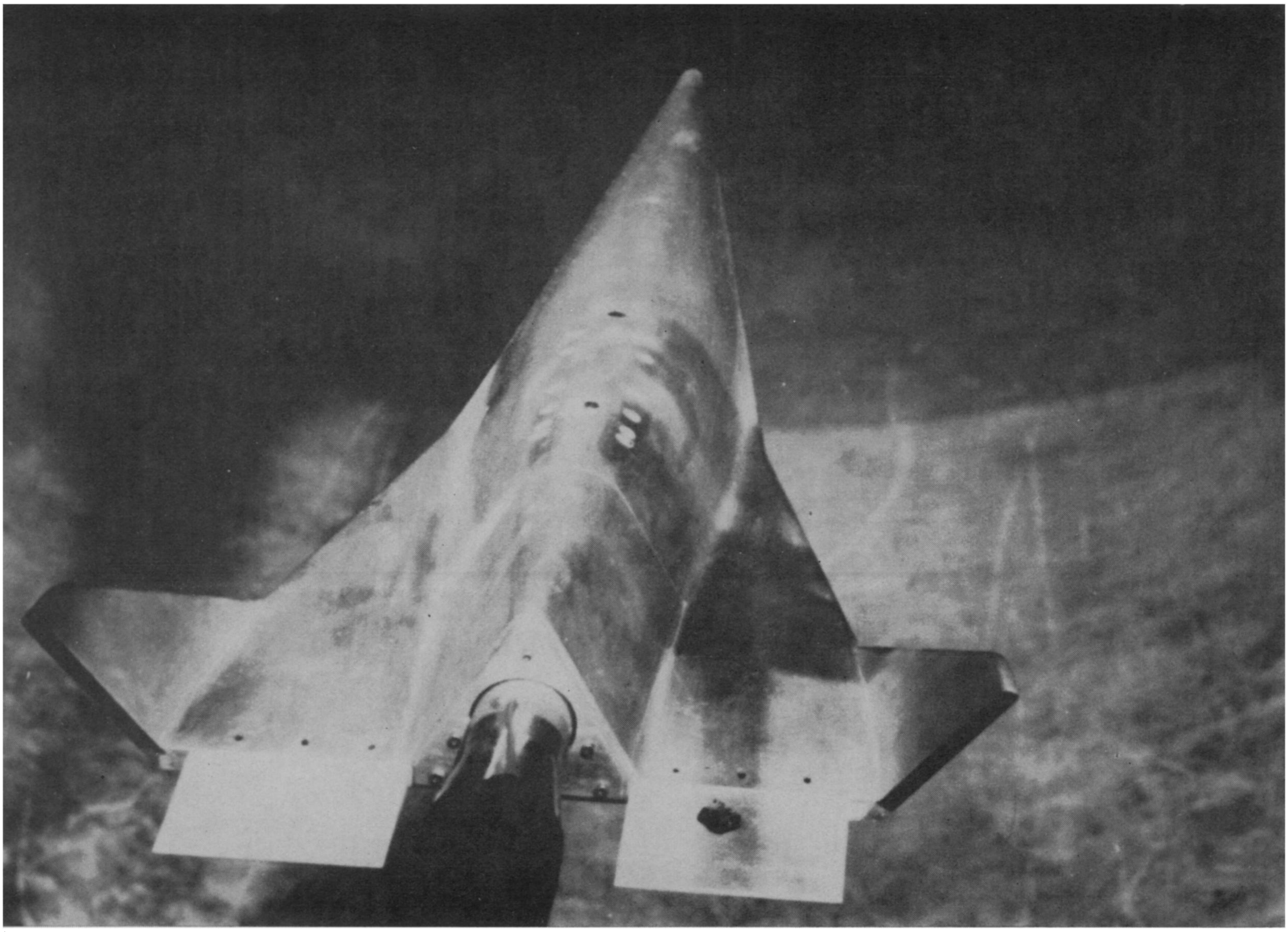

Lockheed-California Co.

HST designs can see into the future in this high-speed test tunnel, which blasts them with air at up to Mach 20.

AERONAUTICAL ENGINEERING

When the SST Is Too Slow . . .

The hypersonic transport will bridge the gap from the airways to orbit.

by Jonathan Eberhart

The first U.S. supersonic transport will not take to the air for four years, and will not carry commercial passengers for three years after that. Yet almost a decade ago, aircraft designers began planning a craft that will travel anywhere from 3,500 to 17,000 miles per hour, and make the SST look as though it is standing still. Millions of dollars have been poured by the Government into the esoteric engineering problems of a vehicle that may not appear for a quarter of a century.

Born of space rocket out of airplane, this is the hypersonic transport. Nor is this a loosely-applied description. In fact, the more studies that are made of the HST, the thinner the line becomes between it and earth-to-orbit shuttlecraft that could be used for everything from servicing satellites to traveling anywhere in the world in under an hour. Even conservative estimates speak of HSTs crossing the country in less than two hours.

The biggest problem facing HST planners is heat. The European supersonic Concorde will be limited by the heat its aluminum construction can stand to a speed of about 1,400 miles per hour, some 2.2 times the speed of sound. The U.S. version will be capable of more than 1,800 mph, but the titanium skin that will make this possible is an engineer's nightmare. Most of the techniques for cutting, casting and machining the huge pieces of titanium required have had to be developed right along with the parts for which they were needed.

The HST will make these problems seem like child's play. Many designers feel that to be worth the cost of developing the new technologies that will be required, the craft will have to be capable of at least 3,500 mph, or about Mach 5.5, and studies have been made up to Mach 20. Still another jump would be needed for orbital velocity, which is about 17,000 mph, or Mach 27.

At HST speeds, surface temperatures could run as high as 3,300 degrees F. or more, especially on the nose and at points where the air flow must change direction, such as the junction of the fuselage and a fin. To handle such heat, the aircraft will probably need a spacecraft-style nose cone made of some ceramic material. Studies at Lockheed Aircraft Corp., Burbank, Calif., have indicated that even the coolest skin areas—horizontal surfaces on the top side of the plane—will require superalloys of nickel or cobalt, while leading edges and horizontal surfaces underneath the aircraft may force designers to use exotic refractory alloys such as columbium, molybdenum or tungsten.

While such metals may do the job better, however, they are proportionately harder to work with. Oxidation is a particular problem, as is the fact that many of the lesser metals in high-temperature alloys simply evaporate as the heat increases, often causing radical changes in the alloys' properties. These effects increase with exposure, so the problems become more severe as the daily number of intended flights goes up.

The researchers working on power plants for the HST are farther along than the metallurgists. As long as the aircraft is being used within the atmosphere, rocket motors are unnecessary and indeed are a disadvantage, since they would require the vehicle to carry the additional weight of an oxidizer. The best bet, and the one agreed on by most investigators, seems to be the scramjet, or supersonic combustion ramjet.

Ramjets get their oxygen by their own forward motion through the air and therefore require another sort of power plant, such as a turbojet, to get them up to operating speed. In a conventional ramjet, incoming air is slowed to subsonic speeds in the engine inlet; fuel is introduced, mixed and burned; and the exhaust is accelerated out through a nozzle. In a scramjet, however, the incoming air is simply slowed to supersonic speed, and the fuel is introduced and burned so that the flow remains supersonic. The exhaust is accelerated to even higher speeds by passing it through a divergent duct that leads to the nozzle.

The Air Force has been interested in scramjets for several years for use in missiles, although interest extends all the way to winged, recoverable space-launch vehicles. Gen. Bernard A. Schreiver, head of the Air Force Systems Command, describes the scramjet as "the most promising approach we have today for sustained hypersonic flight."

The National Aeronautics and Space Administration also has a scramjet program, of which the biggest piece was a $15 million contract awarded to Garrett Corp. last summer to design, build and test a series of small engines usable from Mach 3 to Mach 8, or up to about 5,000 mph. The engines are to be flight tested on the X-15 rocket plane, probably early in 1970. Meanwhile, three of NASA's research centers are working on similar projects.

Like today's most efficient rockets, such as the Centaur upper-stage boosters that have given the Surveyor spacecraft their big push to the moon, the scramjet burns liquid hydrogen. Here the problem is not heat, but cold. Liquid hydrogen must be kept at minus 423 degrees F., so storing it in a vehicle whose skin is 1,000 to almost 4,000 degrees hotter only inches away is a major difficulty.

Another liquid hydrogen headache is cost. According to Frank Jarlett, an HST investigator for General Dynamics' Convair division in San Diego, Calif., the electricity and natural gas needed to produce enough liquid hydrogen for 200 HST flights a day with present technology is roughly equivalent to 10 percent of the daily electricity and natural gas consumption of the entire United States. The cost of liquid hydrogen will have to be brought down from 30 cents to about 3 cents a pound, Jarlett says, merely to make HST operating costs comparable with that of the SST, let alone those of today's jetliners.

A different variation on the ramjet, called a ram-LACE (Liquid-Air-Cycle Engine), was developed for the Air Force several years ago by the Marquardt Corp., Van Nuys, Calif., but abandoned when the cold liquid air that provided an oxidizer kept causing dangerous amounts of ice formation inside the engine. More recently, however, tests in environment-simulating torture chambers have revealed that there are agents that can keep the water in the air from freezing. As a result, Lockheed's hypersonic vehicles manager, G. Daniel Brewer, calls the ram-LACE "one of the more promising . . . compromises between the ideal propulsion system and one that has a high probability of developmental success."

Though the ram-LACE is classified by the Air Force, one advantage is believed to be that, at subsonic speeds, a retractable turbofan pops out into the airstream enabling the engine to be used for both low and high speed flight.

The most speculative area of HST research is the shape of the vehicle itself. Three years ago the Navy patented a design for a delta-wing HST. Last year General Dynamics reported, in a study for NASA, that a double-delta design was most promising. In the meantime, Lockheed says that no separate wing-and-body configuration would do at all; instead, the company recommends a lifting body approach, in which the entire fuselage is flattened like a stepped-on ice cream cone and used to carry fuel. A structure as thin as a wing would be prohibitively heavy, says Lockheed, if it were made strong enough to be usable at hypersonic temperatures. General Dynamics says that such a distinction between wing-and-body and lifting body is nonsense, and calls its double-delta design a blended body.

As unsettled as these body designs are, models of these and hundreds more like them are being tested around the country in high-speed wind tunnels called shock tunnels. In a shock tunnel, the classic wind-tunnel image of a huge fan is nowhere to be found. No fan could provide the fantastic airspeeds required for hypersonic tests. Instead, the usual approach is to build a huge chamber connected to a tiny pipe that leads to the instrumented test section. The chamber, separated from the pipe by only a thin membrane is filled with highly compressed air. An explosive charge destroys the membrane, and the suddenly freed air rushes down the pipe, producing simulated speeds and heats equal to those encountered by bullets, missiles, reentering spacecraft, and even meteorites.

The Air Force, NASA and other Government agencies, along with industry and many universities, have such facilities, most valued in the millions of dollars.

Long before the first HST is built, perhaps while it still exists only as a model in some shock tunnel, aviation officials will be faced with the problem of where to put them. The Boeing 2707 supersonic transport presently being designed is supposed to be capable of using any airfield that can handle a 707 or DC-8 jetliner, but such fields are overcrowded already. Even if the HST of tomorrow can still use the same size airports, the distant lands that will be within its easy reach presently have far fewer large fields than are necessary. In addition, the already severe problem of getting to and from airports will be critical for the HST, even if a stop-gap solution is found for the supersonic liner. Without some rapid mass-transit system between airports and urban centers, the great savings in air time made possible by the HST will be lost in traffic jams on the ground.