Evaluating the Societal Impact of Future Commercial Hypersonic Flight Technologies

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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:

One more recent advancement in the aviation industry was the development of hypersonic vehicles, aircrafts capable of exceeding Mach 5 (Dunbar, 2014). One possible application for this technology is that of commercial air travel, which has seen little to no improvement in speed since the 1950's; faster commercial jets have existed in the past, but suffered from gross inefficiencies and difficulty remaining profitable. New advancements in propulsion systems, on-board computers, and high performance aerospace materials may allow for hypersonic vehicles to be successful in light of these challenges. These cutting edge vehicles could be a major part of the commercial aerospace industry as early as 2025 (Bowcutt, 2020).

These aircraft present massive opportunities for better connecting people, industries, and goods around the globe focused around the technology's promised improvements in speed and capacity. This technology will open doors to new unprecedented commercial industries. Hypersonic travel could change who travels, how they travel, and why they travel. Hypersonic travel will contribute to changing the pace of business and consumption globally. Unfortunately, along with these benefits there is also the possibility the technology could contribute to worsening economic, social, and environmental crises, such as growing expectations for online retailers (Saleh, 2019) and climate change (Tabuchi, 2015), upon its adoption to mainstream air travel.

My goal is to evaluate this transportation system's potential outcomes and value, both positive and negative, using technical and ethical frameworks in hopes of truly understanding the greater economic and societal impacts of the hypersonic vehicle system as more than just an aerospace engineering marvel.

Literature Review:

The feasibility of the transportation system will be evaluated in terms of both technological and economical viability. There exists several prior studies on this topic from both theoretical and analytical perspectives. Then, the environmental and societal impacts will be explored. Finally, a comparable transportation paradigm will be explored to understand these complex systems in a historical context. It was discovered that the true impact of hypersonics was not fully captured by any of these sources individually, especially in regards to human-technology interaction; the answer to which exists in a synthesis of the researched information.

Kevin Bowcutt, Boeing's chief scientist of hypersonics, highlighted and compiled a vast array of predictions and models for current hypersonic research with commercial implications. The journal was optimistic of the potential hypersonic flight had but was also cautious towards certain preventative factors. The overarching argument was that hypersonic travel could be feasible in the near future. It was noted that an effective propulsion system for this application would need to be developed, likely a "combined cycle" engine consisting of multiple engine types integrated into a single functional body. Bowcutt deemed this engine type as functionally feasible and obtainable, he also highlighted that these engines could be used to avoid low altitude sonic booms, a critical factor in public acceptance of the technology (Bowcutt, 2020).

One promising current supersonics development project is that of the Aerion AS2 and the theoretically successive ASX aircraft. The developers intend for this aircraft to be a supersonic passenger jet "designed specifically around noise and emissions". To do this Aerion is first developing the "boomless cruise", designers hope this will influence regulation officials to allow the AS2 to be the "first aircraft in history that can fly supersonically over land" (Sillers, 2020).

There are tremendous concerns over safety with hypersonic vehicles: “The temperatures a hypersonic vehicle encounters are so high that conventional materials can’t withstand them”, for this reason hypersonic planes use protective coatings and materials, but there may still be a “breach of insulation that can quickly lead to catastrophic failure” (Atcliffe, 2016).

Economically, Bowcutt argues “there may be an optimum speed/altitude combination that retains the economic benefits of speed while minimizing the technological challenges of flying faster”. He notes trans-pacific routes would be most likely to remain profitable. Bowcutt indicates, for consumers, the technology will be comparable to “premium travel” means. He stated: “money [will be] traded for major improvements in time as opposed to money traded for comfort” (Bowcutt, 2020).

Giordani predicts the time savings are expected to be in-demand for “about 10% of the market of passengers” for “up to the cost of an existing first class ticket”. The paper proceeds to conclude there is an economically stable and profitable model for both supersonic and hypersonic vehicles, that could create an industry to “employ over 500,000 people, and be worth 3.5 billion euros” (Giordani, 2015).

Virgin Galactic describes that a “point-to-point hypersonic travel [system]” could be “transformational for transit and tourism”. They similarly describe the predominant users of the transportation system as “high-paying passengers”, orienting their own company to focus on “customer experience and environmental responsibility” (Brandi, 2020).

Another aspect of hypersonic flight economics that is important to analyze is the manufacturing of vehicles. Scientists predict the most limiting factor of hypersonic design is obtaining materials that can meet the structural and thermal demands of operation. One material that shows potential to do so are Boron Nitride NanoTubes (BNNTs) which are “able to handle high amounts of stress and are extremely lightweight". The technology is extremely limited and extremely expensive-- costing upwards of "$1,000 per gram". However, historically analogous to Carbon NanoTubes, BNNTs are expected to drastically drop in price over the next 20 years as more industry applications are discovered and production rates increase (Cleveland, 2017).

Japanese airlines have concerns over the environmental impact hypersonic vehicles may present. The company has little faith in the initiative to develop cleaner burning jet fuels and argues the technology will "burn three to four times as much fuel per business-class passenger as standard planes, and [will] fail to meet existing fuel efficiency, pollution, and noise standards, worsened by the fact high altitude emissions' impacts are still unknown" (Tabuchi, 2018).

Bowcutt indicated that environmental impact minimization would be a critical factor in public acceptance of this technology. He points out sustainable biomatter hydrocarbon fuels with endothermic properties as being the most obtainable for a hypersonic airliner within the next 20 years. He similarly notes that the impact of carbon pollutants at high altitudes is relatively unknown (Bowcutt, 2020).

Hydrogen fuel is also depicted as being cleaner than current jet fuels as it "would produce no carbon dioxide — although it would emit water vapor and nitrogen oxides, which are greenhouse gases" (Baggaley, 2019).

Aerion is focussed on developing their aircraft to have the "lowest fuel-burn possible" and "operate on 100% synthetic fuels from day one". The company also hopes to achieve carbon neutrality through a reforestation effort (Sillers, 2020).

The most direct benefit of hypersonic commercial travel is that of the time savings-- for both the airlines and it's customers. Aerion predicts, for consistent business travellers, "every person who flies on their airplane, AS2 will save them 142 hours a year" (Sillers, 2020).

The Department of Transportation (DoT) stated that airport congestion is responsible for the “delay or cancelation of 27% of flights” which costs the “U.S. economy over $40 billion”. They predict that by 2015, air travel was expected to accommodate upwards of a billion passengers annually with only minor improvements in infrastructure (Sturgill, 2007). Hypersonic aircraft could travel “beyond the reach of conventional airliners” and their speed could “help ease the [air traffic] congestion” (Baggaley, 2019).

Sanders highlights the potential for a “reusable hypersonic vehicle” that could “serve the future needs of space and research industries, while simultaneously providing a significant increase in the pace of business and commercial transport”. Sanders predicts these vehicles will trigger massive financial growth that “has not been seen in the past 40 years”, even providing opportunities for space tourism (Sanders, 2012).

A historical transportation system that has a massive similarity to the development of hypersonic travel is that of the Chinese bullet train system. China has struggled to escape traffic congestion and maintain effective public transportation. The high speed rail system (HSR) was developed in response to the national need to connect high population centers and ease congestion in existing transportation systems. China acknowledged their transportation system was the source of major inefficiencies and lost time and money for both the government and the people. China’s lack of effective transportation became an inhibitor to economic growth and a cause for public distress. So far, China has established the largest HSR system in the world that has reduced travel times upwards of ~75% (Jacobs, 2019). China’s implementation of this technology appears to be successful, however there are some underlying consequences of its development: the Chinese government has incurred a massive financial debt for construction of this project, the HSR heavily burdens local electricity grids, and the HSR is currently only able to function at partial capacity. The development of the HSR system is described as being "reliant on debt financing, which led to [China's] debt increasing almost tenfold", causing other public works to be put on hold (Davies, 2019).

Another comparable historical transportation system is that of the Concorde supersonic aircraft, which had a "top speed of Mach 2.04" (Baggaley, 2019). The Concorde was deemed "economically infeasible" due to high operational costs, low efficiency, and a low population of customers (Bowcutt, 2020). The main concern over the use of the Concorde was it's safety; "passenger numbers fell after an Air France Concorde crashed" (Lake, 2020).

STS Framework & Research Method:

To better understand the impacts of hypersonic technology, Actor Network Theory (ANT) will be analyzed. To complement this, the system's ethical impact will be evaluated using Technological Mediation (TM) theory and 'Advanced vs. Appropriate Technology' (AAT) theory.

ANT defines everything that interacts with the technological system as an equally contributing 'actor'. Within ANT, there is a large focus on actors that negatively impact the system or prevent its implementation. ANT will evaluate which actors are in control of the hypersonic transportation system, which actors are recruited and interact with the system, how they interact, which actors are against or excluded from this network, and the perceived benefits of constructing this complex network (Cresswell, 2010).

TM theory describes technology as a mediator between human interaction with the world and their perception and understanding of that world. TM theory is highly appropriate for exploring hypersonics as they have the potential to drastically alter human perception of the world-- it could effectively “shrink” the globe with its speed and operational range, creating new patterns of human interaction (Verbeek, 2020).

Appropriate technologies are developed to fulfil a growing, public need, they are characterized by conscientious design regarding accessibility, affordability, and sustainability. Conversely, advanced technologies are often privatized and produced out of a technological curiosity or a drive for profit, these technologies are often not completed with consciousness. AAT questions if hypersonics are being developed for the sake of technological advancement or for the common good as well as their ability to be developed in a conscientious and sustainable manner (Schumacher, 2021).

These frameworks were developed using the main method of document analysis; as the technology is not yet developed, there is not an option to do observational studies or relevant surveys.

Technical journal articles were deemed highly trustworthy documents. They were written by a variety of trusted government and academic professionals, were peer reviewed, and offered a very logical and analytical perspective. These highly objective sources proved to be the most reasonable for answering technical and economic questions, they did, however, lack in explaining the human elements of the system. This includes: Bowcutt, Giordani, Cleveland, Baggaley, Sturgill, and Sanders, who all showed a basis in aerospace and economic fundamentals and the scientific process. However, some corporate studies used quantitative data, but the results were more preliminary and less scrutinized. These tended to focus on using the data to support project objectives, outcomes, and expectations. These studies used directed and exaggerated statements as responses to critical reviews, especially when defending vehicle environmental impacts. Though this does not invalidate their more substantiated claims, it did suggest use of caution when integrating them. These sources included Sillers and Brandi. Lastly, news sources were used to gather information on the technology as well. These sources did have glaring and obvious biases and were assessed with caution. With that being said, these documents were scanned for purely objective information, which would be least susceptible to bias. They provided a useful societal and industrial context for the development of hypersonic technologies in the modern world. These sources included Atcliffe, Tabuchi, Jacobs, Davies, and Lake.

Data Analysis:

Application of ANT Theory:

ANT analysis focuses around the unique cast of actors within the future transportation model. The researched documents suggest there is a plethora of actors that will be preventative to the system as well as many who are intrinsically motivated to establish and complete this network.

Airlines have shown the tremendous financial symptoms of extreme airline congestion and their use of ineffective air transportation infrastructure . They lack the willingness to invest in significant improvements to infrastructure and instead seek external remedies (Sturgill, 2007). Airlines have been eager for the announcement of modern supersonic aircraft, some even investing in several million dollar pre-orders (Tabuchi, 2015). They have already indicated the possibility of recruiting thousands of more staff, for hypersonic vehicle operational purposes (Giordani, 2015). These actors believe there is a sustainable and profitable market for faster air travel that will also improve their existing transportation system investments.

Many aerospace companies have similarly shown a massive effort to begin the development of hypersonic vehicles, hoping to take hold of this high ticket industry from its conception (Sillers, 2020). The possibility of space tourism and cargo transportation as well as the demand for trans-oceanic air travel have shown financial promise (Sanders, 2012). These companies seek to recruit actors such as the military, space exploration organizations, and the aforementioned airlines into the network.

These dominant actors, airlines and aerospace corporations, will be responsible for arousing interest in the network and providing the organization and leadership for the successful interessement, enrollment, and mobilization of new actors into the network.

Businesses are predicted to be one of the primary consumers of this new form of air travel (Bowcutt, 2020), making them a significant actor. The unprecedented time savings is expected to change the pace of international business (Sillers, 2020), likely setting back companies who are not able to afford or participate in it. It is predicted that these drastic time savings will not only benefit these companies' budgets but make expanding into foriegn markets easier as well. These actors will validate the usage of hypersonics commercially and determine if they are actually as impactful as predicted.

Similar to the case of the HSR, the hypersonic transportation network has a myriad of important non-human actors as well. Actors like public policy, local utility and resource systems, and separate ongoing public works projects were aroused by the creation of the HSR, but their translation within the network was not successful (Davies, 2019). Hypersonics will also have the additional trouble of recruiting actors such as the global jet fuel supply and even new advanced materials. These actors will all play a large part in the creation and survival of this network. Existing actors have already begun the process of obtaining legislative approval by demonstrating their interest and progress towards developing clean and non-invasive vehicle platforms (Sillers, 2020). The introduction of hypersonics into the air travel industry will likely increase strain on airport infrastructure and local utilities-- electricity, water, etc (Davies, 2019). These impacts may not be significant for large first world countries with effective local resource systems, but may limit access to other countries who cannot sustain such increased usage. This may be relevant as attracting these actors to join the network, increase production, or select hypersonics as priority over other needed projects may prove difficult without immediate benefits to their locality. Advanced fuels, materials, and technologies needed for the vehicles' flight may be easily recruited for their potential to be developed in other industries outside of aerospace, such as the examples of BNNT's in structural applications (Cleveland, 2017) and biofuels in external transportation applications (Bowcutt, 2020). Suggesting that the hypersonic vehicle network would extend into a much greater economic space than initially anticipated.

Another critical non-human actor in the hypersonic system is that of public perception. Public perception and their willingness to engage with the network will be determinant for its implementation and success. A large factor that contributes to this perception is growing environmental concerns (Tabuchi, 2015). Much of the environmental impacts of hypersonics are unknown, especially for high altitude usage, and will need to be explored before large-scale adoption of hypersonic vehicles can occur (Bowcutt, 2020). There do exist developers who strive for carbon neutrality, but who have major dependencies on technological advancement to do so (Sillers, 2020). Like in the case of the Concorde, hypersonics are very vulnerable to catastrophic accidents (Lake, 2020), amplified by their dependence on thermal protections and potentially high passenger capacities. The technology currently lacks the relevant testing needed to be confidently used in civilian applications (Bowcutt, 2020).

Application of TM Theory:

The time savings from the increased flight speed prompt a change in how business and air travel are conducted around the world (Sillers, 2020). First, air travel will see a sharp change in demographic and likely a large increase in international travel. Since hypersonic air travel will be aimed at long distance flight with a price point nearing that of a premium ticket price (Bowcutt, 2020), the people utilizing the technology will predominantly be wealthy businessmen who can afford such prices. This will contribute to reducing the number of business or first class seats sold on subsonic airlines, likely causing airlines to increase the number of economy seats available to keep flights filled and profitable. This interesting phenomena will likely lead to the reputation of current air transportation systems as being for the common man while the faster hypersonic vehicles become an expression of luxury and wealth. However, airlines will experience a distinct reduction in congestion, leading to less annual losses in overbooked and missed flights (Baggaley, 2019), potentially leading to savings passed to customers.

The time savings may also contribute to a significant loss in relative mobility for normal air travellers, for whom international travel will still take a full day (Sillers, 2020). Theoretically, hypersonic vehicles would allow more manageable and frequent international travel, their passengers would have much greater access to global populations and can more regularly engage in commerce with them, greatly increasing individuals' acumen abroad and their ability to form international companies. Hypersonics may even move more businesses to coastal areas to allow for better access to hypersonic flight. Potentially, the increased travel would increase demand for short term housing, such as apartments, and would cause a noticeable increase in cost for these coastal housing markets, possibly enough to displace existing residents. Further, with international travel being more available and commonplace, increased travel may become a responsibility for employees along with a greater emphasis on hiring multilingual employees, which may lead to a noticeable separation among the current workforce.

Lastly, consumers involved in the technology network will also be benefitted. The increased flight speed allows for the transportation of time sensitive goods over longer distances, potentially giving global consumers increased access to better nutrition and a larger selection of goods. Emergency services could similarly utilize this technology, transporting medical equipment, commodities, and professionals around the globe at will. Hypersonics will change the nature of online consumerism as well, enabling same-day shipping to become more accessible, potentially making it necessary for companies to provide as a service (Saleh, 2018), possibly changing consumer preferences and creating an increased barrier to entry for online retailers.

Again these benefits may only be seen by a select few and the general public may not have such a positive interaction with the technology: its potentially loud “distant thunder” sound may become a nuisance, reducing property values, the vehicles themselves present the possibility of catastrophic accidents, and the network may bring unwanted tourism and traffic to their city.

Discussion:

Hypersonic travel does not present a strong case for being an appropriate technology, there is not a large public demand for them nor is there an urgency in their development. There are certain needs, such as the demand for quicker shipping rates (Saleh, 2018) and accessible space travel platforms (Sanders, 2012), that could be fulfilled using hypersonic vehicles but that are not immediately needed. There are other needs, such as the call for a reduction to airport congestion and better access to time-sensitive commodities that do present a valid case for hypersonics, but the likelihood of hypersonics being the only means to obtain these objectives is slim (Cleveland, 2017). For much of the general public, there are more pressing transportation concerns other than hypersonic flight. The hypersonic air travel price point is relatively unattainable for the common man to utilize frequently (Bowcutt, 2020), public funding and effort spent on the network could be to the detriment of other more impactful alternatives (Davies, 2019). Hypersonics could have a significant strain on global resources and fuel supplies. These concerns suggest that until a more independent vehicle can be affordably developed, commercial hypersonics cannot be an appropriate technology.

There is a much greater argument to be made for hypersonic vehicles as an advanced technology. The likelihood of private influence on the system(s) is strong (Brandi, 2020). Typically, privately funded and sought after technologies will operate outside of the concerns of the appropriate technology ideology (Schumacher, 2021). These companies may not seek to be environmentally conscientious. The dominant concerns of the hypersonic paradigm, through the AAT lens, is that the vehicle and it's infrastructure will perpetuate current struggles with corporate manufacturing, such as the unethical use of overseas, under regulated labor and exploitation of foriegn resources. Further, AAT emphasizes there should be concerns regarding the distribution of wealth within the system, mainly the high barriers to entry to participate in the market for developers, potential tax funding usage, and the control of profit being limited to mainly existing airline and aerospace companies. Usage in the space industry being another for-profit objective, very similar to its usage as a means of luxury travel (Sanders, 2012), again suggesting it is an advanced technology that is not being developed for the general public's benefit. Lastly, considerations over how the technology may prove dangerous to both passengers and nearby populations is a great indicator the technology is advanced and not appropriate.

Conclusion:

The overarching conclusion is that hypersonic commercial transportation systems, though capable of vastly altering the ways humans interact and do business on a global scale, cannot be ethically implemented within the expected time scale of 5 years from now (Bowcutt, 2020) as the materials, resources, and technology to develop the transportation system in a environmentally conscious, socially equitable, safe, and economically profitable manner do not exist yet. These commodities are predicted to be developed and made affordable within the next 20 years (Bowcutt, 2020)(Cleveland, 2017), along with additional research on the hydrocarbon emissions of hypersonic engines, may allow for a re-evaluation of the ethics and economics of hypersonic commercial travel. As it stands currently, the potential technological and ethical drawbacks of the system's development are far greater than any of the system's primarily financial benefits. The economic model of hypersonic commercial transportation lacks an equitable distribution of profit and shows no promise of equality in public usability. Further, there has not yet been proper research performed to determine these vehicles' environmental impact, which is a growing concern in the aviation industry. The brief reprise hypersonic air travel may bring to congested airlines may be outweighed by the added strain they put on global resources, specifically advanced materials and carbon fuels. Lastly, the system's success depends on positive public support, which will be swayed by issues such as cost, safety, and environmental pollution, for which there has not been enough supporting evidence that these concerns will be remedied.

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