HOW PUBLIC RESPONSE IMPACTS A TECHNOLOGY'S PATH OF INNOVATION

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By

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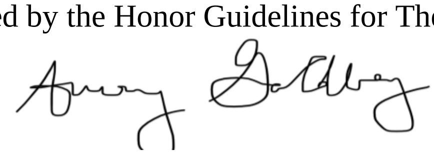
On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.



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The Hypersonic ReEntry Deployable Glider Experiment (HEDGE) aims to prove that CubeSat, a very small satellite, technology can be used for extremely low cost hypersonic testing. For this project, the aerospace engineering students in the Spacecraft Design course at the University of Virginia are working in small teams to design all components of a mission to launch one of these CubeSats that will reconfigure to a hypersonic re-entry vehicle. This is primarily targeted toward the aerospace and defense industry, however, when developing any technology, it is imperative to consider how the public might interact with it and how the perception of the technology can change its path of innovation. 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 et al., 2019). While the technology 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 feelings toward Concorde changed over time as its flights revealed themselves to have negative impacts on the public. Using Concorde as a case study, I will apply the Actor-Network Theory to investigate how the public response to a technology impacts its path of innovation (Heiskanen & Jolivet, 2010). This framework will demonstrate how a poor understanding of the relevant actors and their influence within their networks can cause a technology to fail. The answer to this question will provide valuable insight to how HEDGE should be designed, keeping in mind the potential applications it has in the development hypersonic flight vehicles and what effects these vehicles could have on the public.

HOW PUBLIC RESPONSE TO A TECHNOLOGY IMPACTS ITS PATH OF INNOVATION

Technological development is both a scientific and social process that relies heavily on the available technology of the time period and the needs and wishes of the public that interacts with it. The term "public" refers to the groups of people who interact with the technology but are not involved in the process of physically developing it, including consumers of the technology, individuals who live in the area where the technology is in use, government officials who create legislation that regulates the use and development of the technology, and more. When the public has a problem or obstacle, the response is often the development of a new technology. In this sense, the public is involved in the technological development process. However, the influence of the public often continues far past presenting a problem that the technology will solve. The technology has to solve the problem in a way that the public will approve, meaning the technology must not disrupt public life more than it brings value to it.

According to Heiskanen and Jolivet (2010), the Actor-Network Theory "provides conceptual instruments for a fine-tuned analysis of the contingencies that condition a project's success or failure by focusing on the micro-decisions that intertwine the material aspects of the technology, the site where it is implemented, the participation process, and the social relations in which they are embedded." (p. 6746). The Actor-Network Theory explains how the different groups of people involved with the technology, and how these groups interact, play a significant role in the technology's development and eventual success or failure. A frequently forgotten but highly important actor in any technological development system is the perception of technology. The way that the technology is perceived will influence how much support it will have which impacts how long its development can continue, how it will be developed, how it can be used, and, eventually, whether it will succeed or fail. Understanding this concept is crucial when working on new technologies.

While the engineers are the most familiar with the technological constraints and capabilities within their work, the public creates many of the social constraints that put limitations on the technology. The public can create legislation that controls how the technology can be used and, more importantly, how much funding goes to the development of the technology. In many cases, the government provides funding for technological development and innovation. This is especially true in the aerospace industry as most technological development occurs within the department of defense, meaning most aerospace technological funding goes to and from government agencies. If the public does not support a certain technology or does not see the value in its continued development, the funding for it can be depleted and the technology will fail or stop altogether. The aerospace industry typically develops technology that can have a significant impact on the average civilian as militaristic technologies like missiles and fighter jets play a role in the safety of the public and commercial aerospace technologies, like planes, are used by the public and can be both very helpful, by increasing the speed of travel, or harmful, plane crashes or noise pollution. Seen through this lens, it is clear that including and considering the public when developing or innovating a technology is necessary for it to succeed.

PUBLIC PERCEPTION OF A TECHNOLOGY AS AN ACTOR

The Actor-Network Theory is a framework that explains a system by the groups of people that influence it, actors, and how these groups interact, networks. This framework can help to explain the development of a technology by noting the relevant actors and networks, helping the developers and implementers of the technology do their jobs most effectively. An actor is a source of action, a person or group that acts or to whom activity is granted. A network is a communication channel that groups actors. Networks can be local or global, indicating their breadth and, often, level of influence (Heiskanen & Jolivet, 2010). Applying this framework means understanding who the relevant actors are, what the networks are, and trying to predict how each will respond to the technology or implementation methods. This process is called framing, when "a common world is established between different actors that allows them to achieve a collective scenario of a desired outcome" (Heiskanen & Jolivet, 2010, p. 6748). Framing is a method of prediction that establishes how the different actors are expected to act within their networks and, using this prediction, the developers or implementers of the technology can create their plans so that the actors respond positively to the technology.

Framing is a valuable tool that can make the introduction of a technology to the public much more successful by anticipating the public's response. However, it is not a foolproof method and sometimes unexpected events occur that disrupt the framing. This is called overflowing, "the instability and uncertainty inherent to such process, which might break up at any moment, should any calculation prove wrong, materials depart from expectations, or should other actors set their own alternative scenarios and establish their own frames" (Heiskanen & Jolivet, 2010, p. 6748). Using the Actor-Network Theory, one should try to avoid overflow by anticipating outcomes to multiple potential problems and working to create solutions. Overflow is inherently unpredictable, which makes it very difficult to prepare for it to happen. This framework highlights the key role played by the perception of technology. That actor is one that is very difficult to anticipate and is a main source of overflow. Therefore, to avoid overflow and promote the success of a technology, it is imperative that engineers work with the public to ensure that their concerns are addressed.

Applying the Actor-Network Theory when investigating how the public response to a technology impacts its innovation works by using the perception of the technology as an actor. This implies that perception is a source of action as it compels other actors to behave in certain ways. This framework allows for the interpretation of the magnitude of the public's response as an actor in the technological development of Concorde, the first supersonic, passenger-carrying commercial plane.

SUPERSONICALLY FLYING TOWARD FAILURE

In 1969, the Concorde fleet was developed by aircraft manufacturers in Britain and France. The Concorde, eventually introduced in 1976, was "the first supersonic passenger-carrying commercial airplane" (Britannica, 2022, para. 1). This vehicle was an exciting technological development, instilling ideas about the future of air travel in the general public. Flying supersonically means traveling at a speed faster than the speed of sound, up to five times that speed. To put it in perspective, Concorde was able to fly from New York to London in less than 3 hours, a flight that normally takes about 7 hours (Saddler, 2022, para. 1). Despite the advantages of the technology and the initial excitement, 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 technology and provide a clearer path to garnering public support for future projects like Concorde.

Background of Concorde

The Concorde fleet was first flown around the early 1970s. This time period was during the Cold War era, when people were excited about advances in flight vehicles and there was a lot of pressure and emphasis placed on developing flight related technology quickly and better than the U.S.'s competitor, the U.S.S.R. In 1969, the U.S. successfully landed the first humans on the moon and new high-speed aircraft was constantly being developed. The threat of U.S.S.R. technological development was frightening to the U.S. so having exciting technology within the U.S. and from its allies, like Britain and France, was inspiring to the general public. For these reasons, the Concorde fleet from France and Britain, flying to the U.S., was met with a positive response and excitement. Supersonic flight vehicles were first developed for militaristic purposes in the 1940s (Williams, 1992). Eventually, the technology became strong and popular enough to reach the commercial market. However, as an early technology in this area, it came with an expensive price tag and was only available to the wealthy who could afford a ticket, a group that did not typically include the people living near Concorde's takeoff and landing sites. The tickets to fly on Concorde were over $400 in the 1970s which, adjusted for inflation, is over $2,000 current day for a one-way ticket (Curran, 2020). The Concorde flights were flown into and out of Washington Dulles International Airport in Dulles, Virginia, a suburban residential area (Simple Flying Staff, 2022, para. 5). The people living near Dulles Airport were typically not the passengers of Concorde, meaning that their opinions and concerns about the flights were somewhat ignored by Concorde's technologists and distributors. Although the technology did not change to accommodate the public, the public changed to stop accommodating the technology. Over time, the positive perception of Concorde began to diminish as its flaws seemed to outweigh its successes. According to Overly (2021), "the supersonic boom caused by traveling faster that sound was a safety issue and nuisance" which led to legislation restricting the flight of Concorde (para. 18). After years of worsening public image, "the Concorde retired in 2003, and there's yet to be a reemergence of a commercial supersonic jet." (Appolonia & Nigh, 2021). Applying the Actor-Network Theory framework, we can understand how this case of overflowing led to the failure of Concorde and learn to avoid these mistakes in the development of future technology.

Applying the Actor-Network Theory to Concorde

The case study of Concorde describes the failure of a technology resulting from a lack of consideration of all the relevant actors in their networks, rather than because of faulty engineering. The actors in the Concorde case study were the neighbors, local legislators, national legislators, manufacturers and distributors, aircraft engineers, passengers, and perception of Concorde. The neighbors are the people who lived in the area near Dulles Airport where Concorde was flying, experiencing the effects of the sonic boom. The local legislators actor refers to the legislators of the Dulles, Virginia area who made local decisions and laws. The national legislators actor refers to the United States federal government. Manufacturers and distributors refer to the companies which made and sold Concorde aircraft, including British Airways, Rolls Royce, Aerospatiale, and SNECMA (Britannica, 2022). The aircraft engineers are the technologists who did the designing and testing of Concorde aircraft. The passengers are the individuals who flew on Concorde, and potential customers of Concorde. The perception of Concorde describes the general public opinion of Concorde. As depicted in Figure 1 (2022) below these actors communicated within five main channels: the network of locals, the network of change-makers, the network of technologists, the network of legislators, and the global network.

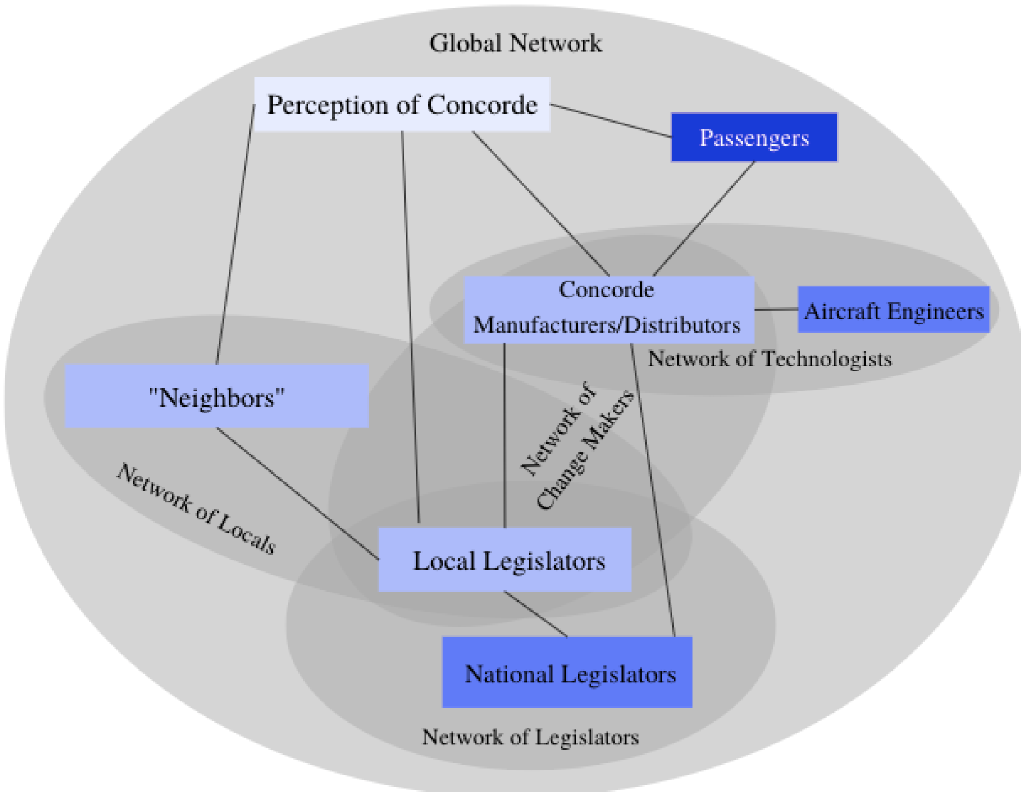

Figure 1: Actor-Network Theory applied to Concorde: The colors of the actor squares correspond to the level of significance in the downfall of Concorde with the lightest blue being the most significant and the darkest being the least (Goldberg, 2022).

The actor-network construct in Figure 1 uses hindsight of framing and overflow in the Concorde case study to correctly identify all relevant actors and their networks. However, at the time of Concorde's introduction, the actor-network system would likely have been predicted to look as it does in Figure 2 (2023).

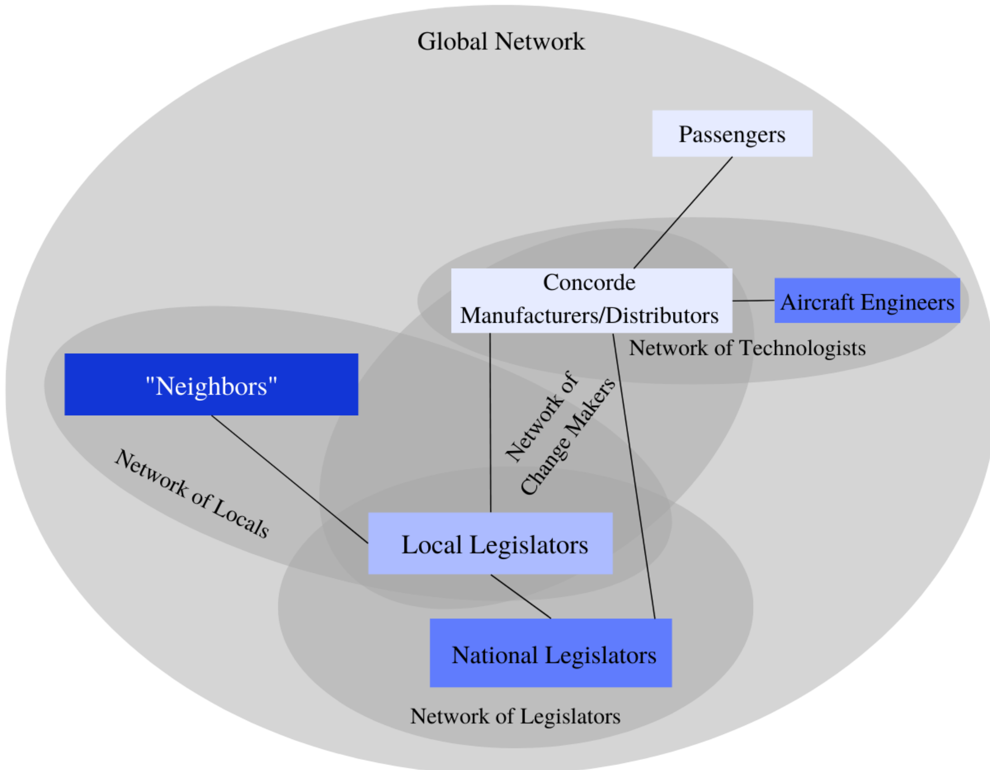

Figure 2: Prediction of Actor-Network Theory applied to Concorde at time of introduction: The colors of the actor squares correspond to the level of significance in the downfall of Concorde with the lightest blue being the most significant and the darkest being the least (Goldberg, 2023).

In Figure 2, the neighbors lose significance and the passengers and Concorde's manufacturers and distributors gain significance. The key change in this model is that perception of Concorde is not considered an actor. The actors involved with planning where Concorde would fly and how it would be implemented are within the network of technologists. These actors would have been those who established the framing for the introduction of this technology. Framing is a methodology which is used, knowingly or not, by the implementers of a new technology as they attempt to introduce it in a way that will make it well received. The aircraft engineers worked to design the Concorde aircraft, working within the limits of physics, available technology, funding, and regulations. These actors would be employed by the manufacturers and distributors who dictated the regulations and desired design specifications.

These two actors, mostly the manufacturers and distributors, would be responsible for anticipating the response to Concorde's introduction.

The Impact of Public Perception of Concorde as an Actor

The manufacturers and distributors of Concorde made a few key errors when framing and, in turn, introducing and maintaining the Concorde aircraft. Applying the Actor-Network Theory, it can be seen that these errors stem from poorly understanding the relevant actors and networks. When Concorde was first introduced, there was excitement about such a groundbreaking technology entering the public sphere, however, the technology itself never really entered the public sphere. The general public had almost no interaction with the technology in terms of reaping the benefits of its presence. As a result, the manufacturers and distributors, the key actor, miscalculated the significance of the neighbors as actors. As seen in Figure 2, the perception of Concorde was not originally considered an actor by the introducers of the technology. As previously stated, there was general excitement about Concorde's introduction, but there was also concern about how it would impact the public. In 1975, just one year before Concorde was introduced to the public, there was already public dissent concerning the amount of noise Concorde flights would bring and a fear of the potential health and safety risks that would come with frequent flights of a plane consuming so much fuel and traveling at such high speeds (Witkin, 1975). These concerns led to local government involvement, placing restrictions on the number of flights that could take place and the amount of noise that would be tolerated. The neighbors and local legislators actors took physical action in this scenario, but they were acting in response to the perception of Concorde actor. Referring back to Figure 1, the neighbors have already begun to establish themselves as relevant actors, working within the network of locals to convey their opinions and have their concerns addressed by the key actor. In Figure 3 below, the framing and overflow for neighbors as actors is depicted, highlighting the relevance of the perception of the technology as an actor.

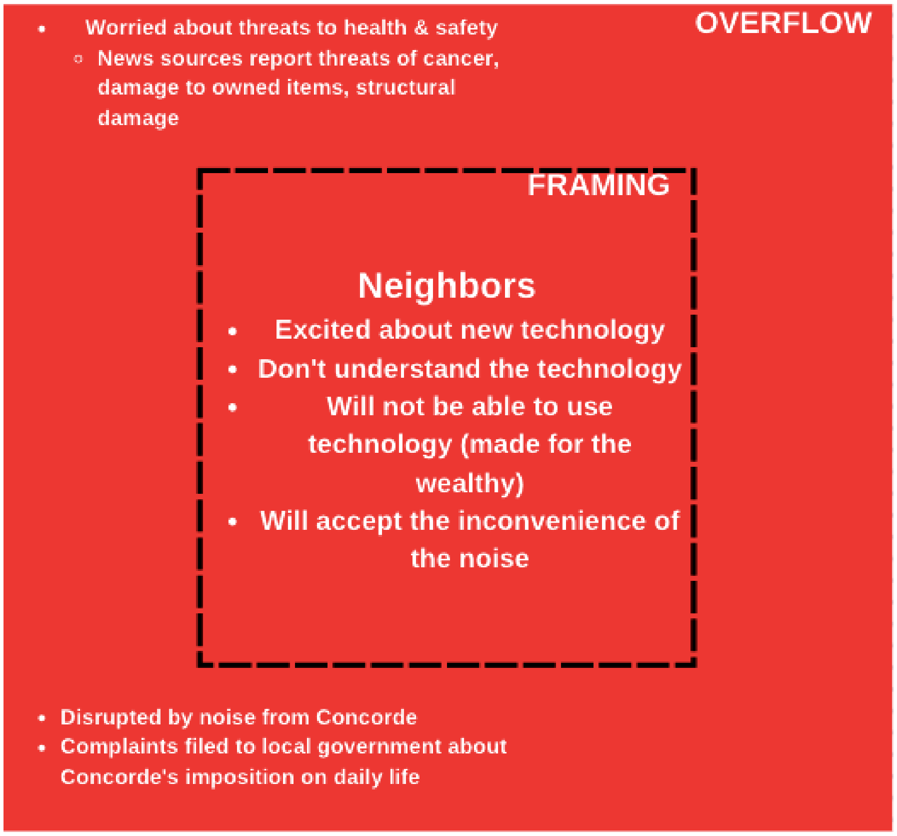

Figure 3: Framing and Overflowing for Neighbors as Actors: The box inside the dotted lines highlights the anticipated, or framed, feelings and actions of the public local to Concorde's flights. Outside the box is the overflow of occurrences and feelings which were unanticipated and led to a breakdown in the technology's development (Goldberg, 2023).

The manufacturers and distributors of Concorde were unable to foresee the amount of disruption that the Concorde flights would cause in the neighbors' lives. Further, they were unable to recognize how important it would be that the neighbors support Concorde. Another undervalued actor is the group of local legislators or local government. The local legislators had access to both the neighbors and the aircraft manufacturers, yet their ability to make change was largely underestimated. The local legislators act on behalf of the neighbors and, although economics often finds a way to overpower social responsibility, the Concorde manufacturers had difficulty preparing for the problems that would be caused by Concorde and their unattractiveness to the local area. According to Lampert and Freed (2018), “cities issued numerous noise complaints whenever Concorde flew overhead” and “the cost of fuel quickly exceeded the profit made from the flight and rendered Concorde unprofitable to operate.” (para. 9). With the growing anti-Concorde sentiment of the residents within the jurisdiction of the local legislators and the lack of economic benefit, the local government’s support of Concorde dwindled. As seen in Figure 4 (2023), the manufacturers and distributors of Concorde faced overflow when framing the response of the local government to Concorde’s introduction.

Figure 4: Framing and Overflowing for Local Government as Actors: The box inside the dotted lines highlights the anticipated, or framed, feelings and actions of the local government where Concorde’s flights took place. Outside the box is the overflow of occurrences and feelings which were unanticipated and led to a breakdown in the technology’s development (Goldberg, 2023).

Figures 3 and 4 highlight the errors in judgement made by the manufacturers and distributors of Concorde regarding two of the actors in the system. While the specific behavioral predictions made by the introducing actor were flawed, their key mistake was in misunderstanding the level of importance that each actor would have. Had the local government and neighbors been less significant actors, the overflow they caused would likely have had a lesser impact and it is possible that Concorde would still be flying today.

The actor who went unnoticed, with the worst consequences, was perception of Concorde. As seen in Figure 5, the perception of Concorde, initially very positive, began to worsen over time.

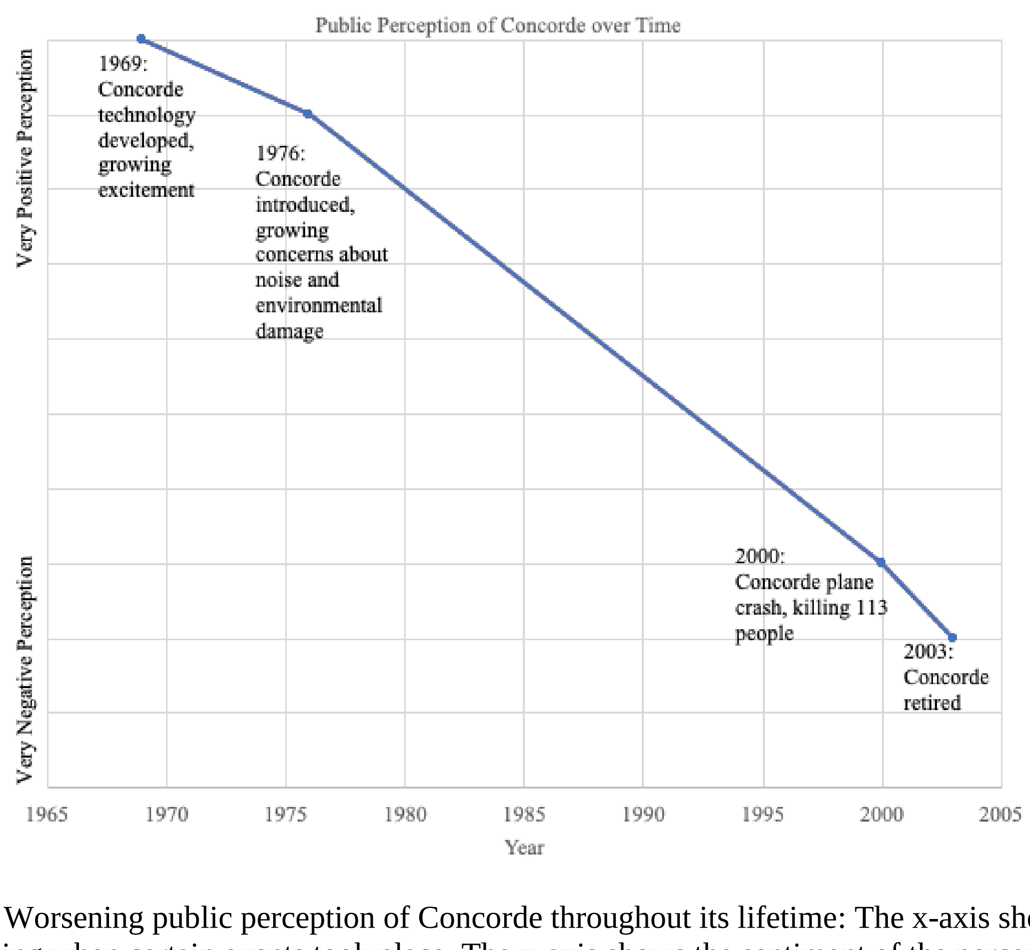

Figure 5: Worsening public perception of Concorde throughout its lifetime: The x-axis shows years, dating when certain events took place. The y-axis shows the sentiment of the perception of Concorde ranging between very negative and very positive. (Goldberg, 2023).

When the technology was being developed, the perception of it was almost exclusively positive. Concorde's first flight in 1969 was amazing to all relevant actors and it had varying effects on each. The public's perception of the technology was positive as it showed promise for a technologically advanced future when the time for air travel could potentially be cut in half, demonstrated the technological savvy of the United States and its allies, and presented an opportunity for economic gain. As an actor, the perception of Concorde at this time allowed the technology to be well received and continued from its early stage to its introduction to the commercial world in 1976. By this point, there was growing excitement from the passengers who would soon get the opportunity to fly at supersonic speeds. The support from this actor group's positive perception of the technology spread to the manufacturers and distributors who anticipated high profits. When the neighbors began to express concern about noise pollution, the perception of Concorde began to worsen and, receiving these complaints, the local legislators' perception worsened as well. Post the early introduction of Concorde, more problems began to arise that would damage how it was perceived. The passengers were outnumbered by those who could not afford tickets and, as the novelty of a supersonic plane wore off, this second group was increasingly vocal in their complaints. The noise pollution and damage caused by the sonic boom paired with the fact that the neighbors would not get to experience a flight on Concorde created a very negative perception of the technology. The manufacturers and distributors could not significantly lower the price of tickets because the price of operating Concorde was incredibly high as it burned through enormous amounts of fuel with each flight. By the year 2000, when one of the Concorde aircraft crashed soon after takeoff, killing 113 people, almost all of the actors in the system held a negative perception of Concorde. Even the manufacturers and distributors had an increasingly negative perception as Concorde cost so much money to operate and was receiving so many complaints. Just three years after that plane crash, the Concorde fleet was retired. Seemingly only the aircraft engineers still held a semblance of a positive perception as the drive for creating more high-speed aircraft remained present. Applying the Actor-Network Theory to this case study demonstrates how the ignored actor, perception of Concorde, would have been the key to its success but instead led to its demise.

The perception of Concorde allowed the technology to be introduced and, by ignoring it, led to the technology's failure. In future cases, this lesson should be applied by taking careful note of how the technology is being received, not only by those directly interacting with it, but by all individuals and groups impacted by its presence. The Actor-Network Theory framework can help to do this by highlighting all relevant actors and how they will communicate so the introducers of the technology can find representatives from these groups to consult and make decisions that will not lead to unrest within any groups of actors or networks.

PUBLIC RESPONSE TO A TECHNOLOGY IS KEY TO ITS SUCCESS

The public can be unpredictable and a technology may not have the impact that those who introduce it desire or expect. To prepare for this inevitability, the Actor-Network Theory can provide insight to how the adopters of the technology behave and with whom they interact. Doing this can emphasize the priorities of the actors and identify what actions each actor can take, and whether they might take them. Framing, as such, must be done with caution and thoroughness for it to be effective. Based on the lessons from the Concorde case study, this means that the perception of the technology should be deeply considered when establishing framing and communicating within networks. Besides poorly identifying the perception of technology actor in the Concorde case study, a notable mistake was the rigidity of the framed system. When problem arose, like the unexpected intensity of noise complaints or the unmanageably high cost of operation, the manufacturers and distributors of Concorde were left with very few options, especially when paired with the negative perception of Concorde keeping actors from coming to Concorde's aid when, perhaps, they could have. From the Concorde case study, it is clear that users will try to socially construct technology, meaning the public has their own set of constraints to put on a technology's design that is not necessarily reflected in the technology's limits or the regulation limits (Kline & Pinch, 1996). In the future, it would be in the best interest of the engineers to work alongside the public in order to maintain a positive perception of their technology and try to ensure its success. In the aerospace industry where a significant portion of the technology is designed in a very isolated setting, for space or defense missions, it is imperative to demonstrate the need for and value of a technology, even if the technology is not intended for commercial use. The public has significant influence in technology development by communicating through the networks to the change-makers who can control what the engineers design.

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