LARGE-SCALE TESTS BOOST SCRAMJET DATA BASE

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SCRAMJET TEST BRIDGES HYPersonic EFFORTS

MEASURING about 16 ft. in length, the non-flightworthy Concept Demonstration Engine is the largest integrated scramjet tested by the X-30 program.

Upcoming tests of a large-scale ramjet scramjet powerplant in a wind tunnel at NASA’s Langley Research Center will allow National Aero-Space Plane investigators—for the first time—to determine how scale effects have influenced design calculations used in scramjet research and development.

To date, information used to establish the existing U.S. ramjet scramjet design data base has been derived exclusively from tests of relatively small-scale integrated models and large-scale components. The upcoming investigations at NASA-Langley will provide researchers with an opportunity to fine-tune the data base before the NASP program transitions this Fall to HySTP, the Hypersonic System Technology Program.

Under HySTP [pronounced high step], the Air Force and NASA will focus on developing the technologies necessary for air-breathing hypersonic vehicles, now that they have abandoned near-term plans to build a single stage-to-orbit X-30. HySTP activities will focus on propulsion risk reduction, and officials envision launching several scramjets atop surplus ICBM boosters. The launches will provide powerplant operability and efficiency data obtained under conditions that can not be reached in ground tests, USAF Col. Robert S. Heaps, director of the NASP Joint Program Office (JPO), said (AW&ST Jan. 10, p. 29).

THE UPCOMING TESTS at NASA-Langley will examine the efficiency and operability of the Concept Demonstration Engine, or CDE, under conditions simulating Mach 6.2 and 6.8 flight speeds. Mach 6.2 represents the point where the engine transitions from ramjet to scramjet operations. Mach 6.8 conditions will allow investigators to examine the engine as a fully functioning scramjet. Tests under Mach 5 conditions also were envisioned to exercise the engine in full ramjet mode. But historical ramjet data is available and these runs were scuttled, for now, due to budget cuts. Other goals for the upcoming investigation are to explore scale effects on combustor efficiency, thrust, boundary layer effects and drag within the engine.

According to James Arrington, NASA principal deputy at the NASP Joint Program Office, the CDE is a non-flightworthy test article that integrates an inlet, ramjet scramjet engine and nozzle to simulate the actual flowpath of a flightworthy engine. The inlet is equipped with vertical flaps at its sides to isolate test tunnel wall effects. The powerplant is about 30% the size of the engine originally envisioned for the now-canceled X-30 and is made primarily from copper alloys and steel to act as a heat sink. Some areas, however, such as leading edges can be water-cooled to offset tunnel temperatures that can reach as high as 3,100°F.

For test purposes, the 16 ft.-long test engine is mounted on a force measurement system built by subcontractor Ormond, Inc. The combined weight of the engine and the force balance, which will be used to determine engine thrust, is about 40,000 lb. A lift, which will be used to position the powerplant in the test facility at Langley, adds another 10,000 lb. to the test apparatus, USAF Lt. Col. James Fiene, NASP program propulsion manager, said.

Pratt & Whitney was the prime contractor for the engine under the NASP National Contractor Team, and major components were made by Rohr Industries. Approximately $10.4 million was allocated in Fiscal 1993 for constructing the powerplant. Engine test, data analysis and reduction will cost another $4.6 million in Fiscal 1994.

THE TEST SITE for the CDE will be the 8 ft. dia. High Temperature Tunnel at NASA-Langley, which has been operational since 1964. For the CDE tests, however, the tunnel received about $2.7 million for upgrades—primarily to add an oxygen enrichment system and a system to supply gaseous hydrogen as a fuel to the CDE.

For the upcoming CDE tests, the engine will be located in the tunnel’s 8-ft.-dia., 12-ft.-long test chamber. Air for the engine tests will be combusted with methane to achieve the necessary temperatures and pressures for the test. Combustion products from the air-methane burning should not pose a problem to scramjet operability, Fiene said.

To ensure that the scramjet has a supply of oxygen equivalent to that which it would have at flight altitudes, oxygen will be mixed in with the heated air before entering the scramjet.

Upgrades to the tunnel facility were completed last year, and CDE installation began last September. Cold flow tests with the engine in place were run in December, while runs with hot gases were made in January. The upcoming scramjet operability and efficiency tests are expected to begin next month and conclude in mid-July. Approximately two test runs per week are scheduled, for a total of 45 runs.

During a run, test conditions are available for about 35 to 40 sec. Prior to this it takes about 50 sec. to establish the proper conditions in the tunnel. During this period the engine is partially lowered by its lift out of the nozzle stream that provides test air to the engine’s inlet. Once stable test conditions are reached, the engine is raised by its lift into proper position for a run. About 1,000 data collection
channels will be operated during a run. Data collected in the tunnel will be used to refine scramjet design techniques. If significant improvements are developed, they will probably be tested first in the SXPE engine, a one-eighth-scale scramjet that was run successfully in tests that began last summer and concluded earlier this month. SXPE tests were conducted in an arc jet facility at NASA-Langley, and performance data at speeds up to Mach 8 were collected. Once improvements are examined in the SXPE, they could be retrofitted into the CDE, the JPO’s Heaps said.

Data from all these projects will then be used to support the development of scramjets for flight test under the HySTP program. According to Heaps, the NASP JPO was directed towards HySTP in January, following a meeting of the program’s Quarterly Technical Review Group in December. Members include James Mattice, deputy assistant secretary of the Air Force for research and engineering; Wesley Harris, NASA’s associate administrator for aeronautics, and USAF Lt. Gen. James A. Fain, Jr., commander, Aeronautical Systems Center, as the NASP designated acquisition commander. Also on the panel are the directors of the various NASA re-

Concept Demonstration Engine inlet is designed to replicate airflow conditions created on an X-30 during Mach 7 flight. CDE leading edges are actively cooled to offset high test temperatures.
search centers and a representative from the White House’s Office of Science and Technology Policy. The X-30 NASP program will officially be renamed the HySTP program in October to coincide with the new fiscal year.

CURRENTLY, THE NASP JPO and the NASP contractor team are developing plans on how to complete the current phase of the X-30 program and what studies may be necessary as a bridge between NASP and HySTP. The team includes Pratt & Whitney, Rocketdyne, Rockwell’s North American Aviation Div., McDonnell Douglas and Lockheed. Additionally, the 70-strong NASP

high hopes to get a decision on which of the acquisition strategies to pursue in late May/early June. “We need a timely decision so we can execute it next year,” Heaps said.

Regardless of which acquisition strategy is selected, HySTP schedules now call for launching four scramjet experiments atop surplus ICBM boosters. Small-scale design work could begin next fiscal year, and first launch would be in Fiscal 1997. The remaining three would follow at 6- to 12-month intervals with the last launch in late 1999. Data analysis from the launches would be complete in 2000. Depending on funding profiles, the launch schedule could be accelerated, but how quickly also depends on the launch platform.

**WE ARE EXAMINING** three classes of experiments and will make our decision on which to use based on cost and technical performance,” Heaps said. To minimize cost, the same basic type of flight article will be carried on each launch, and launch vehicles will be uniform throughout the program. “Our flight test program will use a single type of booster, and our experiments will be basically the same, except for instrumentation changes,” Heaps said. This differs significantly from the earlier $2.1-billion HyStS proposal that would have used a variety of scramjet experiments and launch vehicles (AWST May 10, 1993, p. 22).

According to Heaps, the three classes of flight experiments now being examined by JPO integrated design teams are:

- **Class 1**, which represents the least expensive way to reach the Mach 15 flight conditions necessary for the planned tests. Here, the scramjet experiments would have to fit under the 30-in.-dia., 120-in.-tall payload shroud of a Minuteman ICBM, and existing Minuteman controls would be used.
- **Class 2**, which would fit on the third stage of a Minuteman, but not within the shroud. The limiting factor here would be weight, since the missile would not be capable of attaining Mach 15 flight speeds if experimental payloads went above about 4,500 lb. To cope with an experiment larger than the missile’s payload shroud, the booster would have to be positioned outside of its silo prior to launch. The missile’s control system also would have to be modified to accommodate the payload.
- **Class 3**, which would exceed the capabilities of the Minuteman and require a Peacekeeper for launch. Using this booster, potential scramjet experiments would not be as limited in payload or size, Heaps said. Peacekeeper costs would be significantly higher than Minuteman launches, though. Program officials believe it will cost about $3 million to acquire a Minuteman booster, while the cost of Peacekeeper would be about $12 million.

Minuteman and Peacekeeper are the two solid-fueled boosters receiving the most attention because of cost and availability. For HySTP, plans call for launches to be conducted out of Vandenberg AFB, Calif., with the test apparatus to impact in the ocean within the Pacific Missile Test Range. Time actually spent at test conditions is “less than a minute,” with specific durations dependent upon each test apparatus. The test scramjets would be hydrogen-fueled.