft 1, **September 22** to me and final from UAH to UAF on **September 28**.

Acronyms

BVLOS - Beyond Visual Line Of Sight
PSP - Partnership for Safety Plan
DoD - Department of Defense
NAS - National Airspace System
MSCAA - Memphis-Shelby County Airport Authority
SOP - Standard Operating Procedure
FAA - Federal Aviation Administration
UAS - Unmanned Aircraft Systems
RTCA - Radio Technical Commission for Aeronautics
DAL - Design Assurance Level
FDAL - Functional Design Assurance Level
IDAL - Item Design Assurance Level
UAH - University of Alabama in Huntsville
COTS - Commercial Off The Shelf
VLOS - Visual Line Of Sight
SCI - Sanmina Corporation
V&V - Verification and Validation
RTA - Runtime Assurance
SAE - Society of Automotive Engineers
MTSI - Modern Technology Solutions Inc.
NASA - National Aeronautics and Space Administration
GCAS - Ground Collision Avoidance System
ACAS - Airborne Collision Avoidance System
EVAA - Expandable Variable Autonomy Architecture
USAF - United States Air Force
MM-RTA - Multi-Monitor Runtime Assurance
ASTM - American Society for Testing and Materials

(DRAFT)Logistics and Integration (9/16/21)

A great deal of the information that exists for the integration and logistical implementation of Cargo capable aircraft operating at an airport is in large part, conceptual. The primary focus of the research material being discovered speaks mainly on the “how” to get cargo delivered and best vehicle to do that, and exists almost exclusively as operational test subjects. Due to the lack of Beyond Visual Line of Site (BVLOS) certification, companies are participating in programs such as FAA’s ASSURE and Partnership for Safety Plan (PSP) which affords some latitude to experiment and document best practices of flight events with elevated risks. There are several companies such as Xcel Energy, UPS and Florida Power and Light that are currently participating in the PSP program. Very few of the participants in these programs have attained a waiver to operate their aircraft in BVLOS conditions. The BVLOS certification is being reported as a difficult hurdle to overcome for most unmanned programs seeking to earn certifications from the FAA. This is specifically suggested to be causing some delays in the progress of integration and logistics for unmanned aircraft cargo purposes. Based on the material available, and with the limitations imposed on flying organizations the areas being tested have not produced information significant or relevant enough to adequately determine best practices for integration and logistics certification of cargo UAS at a functional multi-role airport. Other companies that are not affiliated with the FAA programs are implementing lessons learned internally and evolving their way of thinking to suit their individual goals. Some level of success is being seen with companies that team with DoD customers with restricted airspace available to conduct tests. This is not available or ideal for most companies as it is time restrictive, competitive, or cost prohibitive to operate in the restricted areas. There have been some instances of small scale, small weight cargo being delivered by small (less than 55lbs) unmanned aircraft, however, this has not typically been tested on airport premises. The aircraft being used are outfitted with cargo compartments or apparatus and flown from isolated yet very controlled test locations. Companies that are aiming to develop the ideal cargo operation have certainly placed logistics and integration on their scope of research, however, their focus seems to be primarily on discovering the best vehicle by which to conduct these operations, closely followed by finding a solution to operating their aircraft safely into the NAS. The testing activity being conducted on active airports is small-scale, very controlled, and conducted at a pace that is commensurate with the comfort of FAA and industry technology advancements. One instance of there being a test conducted on an airport is in Tennessee, with the Memphis-Shelby County Airport Authority (MSCAA).

> “Memphis, TN (November 2, 2020) – On Friday, U.S. Secretary of Transportation Elaine L. Chao announced the three-year Unmanned Aircraft Systems (UAS) Integration Pilot Program (IPP) successfully concluded on Oct. 25. Eight of the nine state, local and tribal governments that participated in the program – including Memphis-Shelby County Airport Authority (MSCAA) — have signed new agreements with the Federal Aviation Administration (FAA) to continue to tackle remaining UAS integration challenges (MEM - Memphis International Airport (2020)).”

Partners in the Memphis program include FedEx, City of Memphis, 901Drones, Tennessee Department of Transportation Division of Aeronautics, Asylon, and DJI (MEM - Memphis International Airport (2020)). These groups are working with the FAA to develop procedures to benefit the FAA's pursuit of regulations for UAS in the NAS. The FedEx flight testing began with a rigorous internal review of capabilities, safety protocols, and processes for all stages of flight as well as developing a comprehensive mishap response plan. According to FedEx, having a Standard Operating Procedure (SOP) specifically for operations at the Memphis-Shelby airport was essential and furthermore, required before any unmanned aircraft left the ground on airport property. The FedEx team conducted sit down meetings with airport safety to discuss unmanned aircraft operations at the field and a cooperative relationship between Memphis-Shelby Air Traffic Control, other commercial airlines operating at MSCAA, and FedEx have provided valuable information on what unmanned aircraft cargo operations on an airport may look like in the near-future (Warr et al. (2021 September 9)).

As FedEx representatives move further into this effort they too suggest that the lack of certification and the FAA's tight restrictions on BVLOS flights is a contributing factor of the throttled pace of progress. Another factor suggested as a limitation for progress, is weather tolerances of commercially available aircraft. FedEx reports that they are employing several models of the DJI suite of aircraft, however, these aircraft are not constructed with all-weather capabilities in mind. Considering that some airports have unfavorable weather conditions for several months a year, an aircraft's ability to operate in various conditions appears to be a profound consideration with regards to the success of unmanned cargo operations (Warr et al. (2021 September 9)).

Another prominent contributor for developing processes, procedures and regulations for unmanned cargo aircraft is UPS. UPS has been experimenting with new ideas of cargo delivery between a variety of sizes of aircraft using FAA's part 135 rules. UPS does not currently utilize the FAA's Part 107 program. One major difference is that UPS is not testing their new ideas at an airport, but instead employing the idea of a fixed-point location away from an airport that services a smaller area. They described it as the "last mile" delivery. Several considerations for this stand-alone concept to be successful is to meet the manufacturers maintenance and operations requirements for the air vehicle, have an area that meets minimum operational requirements for launching, landing, and recharging as well as establishing and maintaining the power generation requirements. UPS has teamed up with clients such as a medical district in Wake Forest NC, and CVS pharmacy to experiment with this unique method of cargo delivery. UPS is employing the authority to operate this way from the Secretary of Transportation's risk-based approach to determine whether an airworthiness certificate is required for a drone to operate safely in the NAS. The details to this authority can be found in *49 USC 44807: Special authority for certain unmanned aircraft systems*. By using this as their approach to the research effort, UPS will test certain UAS capabilities as well as work towards an airworthiness certification for the aircraft that best suits their needs. UPS is currently partnered with BETA aircraft to also explore larger cargo movements but is challenged by the lack of a BVLOS authorization. UPS has suggested that for this to be successful, there must be more consideration put towards risk mitigation, ground operations with coordination at ATC, and more available ground services. One hurdle for UPS while using Part 135 rules is the singular use intentions of the Part 135 construct. When those rules were developed the availability of certain technology and aircraft with such capable performance, was not available. A continuous assessment of the industry and available technology is mandatory. UPS also suggests that a continuous approach to find a means to comply with Ground-Based Sense & Avoid (GBSAA) requirements and utilizing sensors with infrastructure already in place would be growth in the right direction. A major consideration to UPS's testing efforts have been risk mitigation and safety. UPS employs aircraft with failsafe measures such as a Return to Home (RTH) function and for the more advanced safety responses, they use an aircraft that can be shut down in flight and safely brought down by parachute (Warr et al. (20 September 2021)).

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UAS are sophisticated and stochastic systems. A UAS vehicle's attitude, trajectory, and position are influenced by its unpredictable environment. In the scope of cargo operations for UAS, deployment of complex autonomous systems in diverse environments pose significant challenges to their verification and validation (V&V). Any software onboard an aircraft is considered a subsystem. All subsystems onboard an aircraft require full approval in order for certification to be finalized. V&V of flight code and software criticality level are addressed in Society of Automotive Engineers (SAE) ARP4754A, "Guidelines for Development of Civil Aircraft

Systems" and ARP 4761, "Guidelines and Methods for Conducting the Safety Assessment Process on Civil Airborne Systems and Equipment." Document DO-178C, "Software Considerations in Airborne Systems and Equipment Certification," is referenced to verify flight code design and operation. Classically, V&V is accomplished through vigorous scenario testing and simulation. Though advances have been made in design-time V&V, certification of cutting-edge control system algorithms can prove difficult. Advanced and adaptive control systems outreach current design-time V&V techniques for autonomous vehicles (RTA Framework...Systems). According to *Runtime Assurance Framework Development for Highly Adaptive Flight Control Systems*, published by the Airforce Research Laboratory (RTA Framework...Systems), "such systems are impossible to fully analyze at design time, and it is impossible to explore, study or simulate every possible state or outcome." Hence, in addition to traditional V&V techniques, runtime monitoring or runtime assurance (RTA) will be essential for the certification of cargo UAS with advanced onboard autonomous systems.

> "It is expected that through the combined use of new advances in design-time V&V approaches along with the use of RTA systems during online operation, the system behavior can be provably bounded [Schierman 2014(a)], [Schierman 2008], [Rudd 2009], [Aiello 2010], [RTA Framework...Systems]."

RTA is a defense mechanism employed to ensure appropriate behavior of complicated autonomous systems (MellonU). RTA allows the benefits and capabilities of advanced autonomy while protecting against unpredictable and unsafe system activities that can compromise a mission. Runtime assurance schemes monitor a platform's state parameters during operation. RTA uses tests to determine whether unsafe conditions will emerge due to an error in the advanced system. If an error is detected, RTA disables the advanced system and switches operation to a revisionary or system that is certified at design time (RTA Framework...Systems).

RTA systems for UAS are being developed and seeking certification. In 2018, NASA and Modern Technology Solutions, Inc. (MTSI) under the Resilient Autonomy project started the development of a framework that can be used to achieve FAA certification for autonomous aircraft. The project's goal is to develop an architecture for the certification of a fully autonomous system's software using a technique called multi-mode run-time assurance (MM-RTA) (Cite AUVSI). NASA Armstrong Flight Research Center's Resilient Autonomy project is also currently developing collision avoidance software that can be applied to future UAS. Expandable Variable Autonomy Architecture (EVAA), a predecessor of the F-16's Automatic Ground Collision Avoidance System (Auto GCAS) and Automatic Collision Avoidance System, is designed to be utilized in UAS to prioritize human safety and avoidance of property damage. EVAA utilizes refashioned GCAS and ACAS algorithms as separate monitors. These separate monitors are guided through a central function that controls the aircraft to the highest consequence task. EVAA is currently in development and seeking approval and certification from the FAA. EVAA can potentially be utilized in general aviation and future UAS platforms (EVAA cite).

The use of revisionary systems like RTA are not new concepts to the aerospace domain. Early versions of run-time assurance concepts were utilized for NASA/USAF experimental aircraft control system testing. These flight tests often employed revisionary back-up controllers for more stable flight in the case of control system failure. This early work gave rise to triple or quadruple redundant flight control systems that have been utilized for years. Therefore, back-up control concepts have been key in safety assurance for certified flight hardware and software (Cite Initial considerations of a multi-layered run). The accumulation of work related to RTA like EVAA and MM-RTA have led to runtime assurance-based verification concepts to be included in the civilian aircraft certification process.

Runtime catastrophe avoidance software like EVAA and MM-RTA are leading the way in advancements in autonomy certification for UAS. The aforementioned DO-178C contains language that allows for reduced design assurance levels for systems that include operational monitoring. The ASTM F38 committee, in collaboration with government, industry, and academics has created an industry standard document that recognizes RTA for the certification of highly-autonomous, unpredictable, or highly complex piloting systems for sUAS (Cite 15,16, and Initial considerations of a multi-layered run). These advancements in autonomy certification will benefit in favor of complex autonomy endeavors and cargo UAS platforms alike.

Avionics Draft with Citations 1 9/16/2021

As cargo unmanned aircraft emerge in the NAS, the development and implementation of advanced avionics solutions will be required to support such operations. Current industry standards for avionics certification are well documented. However, the increased production of unmanned aircraft, as well as, the request for unique UAS operations has elevated the demand for state-of-the-art sensors and communication systems. Therefore, industry standards for certification of avionics need to be congruent with the ever-changing UAS landscape. Knowledge of current avionics certification standards, in addition to, working with aerospace technology leaders will assist in the transition of manned to unmanned cargo aerial vehicles.

The procedures for receiving certification of avionics software and hardware are similar. Radio Technical Commission for Aeronautics (RTCA) DO-178, "Software Considerations in Airborne Systems and Equipment Certification" is referenced for the verification, validation, and certification of avionics software. DO-178 was developed in the 1980's and is considered the "bible of avionics software development (Hilderman et al. (2014 a))." This standard has evolved over three separate iterations; DO-178C is the latest revision replacing 178B in 2011 (QA SYSYTEMS (n.d.)). DO-254 (2005) is a formal avionics hardware standard and is similar to DO-178C's predecessor, DO-178B. Since avionics are composed of both hardware and software and each have an equal effect on airworthiness, many avionics projects fall under a DO-254 for certification or compliance mandate (ConsuNova (n.d.)). DO-178 and DO-254 require all software and hardware onboard an aircraft be assigned a Design Assurance Level (DAL) or "criticality level." Criticality level refers to the effort put into software planning, development, as well as, its correctness. The criticality level of a developed software or hardware directly correlates to its assigned DAL. There are five separate DAL levels that range from the most critical (Level A), to the least critical (Level E). Level A criticality indicates that a hardware or software failure would result in a 'catastrophic' failure of the aircraft. Level E criticality indicates that a hardware or software failure would have 'no effect' on the aircraft's safety. After a software or hardware's criticality level has been determined, DO-178 and DO-254 assign specific required objectives and the avionics software or hardware certification process begins (Hilderman, et al. (2014 a)).

ARP-4754A, "Guidelines for Development of Civil Aircraft and Systems," provides a system safety assessment (SSA) which defines two types of DALs for avionics development. Functional DAL or FDAL determines the DAL of the function of the item. Therefore, FDAL defines the DAL for 'what' the item is designed to do. Required development objectives are provided in Appendix A of ARP-4754A. Item DAL or IDAL is the DAL assigned to the hardware and software of an avionics product. The objectives required for hardware and software for each IDAL are provided in DO-178C. It is important to note that most aircraft and system developers build or buy ARP-4754 planning documents and checklists (Hilderman, et al. (2014 b)).

Currently, there are no such DAL levels for cargo UAS or DO-178/254 language that mentions such operations. FedEx's BEYOND program is currently using UAS for small deliveries (<5 lbs) at the Memphis-Shelby County Airport (MSCA). In an interview with the University of Alabama in Huntsville (UAH), FedEx representatives stated that their UAS avionics do not hold DO-178 standards. To ensure hardware integrity, they do a spectrum analysis on the area of operations (AO). Additionally, they closely monitor the weather and any obstructions, e.g. wake turbulence, in the AO. Their delivery drones use commercial off the shelf (COTS) avionics to successfully complete their visual line of sight (VLOS) cargo UAS missions (Warr et al. (2021 September 9)).

In an interview between the University of Alabama in Huntsville (UAH) and Sanmina Corporation (SCI), an advanced avionics design and manufacturer, representatives from SCI stated that certification for advanced avionics requires an abundance of time, effort, and money. For clarity, SCI develops avionics for Department of Defense (DoD) applications, therefore, they do not seek DO-178C/254 certification for their products. However, SCI expressed that achieving certification for developing, state-of-the-art, avionics is nearly impossible. When asked about avionics certification for cargo UAS in the NAS, representatives from SCI posed aircraft integrated with the developing software/hardware with a pilot-in-the-loop as a fail-safe. This way, a highly-sophisticated system (e.g. fully autonomous BVLOS) could be tested safely (Warr et al. (2021 September 14)).

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RTA is a defense mechanism employed to ensure appropriate behavior of complicated autonomous systems (De Niz, D. (2018)). RTA allows the benefits and capabilities of advanced autonomy while protecting against unpredictable and unsafe system activities that can compromise a mission. Runtime assurance schemes monitor a platform's state parameters during operation. RTA uses tests to determine whether unsafe conditions will emerge due to an error in the advanced system. If an error is detected, RTA disables the advanced system and switches operation to a revisionary or system that is certified at design time (Shierman et al. (2015)).

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Runtime catastrophe avoidance software like EVAA and MM-RTA are leading the way in advancements in autonomy certification for UAS. The aforementioned DO-178C contains language that allows for reduced design assurance levels for systems that include operational monitoring. The ASTM F38 committee, in collaboration with government, industry, and academics has created an industry standard document that recognizes RTA for the certification of highly-autonomous, unpredictable, or highly complex piloting systems for sUAS (Cook, S. P. (2017)), (ASTM F3269-17 (2017)), & (Hook, L. R. et al. (2018)). These advancements in autonomy certification will benefit in favor of complex autonomy endeavors and cargo UAS platforms alike.

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