Development of Hypersonic Re-Entry Deployable Glider Experiment (HEDGE)

Analyzing the Effects of Collaborative Engineering on the European Aerospace Industry

A Thesis Prospectus
In STS 4500
Presented to
The Faculty of the
School of Engineering and Applied Science
University of Virginia
In Partial Fulfillment of the Requirements for the Degree
Bachelor of Science in Aerospace Engineering

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December 9, 2022

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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.

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Introduction

Projects and emerging technologies in the aerospace industry are reaching technical achievements not seen before, with concepts of reaching cruising speeds in the hypersonic regime, or speeds 5 times faster or more above the speed of sound, for both defense and commercial uses (Sampson, 2021). Others are working to fix issues faced by past aircraft, making a new one that is more viable economically, and try to correct oversights made by previous engineering teams so that these new products can succeed in the coming years (Cao, 2022). These aircraft require a significant amount of design, manufacturing, testing, and then final development. Because of the scale of these projects, it is the case that multiple countries, companies, or interested parties are involved in aircraft development to help disperse the many responsibilities that accompany such a project. Examples of these can be seen in many planes of the past and present-day, with a heavy emphasis on the European aerospace industry. France and England have worked on multiple aviation projects, such as the Concorde, and then there's Airbus, a multinational European corporation that competes against America for manufacturing. Airbus holds agreements with other countries to aid in assembly and manufacturing factories, with the final assembly lines placed in Europe and China (Weiss, 2022).

These projects listed above have all experienced varying degrees of success, with some being used for decades and are still in production, and one being grounded due to engineering and economic concerns over the design. Namely, the Concorde which was grounded from flight completely in 2003 following concerns about fuel costs and economic viability, and Airbus still competing with Boeing as one of the major aircraft manufacturers today. The main reason that I am choosing to use these cases for comparison comes from an accident with the Concorde on July 25, 2000 which was caused by runway debris and led to the deaths of everyone onboard

(Cusick, 2017); this provides a tangible event that led to investigations into the plane and can be used to identify causes that trace back to the organization of the project, providing an excellent motive to avoid similar decisions in modern projects. This event caused a suspension of airworthiness and investigations were made into the vehicle itself; in 2003, the vehicle made its final flight to Seattle and the model was grounded permanently. There were many reasons that the design was scrapped, including economic viability, the restrictions of supersonic flight, and organizational structure from the beginning (Farah, 2019).

In the 1950s, the proposals for supersonic aircraft were given by government organizations/committees to the French and British, and after competing companies vied for the contract, the Anglo-French partnership was born in the early 1960s. (Hamilton, 1968). Furthermore, as Hamilton describes, 6 parties are involved with the Concorde: the French and British governments, 2 aircraft contractors and 2 engine contractors. The reason that this becomes a problem is that each governing body cannot focus all their attention on the Concorde, so they created sub-boards, who extended this and made smaller groups that formed and disbanded as needed over the duration of the project. As for Airbus, they are still around and are succeeding in the aerospace industry by manufacturing, designing, and delivering aircraft. On their website, Airbus says they are "the largest aeronautics and space company in Europe and a world leader" (*Who We Are | Airbus*, 2021). With Airbus' extensive collection of products, they have broken their board up into each division: Helicopters, Defense and Space, plus Top Management (*Executive and Operational Committees | Our Governance | Airbus*, 2021), which allows for focus on each sector so that the products become their best with the attention that is needed. The vastly different structures and results for these two cases are worth analyzing, leading to conclusions about how to set up a collaborative project based on these cases.

Both the focus of my STS paper and the technical project for my capstone involve the delegation of work to sub teams and the development of novel technologies and designs, although the technical project is not at the same scale as the ones in the STS paper. The nature of our work in the technical project could draw interest from our government or companies in the industry, which would align the two topics more, however there are still connections in their current states. In my STS project, I will be examining how the faults of one project, the Concorde, compares to and could have influenced future ones like Airbus and their products, specifically looking at their structural differences and their effectiveness in producing a vehicle that integrates into society. In my technical project, I will be developing one of the first University-driven research vehicles in the emerging field of hypersonics; the Concorde relates since it was the first supersonic commercial passenger aircraft and operated for many years before its grounding.

Technical Topic: Hypersonic Re-Entry Vehicle Project (HEDGE)

HEDGE, or Hypersonic Re-Entry Deployable Glider Experiment, aims to prove that undergraduate students and University-driven work can provide a suitable vehicle to perform research during re-entry (hypersonic regime) for a very low cost. With this we hope to not only show the feasibility of CubeSats (cube satellites) as a platform for aerospace research, but that with this low-cost experiment, functional data can be taken and used in large-scale projects in the same regime (Goyne, 2022). The CubeSat standard was formed at California Polytechnic State University, San Luis Obispo, and Stanford University in 1999 and provides regulation for students and groups to build experiments that can be launched into space to "facilitate access to space for university students" (*About*, n.d.). The design of these is modular cubes that serve as miniature satellites, hence their name, that perform tasks unique to each experiment. Hypersonics are of interest for aerospace as new weapons and vehicles are being developed to advance air capabilities of nations, and being able to conduct cheap, relatively quick design and implementation, and getting usable data would be used to improve designs for ongoing projects in these fields. This type of research for hypersonics is not only being done with our project; Dynetics was granted a contract to develop a test bed for quickly testing designs for vehicles/weapons that can leverage military and commercial needs at a much larger scale than a university's project can (Dynetics, 2022).

The subsystems that are involved for HEDGE are attitude determination and control (responsible for control of its orientation), structures and integration (modeling the physical vehicle and combining subsystem parts into final design), power, thermal, and environment (designing exterior to withstand large forces and temperatures during flight), avionics and software (program the flight computer to handle the data and command of other subsystems), communications (sending the data to ground station in an efficient manner), and program management (oversee whole project and each team accordingly); my position resides in the avionics and software subsystem with 4 other members. Throughout the fall and spring semester, we will work to design and implement a flight computer that can handle the data handling needs and interface with every subsystem to ensure complete control and functionality of the vehicle.

The main challenges that the project faces are mainly from the type of environment that it will experience in flight, with the design conforming to the aforementioned CubeSat standard. Being able to build electronics made to function in regular conditions and then bringing them to an environment that is above 1000 K (room temperature is about 298 K and water boils at 373K), as well as large forces due to the speed at which it is traveling, which can reach Mach 25 (Sia, 2021), is an extremely difficult task, especially for undergraduates. Even if we are confident that our avionics will survive the flight conditions, our work will involve interfacing with individual subsystems and ensure their instructions and data are handled appropriately, as well as ensuring our vehicle functions properly while on the ground. There are examples of vehicles that survived these flight conditions, and drawing on them will help my team develop a successful prototype prior to the end of the spring semester, the main deliverable alongside a critical design review (CDR) which will be passed along to next year's team to manufacture the design my project team makes this year. With their work in the next academic year, the goal of the project is to have a final model of the vehicle that is flight-ready and can capture data upon re-entry into the atmosphere. While this will most likely not be implemented directly inro research and development, it serves as a demonstration of the program's feasibility and a reason for future innovation in the area of university-industry collaboration.

STS Topic: Organizational Structure of the European Aerospace Industry

The Concorde and Airbus (the A300 or A320 if a model is useful for comparison) both stem from collaborative programs and projects in Europe, and each serve/served as a commercial transport aircraft, but their organizational layouts and results differ drastically. Looking at the project that was Concorde and the corporation of Airbus and its projects, it is worth asking how did the Concorde and its organizational structure impact the European aerospace industry and its future projects? With the setup of the Concorde project, the countries involved in its making were initially unsure of what they wanted out of the plane, and even once a design was chosen, the use of it for medium or long range was not reconciled between the firms working on it; there were also numerous subcommittees that oversaw the project and muddied the decision making (Koenig, 1988). Koenig in that piece also mentions that the commercial disaster that the Concorde ended up being can be traced back to this organizational setup.

On the contrary with Airbus, who still are very prominent in the aerospace industry, they are making steps to consolidate their organization, as in 2017 when they merged with their parent group (“Factbox,” 2017) and list on their company website that their “Corporate Governance ensures that Airbus is managed according to our Regulating Laws and Articles of Association, and evolves in order to match our growth ambitions, meet our obligations and reach the goals we set ourselves.” (*Executive and Operational Committees | Our Governance | Airbus*, 2021). This shows that Airbus makes a conscious effort to adapt to the industry as time passes, and to make their product the best that it can be for their multiple markets in Europe and across the globe, while Concorde was rather static in its structure.

Like most projects that are ultimately taken out of the market, there were many problems associated with its operation, but once an investigation began the defects were exacerbated with the context of an accident. It is worth pointing out that Air France Flight 4590, the fatal crash involving the Concorde, was not the sole reason for its discontinuation. Using the A320, the Concorde used almost 7 times as much fuel per passenger mile (used to normalize data to length of flights and number of passengers) as the A320, with causes being identified as cruising at speeds higher than the desired speed, and the physical design not being optimized for this type of flight (Liu, 2022). With the excessive fuel use, concerns about sonic booms over populated areas and the emissions into the higher levels of the atmosphere are also possible causes of its grounding.

Compiling data such as this requires an STS framework that can handle such complex interactions, between both the people involved and the product itself. SCOT, or the social construction of technology (Pinch & Bijker, 1984), is the framework that would work well in this situation, being able to compare structures and influences between the two products and then analyze effects on the success of each. The reasoning behind using SCOT lies in the basis of the framework; “those who seek to understand the reasons for acceptance or rejection of a technology should look to the social world.” (Klett, 2018). By looking at the interactions between the projects and their organizers, the success and failure of each can be analyzed with the framework using relationships between groups and the vehicles themselves with their impact. As mentioned in the Introduction, there were multiple parties that were present for the Concorde’s development, namely the French and British governments and their contractors, who all saw the project as a way to produce revenue, but then the customers of the plane (airports and the people traveling on it) view the plane as a means of transportation, a luxury since you can travel faster. This is what SCOT allows with relevant social groups, the ability to separate groups of people that interact with the technology based on how they view and think of it. The development team and overseers have different ideas over what they can do with the plane than some of those that use it, and with this comes certain concerns and effects over time with the technology.

The challenge with using SCOT in such a context would be to be able to draw relevant and accurate conclusions about the interactions of groups and the project. However, drawing from other examples of SCOT being applied in a similar situation would allow me to draw better conclusions in my context. The bicycle, a normal technology used by many people is a good case study for such an application, as Pinch and Bijker talk about, had many interpretations depending on the uses for the bike. (Pinch & Bijker, 1984) Some would use it for sport, while others would leisurely use it, and then some opposed it altogether. Being able to take such an apparently simple technology and analyzing it in this manner will allow me to have as effective an analysis as I possibly can, essentially by using the framework correctly.

Research Question & Methods

When looking at projects that involve so many people and exchanges of ideas, information, and hardware, being able to configure every relationship will be a large challenge. Knowing this, the relationship I will be exploring is how did the Concorde and its structure affect other European aerospace projects, specifically Airbus, based on the success and failure in the late 20th century? I plan to find documents from the Concorde project and Airbus that diagram their organizational structure, such as conference papers that provide a timeline for the project and progress made, or the executive and project structures from Airbus, as they have the most comparable products and multinational backing as Concorde. Some examples are from AIAA conferences where things such as the origins of the project, intentions behind design choices, and the plane's interactions with other nations and markets (Hamilton, 1968).

As for Airbus, case studies have been done on their products as an exercise in collaborative engineering, which promotes the cooperation of different levels in the organizational structure of projects to aid in dispersed workforces and make critical decisions that all are aware of in the information chain (Taber, 2021). Such case studies explore the impacts that adopting such strategies in the design process have had on products and the rest of the project (Mas et al., 2013), and then other articles exist that look at the European aerospace industry and how it functions differently from the US. Looking at data provided in these types of publications will allow me to have a comprehensive picture of the Concorde and Airbus projects and initiatives, and with Airbus having a large list of products, I will be able to draw conclusions of the company as whole. It may also be relevant to look at the European aerospace industry alongside Airbus to provide context, and studies have been performed to look at their use of collaboration in projects spanning decades in the past.

Conclusion

Based on the information gathered in preparation of this project, it is apparent that there were flaws in the ways that the Concorde was setup from its inception. With both parties involved being unclear about the motives and intentions with the design, there were bound to be mistakes made at most levels in the project. While it was eventually flown successfully, they did not meet their expected sales in the market, and economic viability became a major reason in its grounding. Other projects that were a result of European collaboration, such as the Jaguar, were made in large quantities and were useful for decades serving as a supersonic fighter jet on foreign markets (Alex, 2022). Based on this, the analysis will most likely show a divergence from numerous committees and subcommittees and became more of a fluid collaboration between different aspects of the project group. Since decisions were not necessarily agreed upon by everyone, and took a long time to make, structuring other projects and organizations in this collaborative engineering-type scheme will lead to more efficient and effective designs.

Should these projects be successful, there will be a viable design and prototype of a low-cost re-entry vehicle that could draw interest from the aerospace industry for research in a burgeoning area that is of major interest of multiple sectors in the US, and an analysis examining the ways that structure and collaborative efforts affect the effectiveness of a design by using case studies of a successful and commercial failure in similar contexts and an STS framework to interpret relationships and effects of organizational choices. Along with a successful analysis of the European aerospace industry, the information found could be used to modify existing projects, or to influence projects to come to make intelligent decisions to make the design and iteration phase much more functional. I anticipate any effects in the aerospace would be focused at research and development projects, or ones that are currently only in the conceptual phase.

References

About. (n.d.). CubeSat. Retrieved October 26, 2022, from https://www.cubesat.org/about

Alex, D. (2022, January 29). *SEPECAT Jaguar*. https://www.militaryfactory.com/aircraft/detail.php?aircraft_id=92

Cao, S. (2022, September 23). Decades After the Concorde, a Startup Wants to Bring Back Commercial Supersonic Flight. Aviation Experts Have Many Questions. *Observer*. https://observer.com/2022/09/boom-supersonic-jet-air-travel/

Cusick, S., Cortes, A. & Rodrigues, C. (2017). Case Study: Air France Flight 4590. *Commercial Aviation Safety, 6th Edition*. New York: McGraw-Hill Education

Dynetics. (2022, October 20). *Dynetics Awarded New Contract to Increase Hypersonic Flight Testing Tempo*. https://www.prnewswire.com/news-releases/dynetics-awarded-new-contract-to-increase-hypersonic-flight-testing-tempo-301654753.html

Executive and Operational Committees | Our Governance | Airbus. (2021, July 5). https://www.airbus.com/en/who-we-are/our-governance/executive-and-operational-committees

Factbox: Airbus structure before and after reorganization. (2017, February 21). *Reuters*. https://www.reuters.com/article/us-airbus-reorganisation-factbox-idUSKBN1601ZY

Farah, N. T., Xavier Eidsmore, Abdul. (2019, June 25). *Why The Concorde Was Discontinued and Why It Won't Be Coming Back*. The Museum of Flight. https://blog.museumofflight.org/why-the-concorde-was-discontinued-and-why-it-wont-be-coming-back

Goyne, C. (2022). *Hypersonic ReEntry Deployable Glider Experiment Conceptual Design Review* [PowerPoint slides]. https://collab.its.virginia.edu/portal

Hamilton, J. (1968, October 21). Concorde—An exercise in collaboration. *5th Annual Meeting and Technical Display*. 5th Annual Meeting and Technical Display, Philadelphia, PA, U.S.A. https://doi.org/10.2514/6.1968-990

Klett, J. (2018, July 20). *SCOT | STS Infrastructures*. STS Infrastructures, Platform for Experimental Collaborative Ethnography. https://stsinfrastructures.org/content/scot

Koenig, C. (1988). Managers, engineers and government: The emergence of the mutual organization in the European aerospace industry. Technology in Society, 10(1), 45-69. doi: 10.1016/0160-791X(88)90025-5

Liu, K. H. (2022, June 27). From Concorde's Atrocious Fuel Economy and Demise of Rear-mounted Engines to Future Supersonic Transportation. *AIAA AVIATION 2022 Forum*. AIAA AVIATION 2022 Forum, Chicago, IL & Virtual. https://doi.org/10.2514/6.2022-3314

Mas, F., Menéndez, J. L., Oliva, M., & Ríos, J. (2013). Collaborative Engineering: An Airbus Case Study. *Procedia Engineering*, *63*, 336–345. https://doi.org/10.1016/j.proeng.2013.08.180

Pinch, T. J., & Bijker, W. E. (1984). The Social Construction of Facts and Artefacts: Or How the Sociology of Science and the Sociology of Technology Might Benefit Each Other. *Social Studies of Science*, *14*(3), 399–441.

Sampson, B. (2021, August 9). Hermeus plans to fly Quarterhorse hypersonic aircraft in 2022. *Aerospace Testing International*.

https://www.aerospacetestinginternational.com/news/flight-testing/hermeus-plans-to-fly-quarterhorse-hypersonic-aircraft-in-2022.html

Sia, J. S. (2021, June 24). Rocket Physics, the Hard Way: Re-entry and Hypersonic Flight. *The Mars Society of Canada*. https://www.marssociety.ca/2021/06/24/rocket-physics-the-hard-way-re-entry-and-hypersonic-flight/

Taber, M. (2021, February 11). *What is Collaborative Engineering?* https://www.ptc.com/en/blogs/plm/what-is-collaborative-engineering

The Bicycle as an Artifact of Social Construction. (n.d.). Retrieved October 27, 2022, from https://www.brown.edu/Departments/Joukowsky_Institute/courses/13things/7539.html

Weiss, S. (2022). *Airbus Industrie | History, Headquarters, & Facts | Britannica*. Retrieved October 26, 2022, from https://www.britannica.com/topic/Airbus-Industrie

Who we are | Airbus. (2021, June 14). https://www.airbus.com/en/who-we-are