Proceedings of the 2021 International
Aerospace Engineering Conference
Oxford, United Kingdom. 24th & 25th June 2021.

Large Unmanned Cargo Aircraft Airline Operation Requirements and National Airspace Integration

Mark Patrick Collins

Indiana State University Associate Professor, Unmanned Systems
Mark.collins@indstate.edu
www.indstate.edu
Ph.D Student Unmanned Systems Applications Capital Technology University
mpcollins@captechu.edu

***Abstract*:** The FAA has decades of experience regulating the safety of manned aircraft but less than a decade regulating the safety aspects of unmanned aircraft in the NAS. This has caused the FAA to take a cautious approach to integrating unmanned aircraft into the NAS by integrating small unmanned aerial vehicles (sUAV) before large unmanned aircraft. The aim of this research is twofold: To investigate requirements for large unmanned cargo aircraft (LUCA) airline operations and to evaluate the anticipated needs of the FAA to support integration of LUCA airline flights into NAS. Stakeholders must weigh the costs of transportation with the time and make a decision how they will ship their cargo. If the air cargo costs can be reduced by 30-40% then it will drive the LUCA market to expand. The traditional freight industry made up of airplanes, trucks, trains, and ships is ripe for disruption. The transportation costs for $USD / Ton KM has a potential to be less than truck transport which would make a LUCA operator quite profitable.

Keywords: Large Unmanned Cargo Aircraft (LUCA), Small Unmanned Cargo Aircraft (sUCA), Optionally Piloted Aircraft (OPA), National Airspace System (NAS), Federal Aviation Administration (FAA), Unmanned Aircraft System (NAS), Code of Federal Regulations (CFR)

I. Introduction

This article is being written in advance of a dissertation the author is completing. The contents of which are a summary of literature and previous research the author has completed. On Oct. 5, 2018, President Trump signed into law the FAA Reauthorization Act of 2018 (Public Law 115-254), which reauthorizes funding for the FAA through Sept. 30, 2023. This is the first long-term FAA reauthorization since 2012 that has been signed into law. The new reauthorization takes significant steps forward in the continuing integration of unmanned aircraft systems (UAS), or drones, into the National Airspace System (NAS) (Roberson, 2018). Just like the FAA Modernization and Reform Act of 2012 mandated the integration of UAS in the NAS, the FAA Modernization of 2018 takes it one step further by mandating that the FAA start to authorize drone deliveries in the NAS. Since this time, we have seen two commercial cargo drone carriers receive FAA 14 CFR Part 135 Air Carrier and Operator certification for small < 55 lbs unmanned cargo aircraft (sUCA). Wing a subsidiary of Alphabet and United Parcel Service (UPS) are now operating under Part 135 small cargo drones in uncontrolled

Class G airspace under 55 lbs below 400 above ground level (AGL) to delivery small parcels for the final delivery mile. This is just a small incremental step towards integrating larger unmanned cargo aircraft in altitudes where manned aircraft operate.

In order to simplify the classification of unmanned cargo aircraft (UCA) The Platform for Unmanned Cargo Aircraft (PUCA) classified UCA in two categories. The first category is for short distance small to medium sized UCA that deliver specialized items like medicines and packages. The acronym used for this classification is sUCA. The payloads for these types of sUCA are typically 1-55 lbs (.43-24.9 kg) and would operate in an urban environment for delivering packages 9-19 km from a central distribution point. In rural areas, these sUCA would be traveling 20-50 km to deliver their cargo by using delivery trucks to launch and recovery sUCA in conjunction with central distribution points. This is similar to the Amazon Prime Air multirotor package delivery system. As defined by PUCA, the second category is for long distance unmanned cargo transport. These long distance large unmanned cargo aircraft (LUCA) have the potential of carrying 100-25,000 lbs. (45-11,340 kg) and with a range of 200-10,000 miles (321 – 16,000 Km) (Collins, 2017).

The aftermath of the Hurricane Maria in 2017 left Puerto Rico and its residents' cutoff from food, fresh water, and medical supplies. Many of its residents died from these experiences. The bridges, airports, harbors, roads, and communications systems were all destroyed, making it next to impossible for many people to find access to these resources (Huber, 2018). FAA approved LUCA operations would have helped the residents of Puerto Rico receive the resources they needed to survive. For example, LUCA could have transported food, medical supplies, and water from ports in the United States or ships directly to the affected residents. This could have saved lives and prevented further escalation of the situation. In an effort to prevent this type of humanitarian crisis from happening again, further research is needed to evaluate the feasibility of commercial LUCA operations.

II. LIMITATIONS FACING LUCA TO NAS INTEGRATION

Assuming that FAA regulations allow remotely piloted passenger aircraft in the NAS, convincing the public that integration is safe is a major limitation facing integration. Other limitations include safety, liability, over flying populated areas, and technology constraints (Collins, 2017). Another significant limitation is that the FAA has decades of experience regulating the safety of manned aircraft but less than a decade regulating the safety aspects of unmanned aircraft in the NAS. This has caused the FAA to take a cautious approach to integrating unmanned aircraft into the NAS by integrating small unmanned aerial vehicles (sUAV) before large unmanned aircraft. In the fall of 2019, the FAA certified Wing Aviation

LLC, a subsidiary of Alphabet and UPS Flight Forward Inc, to operate sUCAs under 14 CFR Part 135 in urban environments below 400 ft. Under the Part 135 certification, Wing and UPS can provide commercial non-scheduled small cargo delivery using sUCA. The Wing drone is a vertical takeoff fixed wing UAV that is being used to deliver FedEx Express packages in the Christiansburg, Virginia area, while UPS has partnered with Matternet to deliver medical samples via a Matternet quad-copter drone across the WakeMed Raleigh, North Carolina medical campus. Both companies plan on rolling out their approved drone service nationwide in the coming years (FAA, 2021).

Thus far, no air carrier has been approved by the FAA to commercially operate LUCA or remotely piloted passenger aircraft in the NAS. This problem shows the need for researching the future FAA operational requirements for an air carrier certificate to operate LUCA in the NAS. This includes identifying differences between commercial manned Part 135 air carrier cargo flights and those for LUCA flights in the NAS. Further research should identify safety characteristics and reliability for LUCA NAS integration.

III. LUCA Research Aims and Objectives

To further the advancement of the LUCA industry and as parts and the requirements to complete a dissertation on this subject the author is conducting interviews and a survey with experts in the air carrier cargo airline industry and UAS experts. The aim of this research is twofold: To investigate requirements for LUCA airline operations and to evaluate the anticipated needs of the FAA to support integration of LUCA airline flights into NAS.

The research objective of the study is as follows:

1. To design, pilot and validate a questionnaire and an interview for the enquiry into requirements for LUCA airline operations.
2. To design, pilot and validate a questionnaire and an interview for the study of needs of the FAA to support integration of LUCA airline operations into NAS.
3. To carry out interviews using manned air carrier cargo airline experts and unmanned aircraft systems experts.
4. To develop a model of LUCA airline operations.
5. To develop a model of integration of LUCA airline operations guided by research, the results from the expert interviews and the results from the questionnaire.

IV. Economics of LUCA

Before looking at LUCA operations in the NAS it is important to evaluate the current state of the U.S. transportation systems to help determine potential markets for LUCA air carrier operations. Such as areas where there is a need for cargo but no airports, no roadways, no

railways, or waterways to delivery cargo. Examples could include remote areas of Alaska, Nevada, or other remote areas in the United States. Also, as part of the research looking at trucking delays and congestion areas and determining if LUCA air carrier operations should be considered as an alternate mode of transportation for those areas. Another benefit of this research is that it could reveal LUCA air carrier niche markets and find potential lucrative LUCA air carrier supply chain routes. Any disruptions in the transportation supply chain caused by weather, no infrastructure, poor infrastructure, trucking delays, congestion, or driver shortages could be possible market opportunities for LUCA air carrier operations.

The United States Department of Transportation (USDOT) produces an annual report each year. This report represents an overview of the U.S. Transportation system and includes statistics on cargo movement, economics of transportation, transportation safety, environmental impacts on transportation, and other data on the U.S. transportation system. The report shows that in 2018, the total truck shipments represented 61% or 11.5 billion of the total value of all the U.S. shipments. This high value for truck shipping is increased to over 72% when you include those cargo shipments that went by multiple transportation modes such as those shipments that went by water/truck, train/truck, pipeline/truck, and those that go by mail.

The American Transportation Research Institute (ATRI) collects and processes truck GPS data in support of numerous USDOT freight mobility initiatives. Using truck GPS data from over 1 million freight trucks, ATRI develops and monitors a series of key performance measures on the nation's freight transportation system. Among many GPS analyses, ATRI converts its truck GPS dataset into an ongoing truck bottleneck analysis that is used to quantify the impact of traffic congestion on truck-borne freight at over 300 specific locations in the national highway system.

According to research by ATRI, traffic congestion on the U.S. highway system added nearly *$74.5 billion* in operational costs to the trucking industry, a 0.5 percent increase over 2015. This is nearly *1.2 billion* hours of lost productivity and equates to *425,533* commercial truck drivers sitting idle for a working year. These congestion costs are concentrated on a relatively small proportion of the national highway system (NHS). 86.7 percent of total nationwide congestion costs occurred on just 17.2 percent of NHS segment miles. ATRI's analysis also documented the states, metropolitan areas, and counties that were most impacted by these delays and subsequent cost increases. As listed in *Table 1* the top 10 states experienced trucking congestion costs of more than $2.4 billion each. This was led by Texas at $6.5 billion, Florida with over $5.5 billion, California with $5 billion, New York at $4.3 billion, New Jersey at $3.3 billion, and Illinois at $2.9 billion in cost due to congestion. These 10 states combined

accounted for 51.8 percent of the congestion costs nationwide (Hooper, 2018). It is well known that the trucking industry is facing unprecedented driver shortages. These shortages are caused by low pay, lack of respect for drivers, poor working conditions, trucking companies paying drivers on mileage not time, and the stressful demands of the job. ATRI reports that the driver shortage increased to 60,800 in 2018 and is expected to double to 160,000 over the next decade.

*Table 1*ATRI Top Ten States Total Cost of Trucking Congestion (Brewster, 2018)

2016 Rank	State	Total Cost in Billions of $	State Share of Total Cost	2015 Rank
1	Texas	$6,370	8.6%	1
2	Florida	$5,637	7.6%	2
3	California	$5,059	6.8%	3
4	New York	$4,347	5.8%	4
5	New Jersey	$3,350	4.5%	5
6	Illinois	$2,903	3.9%	8
7	Pennsylvania	$2,885	3.9%	6
8	Tennessee	$2,838	3.8%	7
9	Ohio	$2,769	3.7%	9
10	North Carolina	$2,429	3.3%	10
	Total	**$38,587**	**51.9%**	

When comparing the economic potential of LUCA air carrier operations to other shipping modes stakeholders should consider both transportation time and costs. Based on previous research performed by Collins (2017) and PUCA the operating costs for LUCA will be lower than current air cargo transportation but more than other transportation shipping modes like trucking, water, train, or pipeline. However, the shipping time LUCA takes for the cargo to reach its destination is forecasted to be less than any other shipping modes. In today's market without considering LUCA as one of the shipping modes, transporting cargo by air is the costliest but the fastest way to get your cargo to its destination. Stakeholders must weigh the costs of transportation with the time and make a decision how they will ship their cargo. If the air cargo costs can be reduced by 30-40% then it will drive the LUCA market to expand. For example, stakeholders will have the ability to use LUCA instead of manned air cargo or in situations where trucking takes too much time. *Figure 1* details transportation mode trade-offs for transportation time versus its cost. The size of the oval shown for the transportation modes in Figure 1 represent the proportional dollar value of the cargo shipped in United States in 2018.

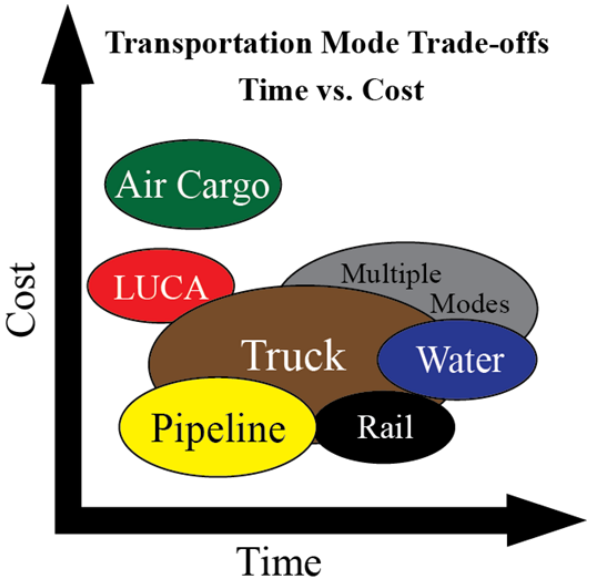

*Figure 1*Transportation Mode Trade-Off Time vs. Cost

V. CONVERTING MANNED AIRCRAFT TO LUCA

Only those companies that are seeking FAA type, production, and airworthiness certification under14 CFR Part 21 & Part 23 were considered for this research. There are less than a dozen of different LUCA companies working with the FAA for aircraft and part certification. Only a few of them will be explored. They are all at different stages of completion. Some of them are converting manned aircraft to LUCA while others are designing, testing, and engineering them separately without any humans onboard. Both company approaches to LUCA has limitations and its advantages. For example, LUCA designers starting from scratch do not need those systems for manned aircraft. Some of the companies starting off by converting manned aircraft to cargo aircraft. These include companies like Reliable Robotics, Xwing, Merlin Labs Inc., Dorsal Aircraft Corporation & Romaris Corporation. In order to test the systems in the NAS they are using a pilot to monitor the systems from the air while the aircraft are being controlled by a remote pilot on the ground.

Reliable Robotics is one of the leaders developing and testing systems that will result in planes taxiing, taking off, maneuvering in the air, and landing without a pilot. Reliable was co-founded in 2017 by Robert W. Rose and Juerg Frefel from SpaceX. Robert Rose previously worked as the Senior Director of Autopilot at Telsa Motors and was responsible for developing the autopilot systems for Tesla. Reliable is headquartered in Mountain View, California where engineers write software, develop actuators, test prototypes, and the machinery needed for their autonomous aircraft (Vance, 2021). Reliable Robotics completed

a series of remotely operated test flights directed by a pilot stationed in its Mountain View headquarters over fifty miles away. The remote pilot in the control center instructed an upgraded Cessna 208 Caravan to taxi, takeoff, maneuver over a populated region, and land while communicating with nearby air traffic through the aircraft's onboard radios. A picture of the converted Cessna Caravan is shown in *Figure 2.*

Figure 2 Reliable Robotics Cessna Caravan converted LUCA (Thurber, 2020)

VI. Conclusion

The most common mode of cargo shipping is by truck using the national highway system (NHS). The costs are going up and the delays are getting worse. Billions of dollars are required to improve access and throughput otherwise disruptions in shipping will continue. However, this doesn't mean that trucking shipping mode will be the best solution. It is predictable from looking at the cost of highway congestion by state in Table 1 that LUCA air carrier operations would be a commercially viable transportation mode starting in states with the highest costs due to congestion. Another great motivator in starting LUCA air carrier operations in the NAS is that it would not have any direct competition. So, the traditional freight industry made up of airplanes, trucks, trains, and ships is ripe for disruption. The transportation costs for $USD / Ton KM has a potential to be less than truck transport which would make a LUCA operator quite profitable.

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