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Future Applications for Hypersonic and Sub-Orbital Transports in the Air Transportation System

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Abstract

The viability of high-speed commercial aircraft within the existing air transportation system is uncertain. Technology currently exists to build supersonic transports (SST), but research and development are still required to build hypersonic transports (HST) and sub-orbital transports (SOT). As the Concorde has shown, however, even producing such aircraft is not a panacea for individual airline companies. Additionally, development would most likely be cost prohibitive for most aircraft manufacturers. For this reason, many governments and a few entrepreneurs have assumed the expense for researching the technologies associated with high-speed aircraft. This paper describes the current state of research for the SST, HST and SOT. It examines the technologies, potential advantages and potential drawbacks for such aircraft if they are introduced.

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Future Applications for Hypersonic and Sub-Orbital

Transports in the Air Transportation System

Since Wilbur and Orville Wright successfully tested their flying machine in 1903, man has attempted to perfect the air transportation system by increasing the speed, size, range and capacity of aircraft. From the perspective of the passenger, one measurement of success for these efforts has been the amount of time that one must spend in an aircraft while on a flight between two cities. Consequently, the development of high-speed commercial aircraft has always been a priority for aircraft designers.

When the first commercial transportation by aircraft began in the years immediately preceding the First World War, the aircraft were small and slow. The DC-3 was not only the first profitable airframe within the air transportation system, it was one of the fastest commercial aircraft of its time. Later, with the application of jet engine technology, the Comet and Boeing 707 further shortened the time required for an air journey. The ultimate example of an aircraft developed principally for passengers hoping to vastly reduce transportation time was the Concorde, the only commercial supersonic transport (SST) ever to operate within the air transportation system.

When President Ronald Reagan spoke of "a new Orient Express that could…take off from Dulles Airport, accelerate up to 25 times the speed of sound, attaining low Earth orbit or flying to Tokyo within 2 hours," the goal seemed unattainable (Reagan, 1986). The technology required for transports faster than the Concorde was only theoretical and aircraft manufacturers did not possess the capital to develop Reagan's "Space Plane." Instead, the governments of the major industrial powers decided to take on the burden of developing the next generation of

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aircraft, including the hypersonic transport (HST) and the sub-orbital transport (SOT). These aircraft will drastically revolutionize air travel, perhaps more than any previous aviation advance.

Required Technologies

Before determining whether a high-speed transport could be successful in the air transportation system, one must examine the engine technology required for such aircraft. Limits on propulsion systems have, until recently, completely prevented the manufacture of any high-speed transport. Even after the power plant limitations are overcome, the sustainability of aircraft materials must be improved.

Conventional turbojet engines do not provide adequate thrust to send a large vehicle to high altitudes or high speeds. Even if they could be made large enough and fast enough, the combustion temperature required at speeds greater than Mach 3 would melt the turbine blades of a turbojet engine (Anderson, 1985). To overcome this limitation, engineers developed a type of engine without rotating internal machinery. This engine, the ramjet, provides thrust by introducing air into an inlet, decelerating it in a diffuser, burning fuel with air and blasting it out of an exhaust nozzle at very high velocity (Anderson, 1985). Unfortunately, an aircraft flying with a ramjet engine must first be accelerated to supersonic speeds with another type of engine. The ramjet also faces a combustion temperature limitation, since the walls of the ramjet begin to melt near Mach 5 (Anderson, 1985). This type of propulsion is used in numerous guided missile designs, but not manned vehicles.

Once the limitations of the ramjet stunted further development of higher speed aircraft, engineers decided to use the properties of high-speed air to their advantage. For this reason, most recent research and development of propulsion technology for high-speed transports have involved tests on the supersonic combustion ramjet (scramjet). This type of engine also has no

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internal moving parts but, unlike the ramjet, the air entering the inlet is not decelerated. Instead, the air flows through a series of fuel injection struts, allowing the properties of supersonic air (shockwaves) to maximize thrust (Anderson, 1985). Since the scramjet eliminates the temperature concerns of the ramjet, it can travel at much higher speeds, even as high as Mach 15. Further, though it must be accelerated to Mach 4 with the help of another engine, the scramjet is capable of flying at hypersonic speeds without carrying heavy oxygen tanks (National Aeronautical and Space Administration, 2004).

The survivability of materials in such hostile environments as ground launch, Space cruise and atmospheric reentry will require major advances in metallurgy. Improvement of existing materials for use with a high-speed transport is therefore a significant goal of engineers. In 1995, the National Aeronautics and Space Administration (NASA) stated that its goal was to "develop improved airframe materials and structures that are 33 percent lighter and can sustain 350 degrees Fahrenheit for 60,000 hours" (National Aeronautical and Space Administration, 1995, ¶ VI - Thrust #2). These goals must be attained before introduction of any high-speed transport.

Types of High-Speed Transports

The final, logical, result of decades of supersonic and hypersonic research is the design, testing and manufacturing of a high-speed transport. Until now, however, the role of examining the performance of such vehicles has been given almost exclusively to military test pilots. The era of high-speed aircraft began when Chuck Yeager flew the first manned supersonic flight in the X-1 on October 14, 1947 (Wilson, 1986). The zenith of military tests on high-speed vehicles was reached in the 1960s with the flights of the first manned hypersonic aircraft, the X-15 (Anderson, 1985). Later, the SR-71 proved that high-speed aircraft would be viable for military

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applications. However, it was not until the Concorde was built in the early 1970s that commercial applications became a reality.

Currently, there are at least three types of high-speed transports that might be easily accepted within the air transportation system. This author has intentionally chosen to avoid discussion of a fourth, an orbital transport, because its capabilities far exceed any required for Earth based transportation systems (such a vehicle could be more accurately described as a spaceship, not an aircraft). Descriptions of the SST, HST and SOT are presented below.

Supersonic Transports

An SST (defined here as a supersonic aircraft that can maintain speeds between Mach 1.0 and 4.9) uses air-breathing engines, taking off and landing like a conventional aircraft. Technology for the SST was readily available after many military tests on similar aircraft: all that remained for the British and French developers of the Concorde was to engineer a passenger design and introduce the aircraft into the already existing air transportation system. Passengers were willing to pay the exorbitant cost for a ticket because the aircraft could travel between London or Paris and New York City in approximately three hours. However, British Airways and Air France, the principal operators of this SST, were also saddled with the high cost of each flight.

Until the Paris crash of July 2000, the Concorde was able to maintain profitability for the airlines, even with load factors of 50% (Concorde SST, n.d.). Despite the increased costs then brought on by required safety upgrades, British Airways and Air France planned to remain profitable with load factors of 75% and by adding additional flights to the schedule (Concorde SST, n.d.). But following September 11, 2001, the premium first class market that the Concorde had serviced was nearly completely eliminated. Since the airlines involved also fly other types of

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aircraft, the SST was deemed too expensive a risk to maintain company profitability and the Concorde was retired (Concorde SST, n.d.). Thus there are no SSTs flying in the air transportation system. Consequently, aircraft manufactures remain reluctant to build any further variants.

Hypersonic Transports

An HST is an aircraft capable of achieving Mach 4 with conventional jet engines or rocket boosters and then, by using a scramjet engine, accelerating to speeds up to Mach 15. No commercial example of an HST exists. In fact, very few manned hypersonic vehicles have ever been manufactured. Only the X-15 has a proven record, with 199 flights, but the fastest speeds never exceeded Mach 7.0 (Anderson, 1985). After the introduction of the Space Shuttle, many of the government-sponsored programs for manned hypersonic aircraft were cancelled. Instead, testing has been restricted almost exclusively to unmanned vehicles.

Currently, the United States is pioneering hypersonic engine technology with its Hyper-X program. In this endeavor, an unmanned experimental vehicle called the X-43A first flew at speeds in excess of Mach 7.0 on March 27, 2004 (Collis, 2004). The stated goal of the program, to achieve Mach 10.0, was reached on November 16, 2004 (NASA, 2004). Further tests are scheduled and the Hyper-X scramjet should lead to additional advances in propulsion for eventual introduction of an HST.

Sub-Orbital Transports

One further type of high-speed aircraft design will travel through Space. Most aircraft operate at much lower altitudes since conventional air breathing engines cannot practically or efficiently operate in this environment. An SOT is a vehicle that flies a part of its mission in the

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area within or above the Earth's atmosphere exceeding 100 kilometers above mean sea level. But, as the name implies, this high-speed transport will not actually achieve orbit.

After the success of the Space Shuttle and in keeping with Reagan's vision, the governments of the United States, the European Union and Japan proposed designs for an SOT that could take off under its own power with conventional engines and transition to rocket engines by the time it reached Space, finally returning to earth under its own power. In many respects, this design of SOT would appear to be a common aircraft and would easily operate within the air transportation system. However, most such government funded proposals have never made any progress beyond the design stage and have since been cancelled or significantly modified. Since the 2003 Shuttle disaster, in fact, the primary focus of research and development of an SOT has instead turned to building a reliable and inexpensive reusable launch vehicle (RLV).

Despite the redirection of government design programs, entrepreneurs are independently attempting to make the SOT a viable participant in the air transportation system. The Ansari X-Prize, providing a $10 million award to the first privately financed and launched RLV that could make two successful launches within a two week period, has energized private involvement and made an RLV possible for commercial use. Burt Rutan's company, Scaled Composites, designed a sub-orbital passenger carrying "space plane" and successfully met the parameters of the Ansari X-Prize contest on October 4, 2004 with SpaceShipOne (SpaceFuture.com, n.d.). Simultaneously, this vehicle became the first manned non-governmental spaceship. Other private companies are also examining the commercial profitability of using such an SOT.

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Benefit of High-Speed Transportation

The prime advantage of any high-speed transport is its ability to quickly move passengers or cargo to its required destination. Current trans-continental or trans-oceanic routes currently require multiple stops or lengthy flights. With high-speed aircraft, one could travel (in one flight) from New York City to Sydney, Australia, in three to four hours.

Risks of High-Speed Transportation

As the Concorde demonstrated, there are more than a few risks involved with operating a high-speed transport. The benefit of speedy delivery of passengers and cargo will always drive the quest to develop such vehicles, but governments, manufacturers and airlines must take cautious steps before completely embracing an HST or SOT. Some of the risks involved are listed below.

Financial

Development costs for high-speed aircraft are so prohibitive that most aircraft manufacturers will not be willing to commence research or build a vehicle that will not immediately provide a profit. Even if governments absorb the initial costs, the airlines will still have to be convinced to utilize high-speed transports. The amount of fuel required for propulsion of an aircraft to hypersonic speeds or sub-orbital altitudes would lead to gargantuan costs for an airline company. For this reason, government assistance, direction and subsidies must be provided until high-speed aircraft technology is cheap and reliable. If the industry is not regulated, a manufacturer or airline (or both) could immediately fail. The introduction of an HST or SOT into the air transportation system could even drastically affect the entire economy of a country.

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Environmental

NASA has already identified some of the main concerns that must be resolved before introducing further high-speed transports (NASA, 1995, ¶ VI – Thrust #2). Clean burning fuels are obviously important, especially as they relate to the ozone layer. As with the Concorde, the noise generated by powerful engines required for such vehicles would be problematic for most major airports. Specifically, future aircraft must be designed to comply with Federal Aircraft Regulation (FAR) 36- Stage 3 noise rules. Additionally, the "sonic boom" and its effect on the environment will need to be addressed. Perhaps most worrisome is the potential for further saturation of current airports and airways.

Physiological

Human survival systems must be perfected to ensure safety in weightless and high altitude environments. Even then, the physical constitution of passengers will be a major concern. With government operated Space Programs, the crew and passengers are usually selected from a group of highly trained and physically superior military candidates. Aviation medical, psychological and safety specialists will need to determine the ultimate effect of the introduction of "average" humans into the high-altitude and Space environment. Undoubtedly, rules governing the sale of tickets to passengers who do not fit the established criteria of physical fitness will also require the assistance of legal professionals.

Outlook

In 1995, NASA determined that the technology of high-speed transports would allow for commercial application of such aircraft within the first decade of the 21st Century:

> Industry trade studies indicate that a market for a high-speed civil transport (HSCT)… exists to serve long-distance routes provided (1) acceptable environmental standards for

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aircraft noise and sonic boom levels can be met; (2) the projected fleet will have no harmful effects on the atmosphere; and (3) ticket prices will be less than 20 percent higher than corresponding next generation long-haul subsonic transport fares. (NASA, 1995, ¶ VI – Thrust #2).

Despite these predictions and reasonable assumptions, the SST failed to remain profitable while the technology for building an HST or SOT is only now proving itself. This author is actually convinced that these vehicles will not be introduced into the air transportation system until after 2010. When they do appear, however, one can imagine several promising uses for high-speed transports.

Military

Almost certainly, the military will find an immediate use for a high-speed transport. In today's climate of uncertainty and global military commitments, the United States would probably lead the way in the development of the first HST. Quick response units equipped with a high-speed transport could also possibly eliminate the need for certain overseas military bases. One can imagine a future political crisis in which time-critical troops and supplies would be airlifted within three hours from any part of the world, thus preventing or delaying a military conflict.

Commercial Cargo

The demand for overnight or same-day package delivery to any point on the Earth will likely drive the commercial introduction of an HST or SOT. With cargo, the carrier could probably charge almost any amount to have a package transported from a London office to a Tokyo office within three hours. The cargo application will probably be the most commercially

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profitable use for high-speed transports. One can imagine a new version of the Federal Express business model (Hyper-Ex?) with service between major cities around the world.

Space Tourism

The SOT could be quite successfully employed as a tourism platform. In the current environment, only a wealthy person can afford the $20 million cost for visiting Space. Once the cost and reliability of RLVs improve, however, the price would fall to a more affordable level ($20,000). This would probably still be too expensive for the average tourist, so entrepreneurs will need to determine alternate solutions in the marketing for the Space tourist. One suggestion to alleviate the cost involves the sale of lottery tickets (for $100) to determine who will be able to fly in an SOT to the edge of Space (David, 2002). Assuming that a person would spend a small amount of money for even a chance to take such a vacation, this idea could make the SOT a viable part of the air transportation system.

"The Startup"

Perhaps the ultimate test of the viability of high-speed transports within the air transportation system would involve an airline executive's attempt to create a high-speed "Startup." If history is any indication, at least one airline company will attempt to be the first carrier to possess and operate an HST. This will either be a foolish and costly disaster or a brilliant decision. In response to the initiatives of the "Startup," an existing major airline might be willing to risk its entire company to remain competitive. The entire future of high-speed transports could be decided by the outcome of this scenerio.

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