Corvus: Urban Air Mobility Solutions for Package Delivery

(Technical Paper)

Lessons from the Boeing 737 Max 8

(STS Paper)

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David Normansell
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Technical Project Team Members

Cristhian Vasquez	Daniel Choi	Joseff Medina
Brett Brunsink	Derrick Devairakkam	Justin Robinson
Henry Smith III	Gino Giansante	Philip Hays
Timothy Mather	JD Parker	Alejandro Britos

On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

Introduction

This proposal attempts to solve two independent problems, the development of a system of autonomous delivery drones, and an analysis of the recent Boeing 737 Max 8 disasters. The sociotechnical aspect of this project will focus on the recent Boeing 737 Max disasters and subsequent groundings, and assess the culpability and consequences. When Boeing delivered the 737 Max to customers, they did not fully publicize the details of the flight control system to avoid the need to recertify. Boeing counted on the pilot to act appropriately in the event of a system failure, something the National Transportation Safety Board (NTSB) concluded was an unreasonable assumption (NTSB, 2019). All interested parties, including Boeing, the airlines, the FAA, and the pilots, have blamed the others for the disasters, while denying primary responsibility. The technical portion of this thesis is to design an autonomous drone delivery system for transporting small packages over short distances quickly. This project will include the design of the drones themselves, as well as the infrastructure to deploy the autonomous delivery system, and the business plan to make money doing so.

The technical proposal is not directly related to the STS portion. They are both studies of aerospace developments in the 21st century. The useful relation is that the STS paper provides a framework and baseline for the role of the responsible engineer, which can then be applied to the design and development of an autonomous drone delivery service for the technical project.

Technical Project

The shipping industry loses almost 2 billion dollars a year on last-mile deliveries, due to the costs of drivers and vehicles involved in the operation (UAM study, 2018). Autonomous drones have been proposed as a way to manage those costs. To that end, the objective of this technical project is to "Design a safe, reliable autonomous system to deliver small packages to extremely short take-off and landing platforms within an urban environment (NASA, 2019)." There has been an exponential growth in the field of urban air mobility over the last decade, so NASA's Aeronautics Research Mission Directorate (ARMD) designed the annual Aeronautics University Design challenge for 2019-20 to explore this area. The ultimate goal is to enable the rapid delivery of goods, and eventually people, through a fully autonomous, unmanned aerial system.

This project will be completed by a class of 13 aerospace engineering students over the course of an academic year. To complete this project, engineering students will divide into groups specializing in aerodynamics, performance, and propulsion, and research state of the art technologies in each category. Engineering Students will also collaborate with students from the School of Commerce, or economics students to help develop the business plan. The autonomous drone topic is not directly suited to the team topics, so there will also be research into the state of the art of electronics and machine learning systems. The final deliverable will be a system that is a combination of the state of the art research and the ideas of individual students in the class.

This goal will require numerous innovations and developments to see successful implementation. The foremost factor restricting current drone development is the power source. Batteries and electric propulsion fulfill all the stated design requirements for noise, economics, and sustainability, but currently do not have a sufficient energy density to supply all of the systems needed with sufficient margin of error to be safe. While many battery powered drones do exist, the power needed for a detect and avoid system, fleet autonomy, and the propulsors is not currently available in commercially available batteries. Conventional fuels currently have almost 60 times as much energy per unit mass as lithium ion batteries, and are projected to still have more than 20 times the energy in 15 years (Brelje & Martins, 2019). However, conventional fuels require combustion engines to produce thrust, which are noisy, polluting, and expensive because of fuel consumption. These factors all represent serious drawbacks for an unmanned aerial system (UAS) reliant on fossil fuels. Unfortunately, this project will rely on projected improvements to electric power technology using models and trends of previous improvements, as developing new battery technology is beyond the purview of the design project.

Additional technical limitations are the current absence of an Unmanned Aircraft System Traffic Management (UTM) system, with which the proposed drones are to integrate with. A functional UTM system will enable the real-time identification, tracking, and piloting of autonomous drones across a city, similar to current air traffic control systems detecting and advising commercial aircraft navigation. Implementing the communications hardware both on the aircraft and across an urban environment will be costly and difficult, and thus is a difficult problem to overcome. However, a bureaucratic issue regarding drone flight is currently the largest barrier to the deployment of a functioning UAS in the near future. Current FAA regulations place many restrictions on drone flight that make such a system impossible to implement, namely the ban on autonomous flight. Drones must be piloted by a human, and, the drone must never leave the naked-eye sightline of the person operating the drone. Such a restriction makes the widespread adoption of package delivery drones impossible, as flying within the proposed 10 mile radius would require fully autonomous navigation. Additionally, even in small-scale applications, flying behind an obstacle would invalidate the line-of-sight condition, making flying between large buildings in cities impossible without the pilot traveling alongside the drone. A new Federal Aviation Authority initiative regarding the deployment of a UTM system has been proposed, however this system is not likely readily available before 2021 at the absolute earliest (Barbeau and Javob, 2017). Given the generally slow pace large government bodies have in rolling out new technologies, a proper UTM apparatus will likely not be ready before 2030 (FAA, 2019), which is consequentially when battery technology enables a profitable drone performance and operation condition, as can be seen in the figure below (UAM Study, 2018).

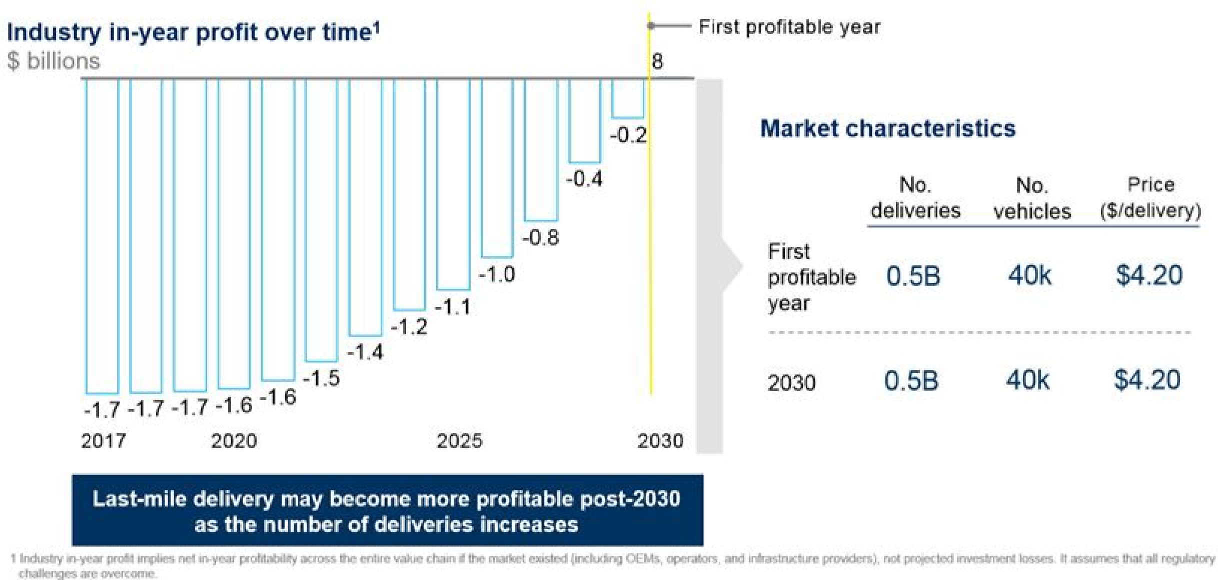

Figure 1: Industry in-year profit for Unmanned Aerial Systems (UAM Study 2018)

When completed, this project will be submitted to NASA ARMD in a contest with other universities from around the country. The winning system design will achieve the design objectives, while simultaneously developing a business case, reducing noise, and ensuring safety. Designs will make use of currently available technical data to provide justification for claimed performance figures, as well as incorporating projections for likely technical developments within the near future.

STS Project

On October 29, 2018, a brand new Boeing 737 Max 8 airplane carrying 189 passengers and crew from Jakarta to the Bangka islands crashed shortly after takeoff, killing everyone on board (NTSB, 2019). On March 10, 2019, another new Boeing 737 Max 8 airplane carrying 157 people from Addis Ababa to Nairobi crashed shortly after takeoff, killing everyone on board (NTSB, 2019). Initial failure assessments blamed the software system Boeing had implemented to help prevent stalls in the plane as a result of the new, larger, engines attached on the Max 8 model (Kitroeff, 2019). Within a week of the second crash, the airplane was grounded worldwide, and remains grounded to this day (Langewiesche, 2019). Boeing lost 5.6 billion dollars in the second quarter of fiscal year 2019, with no signs of improvement in the immediate future, with a large proportion of Boeing's revenue stream grounded indefinitely (MacMillan, 2019). In addition, Boeing has had to delay the 777X series of aircraft in development to focus on the correction of the 737 Max 8. The upcoming aircraft has 344 orders, representing billions of profits to Boeing (Root, 2019). Major airlines flying the 737 Max are also expected to sustain major losses. American Airlines, for example, was projected to lose almost 350 million dollars in 2019 over the groundings assuming the aircraft was back in service by August of 2019. The plane is still not in service, and American executives estimated they could lose as much as 180 million dollars per quarter in the near future (MacMillan, 2019). The result of these crashes has been dramatic. Billions of dollars were lost, the aerospace industry was shaken, and regulation practices have been suddenly reexamined. 346 people died. But why? What went wrong, and who is, and should be held responsible?

This STS research will analyze these questions, and the role of the engineer in the disasters, and in public safety in general, through the framework of Co-Production. Co-production attempts to overcome the simplifications of technical determinism and social constructivism, focusing on how society and technology develop simultaneously and interact through mutual development (Jasanoff, 2004). This framework will be useful to analyze the socio-technical relationships at play with the disasters: the public puts its trust in those with technical knowledge, allowing the technology to develop society as long as the public feels comfortable. But in cases such as this, it becomes evident that society has a strong effect on the technology, as the backlash from the crashes immediately impacted the technical development of the 737 max and other planes. The use of Co-production theory in this paper will have to be carefully constructed, as Co-production has been critiqued as reducing power relationships between actors in a system (Boyle & Harris, 2009), which will play a key role in the analysis of the interplay between regulators and engineers. Co-production has also been critiqued as being defined so broadly as to lose practical value, and a lack of fundamental understanding of the theory will lead to invalid analysis (Boyle & Harris, 2009). These issues will not preclude the use of co-production theory, but are worth considering, to ensure a valid and useful conclusion can be drawn. This paper will analyze news reports and analyses from the time of the accidents through to March of 2020, before writing completion in April of 2020.

Research Question

This paper will try to answer the question: What went wrong that led to the Boeing 737 Max 8 crashes and groundings, and how do the disasters inform the role of the engineer in ensuring public safety?

Method 1

This paper will use documentary research methods for analysis of the responsibility for the crashes. Numerous articles have been written about the incidents, assigning blame to everyone from Boeing engineers to the FAA to Lion air and Ethiopian Airlines. Documentary research is used to create a larger narrative from a multitude of documents surrounding an issue or event (Iowa State University, 2019). This technique will be essential to fully gather all the relevant positions and perspectives surrounding the disasters. A number of articles will be used as documentary research, such as “Boeing Underestimated Cockpit Chaos on 737 Max, N.T.S.B. Says,” “What Really Brought Down the Boeing 737 Max?”, “ Assumptions Used in the Safety Assessment Process and the Effects of Multiple Alerts and Indications on Pilot Performance, Assumptions Used in the Safety Assessment Process and the Effects of Multiple Alerts and Indications on Pilot Performance”, and “Latest 737 Max Fault That Alarmed Test Pilots Rooted in Software.” (NTSB 2019)(Levin, 2019)(Langewiesche, 2019)(Kitroeff, 2019).

Method 2

Historical analysis will also be used in this paper to answer the question of what went wrong. To accurately assess the validity of opinion pieces about the disasters will require extensive background knowledge about the historical events that occurred. Historical case studies are applicable to events in history, and are used to compare with current events (Seabrook, 2019). While in this case “history” is only a year old, and the events are still ongoing, a distinction is made between documentary research and historical cases studies. The former are the opinion pieces assessing blame, and the latter are objective accounts of the incidents without extensive consideration of culpability. Some articles will feature both objective recounts and subjective analysis, and will be used in each method. Most of the sources for this historical case study will be news reports, with some editorials from subject matter experts. Source collection is expected to stop around March of 2020, to have the most complete picture of the events before the completion of this research. There will be a number of sources used for this piece, such as "Boeing CEO to testify at House hearing on 737 Max, his first appearance before lawmakers since two fatal crashes," "Lawmakers slam FAA over handling of Boeing 737 Max," "Boeing takes $5.6 billion revenue hit to compensate 737 Max customers," "Assumptions Used in the Safety Assessment Process and the Effects of Multiple Alerts and Indications on Pilot Performance, Assumptions Used in the Safety Assessment Process and the Effects of Multiple Alerts and Indications on Pilot Performance," "Boeing Delays Development of Another Important Plane. Investors Will Blame the 737 MAX," "FAA Updates on Boeing 737 MAX," and "Boeing Unifies Safety Responsibilities" (Josephs, Sept. 2019)(Josephs, July 2019)(MacMillan, 2019)(NTSB, 2019)(Root, 2019)(FAA, 2019)(Cameron, 2019).

Method 3

This paper will feature discourse analysis because there are so many differing views on the disasters and the results. Discourse analysis, broadly speaking, seeks to analyze textual evidence and varying positions on relevant issues (Ruiz, 2019). This paper has many viewpoints, so discourse analysis will be used to string everything together and construct a position of academic value.

Conclusion

The technical portion of this report is the design of a system of autonomous drones for package delivery. The technical project will conclude with a comprehensive report of the system design of autonomous drones developed by the students working on the NASA design challenge. There will be no physical system developed, only a conceptual development. The STS report is an analysis of the mistakes and faults in the Boeing 737 Max disasters. The STS portion of this report will provide an increased knowledge of the events, and assign some culpability. The goal deliverable of the STS report is to learn what can be done to prevent future accidents from happening from similar issues. Both projects will be completed in April of 2020.

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