JOURNAL OF PROPULSION AND POWER
Vol. 8, No. 3, May–June 1992

Acceleraters and Decelerators for Large Hypersonic Aircraft

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Abstract

HYPERSONIC aircraft will be considerably different from subsonic aircraft. They will be very large, deltoid-configured aircraft with needle noses. Thus their shape will be almost the opposite that of subsonic aircraft which have much higher aspect-ratio wings and raindrop-shaped fuselages. A result of these differences is that hypersonic aircraft will have much higher takeoff and landing speeds, and they will be less efficient when flying at subsonic speeds. To overcome their low-speed inefficiency, more powerful subsonic engines would be required. Since noise increases with power, more noise would be created during subsonic operation. And because of their large size, hypersonic aircraft will generate intense sonic booms when flying at supersonic speeds.

With these vast differences it is unreasonable to assume that hypersonic aircraft will be operated the same way as subsonic aircraft, i.e., that they will take off with onboard power and land on a long runway at any large airport. On the contrary, hypersonic aircraft, with their onerous characteristics, will probably be over-the-ocean craft, like the historical flying boats. Thus they will take off and land at only seacoast sites where the noise and sonic boom will be generated over an ocean. With takeoffs and landings at only a few sites, it will be economically feasible to have a considerable amount of ground-based equipment at each site.

For good economics the operation of hypersonic aircraft must be very reliable. The use of ground-based, rather than airborne, equipment will increase their operational reliability because:

1) Ground-based equipment does not have the severe weight and volume limitations that airborne equipment has; so it can be designed more conservatively with larger margins of safety.

2) Ground-based equipment does not have to endure the vibrations, large temperature changes, and other hazards of flight.

3) Ground-based equipment will be available for maintenance most of the time. It will not be in the air where it cannot be serviced or repaired.

Thus the goal should be to minimize the amount of airborne equipment by developing as much ground-based equipment as can be used.

To fulfill this goal it is found that:

1) It is possible to design and build a ground-based accelerator that can precisely control the attitudes of very large aircraft while they are accelerated through the speed of sound and then launch them at a speed of Mach 2.

2) It is also possible to design and build a rotatable, ground-based decelerator that can land a large, fully-loaded aircraft that is traveling at a speed of 450 mph.

Presented as Paper 90-1986 at the AIAA/SAE/ASME/ASEE 26th Joint Propulsion Conference, Orlando, FL, July 16–18, 1990; received July 30, 1990; synoptic received March 14, 1991; accepted for publication March 28, 1991. Full paper available from AIAA Library, 555 W. 57th Street, New York, NY 10019.

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Ground-Based Accelerator

For a launcher to be capable of accelerating large, hypersonic aircraft to a supersonic speed, there are three basic requirements: First, the aircraft must be locked to the ground during the entire acceleration so they cannot be pulled or pushed off of stationary tracks until they are released. Second, during the subsonic portion of the acceleration the launcher must maintain the aircraft at a zero, or slightly negative, lift angle of attack, so the center of pressure would move aft to its supersonic position when there would be no lift force. After passing through the speed of sound, the launcher must raise the aircraft noses to provide a positive lift angle of attack for the takeoff. Third, the basic design of the accelerator must be independent of size, so it can be made as large as necessary.

To lock the aircraft to the ground and prevent any force from pulling or pushing the accelerator carriage off of its tracks, strong cover tracks, as schematically depicted in Fig. 1, are required. For these cover tracks there will be an additional upper set of wheels, which will rotate in the direction opposite that of the bottom wheels. These cover tracks will be connected to as large an underground mass as necessary to prevent the tracks from moving. In addition, between the upper and bottom wheels, there could be horizontal wheels that would counter any unbalanced side forces. This would complete the directional control, so the only direction in which the carriage and aircraft would be able to move would be straight down the covered tracks.

To raise the noses of the aircraft after passing through the speed of sound, the carriage could be hinged at a rear beam, so the front ends of longitudinal beams that support the aircraft could be raised. These front ends could be raised by an airfoil beam, the attitude of which would be controllable. Since the velocity of the carriage at this point would be greater than 340 m/s, this airfoil, when rotated to a positive lift angle of attack, would be able to lift the noses of the aircraft.

With an airfoil beam to lift the noses, the carriage could be made as wide as necessary. Thus its basic design is independent of the size of the accelerator.

There are two limits on the launch speed. The first is not on the launcher itself but rather on the aircraft on it. This is the dynamic pressure. For a launch speed of Mach 2, this would be about 6000 psf. If all of this is to be countered by pressure in the propellant tanks, it would take about 60 psia. The second limit is on the angular velocity of the carriage wheels. This angular velocity can be minimized by making the diameter of the wheels as large as possible. For 1-m-diameter wheels at a speed of Mach 2 the angular velocity would be about 13,000 rpm. This maximum would only be sustained for a brief period of time. Thus this angular velocity can be accommodated with present bearing technology.

The accelerator has to be large enough to provide economical transportation. To do this it is assumed that it has to accelerate 1000 metric tons of aircraft to Mach 2. For the Earth orbiting application it is assumed that the acceleration would be done at 3 gs. For this, on the order of 10^{11} J of energy must be released in less than 24 s. This energy would provide a carriage propulsive force of 60 mn or 13.5 million pounds. Energy that is stored in a form that can be directly used will be the most reliable.

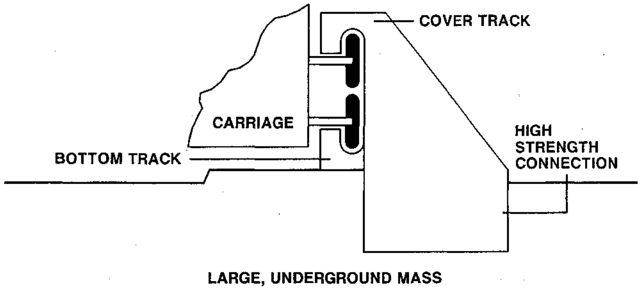

Fig. 1 Schematic of strong cover tracks.

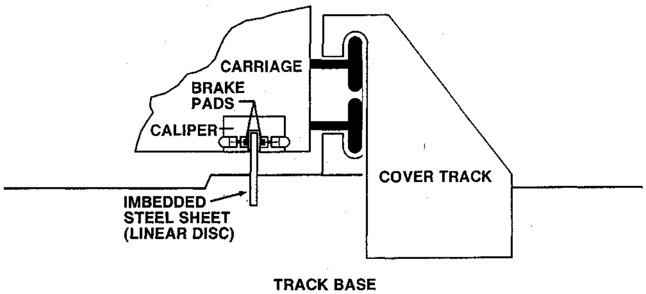

Fig. 2 Schematic of linear disc brakes.

There are at least four possible sources of this large amount of readily available, stored energy. Two possible long-term sources are described in Ref. 1. These are compressed gas in a launcher-length pressure tube or electricity stored in superconducting electromagnets. These are long-term sources because they would not put additional pollutants into the Earth's atmosphere. Two possible short-term sources are described in Appendix 1 of the full paper. These are solid propellants or pressure-fed, liquid propellants in rocket motors without thrust vector or gimbal control systems. Without thrust vector or gimbal control systems, these would be very simple carriage propulsion systems with few moving parts. Thus they have the potential for being highly reliable.

As shown in Appendix 1 of the full paper, rocket engines have the right characteristic for carriage acceleration. The depletion of the propellants provides an increasing amount of energy for overcoming the increasing drag.

Ground-Based Decelerator

The first task of a landing system is to align the aircraft's velocity vector with the center of the runway. Since this velocity vector is determined not only by the aircraft's heading but also by the direction of the wind, the direction of the wind must be taken into account. This can be done by developing a system that can be rotated, as described in the full paper, so all landings can be made in the downwind direction.

For minimum repercussions, it is desirable to make the aircraft's contact with the ground at as nearly zero relative velocity as possible. This can be done by having a landing strut, which is extended from the tail of the aircraft, contact a cable that is moving at the same velocity as the aircraft in the direction of the runway.

As described in the full paper, there will be two cables, one on each side of the center of the runway. They will be oriented so that if the aircraft's velocity vector is not in line with the center of the runway, its tail strut will run into one of the cables. The impacted cable will then push the tail of the aircraft toward the center of the runway. Rocket thrusters on both sides of the nose of the aircraft could be used in a feedback control system to keep the whole aircraft aligned with its velocity vector. With this pushing and thrusting the aircraft's strut could be mechanically guided to a specific point on the ground. Thus, these cables could guide the aircraft's strut to an inlet of a capture tube.

After an initial tapered section above the runway, the capture tube would be a slotted, rectangular tube under the center of the runway. The aircraft's strut would fit into the slot. There could be wheels on the end of the strut. These wheels would make the strut travel freely down the tube. With the strut in the tube, the aircraft's tail would be locked to the runway. The strut could then be retracted into the aircraft to get and keep the tail of the aircraft close to the center of the runway. Thus the aircraft would be in position to land on a form-fitting, decelerator carriage.

Assuming a landing speed of 450 mph (200 m/s), the decelerator carriage, which is described in the full paper, could be setting 100 m down the runway. At the instant the aircraft gets to the beginning of the runway, rocket motors in the decelerator carriage could be fired to provide a 20-*g* thrust for 1 s. This would make the velocity of the decelerator carriage 205 m/s when it is about 200 m down the runway, and it would be just ahead of the aircraft. The linear disc brakes, which are depicted in Fig. 2, could then be used to slow down this carriage and land the aircraft on it. As shown by the energy analysis in Appendix 2 of the full paper, these linear disc brakes could then easily decelerate large, fully loaded aircraft at 3 *g*.

Conclusions

It is possible to design and build a ground-based accelerator that can precisely control the attitudes of very large aircraft while they are accelerated through the speed of sound and then launch them at a speed of Mach 2. It is also possible to design and build a rotatable, ground-based decelerator that can land a large, fully loaded aircraft that is traveling at a speed of 450 mph.

Reference

[1]Lantz, E., "Mass Transportation to Earth Orbit," AIAA Paper 89-0090, 1989.