THE FUTURE MARKET FOR LARGE
UNMANNED CARGO AIRCRAFT IN
THE NATIONAL AIRSPACE SYSTEM

By

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THE FUTURE MARKET FOR LARGE
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ABSTRACT

The unmanned aircraft systems (UAS) federal aviation regulations (FAR) allows small UAS to fly in the national airspace system (NAS). However, some in the aviation community feel that the new UAS rules did not go far enough and are stifling commercial growth by not keeping pace with technology. This raises the question of how long it will take for the stakeholders to come together to develop the aircraft and systems that will enable the use of large unmanned cargo aircraft (LUCA) to fly in the NAS? The aim of this thesis is to develop the marketing information needed for stakeholders to determine economic validity for the LUCA concept. To understand the potential market of LUCA, a research market survey was conducted with 110 aviation minded professionals throughout the United States, worldwide aviation, and UAS community. The results of the research market survey revealed some key marketing opportunities that will be beneficial for potential LUCA stakeholders. However public perception, concerns for safety, and lack of safety regulations remain some the largest limitations facing LUCA integration. The biggest markets continue to be with the military but once regulators allow LUCA use in the NAS many new markets will open. Those types of markets found included long haul point to point cargo service and delivery of goods to and from remote areas of the world where the infrastructure is lacking. Other LUCA markets included shipping high value cargo over long distances where multiple manned crews would normally be necessary. In the early days of NAS integration, large unmanned manufactures should focus their development efforts on unmanned cargo aircraft rather than autonomous passenger aircraft and develop LUCA for both the civil and military cargo markets.
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CHAPTER I

INTRODUCTION

Significance of the Study

The technology innovations in the unmanned aircraft industry over the last few years are the start of a revolution in commercial aviation industry. The extensive use of military unmanned aircraft systems (UAS) overseas has put a spotlight on the growing interest in unmanned aircraft for domestic and civilian applications. However, most of the growth and research with commercial UAS between 2010 – 2017 has been in small unmanned aircraft systems (sUAS) used for remote sensing and more recently for small package delivery. Therefore, the literature review and research market survey will focus on large unmanned cargo aircraft (LUCA). Large unmanned cargo aircraft (LUCA) will be defined as unmanned aircraft carrying 100-25,000 pounds and with a range of 200-10,000 miles.

Statement of the Problem

In 2012, the United States Congress mandated the Federal Aviation Administration (FAA) to provide provisions for the use of Unmanned Aerial Systems (UAS) in the National Aerospace System (NAS). Congress did this through the passing of the FAA Modernization and Reform Act of 2012 (FMRA). Finally, on August 29th, 2016 after years of research and development, consultation with the public, and experts in the industry the FAA created new rules for the use of UAS in the NAS system. These new regulations, 14 CFR 107 defined the commercial and recreational uses of small UAS in the NAS. The policy for the first time provided regulations for new commercial UAS operations for small aircraft under 55 lbs. However, some in the aviation community feel that the rules are stifling commercial growth by
not keeping pace with technology, requiring operators to stay within visual line of sight (VLOS), below 400’, or using aircraft smaller than 55lbs. This raises the question of how long it will take for the stakeholders, manufactures, and regulators to come together to develop the aircraft and systems that will enable the use of large unmanned aircraft to fly in the NAS.

**Purpose Statement**

Due to safety concerns and public perception of drone safety it is believed that unmanned cargo aircraft will be developed before large scale use of autonomous passenger aircraft. Therefore, this thesis examines the history of LUCA, current and future regulations for use, future technology, potential economic impact, and future markets for enabling LUCA to fly in the NAS. This examination will also evaluate the limitations facing LUCA integration. These include technology, security, safety, public perception, liability, and other limitations. It will also evaluate LUCA market opportunities to help provide insight for future LUCA stakeholder investment.

**Research Objective**

Assuming regulators allow the use of LUCA, what will the commercial market for LUCA look like? This exploratory paper evaluates participant responses, attitudes, opinions, and literature of the future demand of the unmanned air cargo to determine LUCA investment pathways. One objective of this thesis is to develop the marketing information needed for stakeholders to determine economic validity for the LUCA concept so that the stakeholders will eventually invest as either operators of LUCA or as manufactures of LUCA.

Additional objectives of this research are to create further discussion on this topic and exploring the possible marketing potential to help enable the industry to move forward at a faster pace. Other possible outcomes of this research are the further development of networking
groups made up of manufactures and operators focused on the LUCA industry within the United States and Canada. It should be noted that the issues discussed in this paper facing LUCA and its uses are similar to those for other types of UAS, large and small.

**Hypothesis**

The future demand for wide scale use of LUCA will be for long haul point to point service of high value cargo.

**Delimitations**

The environmental and privacy impacts of LUCA were not considered in the research or with the market survey questions. It is believed that the privacy impact is of greater importance to small UAS than it is with large UCA. Therefore, no research was done with UAS privacy. However, further research and discussion would be recommended for LUCA environmental impacts versus manned aircraft and using electric propulsion vs traditional propulsion methods. The commercial market potential of using LUCA for agriculture purposes such as crop spraying was not researched and would be an area that deserves further study.

**Limitations and Assumptions**

It is assumed that once the FAA authorize UAS in the NAS that other regulators would follow with UAS integration. Consequently, most of the research for the literature review focused on the United States and its current regulations, future technologies, and future regulations. Due to safety concerns and public perception of drone safety it is believed that unmanned cargo aircraft will be developed before large scale use of unmanned autonomous passenger aircraft. Based on previous studies and aircraft design it is believed that LUCA will have a lower direct operating cost compared to manned aircraft. It is assumed that the credibility
of the research market survey results would be greater from those people that are working in aviation and UAS industry therefore the survey was targeted to those participants.

**Definition of Terms**

Large unmanned cargo aircraft - unmanned aircraft carrying 100-25,000 pounds and with a range of 200-10,000 miles.

Unmanned Aircraft System Traffic Management - a "traffic management" ecosystem for uncontrolled operations that is separate but complementary to the FAA's Air Traffic Management (ATM) system.

**List of Acronyms**

(ATM) - Air Traffic Management

(ADS-B) - Automatic Dependent Surveillance-Broadcast

(CAA) - The Civil Aviation Authority

(DAA) - Detect and Avoid

(DAC) - Drone Advisory Committee

(DAIDALUS) - Detect and Avoid Alerting for Unmanned Systems

(EASA) - The European Aviation Safety Agency

(FAA) - Federal Aviation Administration

(FMRA) - FAA Modernization and Reform Act of 2012

(GPS) - Global Positioning System

(LAANC) - Low Altitude Authorization Notification Capability

(LUCA) – Large Unmanned Cargo Aircraft

(LUAS) – Large Unmanned Aircraft Systems

(NAS) - National Airspace System
(NASA) - National Aeronautics and Space Administration

(OPA) - Optionally Piloted Aircraft

(PUCA) - Platform for Unmanned Cargo Aircraft

(sUAS) - Small Unmanned Aircraft Systems

(SWIM) - System Wide Information Management

(TCAS) - Traffic Alert and Collision Avoidance

(TCCA) - Transport Canada Civil Aviation

(UAS) - Unmanned Aircraft Systems

(UTM) - Unmanned Aircraft System Traffic Management
CHAPTER II

REVIEW OF LITERATURE

The Platform for Unmanned Cargo Aircraft (PUCA) defines unmanned cargo aircraft (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 payloads for these type UCA would be between 1-50kg and they would operate in an urban environment for delivering packages 5-10 miles from a central distribution point. In rural areas, these UCA would be traveling 20-50 km to delivery their cargo. 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 unmanned cargo aircraft (LUCA) have the potential of carrying 100-25,000 lbs. and with a range of 200-10,000 miles. This second category for LUCA will be the focus of this paper.

The U.S. Department of Defense (DOD) started a group classification system for UAS including LUAS. The “Group” systems have 5 categories, depending on size and capability. DOD Groups 1 & 2 are for aircraft that are under 55lbs and this area is what is being governed now by the new FAA Regulations (FAR) Part 107 for Small Unmanned Aircraft Systems (sUAS). This rule defines the commercial operating rules for small unmanned aircraft systems (sUAS) and the certification for remote pilots. DOD Group 3 is for UAS between 55 pounds and 1,320 pounds operating at altitudes less than 18,000 ft. DOD Groups 4 & 5 are for UAS weighing greater than 1,320 pounds and with the ability to fly18,000 ft. or greater. DOD Groups 3, 4 & 5 would fall under the capabilities definition of LUCA. Over the last two decades only military UAS have been built capable of heavy payloads and long distance. This is about to
change as the industry enters into a commercial era of unmanned aircraft operating with other manned aircraft in the National Airspace System (NAS). This will have a huge economic impact on the aircraft cargo industry and the way high value cargo will be forever shipped.

**Brief History of LUCA**

Originally, balloons were thought of as a primitive way to fly an object without a human control onboard. Austrians are believed to be the first to use some 200 balloons to drop bombs in Venice during fighting with Italy in 1849, as shown in Figure 1. The U.S. also deployed balloons laden with explosives during the civil war (Altervista, 2016).

The Kettering Bug was developed during World War I and it was a bomb-carrying unpiloted biplane that flew on a pre-set course to its target. Once its autopilot was set, the plane was on its own. Prototypes were built and successfully tested, but by the time the Bug made its first flights the war was over. Nevertheless, it was the precursor of the modern cruise missile and unmanned aircraft (Miller, 2013).

*Figure 1 & 2 Artist rendition of balloon attack on Venice 1849 (Altervista, 2016) & a picture of the Kettering Bug (Darling, 2016)*

World War II saw the first use of large unmanned aircraft used in wartime. Navy officer Delmar Fahrney was among the first visionaries to realize that remotely piloted aircraft could be used to deliver ordnance without putting soldiers at risk. Fahrney was instrumental in creating
three Special Task Air Groups (STAGs) to deploy drones in the Pacific Theater (UAS Vision, 2017). The program, started in 1942, used cheap-to-make and easy-to-fly twin-engine drones, designated TDR-1s, shown in Figure 3. TDR-1 were used by the Navy to attack targets up to 160 miles from its base of operations. Equipped with a first-generation TV camera and radio remote controls, TDR-1 was capable of making highly accurate attacks. Despite modest successes—and even though no American lives were lost—by the end of October 1944 the TDR-1s were grounded, the victim of military politics, and general skepticism about the technology. The STAG units were disbanded, and the drones discarded (UAS Vision, 2017).

Figure 3 A collection of TDR-1 parts placed near the war plant hanger in DeKalb, IL (Hallie, 2016)

In the European Theater, Joseph P. Kennedy Jr., brother of past president John F. Kennedy, died in a drone aircraft designed to be used for an unmanned attack against V-2 rocket launching site in Normandy shown in figure 4. This aircraft drone B-24 Liberator bomber was loaded with 21,170 pounds of high explosives. It could not take off safely on its own, so the crew including Joseph P. Kennedy had to take off and fly to 2,000 feet before activating the remote-control system, arming the detonators, and parachuting from the aircraft. Unfortunately, the explosives in the aircraft detonated before he could parachute out, he and his co-pilot died (JFK Library, 2016).
Large Unmanned Cargo Aircraft (LUCA) of Today

The U.S. military have been operating LUCA in the NAS now for over two decades. Despite this long history of use, commercial use of LUCA in the NAS is relatively new to the commercial aviation industry consequently only a few aircraft types exist today, and only a few are being developed. Through the efforts of the Platform for Unmanned Cargo Aircraft (PUCA), an organization based in the Netherlands, the aviation community is just beginning to understand the commercial possibilities of large unmanned cargo aircraft. PUCA are trying to generate interest with stakeholders in LUCA. However, without an existing design, the potential market is unrealized. Without a potential market, the design might never get built. “Everyone is waiting for everyone else, shippers and operators are saying ‘show us the aircraft’, manufactures are saying ‘tell us if you want it, and we’ll build it’ and governments are saying ‘we can look at if the market asks for it’ (Heerkens, 2017).” PUCA is urging potential operators, shippers, IT companies and logistics companies to get involved in the project.

This trend will not continue for long and does have an upside. New manufactures of LUCA are available on the market today. For example, Aurora Flight Sciences which is part of the Boeing Company have developed a twin-engine aircraft called The Centaur, shown in Figure
6. The Centaur, is an optionally piloted aircraft (OPA) that combines the best of manned and unmanned aircraft capabilities boasting three modes of operation (manned, unmanned and augmented). It has a general aviation certified airframe, 44 ft. wingspan x 28 ft length, service ceiling of 27,500 ft, 20-hour flight endurance with a 200 lb payload. The company promotes on its company website that it can operate in conditions too dangerous for manned aircraft. Also, that it can be deployed through controlled airspace to remote sites for unmanned operations without the need for transport, support equipment or personnel (Aurora, 2017). In a June 27th, 2015 CNN article on the aircraft, CEO John Langford describes that the unmanned airplane revolution will make aviation safer for everybody (Patterson, 2015).

![The Centaur OPA by Aurora Flight Sciences](Aurora, 2017)

*Figure 6* The Centaur OPA by Aurora Flight Sciences (Aurora, 2017)

Another example of an existing LUCA aircraft is the Singular FlyOx, shown in Figure 7. It has been developed for commercial operations. It is flying boat, twin engine, high wing amphibious aircraft able to land and take off from short unpaved airstrips and water. The FlyOx aircraft has been tested successfully and is still ongoing tests in Spain and in Iceland. Once production begins, it will have four main configurations for use: agricultural, firefighting, surveillance and general cargo capability of just over 4,500 lbs (Singular Aircraft, 2017).
Lockheed Martin and Kaman Aerospace have developed an unmanned helicopter capable of autonomous or remote-controlled operations. The K-Max, shown in figure 8 is currently in military use and is providing cargo resupply and logistics services for life saving military missions in the war in Afghanistan. The Karman K-Max is optimized for external cargo load operation, and can lift a payload of over 6,000 pounds which is more than the aircraft’s empty weight. It has been used recently for the first time in an unmanned operation for cargo resupply in the war in Afghanistan.

General Atomics is looking at the commercial market for the type certifiable version of the Reaper, called SkyGuardian, shown in Figure 9, now under development. This 12,500 lb.
UAS can fly for 40 hr at 40,000 ft carrying a 4,000 lb payload (Warwick, 2017). According to the company website the Predator® B version is being used for firefighting, flood monitoring, border patrol, and humanitarian assistance. This aircraft has been accessing the NAS on routine basis, and has done so for over a decade. Predator B has reshaped the aviation landscape within America’s borders and has been accepted in the NAS because it is reliable and has an instrument-rated pilot-in-the loop (General Atomics, 2017). According to Peter McNall, manager of strategic business development at General Atomics, “Freight is where I see the industry going,” but admits, “we are not seeing a market pull to large UAS” (Warwick, 2017).

A China News Service in February 2017 announced a new LUCA aircraft. This LUCA, named AT200, was co-developed by the Institute of Engineering Thermo physics of the Chinese Academy of Sciences and other institutes. The AT200, shown in Figure 10, is 11.84 meters long and 4.04 meters high, with a maximum takeoff weight of 3.4 tons. With a cargo space of 10 cubic meters, the plane can carry 1.5 tons of cargo. According to the research and development team, the AT200 is equipped with an advanced control system, which makes it easier to
manipulate the aircraft and reduce the freight cost. Key technical breakthroughs have been achieved during the development and manufacturing of the plane, which is able to fly at 313 kilometers per hour for about eight hours. The AT200 is also capable of taking off and landing in rough terrains, such as mountains and islands. The research and development team said they are working to put AT200 into commercial operation soon (Sputnik news, 2017).

A Chinese company based in Shanghai has an amphibious LUCA named U650, shown in figure 11, with plans to use it to deliver goods, transport supplies to islands and detect submarines, according to the manufacturer. Liu Jiandong, founder and chairman of UVS Intelligence System, a privately-owned drone-maker in Shanghai, said mass production of its U650 seaplane has begun and will enter commercial operation this year with a Chinese express delivery company and a client in Southeast Asia. The 5.85-meter-long unmanned seaplane, made of carbon fiber, can stay aloft 15 hours with a cruising speed of 180 kilometers per hour and a flight range of 2,000 km. It is capable of takeoffs and landings from short unpaved airstrips, grassland or water. The amphibious LUCA can carry up to 250 kilograms of cargo and its wings can also carry four payloads, such as inflatable life rafts (China Daily, 2017).
Future Outlook for LUCA to NAS Integration

Pilots solve problems on every flight that new software programs will have to solve. In addition to mechanical problems, there are airspace sharing issues, and weather problems that require flexibility, foresight, and systems knowledge. Many of the nation’s airports already run at maximum capacity without flexibility to solve these problems so new enabling technologies must solve these complicated problems before LUCA will be able to integrate in the NAS safely.

Michael Guterres, a leader in the efforts to integrate drones in the NAS was asked by Debra Werner in a discussion about detect and avoid (DAA) technology to respond to the following question. What is happening in the large UAS category?

Guterres replied, “There has been a pretty significant standards development effort. The RTCA [Radio Technical Commission for Aeronautics] brought together industry and government to develop a set of requirements and performance thresholds for larger aircraft, like Predator and Global Hawk, to transition to Class A airspace [above 18,000 feet]. Those standards, when published, will make it easier for operators using some of these larger systems to transition through those first 18,000 feet to Class A airspace. That transition phase from ground to 18,000 feet is a little bit riskier [than flying above 18,000 feet] because there are a lot of folks flying in that airspace that are not necessarily
equipped. The UAS has a responsibility that normally would be handled in a manned aircraft by the pilot and co-pilot. When the aircraft are in Class A, they work with air traffic control. Some of the larger unmanned aircraft are able to carry TCAS [Traffic Alert and Collision Avoidance System], a system used by manned aircraft, and on-board radars” (Werner, D. 2017).

**FAA Outlook for LUCA in NAS**

How does the industry remain safe, what roles will state, and local governments play with rulemaking, what roles will private industry take, what are the standards that can be applied internationally? These are all questions that the FAA and other regulators are trying to answer before they will allow LUCA in the NAS. To accelerate acceptance for large unmanned aircraft to operate with manned aircraft in the NAS, the industry and stakeholders should develop the capability while the FAA should develop the regulations to ensure the safe use equal to that of FAR Part 121 commercial airline operators.

The FAA are working on many fronts to integrate LUCA in the NAS. They have set up advisory groups, developing the technology infrastructure, created seven UAS test sites, and have started a UAS integration pilot program to facilitate this process. The seven UAS test sites are in seven U.S. states. It is the goal from all these test sites, advisory groups, and UAS pilot programs to make recommendations to improve data quality and consistency for UAS to NAS operations. Those U.S. states included in this program are Nevada, New Mexico, Texas, Virginia, New York, & North Dakota. The research from data requires analysis to determine technical and operational trends to derive conclusions that support critical safety decisions required to integrate UAS into the National Airspace System (NAS) (FAA, 2017).
At a UAS symposium on May 8th 2017, Michal Huerta FAA Director met with other FAA executives to discuss the agency’s efforts of integrating UAS in the NAS. One of the key challenges they discussed was the difference in the cultures from manned aircraft groups to the unmanned aircraft groups. The manned aviation industry is familiar with the FAA rules whereas the new people involved in unmanned aircraft are non-aviators that are generally not familiar with the rules. The first challenge for the FAA was working with these non-aviator people who do not know the rules is bringing them to the same table as the aviators through efforts like the DAC. According to the FAA, this cooperation has helped spearhead the rulemaking process while at the same time maintaining and improving upon its safety.

The FAA are also working on integrating UAS with manned aircraft traffic in and around airports by using a traffic management system that will drastically speed up authorizations for remote pilots to operate within the confines of busiest Class B airports. This new system is called LAANC, standing for Low Altitude Authorization Notification Capability. Through industry partnerships the FAA have developed detailed low altitude airspace maps for all the major airports. These maps will be used to speed up authorization. Currently the FAA processes authorizations and waivers requests manually so it is not unusual for them to have thousands of requests waiting to be processed. LAANC will drastically speed up the authorization process for low altitude UAS flights thereby increasing the economic potential to commercial UAS operators. Those operating within the new FAA Part 107 guidelines can usually get immediate authorization using LAANC to operate in and around the busiest airports. Despite it being developed for use with sUAS this enabling technology will be an important step towards total integrating of LUCA in the NAS.
The FAA are working towards developing these solutions so that they are acceptable for everyone in order enhance public education, its favorable opinion, the funding for research, the safety aspects, the privacy guidelines, and identifying safety problems. The DAC helps provide the resources for the FAA to develop its rules and regulations through the notice of proposed rule making process. The notice of proposed rulemaking takes time as people must be able to comment therefore the final rule making which takes 2-3 years minimum to finish, however not every regulation needs to be completed as some rules are developed through voluntary or consensus standards.

**NASA and Industry Role on Integrating UAS in the NAS**

NASA's Armstrong Flight Research Center at Edwards, CA, is leading a project designed to help integrate unmanned air vehicles into the world around us. The Unmanned Aircraft Systems Integration in the National Airspace System (NAS) project, or UAS in the NAS, will contribute capabilities designed to reduce technical barriers related to safety and operational challenges associated with enabling routine UAS access to the NAS. The UAS in the NAS project envisions performance-based routine access to all segments of the national airspace for all unmanned aircraft system classes, once all safety-related and technical barriers are overcome. The five focus areas of the UAS integration in the NAS project include: 1) Separation Assurance 2) Communications, 3) Human Systems Integration, 4) Certification & Integration Test, and 5) Evaluation (NASA, 2017), as depicted in Figure 12.
The NAS project will provide critical data to such key stakeholders and customers as the FAA and RTCA Special Committee 203 (formerly the Radio Technical Commission for Aeronautics) by conducting integrated, relevant system-level tests to adequately address safety and operational challenges of national airspace access by unmanned aircraft systems (UAS). In the process, the project will work with other key stakeholders to define necessary deliverables and products to help enable such access (NASA, 2017). These tests are integral to the integration LUCA in the NAS.

The FAA, NASA, other federal partner agencies, and industry leaders like AeroVironment are collaboratively exploring concepts of operation, data exchange requirements,
and a supporting framework to enable multiple beyond visual line-of-sight UAS operations at low altitudes (under 400 ft above ground level (AGL) in airspace where FAA air traffic services are not provided (FAA, 2017). Unmanned Aircraft System Traffic Management (UTM) is a "traffic management" ecosystem for uncontrolled operations that is separate but complementary to the FAA’s Air Traffic Management (ATM) system. With UTM, there is a cooperative interaction between operators and the FAA to determine and communicate real-time airspace status. The FAA provides real-time constraints to the UAS operators, who are responsible for managing their operations safely within these constraints without receiving positive air traffic control services from the FAA. The primary means of communication and coordination between the FAA, operators and other stakeholders is through a distributed network of highly automated systems via application programming interfaces (API), and not between pilots and air traffic controllers via voice (FAA, 2017). These automated systems will help with the overall integration of LUCA in the NAS especially as the number of UAS increase over time.

**Enabling Technologies for LUCA in the NAS**

The FAA are incorporating NexGen with a host of new technologies that will be crucial to the safe integration of large UCA in the NAS. This is what the FAA are calling the System Wide Information Management (SWIM). This will be an FAA advanced technology program designed to facilitate greater sharing of Air Traffic Management (ATM) system information, such as airport operational status, weather information, flight data, status of special use airspace, and National Airspace System (NAS) restrictions. SWIM will support current and future NAS programs by providing a flexible and secure information management architecture for sharing NAS information with manned and unmanned aircraft. The SWIM program will lead to a variety of enabling benefits for using large UCA in the NAS that will allow exponential growth.
SWIM will help improve aviation safety through increased common situational awareness by allowing more decision makers to access the same information. This will provide consistent information to different users (pilots, remote pilots, controllers, dispatchers, and other stakeholders) that supports proactive decision-making (FAA, 2017). Remote pilots of unmanned aircraft can use Automatic Dependent Surveillance-Broadcast (ADS-B) in the same way as manned aircraft to see and avoid other aircraft. ADS-B uses GPS satellites to determine aircraft location, ground speed, and other data, and provides traffic and weather information directly to the cockpits of properly equipped aircraft.

AeroVironment SmartC2 Team and NASA are working on a communications data interface with the approval from the FAA for safe flight and integration of UAS in the NAS. These types of technologies will speed the development of beyond line of site (BLOS) and enable the safe integration of UAS in the NAS. SmartC2 sells a software program called VirtualAirBoss (VAB). This is innovative browser based solution helps aviation service groups manage their business operations from end to end. This includes managing unmanned as well as manned aircraft. It is one place where operators can schedule, manage and automatically report on their entire fleet and business processes – crews, customers, payloads, maintenance, COA details, analysis, and invoicing (or cost center allocations). Manufacturers use VirtualAirBoss for supply chain management, warranty and repair tracking. Commercial operations and their service providers use VAB to manage UAS operations (AeroVironment, 2017). Browser based software technology like VAB are just another important factor to integrating manned aircraft with unmanned aircraft.

**Airports and Droneports for LUCA**
In the near future using SWIM and NextGen, air traffic controllers and pilots will not have to convey messages verbally as they are required to today. Operators of manned and unmanned aircraft will be able to send messages electronically allowing a better understanding of situational awareness of all aircraft and weather in and around the airport area. This will allow the safe use of LUCA in both controlled and uncontrolled airports.

The seven FAA UAS test centers and future Droneports will be an important step towards integrating large unmanned aircraft in the NAS. They provide a platform for entrepreneurs to advance UAS technology to test systems before they enter the market and a means for commercial operators to conduct business after regulatory approval allow its use. The FAA have recently received an application for the world’s first public droneport at Boulder City, NV called the Eldorado Droneport. However, the FAA have not granted approval before to a Droneport as they are still trying to figure out what the standards will be for them to operate. For example, the normal airport signing, marking, and lighting are not required for droneports. This is just one of many issues facing the industry one that the FAA will have to address before they grant approval for this and other droneports.

The Eldorado Droneport is a 50-acre, master planned public facility. The main terminal building and surrounding buildable pads will be home to many different companies interested in the advancement in design and use of UAS. This joint development project between Boulder City and The Aerodrome, LLC, will include a 15,000-square foot terminal building as well as “build-to-suit” opportunities with additional structures totaling 860,000 square feet of R&D, warehousing, hangar, office, and training facilities.

**LUCA Security Outlook**
One major concern is that criminals could use UAS technology for menacing purposes by spoofing or jamming communications systems between the aircraft and ground control. Criminals and terrorists could turn the increased use of UAS for law enforcement, surveillance and intelligence gathering to their advantage by exploiting these technical vulnerabilities to interfere with UAS operations or intercept information being transmitted from UAS to a ground control stations (Cho, 2014). Spoofing is a more sinister cause of communications systems failure. This occurs when a control link or a radio navigation system is compromised. While some reports described the purported hijacking of a Lockheed Martin RQ-170 by the Iranian military, such aircraft have navigation systems that are designed to detect spoofing of GPS by using inertial navigations systems referenced to distant stars to operate in environments that are considered GPS-denied. If someone jams or broadcasts misleading information (spoofing) to an aircraft, the onboard inertial navigation system will recognize a different position than the GPS and the system will default to the INS. Such a requirement is essential for the safety of unmanned aircraft operating in areas where GPS coverage is not perfect (Sullivan-Nightengale, 2015).

Cell phones can be used to jam the GPS communications. For example, GPS jammers were allegedly used to reset the GPS-guided precision landing system at Newark International Airport in 2010 (Sullivan-Nightengale, 2015). While encryption can help prevent interference with digital radio information, it can also increase the failure rate. If encryption fails, then the link can be lost. Robust, secure, and redundant communication paths will help reduce lost links and are essential for safe LUCA operations.

Hijacking and jamming radio signals of drones is a serious issue and one that should not be discounted when developing security protocols for LUCA. LUCA can be hijacked through
someone gaining control of the flight control system using it to steer, accelerate, brake, and even crash them. The technology exists today that can be purchased online to jam and hijack drones. One example of those systems is called, “Icarus.” Icarus can seize control of nearby drones as they are in mid-flight, causing the operator to experience a full loss of function, from altitude and acceleration to steering. This is not just a signal jammer; it is total takeover (Murison, 2016).

LUCA Safety Outlook

With the help from Drone Advisory Council (DAC) and International Civil Aviation Organization (ICAO) the FAA are looking at potential UAS hazards and how they can mitigate the risks associated with them. They are doing this by using the principles set forth by the guidelines of Safety Management Systems (SMS). SMS is a top-down businesslike approach to managing safety risk, which includes a systemic approach to managing safety, including the necessary organizational structures, accountabilities, policies and procedures (FAA, 2017). The FAA are mitigating the risks and determining what are acceptable amounts of risk to an un-involved person, in such cases as when operating over people, at nighttime, or beyond line of site (BLOS) much like manned airplanes operate over our heads today. These safety procedures will help with the overall public perception of LUCA. The FAA is beginning to allow these activities with certificate of authorizations (COA) until such point when the FAA develops regulations for their safe use where a COA will no longer be required.

Improving Public Perception of LUCA

LUCA must have a 99.9% reliability without mishap like todays aircraft. A large unmanned aircraft crashing into a populated area will be unacceptable for the public. Certifying LUCA and it pilots like manned aircraft today combined with the FAA safety management systems (SMS) will help improve LUCA safety and make them more acceptable to the public.
So, it is important that regulators develop the safety regulations for LUCA and limit the liability for operators and manufactures so that the industry can move forward faster and safer. Another positive motivating factor for potential and current LUCA operators is that insurance companies are starting to insure commercial UAS operations. The Aircraft Owners & Pilots Association (AOPA) are insuring small UAS for commercial use and will most likely insure large UCA if regulations allow its use. Inga Beale, CEO of Lloyds of London, says the insurance giant has been ready to insure autonomous vehicles such as self-flying planes for two decades. Regulators have proven unwilling to green-light the technology, while the public remains wary of completely handing over the cockpit to computers (Coren, M., J., 2017).

According to the Teal Group an industry market research firm predicts that worldwide civil drone production will sour to $73.5 Billion over the next decade. There may be niche applications for delivery UAS during the forecast period such as deliveries of humanitarian supplies to remote developing areas. Yet regulatory restrictions and the uncertain economics of drone delivery make it impossible to make a forecast for what could potentially be quite a large segment. This economic potential of LUCA is tremendous and is a strong motivator for changing public perception. Once regulations allow LUCA use in the NAS will help invigorate the LUCA manufacturing industry in the U.S. and abroad. This will enable U.S. manufactures to develop new systems, convert military drones for LUCA use, and maintain U.S. competitiveness with other LUCA manufactures like in Europe, Israel, China, India, & Turkey.

**Potential Economic Impact of UAS in the NAS**

The Association for Unmanned Vehicle Systems International (AUVSI) Economic Impact of Unmanned Aircraft Systems Integration in the United States report shows the economic benefit of UAS integration. AUVSI’s findings show that in the first three years of
integration more than 70,000 jobs will be created in the United States with an economic impact of more than $13.6 billion. This benefit will grow through 2025 when AUVSI foresee more than 100,000 jobs created and economic impact of $82 billion. For every year that integrations are delayed, the United States is estimated to lose more than $10 billion in potential earnings. Every year that integration is delayed, the United States loses more than $10 billion in potential economic impact. This translates to a loss of $27.6 million per day that UAS are not integrated into the NAS. This analysis shows that there will be a tremendous commercial market for UAS including those commercial markets for LUCA.

FAA administrator Michael Huerta spoke November 14, 2017 at an Aero Club in Washington D.C. His remarks focused on the importance of building partnerships with stakeholders to continue advancing America’s global leadership on aviation. He went on to say, “The sky above our heads is one of this nation’s most valuable assets. We must protect it, and help it thrive,” Huerta said. “We’ve got some tough questions to answer. But I’m confident we’re prepared to face them head on” (FAA News, 2017).

The FAA estimates that by 2020, there will be 30,000 drones operating in the NAS. They anticipate that UAS’s will have the initial capability to routinely access the NAS by then. However, the FAA do not have a great track record for meeting deadlines and have always cautioned on the side of safety which has delayed integration ever since the 2012 Congress mandate. The FAA estimates and AUVSI forecasts have created a bright outlook for the potential LUCA industry. This will be both monetarily lucrative and an excellent source for new jobs.

**Regulatory Progress for LUCA integration**
The regulation of large drones in the NAS will focus on safety, as the FAA administrator Michael Huerta testified before a senate hearing on drone usage in January 15, 2014. However, some critics say, the regulations of commercial drone technology in United States is hampering commerce and lagging other worldwide regulatory agencies who are making great strides in allowing the use of large UAS. This is despite the Congressional mandate to integrate civil unmanned systems in the NAS. Right now, large commercial UCA are only authorized on a case by case basis through a Certificate of Waiver (COW) or the Certificate of Authorization (COA) process. Currently, to get a Certificate of Authorization or Waiver to allow an operator to fly a large UCA in the national airspace the operator would have to show that the flight operations are safe. This would require showing that injuries to persons or property along the flight path is “extremely improbable”. Most of the regulations that deal with the flying of commercial civilian aircraft require the aircraft to follow right-of-way rules which would be impossible for a LUCA to follow because of specific federal aviation registration (FAR) see and avoid rules. Instead, a complicated process is laid out where an operator can request a COA on a case-by-case basis (Elzweig, 2015).

It is likely that the FAA will require a variety of different technologies to replace the traditional see and avoid systems that are used now in manned aircraft. This will include using detect and avoid (DAA) technologies to avoid other aircraft and objects such as trees, buildings or other assets. Detect and Avoid Alerting for Unmanned Systems, or DAIDALUS, algorithm could very well provide the FAA with the framework for keeping unmanned aircraft "well clear" of other aircraft in the national airspace system, or NAS. That's important because while a large UAS is equipped with several sensors that collect data about its surroundings, there's no pilot in the cockpit to piece that information together. That's where DAIDALUS comes in. It works by
processing the incoming traffic surveillance sensor data. "What it actually spits out is maneuver guidance for the pilot on the ground to remain "well clear" of other traffic. DAIDALUS doesn't just relay passive alerts, though. It also "sees" safe paths out of potentially dicey situations (Atkinson, 2015).

These types of technologies will be crucial for the wide scale use of LUCA in the NAS. Current technologies that will be used include GPS navigation, automatic dependent surveillance (ADS), traffic alert and collision avoidance (TCAS), Mode S secondary surveillance radar, an identify friend/foe transponder and special types of RADAR or other sensors are utilized to mitigate the risk of mid-air collision (Elzwig, 2015). In addition, new types of technologies being developed by the FAA, NASA, and industry such as LAANC, UTM, and SWIM will help enhance NAS safety and allow the integration of large UAS in the NAS. In the future, the FAA will likely establish standard regulations as to what would make the large UAS safe, and the system of case-by-case approval of COAs will be replaced (Elzwig, 2015).

On a positive note for LUCA integration, in November 2017, President Trump and U.S. Secretary of Transportation Elaine L. Chao announced the new UAS integration pilot program to accelerate the integration of UAS into the nations busy airspace and further to help spur innovation. This program is called the UAS integration pilot program. The FAA seeks to make partnerships between state, local, and tribal government entities and private industry to gather operational and other data from advance operational concepts, such as flights over people and package delivery. It will also enable state, local, or tribal entities to determine what kind of pilot program activities, subject to FAA safety oversight, will occur in their respected jurisdictions. The results will help to inform safe UAS operations and help to transition many of the new and
novel operational concepts that we manage today by exception into routine, commonplace aspects of our everyday lives (FAA news, 2017).

**Benefits of Point to Point LUCA Service**

One important item to note is that all high value air cargo (including perishables) that goes on manned aircraft today would be a good example of what could be shipped via LUCA. LUCA in the near future can be designed to take off and land from short runways, grass runways, industrial parks, or corporate offices then fly to destinations four to six thousand miles away. The risk of loss would be less because you can ship directly to the destination instead of going through modern day shipping hubs. LUCA would be able to fly in and out of areas of the world with little to no infrastructure. This opens the possibility of shipping high value cargo from remote areas of India, China, South America to North America or European towns or cities. This method of shipping would be more direct, faster, safer, and more fuel efficient than traditional methods of shipping today.

LUCA has a competitive advantage over manned aircraft in that it can provide more frequent flights at a lower cost. Also, traditionally moving high value cargo requires more than one shipping mode. For example, the materials must be loaded on a truck or train then transported to an airport, where it is sorted and loaded on a plane. The same package must be sorted again at the destination airport, loaded on a new truck, then delivered to the destination. This all could be avoided by using LUCA capable of point to point cargo service. Southwest Airlines have proven that point to point works for passengers so why not with cargo? This same concept can be applied for shipping high value cargo with LUCA.

The internet and just-in-time inventory are helping companies increase efficiency, decrease costs, and wastes by receiving goods when they are needed for the production process.
Just in time inventory allows manufactures to decrease the size of their inventories so to reduce costs by eliminating warehouse storage needs. In parts of the world where infrastructure is lacking, LUCA can play a vital new role in helping manufactures move from warehousing its material to just in time inventory strategy. For example, LUCA can service areas of the world that have the economic potential but not the proper infrastructure such as trains, airports, seaports, or major highways. Small manufacturing communities in the United States, Western Europe, and China will be able to ship point to point with LUCA instead of going through regional or shipping hubs. LUCA will be able to move finished products from remote isolated areas of the world without the need for major infrastructure, like airports, roads, trains, seaports, and loading facilities. This means that they can connect producers in even the remotest locations with their customers with direct flights thus avoiding the cost, hassle, and security risks of cargo stopovers or transfers.

According to PUCA, LUCA come to their own in markets that support only small volumes of cargo because in the short-term LUCA will not be able to compete with large manned cargo aircraft like the Boeing 747F, in which 50% of total air cargo is transported (Heerkens, 2017). An unmanned 747, with a payload of 120 t, will probably not have significantly lower cost per ton of transported cargo than a manned one. However, the cost advantages are obvious for an unmanned version of an aircraft with, say 5% of the 747’s payload 2.4t (Heerkens, 2017). “We don’t believe there’s a market for big aircraft,” said Hans Heerkens, assistant professor of the University of Twente and chairman of PUCA. In the short-term moving goods on ‘thin’ routes that do not support larger, manned, aircraft will be where LUCA will thrive. This is especially true on long routes, where the efficiency advantage of LUCA will be the greatest.
**Future LUCA concepts**

According to PUCA website unmanned cargo aircraft will be an improvement to manned cargo aircraft in many different areas. The duty length of the crew will not be an issue, so the cruising speed can be optimized to consume less fuel. The optimal speed will most likely be around 450 km/h. The low cruising speed makes possible for the use of small unpaved runways and efficient designs. LUCA do not need a pressurized cabin, so they can be made lighter and simpler. Because the cross section of the fuselage does not need to be circular, as is the case with pressurized cabin, it can be shaped efficiently, for example to fit square cargo containers. The cargo area can be relatively small because no humans need to be accommodated. This gives the opportunity to use shapes like a Blended Wing Body (BWB) or flying wing, which is 15-20% more aerodynamically efficient than a conventional aircraft shape, as seen in Figure 13. The future LUCA concept provided by PUCA and developed by the students of the Technical University of Delft Netherlands.

![Image](image_url)

*Figure 13 Future LUCA concept by students of the Technical University of Delft (PUCA, 2017)*
One controller on the ground can control 10 to 30 LUCA. This means huge savings in crew salary costs (a single long-range aircraft may require up to two crews). There are no stopover crew costs. It is possible to assign dedicated controllers to handle all LUCA take-offs and landings at specific airports, like pilots do for ships entering harbors. The knowledge of local circumstances of these controllers can increase safety and efficiency. The risk of fire is an acknowledged safety hazard in cargo aircraft. LUCA open the potential for innovative fire suppression techniques, like filling the cargo area and every empty void in the aircraft with inert gas (nitrogen) generated by onboard equipment (PUCA, 2107).

Converting existing aircraft today into unmanned cargo aircraft could be an early way to develop LUCA for operation in the NAS. BAE Systems proved this point by flying a converted Jetstream aircraft in 2014 known as the Flying Test Bed with no pilot in UK airspace, as shown in Figure 14. However, the trial flights did have a pilot on board, allowing a human to take control in an emergency. But, for the large part, it flew itself (Stewart, J. 2014).

Figure 14 The Flying Test Bed by BAE Systems (Stewart, J. 2014)
A new startup company in Richmond CA named Nautilus claims that they can develop a LUCA that can reduce the cost of air freight up to 50% by more efficient use of fuel and the lack of an expensive air crew. They plan on doing this by eventually carrying up to 200,000 pounds of cargo in massive UCA the size of a Boeing 777, as shown in Figure 15. Nautilus with the approval of the FAA has plans to test a 30-foot prototype that is about the size and weight of a military Predator drone. The flight will mark the first significant step toward upending the global freight forwarding industry. Eventually, CEO Aleksey Matyushev says, the company hopes to fly the prototype on 30-hour test runs, carrying up to 700 pounds of cargo, between Los Angeles and Hawaii. The UCA will be designed to land on water so it will not have a landing gear. It will then be towed into a standard port, where cargo would be unloaded using cranes (Terdiman 2017). The goal is to finish production of the full-scale, over 200-foot drone by 2020, then have it undergo testing and certification before beginning actual commercial flights. Nautilus hopes to build hundreds of the drones, some of which will be sold directly to customers—ideally to companies like UPS and FedEx as well as “medium freight forwarders” like Whole Foods and Costco. Matyushev notes that Nautilus may operate some of the drones itself as a freight airline but fly them under the brand logos of customers (Terdiman 2017).
There are several manufactures today developing large autonomous electric passenger aircraft variously known as personal air vehicles or flying cars. The list includes Airbus’ Vahana venture, which is testing an air taxi in Oregon, as well as Uber and its aviation partners, Terrafugia and Kitty Hawk, China’s EHang, Switzerland’s Passenger Drone, Germany’s Volocopter and Lilium, Slovakia’s AeroMobil and Japan’s Cartivator Project. Kirkland, Washington based Zunum Aero, meanwhile, is developing a new class of hybrid-electric airplanes for regional passenger service, with backing from Boeing and Jet Blue Technology Ventures (Boyle, 2017).

The Airbus startup company called “A-Cubed” is developing the Vahana, as shown in Figure 16 and it will be a vertical takeoff and land (VTOL) electric eight fan tilt wing design to carry a payload weight of 250 lbs. up to 200 miles (estimate). According to the company website, the exact performance specifications of Vahana have not been finalized, but it is believed that the electric tilt wing configuration will provide better lift to drag ratio than a standard electric helicopter design allowing it to travel greater distances on a single charge. This will lead to lower direct operating costs that will enable for greater profits for stakeholders. A-Cubed claim that it will have many other advantages such as reduced noise and enhanced safety for urban mobility. One other unique feature of this autonomous aircraft is that the design team are sharing the design and manufacturing information of this aircraft using a platform called multidisciplinary design optimization (MDO). MDO allows designers to incorporate all ideas simultaneously (Vahana, 2017).
Zenum Aero founded in 2014 is moving forward to manufacture a hybrid-to-electric optionally piloted aircraft (OPA). With the backing of JetBlue Technology Ventures and Boeing Horizon X the founder and CEO Mr. Ashish Kumar PhD and his small team of people are developing a hybrid electric 12 passenger OPA that can take off in just 2,200 ft., cruise at 340 mph, fly distances over 700 miles with max payload of 2,500 lbs. The first OPA is due to be ready for delivery in 2022. The plane offers a cost per seat mile of 8 cents, so it basically costs you 250 dollars per hour to operate the aircraft (Du Besse, 2017).
The literature review found that by Congress direction through FMRA and with recent incentives by the president of the U.S., NASA, DOT, and FAA are all helping to progress the industry to develop the tools where LUCA will be able to operate freely in the NAS. U.S. States and city governments are also helping integrate UAS in the airspace around us. They are working with the FAA at seven UAS test sites, and with LUAS manufactures to help make this happen. Despite this progress, most of the new LUAS manufactures are developing aircraft for passenger transport on not for cargo. Our research found a lack of LUCA manufactures and zero LUCA operators other than the military.
CHAPTER III

METHODOLOGY

Research Approach

To understand the potential market of LUCA, a research market survey was conducted with aviation minded professionals throughout the United States, worldwide aviation, and UAS community. The survey was limited to fourteen questions to decrease survey response time and encourage greater participation.

Market research questions were developed with the help of Erik Baker, Ph.D., Asst. Director of Graduate Studies in Aviation & Transportation Lewis University; Scott Jackman CEO and partner of KC Drone Company; Michael Cherry, Ed.D. Assistant Professor, Organizational Leadership Lewis University; and Hans Heerkens, Chairman of the Platform of Unmanned Cargo Aircraft (PUCA).

Population Sample

The target group of participants for the market research survey was those people working in the aviation or the UAS industry. One of the ways the author was able to target this group so effectively was with the help of Curt Lewis, PhD, CSP, FRAeS, ISASI-Fellow Publisher, Curt Lewis & Associates, LLC (Targeting Safety & Risk Management) and Hans Heerkens chairperson of PUCA. Dr. Lewis distributed the survey to its members who come from aviation industry and Mr. Heerkens distributed the survey via email to its PUCA members. Curt Lewis & Associates provides free aviation newsletter services which are published daily and distributed to more than 36,000 subscribers worldwide. They are a multi-discipline technical and scientific consulting firm specializing in the aviation and industrial safety industries. The firm was established in 2005, targets aviation safety management systems, system safety audits and
aviation safety training programs, aviation risk management, aviation accident investigation, aviation litigation support and quality assessments (Curt-Lewis, 2017).

An invitation to take part in the survey was also sent out via email. These emails were directed towards aviation professional managers working for passenger airlines, cargo airlines and the unmanned aerial vehicle (UAV) and unmanned cargo aircraft (UCA) industries. Emails were collected from company’s websites, through online searches, and telephone contacts. Chairman Heerkens of PUCA sent this email invitation to take the survey to fellow members of PUCA to participate. Also, the survey email invitation to participate was sent out to employees of companies already in the aviation cargo business. These included professional managers and directors currently working for the following companies: Atlas Air Cargo, Lufthansa Cargo, Singapore Airlines, Emirates Airlines, UPS, FedEx, Korean Air Cargo, ABX Air, & ATI International. The email invitation to take the survey was sent out to UAS industry representative at KC Drones, UAV Industry, Platform of UCA, and faculty and graduate students in aviation at Lewis University.

Sources of the Data

The sources of the data came from participant answers to fourteen questions on the research market survey. This survey was conducted to help determine the commercial market for large unmanned cargo aircraft from those people involved in aviation and UAS industry. Other data came from literature review of scholarly articles on the UAS industry and company websites.

Data Collection Device

To maintain confidentiality and to encourage maximum participation, this questionnaire was conducted online using Survey Monkey.com (an on-line survey tool). Survey Monkey is an
internet based software survey tool that allows data collection and data analysis. It allowed the author to conduct the survey anonymously and efficiently, help calculate survey results, and create easy to read result files and charts found throughout this thesis.

**Treatment of the Data**

Questions (Q2, Q5, and Q7) used a ranking style question to compare items to each other by placing them in order of respondent preference. These ranking questions have 6 answer choices, the weights were assigned as follows: The preferred choice was assigned a weight of six and the last (least desirable) choice was assigned a weight of one (1). The weighted average was used to calculate the highest-ranking responses results for each of these survey questions (Q2, Q5, and Q7). The formula for weighted average ranking was calculated as follows, where, w= weight of the ranked position & x = response count for the answer choice.

\[ \frac{x_1w_1 + x_2w_2 + x_3w_3 \ldots + x_nw_n}{Total} \]

Two questions were open response (Q4 and Q10) to encourage free thought. These open-response questions enabled the use of a word cloud (Figure 23 & 30) to visually present the various qualitative textual data into easy to understand pictures.

To help understand the overall sentiment around LUCA and collect specific data on factors that contribute to that LUCA sentiment, two Likert scale questions (Q1 and Q8) were used. Question (Q9) was developed to help determine threats for LUCA NAS integration. To determine the demographics of the survey participants, questions (Q11-Q14) were used. These included questions about the country of residence, age, employment status, and job function of the participants that took part in the survey.

**Hypothesis Testing**
Mr. Jackman was helpful in forming the questions regarding LUCA limitations and threats. Dr. Baker and Dr. Cherry provided help with question development, survey result review, and survey question structure. Chairman Heerkens provided guidance with forming the survey questions on the future markets for LUCA and those associated with the authors hypothesis. Therefore, many of the survey questions (Q1, Q2, Q4, Q5, Q7 - Q9) helped determined future markets for LUCA service and test the validity of this theory. Other research questions (Q3, Q6, Q8, Q10) determined factors for LUCA industry progress and developed the current perception of LUCA from those people (aviation & UAS industry) who will be responsible for its safe operation and use.
CHAPTER IV

RESULTS

Descriptive Analysis

To help understand the future market of LUCA and test the authors theory, an exploratory descriptive analysis was performed from the survey results. A total of 110 participants took the survey with an average completion rate of 97% covering ten survey questions over LUCA and four questions covering survey participant demographic characteristics. These survey questions helped determine public sentiment towards commercial LUCA from aviation professionals whom will be responsible for its future use.

Reliability Testing

For this survey, four questions (Q11-Q14) were asked to determine the demographics of the participants. Question (Q11) asked which country the participants reside. Question (Q12) asked the participants age, Question (Q13) asked what their employment status, and Question (Q14) asked what their job function is.

Eighty-six respondents were from the United States, three respondents were from Australia, two from Germany, two from the United Kingdom, two from Saudi Arabia, two from Europe, two from Canada, one from the Netherlands, one from Taiwan, one from Angola, one from Ghana, one from France, one from United Arab Emirates, and one from Denmark.

Question (Q12) asked the survey participants age. Thirty-four respondents (32%) were between the ages of 50-59, twenty-three (22%) were between the ages of 60-69, sixteen (15%) were between the ages of 40-49, twelve (12%) were between the ages of 30-39, ten (10%) were between the ages of 20-29, nine (8%) were between the ages of 70-79, and two (2%) were 80 years of age or older, as shown in Figure 18.
Figure 18. Histogram of participants age (Q12)

Question (Q13) asked respondents, which of the following categories best describes your employment status? Thirty four of the respondents (32%) are employed with a passenger airline, eighteen respondents (17%) are employed at an aviation school, thirteen (12.3%) work for a cargo airline, eleven (11%) work for an aviation regulator such as the FAA, TCCA, EASA, CAA, or ICAO, ten (10%) are retired but used to work in aviation, four (4%) work for an aircraft engine manufacture, four (4%) in school for aviation, three (3%) work for a repair station, and two (2%) were not employed, as shown in Figure 19 below.
Figure 19. Question (Q13) Which of the following categories best describes your employment status?

Question (Q14) asked, which of the following best describe your job function? This survey question allowed the participant to select, “other” then write in a response result. Eighteen respondents selected “other” with nine of those working as passenger airline pilots, airline cargo pilots, captains, and military pilots. The remaining nine in the “other” category, held aviation job functions in the following areas: Flight ops, FAA policy author, aviation security, advisor, operations, consulting, military regulator, aircraft mechanic, and a graduate student in aviation at Lewis University.

Twenty-eight of the respondents identified themselves as working in safety, ten respondents work in training, six respondents are professors, six respondents in engineering, five in management, four respondents are CEO, CFO or presidents, four respondents selected department head, three respondents work in quality assurance, and the remaining respondent job functions can be found in Figure 20.
Figure 20. Question (Q14) Which of the following best describe your job function?

**Hypothesis Testing**

The first question (Q1) in this survey was the first of two Likert scale questions used in this survey. Question (Q1) asked, “If the regulations allowed LUCA in the NAS, how likely do you think that the first aircraft used will be for cargo vs. passenger?” Eighty one percent (81%) of participants responded that that it would be likely that the first large unmanned aircraft would be used for cargo than for passenger. One participant responded by saying, “Logically, it would be best for manufactures to experiment with cargo and test payloads for unmanned craft, before putting passenger in them.”
Figure 21. Question (Q1) how likely the first UAS will be for cargo vs. passenger.

Questions (Q2) asked, “If regulations allow large unmanned cargo aircraft (LUCA) in the National Airspace System (NAS), what markets do you feel would be enabled? (rank all that apply).” Participants were able to rank six Q2 choices from highest rank one (1) to lowest rank of six (6). The weighted average was used to calculate the score result for each Q2 response. The weights were applied in reverse, since Question Q2 has six answer choices. The highest ranked choice (indicating greater market demand) was assigned a weight of six (6) and the lowest ranked choice (smallest market demand) was assigned a weight of one (1), where a 6.0 weighted average is the best score. A display chart indicating the weighted average responses to Q2 is reflected in Figure 22.
Question (Q4) was one of the two open ended questions in the LUCA survey. This question asked what respondents see as the greatest LUCA market opportunities. A word cloud, shown in Figure 23, was created to help summarize the most often used words. The main themes that came across from the Q4 written survey responses was that the largest markets for LUCA will be for the following: 1.) Long haul cargo transportation, 2.) Military applications, 3.) Transportation of cargo to and from remote areas of the world, 4.) Shipping companies like FedEx, Amazon, & UPS using LUCA to distribute its cargo, 5.) Transportation of perishables and medical supplies, 6.) Long haul cargo across unpopulated areas or oceans / seas, 7.) Overnight delivery into remote locations, as well as continuous supply into and out of disaster areas. One of the respondents to (Q4) replied, “The biggest challenge will be operating the aircraft on the ground. Therefore, long haul where you eliminate the need for multiple pilots and reduce the ground exposure provides the greatest market.”
Question (Q5) asked participants to rank examples of high value cargo that would be important markets to LUCA. A weighted average score was again used for determining the survey responses results. The higher weighted averages indicate a greater market demand, as shown in Figure 24. The highest ranking was shipping perishable items like cut flowers, pharmaceuticals, and medical supplies. The second highest ranking was military supplies and the 3rd highest ranking was the rush movement or aircraft parts when aircraft are on the ground (AOG). Aircraft on ground (AOG) is a term used in aviation indicating that a problem is serious enough to prevent an aircraft from flying. Generally, there is a rush to acquire the parts to put the aircraft back in service, and prevent further delays or cancellations of the planned itinerary.
Figure 24. Weighted average survey result chart for Q5

Question (Q7) asked “What factors would you consider when deciding to incorporate LUCA into your fleet or business? (rank all that apply).” The weighted average score was also used to determine the highest-ranking responses for each Question (Q7) choice, where higher weighted averages indicated greater importance. A favorable public perception had the highest importance followed by LUCA capable of flying 2-10,000 miles, then by LUCA capable of carrying cargo of 25,000 lbs. or more, then by LUCA capable of carrying cargo between 2,000 – 25,000 lbs., then by LUCA capable of soft short field take off’s and landings. The lowest ranking was LUCA capable of carrying cargo under 2,000lbs. The survey results are presented in the Q7 survey result chart Figure 25.
Figure 25. Weighted average score chart for Q7

Question (Q8) was the second of the two Likert scale questions used in this survey to help understand the overall industry LUCA sentiment. Q8 asked “Assume that the regulations allow LUCA in the NAS, how likely are you to add LUCA to your fleet?” Thirty participants responded that it was neither likely nor unlikely that participants would add LUCA to their fleets, as shown in Figure 26. It was equal number of those responses that said it was likely (twenty-one responses), also said it was extremely unlikely (twenty-one responses). One participant responded by saying, “Would only consider after the technology and track history have been proven.” Along this same theme another participant in the survey responded to Question (Q8) by saying, “Answer would categorize as ‘neither likely nor unlikely’; it would depend on cost to operation, regulatory and legal framework, and other external factors.”
Survey Results for UAS to NAS Regulatory Progress

Question (Q3) in the LUCA market survey asked “How would you rate the regulatory progress of commercial unmanned aircraft in the NAS? (select all that apply).” Thirty-seven percent (37%) responded that the regulators are too slow to implement UAS to NAS regulations. Thirty-six percent (36%) of the participants selected that the regulators should do more to protect security and safety. Twenty-three percent (23%) responded that the UAS to NAS regulators are doing just average while sixteen percent (16%) responded that the regulators are doing a poor job. Twelve percent (12%) selected that the regulators for UAS to NAS are doing a below average job. Thirteen percent (13%) of the participants selected, “other” and provided a written response. One of those responses was, “the UASs are in the NAS now, are regulated but unpoliced and are too numerous to guarantee safety to commercial aircraft. There needs to be a much higher level of automation should the ground links fail. Autonomous operation should consider all the possible failures for which we train pilots, not the least is weather.”

Along the same theme another survey participant responded to Q3 by saying, “The FAA is way behind European Aviation Safety Agency (EASA) and other
regulating bodies in figuring out how to integrate UAS into the NAS. And unfortunately, partially at the direction of Congress, the regulations implemented are complete chaos. A person can have a UAS operator’s license and a UAS, and on one day need prior FAA approval to operate at a location as a commercial operator, and the next day be able to operate as they wish under the hobby rules. More importantly, those gaps in the rules are permitting and almost encouraging operators to operate UAS in areas where such operation is incompatible. I flew into a GA airport recently, and a non-pilot hobby operator got on the radio frequency and interrupted my approach to land to tell me he was landing a 9-foot-long jet powered model aircraft in front of me. Worse, the airport operator approved of the flying club operations and saw no issue with that interference. So, in that poorly regulated environment, introducing LUCA operations is of tremendous risk.”

Figure 27 Question (Q3) How would you rate the regulatory progress of commercial unmanned aircraft in the NAS?

Survey Results Limiting LUCA NAS integration
Question (Q6) asked survey participants to “Determine what factors would keep them from incorporating LUCA into their fleets? (check all that apply).” As shown in Figure 28, Sixty three percent (63%) of the participants selected safety, fifty eight (58%) checked liability, forty nine percent (49%) respondents selected public perception, forty two percent (42%) checked insurance costs, twenty eight percent (28%) selected technology, twenty five (25%) responded that it is too risky to invest, twenty percent (20%) selected that LUCA would be too expensive, fourteen percent (14%) do not know the market demand therefore will not invest in LUCA, eleven percent (11%) responded that there isn’t a market for LUCA, eight percent (8%) selected LUCA manufactures, eight percent (8%) responded that they want to invest in LUCA but do not know the demand.

Twenty percent (20%) selected, “other” and provided written response answers to Q6. Technology and risk issues were other limiting factors that people expressed as concerns for UAS to NAS integration. One survey participant responded by saying, “that they would wait until the technology is mature to invest in LUCA.” Other responses were concerned over the loss of pilot jobs and the potential problems with labor unions. One participant responded by saying, “as a pilot I want to protect jobs.” Regulatory issues were also of concern with many of the written responses. One person responded by saying, “the FAA is the biggest block to aviation progress.”
Figure 28. (Q6) what factors would keep them from incorporating LUCA into their fleets?

Question (Q9) centered around understanding reasons associated with the aviation industry perception of LUCA threats. It asked, “If regulations allow LUCA use, what threat to your business model would LUCA present? (select all that apply).” The number one threat response with fifty-seven respondent selections was that the pilot unions might become adversarial introducing LUCA to existing fleets. One participant responded by saying, “The maintenance/servicing of unmanned aircraft will need to be addressed or contracted. Thus, the unmanned operation may likely be a spin-off company to avoid pilot and maintenance union issues.”

The second highest response (thirty-three responses) was that LUCA might require too much cultural change, as shown in Figure 29. One participant responded, “The potential for something to go wrong causing fatalities on the ground would hurt brand image.” Also, thirty of the participants responded that their pricing model might have to be changed with using LUCA. Thirty respondents selected “other” and wrote in a response. Insurance, liability, safety, remained at the forefront of the LUCA integration message when looking at the results of those
who gave written responses to Question (Q9). One respondent said, “Some scenarios require ‘seat of your pants’ real time thought while operating an aircraft.” Another respondent said, “the insurance and liabilities might be too great to overcome.”

Figure 29. Question (Q9) Survey chart results for LUCA threats

Question (Q10) was the second open ended question in this survey covering LUCA market limitations. It asked, “Assuming regulations allow LUCA in the NAS, what do you see as the greatest market limitation?” A total of 92 participants responded to this open-ended question with written responses. To understand trends and patterns in the participant written responses a word cloud was generated from the words which had the highest word concentration, as shown in Figure 30.

Public perception of LUCA, safety concerns, technology constraints, liability issues, labor union integration, flying over populated areas, LUCA reliability, and regulations for LUCA use remain at the forefront of the written responses received to Q10. One response was, “Convincing the general public that it is safe. The UAS’s were in service long before there was even preliminary regulation. The fact that there hasn't been a major accident involving them is a
function of the 'big sky' theory. It will eventually happen (commercial pilots report near sightings every day). The LUCAs will have to be limited to certain airspace and have a complete failsafe hierarchical logic to handle all encounters.” Another response was, “Moving too fast and implementing without understanding consequences. Like current drones, folks thinking it is a convenience and right and not a responsibility.” The safe ground handling and security concerns were also expressed as a possible limitation. One participant responded by saying, “Confidence in the safety and security of goods owned by the customer.”

Figure 30. Word Cloud based on responses for Q10.
CHAPTER V

CONCLUSION

Discussion of the Results

One of the main objectives of this thesis was to understand the future commercial market for LUCA so to help motivate the regulators, unmanned aircraft manufactures, and potential operators to progress faster for NAS integration than it would have under normal conditions. The results of the research market survey revealed some key marketing opportunities that will be beneficial for potential LUCA stakeholders.

Implications of the Results

Convincing the public that LUCA are safe is one of the largest challenge facing integration. The best way to do this is to start flying LUCA operations in remote areas and start tracking the safety results. Over time, enough operations would be developed to show the accident rates and compare them to airline safety performance accident rates. If the results show that LUCA are equal or better than airline safety performance, then this information can be used to help improve the public perception of LUCA and justify flights over populated areas and into the vast airport system used by manned passenger aircraft.

The market research survey question (Q8) was a good reflection of the sentiment towards LUCA. Most of the participants responded that they were neither likely nor unlikely to add LUCA to their fleet despite LUCA enabling technologies and regulations. The results found that this is because of three main reasons: 1) the regulators are taking a cautious approach to LUCA in the NAS 2) the lack of LUCA manufactures building aircraft and 3) the lack of LUCA operators requesting it. More reasons for the slower than normal integration is because the different industries are having to work together for the first time to build integration systems that
are just as safe or safer than manned commercial aircraft operations today. These different industries have varying culture characteristics which contribute to some of this delay. The industries include the commercial aerospace industry, unmanned aircraft industry, and the regulators.

**Recommendation for LUCA Manufactures**

During the first years of LUCA to NAS integration, large unmanned aircraft manufactures should focus their development efforts on unmanned cargo aircraft rather than unmanned passenger aircraft. They should also develop LUCA for both the civil and military cargo markets. Based on the findings of the research and market survey results, potential LUCA manufactures should focus future LUCA designs on those aircraft that can fly up to 10,000 miles with the capability of carrying at least 2.5 tons – 12.5 tons of cargo using short fields or runways. The Nautilus concept of carrying 200t of cargo does not fit into this model and is not a recommended LUCA concept design for an initial LUCA aircraft.

**Recommendation for LUCA operators**

Question (Q9) of the survey was a great indicator for the reason for our recommendation to LUCA operators. It asked, “what threat to your business model do large unmanned cargo aircraft present?” The results found that the labor unions would become adversarial and it would cause too much culture change within existing passenger and cargo airlines today. Therefore, to maintain a competitive advantage and avoid labor disputes it is advised that LUCA operators separate LUCA business from any manned aircraft operation so that to have less labor animosity.

**Recommended LUCA Safety Regulations**

The main issue with the integration of LUCA in the NAS is the lack of safety regulations by the FAA. Safety is the FAA’s most important responsibility in the pursuit of integrating
LUCA into the NAS. For the public to have a favorable opinion towards LUCA the safety standards should be at least equal to or better than those defined for by commercial FAA Part 121 aircraft operators. LUCA operators should be required to have operating certificates to fly in the NAS while LUCA manufactures should be required to have Type Certificates to sell their LUCA. LUCA remote pilots should be aircraft type rated and instrument rated while LUCA should be maintained by FAA certified airframe and powerplant technicians. Also, it is important that safety management systems (SMS) be required for LUCA operators just as it is with commercial airlines today. These proven processes have shown to decrease accidents, improve safety, and public confidence of manned airplanes so it is therefore crucial for integration of LUCA.

**Future Markets for LUCA**

The market research revealed that the biggest markets would continue to be with the military but once regulators allow LUCA use in the NAS many new markets will open. Those top LUCA markets found are those that that limit both risk and liability to all stakeholders. Those types of markets included long haul point to point cargo service and delivery of goods to and from remote areas of the world where the infrastructure is lacking. Other LUCA markets included shipping high value cargo over long distances where multiple manned crews would normally be necessary. The survey results revealed that the following high value cargo will be important markets for LUCA: 1) perishable items, 2) pharmaceuticals, 3) medical supplies, 4) military supplies, and 5) the rush movement of aircraft parts for when aircraft on the ground (AOG) waiting for parts to be airworthy to fly again.

Another LUCA markets include transporting emergency supplies like medicines to disaster areas. Wings for Aid is spearheading this by developing a cooperation formed with the
specialists of the three Dutch Universities of Technology (Delft, Eindhoven and Twente), i+Solutions, AvioniCS and design agency VanBerlo. This consortium will deliver a prototype of a plane that can deliver a hundred kilos of disaster relief products, enough for 200 people for one day. All parties have been involved from the start-up phase and continue to work together closely with international emergency experts to create a practical solution.

**Conclusion**

During the pioneering days of commercial airlines in the U.S., the owner of Trans World Airlines (TWA) Howard Hughes had to reach out to the manufacturers at the time (1930s) to develop an airplane that met their needs. This is what led to the manufacture and use of the DC-1 which led to the further development all Douglas aircraft. The whole point with this example is that it took the airline (TWA) to create the specifications for the DC-1 aircraft before the manufactures started to develop it. Therefore, it is crucial the unmanned cargo airline industry start to request manufactures to develop LUCA to meet their specifications, otherwise the manufactures might not ever manufacture them, and the regulators might not be as motivated to authorize their use.

Based on the literature review, results of the survey, and correspondence with experts in the industry it is speculated that LUCA will be able to access the NAS on a routine basis for commercial operations by 2020 starting in unpopulated areas. It should take approximately 2-3 years for a safety record to be established after which time LUCA should able to access all sectors of the NAS. The new technology systems and future safety regulations will enable LUCA in the NAS to start an economic revolution in commercial aviation industry, likes of which the industry has not seen since that of the jet age and the time of the Wright Brothers.
This will be just as significant as the railroads were in allowing people and cargo to move across the continental U.S. for the first time.

The good news for potential LUCA stakeholders is the FAA have announced that they are developing the systems and the regulations that will enable LUCA to fly beyond line of site, over property, and eventually over people. They are continuing to perform tests with NASA on sharing Class A airspace with UAS, granting flight approvals for LUCA, and proactively working with the industry to make it happen. While LUCA like the Centaur, K-Max helicopter, the FlyOx, and even the revolutionary new Nautilus concept are pioneering the market today, more stakeholders might be missing out on the opportunity to develop a new unmanned cargo airline or manufacture a new LUCA that can fill niche markets throughout the United States and worldwide.

**Recommendations for Future Research**

Since an unmanned cargo airline has never been done before, it is recommended to perform further research on determining the economic validity of an unmanned cargo airline and what one might look like. This research would include determining target market customers, determining potential aircraft and engine type capabilities, speculating the direct operating cost (fuel, labor and overhead), and possible revenue for an unmanned cargo airline. This market information would help in proving such a concept and in determining stakeholder investment. The same recommendation for research would be made for developing an ideal LUCA manufacture.

Other research could be in helping determine the market feasibility for converting existing aircraft to unmanned pilotless aircraft. This would help in determining which existing aircraft would be capable serving as LUCA aircraft. Other recommendations for future research would be looking at the environmental impacts of LUCA vs. manned aircraft and determining
both benefits and limitations. This research should include exploring the possibilities of using electrical propulsion systems or hybrid system for LUCA. Also, further research should be done on how to train the next generation LUCA remote pilots and mechanics to provide recommendation for school curriculum development of human to computer interfaces.
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