HEDGE ATTITUDE DETERMINATION AND CONTROL SYSTEMS AND ORBITS

HOW PUBLIC RESPONSE IMPACTS A TECHNOLOGY'S PATH OF INNOVATION

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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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The development of hypersonic flight vehicles, traveling at or above five times the speed of sound, seems unrelated to the general public. Although hypersonics research is often conducted by the military, the general public can play a key role in the progress of this technology. In 1969, British and French aircraft manufacturers designed Concorde, a fleet of about twenty supersonic, passenger-carrying aircraft in an effort to create high speed planes for the Cold War (Eidsmore, X., Farah, A., & Terefe, N.). While the aircraft was developed for military purposes, it eventually became a commercial aircraft available to the general public, with the purchase of an expensive ticket. The public's excitement about Concorde changed over time as its flights revealed themselves to have negative impacts on the public. This STS topic is moderately coupled with the technical topic. Although the technical project will not directly involve a grand scale social implementation of hypersonics or supersonics, the STS topic is relevant to the future of hypersonics. As the STS topic investigates the public's role in the failure of the Concorde project, it will highlight mistakes to avoid in the innovation of hypersonic vehicles, coupling these topics somewhat tightly. As innovation continues for hypersonic vehicles, it would be valuable to consider the factors that contributed to the failure of Concorde so they can be avoided in future endeavors.

HEDGE ATTITUDE DETERMINATION AND CONTROL SYSTEMS AND ORBITS

IMPORTANCE OF ADACS AND ORBITS

Hypersonic flight occurs when vehicle speed exceeds five times the speed of sound. While hypersonics can have many applications, limitations in the capacity to research them is a growing problem. Aerospace Engineering students at the University of Virginia are developing a mission to solve this problem: Hypersonic ReEntry Deployable Glider Experiment (HEDGE).

With this mission, a CubeSat, a type of nanosatellite, will travel in a launch vehicle to extreme low Earth orbit (ELEO) altitude and then be ejected. It will then deploy fins to transform into a hypersonic vehicle. Upon reentry, after about a one-week lifetime, data will be collected and transmitted, then the craft will burn up in the atmosphere to avoid dealing with regulations for retrievable spacecraft and determining where it would land. In order to ensure the project meets the mission objectives, the class is divided into six subsystems to work on specific requirements: Program Management, Communications, Software & Avionics, Power/Thermal/Environment, ADACS, and Structures and Integration. ADACS, or Attitude Determination and Control System, is a system of components used to determine, adjust, and maintain the position of a craft in orbit. The knowledge and control of the craft throughout its flight allows for manipulation of mission parameters, such as launch windows, flight times, orbital maneuvers, sensor orientation, and reentry zones. Attitude can be controlled both passively through components such as spin stabilizers or fins, and actively with parts such as thrusters or magnetic torquers (NASA, 2021). The ADACS subsystem will determine what type of attitude control systems best fit our mission's goals, parameters, and budget.

OBJECTIVES OF HEDGE PROJECT AND ADACS

Prior to flight, the objective of the ADACS team is predicting and modeling the expected orbital path, planning for any potential disruptive forces that would alter the position of the craft. Upon launch, our team's objective moves to real time attitude determination and adjustment to attain spacecraft stability. This is done to ensure the vehicle enters the atmosphere at an optimal attitude for velocity optimization, according to the structure's aerodynamic abilities, and successful data collection. In addition, the ADACS team will aim to provide reliable and consistent ADACS information so that the remaining subsystem teams can plan and achieve their objectives with appropriate positional data.

APPROACH TO ADACS

Our team's approach to ADACS and Orbits is rooted in stability dynamics and pressure sensors. Collaborating with the Structures and Integration subteam, the ADACS team will ensure that the CubeSat's center of pressure is behind its center of gravity. This will require knowledge of the components that will be included in the CubeSat and their integration and how the stability dynamics will change once the fins are deployed. A main concern for ADACS is tumbling of the CubeSat after its ejection from the launch vehicle. To solve this problem, the ADACS subteam will use previously collected CubeSat data to make predictions about HEDGE's tumbling rate when ejected. With this data, the team will begin to draw conclusions about what would be necessary to slow the tumbling and stabilize the CubeSat. Some potential solutions include a passive attitude control system like a magnet that would use the Earth's magnetic field to stabilize the vehicle, an active attitude control system that could be detached from the CubeSat, or using the aerodynamic stability of the CubeSat to simply self-correct. Making the decision of which method of stabilization to use will require data collection and testing. Measuring pressure is a main goal for HEDGE's data collection. The ADACS team plans to make use of this goal by implementing a flush air data system (FADS) for attitude determination. FADS is a method of attitude determination commonly used in aircraft that "makes use of surface pressure measurements from the nose cap of the vehicle for deriving air data parameters such as angle of attack, angle of sideslip, Mach number, etc." (Mohan et al., 2018, p. 68). Figure 1 on page 4 shows a graphic of how the pressure sensors with FADS would lead to the air data parameter determination.

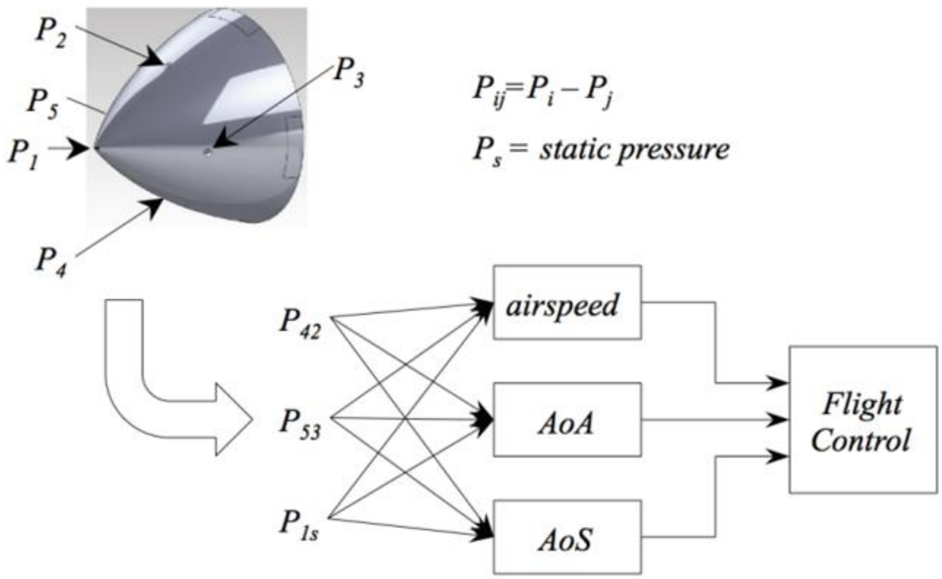

Figure 1: Flush Air Data Sensing System Diagram: The diagram shows the general layout of the flush air data system (FADS) that will be implemented on HEDGE. This system consists of five pressure sensors whose measured data will be used to calculate various flight parameters like airspeed, angle of attack (AoA), or angle of sideslip (AoS). (Langelaan, J. W. & Quindlen, J. F., 2013).

Working with the Power, Thermal, and Environment subsystem, our team will determine whether collecting the necessary pressure measurements for the experiment would be possible using a FADS applicable system. Typically, FADS are used at lower altitudes than that of HEDGE at the point of data collection due to the decrease in pressure allowing noise to have a more significant effect on readings (Mohan et al., 2018). When the vehicle is in the lower-atmosphere portion of its re-entry, this should not be a concern and FADS should be applicable. During the orbital and upper-atmosphere portions of reentry, HEDGE could use a celestial body sensor, likely a sun sensor due to weight and size constraints, for attitude determination. A sun sensor could measure the amount of sunlight absorbed on the spacecraft and determine its orientation relative to the sun (Gaebler, 2007). Another option would be to use magnetometers to measure the magnetic field of the Earth and determine the attitude (NASA, 2018). Based on the requirements for our attitude determination and pressure sensing, the team will choose how many pressure sensors to implement on the surface of the nose. The number of air parameters which must be derived relates to the number of sensors required (Mohan et al., 2018). Another consideration will be the tubing and type of sensors chosen, factors to be discussed with the Structures and Integration team and the Power, Thermal, and Environment team. Finally, our team plans to work with the Communications and Avionics and Software teams in planning how the pressure sensors will collect data and route it to our transmitting device.

AVAILABLE RESOURCES FOR ADACS

Our team has a number of available resources to leverage in accomplishing our goals including a small operating budget and specialized software. As part of the greater class design team, our ADACS subsystem team has an allotment of funds that could be used to purchase and test attitude determination and control equipment. To validate our systems, these resources could be used for prototyping Access to specialized software like the Ansys Systems Tool Kit (STK) will be important to orbit determination and prediction. In order to use this system, we will be referring to the STK user guide from Ansys. The user guide provides directions for creating and modeling our spacecraft (Analytical Graphics Inc., 2022). The advanced space systems prediction capabilities of STK will help us in achieving our goals of predicting and monitoring our spacecraft's orbit.

ANTICIPATED OUTCOMES FOR ADACS

The anticipated outcomes of the ADACS functional team are to find a predetermined orbit with a variable launch point via STK software, determine what specific hardware should be used for attitude and orbit determination, and prepare a critical design review (CDR) to submit for proposal. The predetermined orbit should be applied based on which launch vehicle the team uses and where the CubeSat is released in relation to the Earth. Currently, the launch site is undetermined, therefore orbit determination will have to use all known variables and make an estimation of the orbit that can be easily changed and used for a specific launch site. The specific hardware that will be used for the ADACS subsystem will depend on the team's budget, volumetric constraints, and the effectiveness of the hardware in the reentry environment. The CDR of the subsystem will be accomplished when the hardware is determined and tested on the spacecraft. This will result in a critical design review and a technical paper in the form of a proposal to industry.

IMPACTS OF PUBLIC RESPONSE ON THE PATH OF INNOVATION FOR A TECHNOLOGY

THE FAILURE OF CONCORDE

The development of a new technology is often as much a social challenge as a technical one. When developing a new technology, the technical feasibility and requirements must be considered as these are necessary for its production. However, it is also necessary to recognize the social repercussions of the technology's implementation and the way that the public will respond to it. The Concorde, "the first supersonic passenger-carrying commercial airplane", is a key example of how ignoring this social aspect can be fatal to a project (Britannica, 2022, para.

1). This vehicle was an exciting technological development, instilling ideas about the future of air travel in the general public. However, the project was ultimately a failure, largely due to its negative public response (Overly, 2021). The Concorde's failure begs the question, "how does a social group's response to a new technology change its course of innovation?". An answer to this question could be used to highlight actions to be avoided when implementing a technology and provide a clearer path to garnering public support for future projects like Concorde.

RELATING CONCORDE TO NEW TECHNOLOGY

After the failure of Concorde, the aircraft industry shied away from the pursuit of supersonic commercial aircraft. The complaints from the public about the noise the aircraft made, the cost, and the potential dangers of flying them were too much to overcome. However, currently, companies like "Boeing, Lockheed Martin, and Airbus are all at various stages of development to bring the supersonic passenger aircraft back, and the Federal Aviation Administration stated in 2008 that, 'Interest in supersonic aircraft technology has not disappeared.'" (Appolonia & Nigh, 2021, para. 8). Concorde's failure taught the industry that the social response to a technology can play a crucial role in its developmental path, therefore, when developing new technologies like more supersonic or new hypersonic vehicles, it is imperative that the mistakes of Concorde are considered and avoided or solved. Figure 2, below, lays out a social understanding of Concorde's development and compares it to that of hypersonics, pointing out where the new technology is currently and what to watch for as innovation and implementation continue.

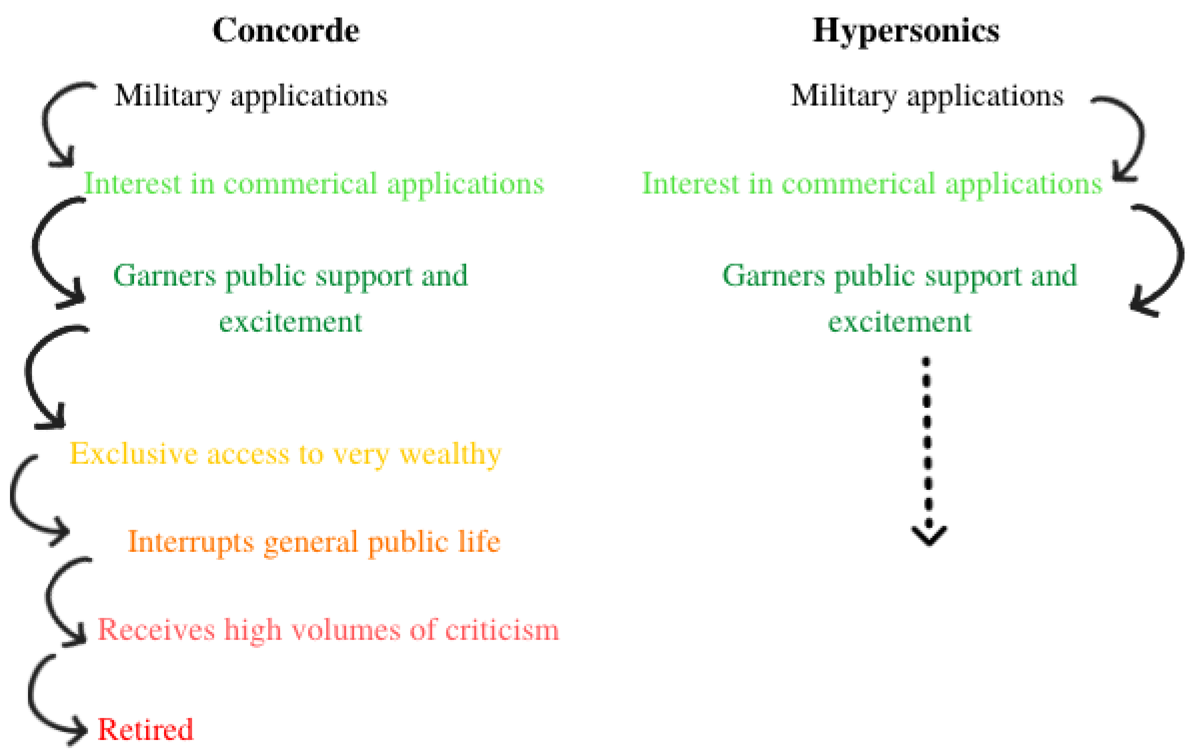

Figure 2: Comparative progression of Concorde and hypersonic flight vehicles: This chart shows the progression of Concorde on the left, pointing out the main points in the project's development, socially. On the right, the same is done for hypersonic flight vehicles. The colors indicate a measure of "goodness" based on how the developmental point either aids or hurts the project. The scale from bad to good moves through the rainbow from red to green, dark red being the worst and dark green being the best, the black indicates neutrality (Goldberg, 2022).

ACTOR NETWORK THEORY AND CONCORDE

The Actor Network Theory (ANT) framework describes the influence that certain groups have on a technology based on how they interact with it and with each other. Applied to the Concorde case, one can see how it was the poor framing and communication within networks, and increasing overflow that led to the project's failure. Figure 3, below, depicts this application of ANT.

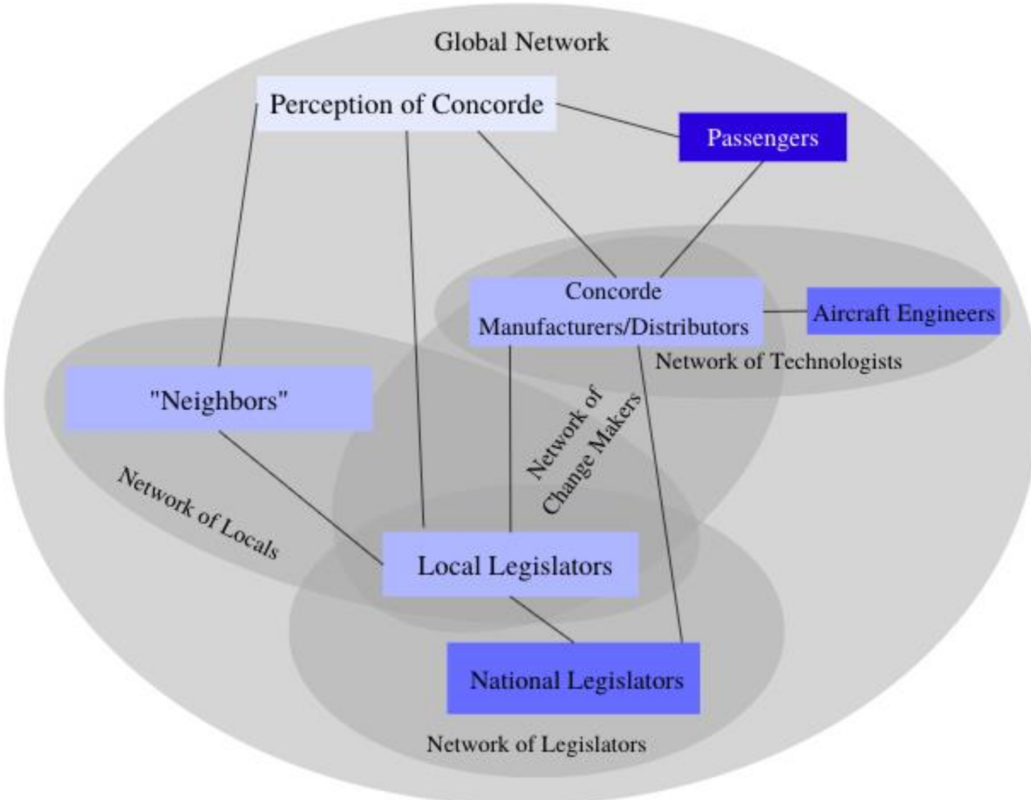

Figure 3: Actor Network Theory applied to Concorde: The colors of the actor squares correspond to the level of significance in the downfall of Concorde with the lightest blue being the most significant and the darkest being the least (Goldberg, 2022).

The large gray circles indicate groups of local and global networks. The squares all represent actors and the lines connecting them illustrate interactions between them. The actors include the perception of the technology, the passengers who use the technology, British Airways, Rolls Royce, Aerospatiale, and SNECMA who were manufacturers of the technology, the engineers who conceptualized and built the technology, the local and national governments who created legislation regarding the flight of Concorde, and the "neighbors" who were locals of the area to and from where Concorde would fly (Britannica, 2022).

LESSONS FROM CONCORDE

This scholarly article will use Concorde as a case study to answer the question "how does a social group's response to a new technology change its course for innovation?". Using sources that describe the conditions of Concorde's failure, conclusions will be drawn about how these conditions could have been avoided. This information will be relevant in understanding the way that ANT can be used to prepare for innovation and aid in achieving success for a project. This knowledge would then be applied to the development of new supersonic and hypersonic flight vehicles in order to avoid the pitfalls of Concorde in this project.

HEDGE SHOULD REMEMBER CONCORDE

The aerospace industry is heavily invested in the development of high-speed flight vehicles and, as such, should do everything possible to ensure the success of research projects. HEDGE is a stepping stone in the development of hypersonic flight vehicles but already serves to address some of the main concerns brought with Concorde. Reducing the cost of hypersonic testing could lead to more accessible technology and more flexibility in the technology's design. Using Concorde as a case study, the research conducted for the STS topic will make it clear that the response of relevant social groups impacts the path of innovation for a technology. With this knowledge, the HEDGE project should work to address the issues people may have with hypersonic vehicles as a tool for ensuring the success of the project.

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