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# HYPERSONIC AIRBREATHING PROPULSION/AIRFRAME INTEGRATION

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Recent interest in airbreathing hypersonic flight has centered around the need to develop advanced space launch systems which can reduce the cost of inserting payloads in orbit and make space more accessible. An effect of the thermal environment is to require the vehicle to operate at high altitudes, in very thin air, to maintain aircraft structural load limits. The high altitudes at which the hypersonic vehicle must operate give rise to the concept of an airframe integrated propulsion system (Fig. 1) to provide a much larger inlet and nozzle to process the required volume of air at low-density, atmospheric conditions. In the integrated system, the forward portion of the vehicle compresses the airflow and serves as the external portion of the inlet; the aftbody completes the expansion process for the nozzle. In addition the engine, which is contained between the body and the forebody shock wave, lends itself to a modular integration of a number of separate engines. In this manner a relatively small engine can be defined to allow engine development in existing ground facilities.

The large forebody and aftbody lead to unique problems associated with the hypersonic vehicle. Figure 2 illustrates a poor forebody design in that the static pressure distribution ahead of the propulsion modules results in a large accumulation of boundary layer in the center of the forebody. Such an airflow distribution would cause an unacceptably thick boundary layer and airflow loss in the center propulsion module. The importance of finite-rate chemistry at high speeds in calculating lateral airflow distribution as well as flow-field profiles between the body and cowl is also illustrated in this figure. The aftbody is unique in that a large portion of the airframe surface becomes involved in producing thrust. Figure 3 is an example of tests that have been conducted on a nozzle aftbody to determine performance characteristics. Parametric tests included the nozzle sidewall fence and air or stimulant gas to represent the nozzle exhaust flow. The stimulant gas was a cold mixture of gases intended to properly reproduce the engine exhaust flow ratio of specific heats throughout the nozzle expansion process. Note that measure nozzle forces are increased when the exhaust flow is simulated as compared to results using air. In addition, increases in nozzle thrust and lift occur when a flow fence is installed since the nozzle is not overexpanded and exhaust flow containment within the nozzle maximizes thrust at higher speeds. In contrast, at transonic speeds a configuration without sidewalls would have less base drag since the nozzle is overexpanded and outside air must be allowed to bleed into the base region.

The wide Mach number range of operation required by an SSTO vehicle also imposes unique challenges on the design and performance of the hypersonic engine module. Operation of both the turbojet and ramjet cycles at the same time requires separate combustors and nozzles as illustrated by Figure 4. Choking the two flows separately using independent operating nozzle throats allows each flowpath to be backpressured separately. Possible advantages include increased thrust and a smoother transition between the two cycles. More efficient methods for combining the turbojet and ramjet intakes have been explored, and have resulted in an arrangement where the ramjet is located under the turbojet rather than having the ramjet combustor wrapped around the turbojet engine (Figure 5). This concept results in a higher level of integration between the turbojet and ramjet intakes. At high speeds when only the ramjet is operating, the supersonic portion of the inlet is identical between the two concepts (Fig.6), whereas at low speeds a portion of the supersonic inlet opens to form an additional inlet for the turbojet. More independence between the two engine cycles results, thereby allowing internal ducting to be designed specifically for each cycle. A major advantage of the over/under turboramjet arrangement is that the high speed cycle is no longer restricted to a ramjet, and may include a dual-mode scramjet.

Contemporary dual-mode engines include the Parametric Engine tested at Langley Research Center (Figure 7). This concept represents an airframe-integrated engine built around a sidewall compression inlet approach. However tests have been expanded to include other shapes such as the 2-D class of engines which may integrate better with the turbojet engine. Tests so far have been conducted at a small scale, limited by facility size, and have included only limited forebody effects resulting from integration with the airframe. The 2.44 meter High Temperature Tunnel at Langley has been recently modified to include propulsion testing in addition to its usual role as a structures test facility (Figure 8). This large facility will allow extensions of previous tests to include airframe integration and multiple module effects with the engine size illustrated in Figure 7, as well as a larger scale engine to allow studies of engine scale effects and to include realistic structure within the test module.

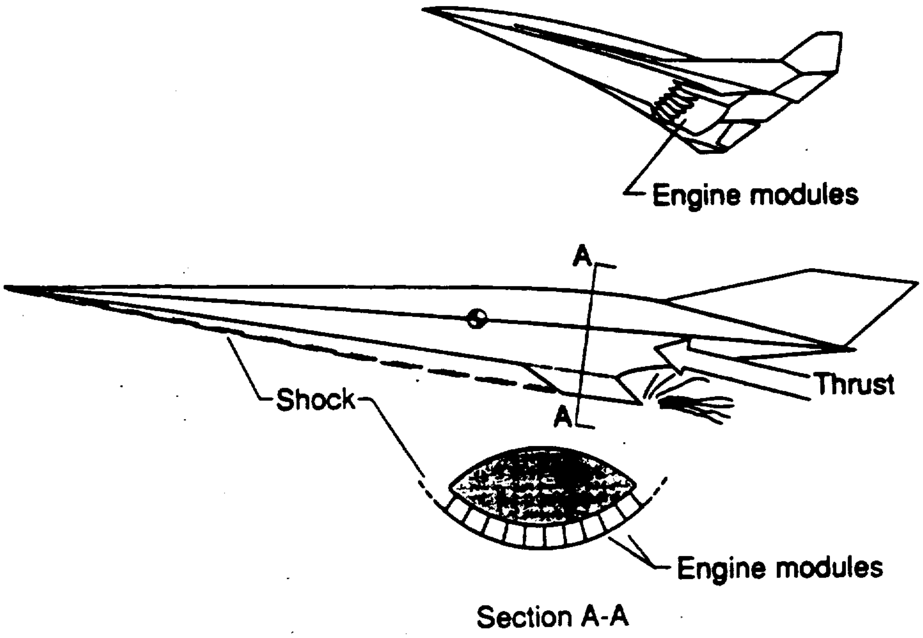

Figure 1.- Hypersonic engine/airframe integration

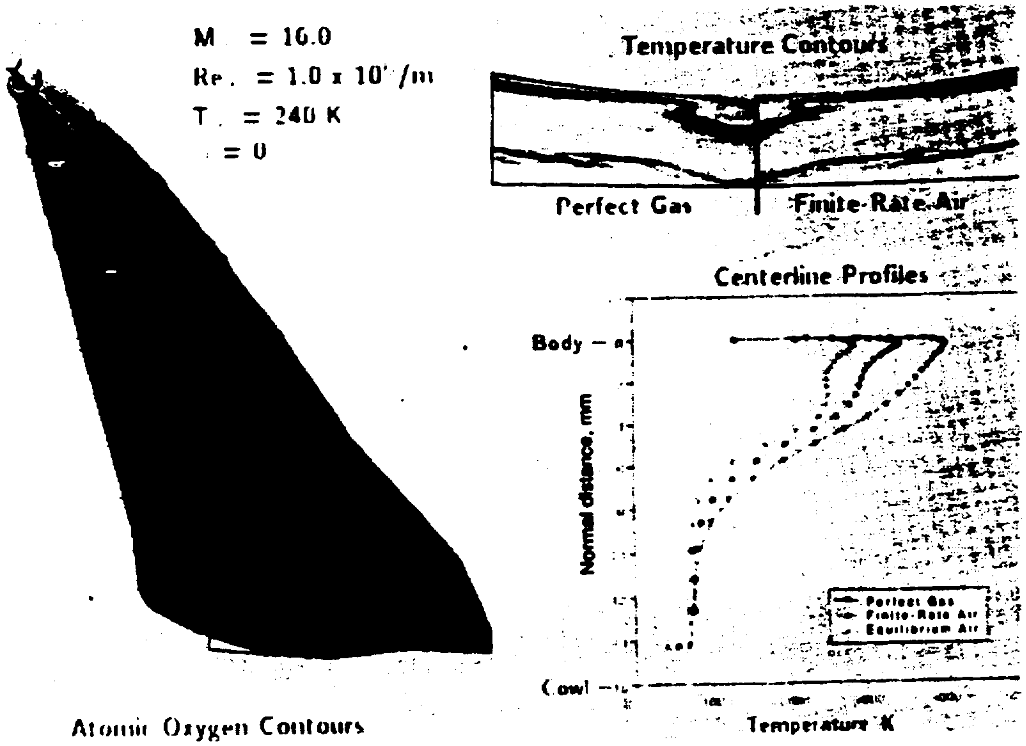

Figure 2.- Forebody analysis on a typical SSTO vehicle

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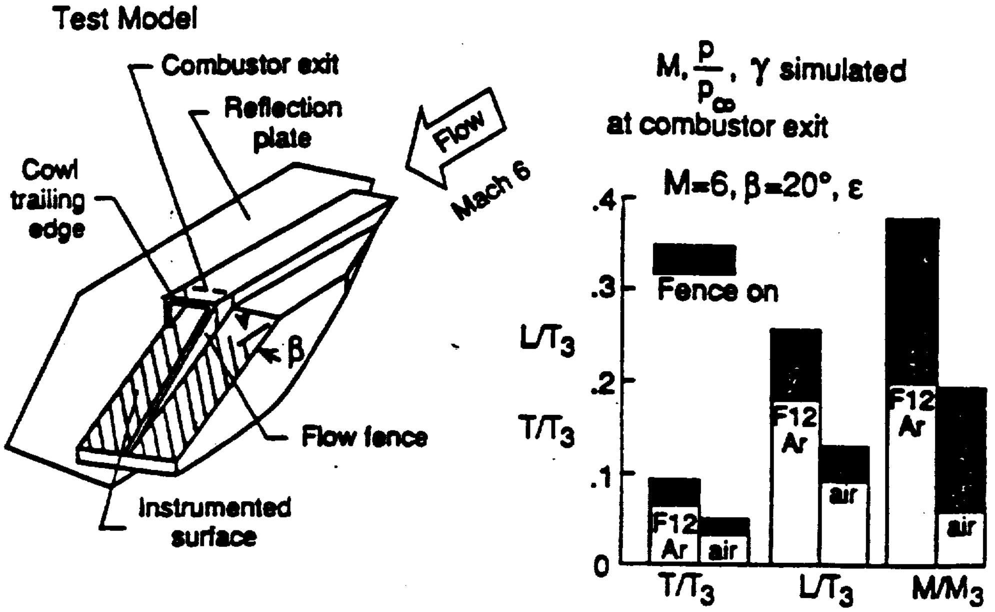
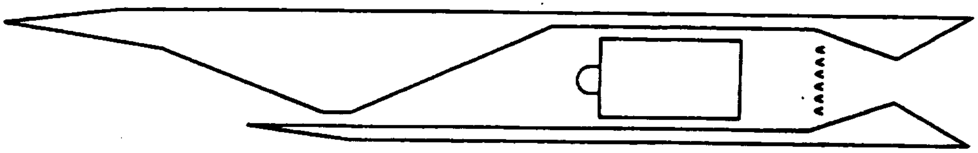
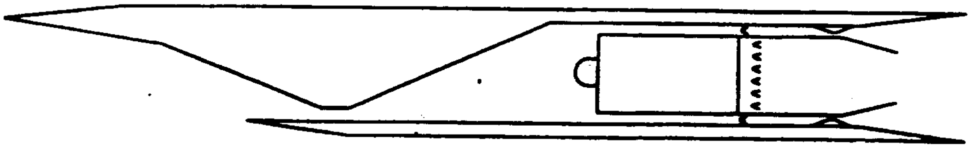


Figure 3.- Hypersonic nozzle exhaust simulation; effect of flow fence and simulant gas

In-line turboramjet



Parallel turboramjet



Fundamental difference in parallel approach

- Dual combustors & nozzle throats
- Simultaneous turbojet & ramjet operation
- Inherently heavier

Figure 4.- In-line vs parallel turboramjet

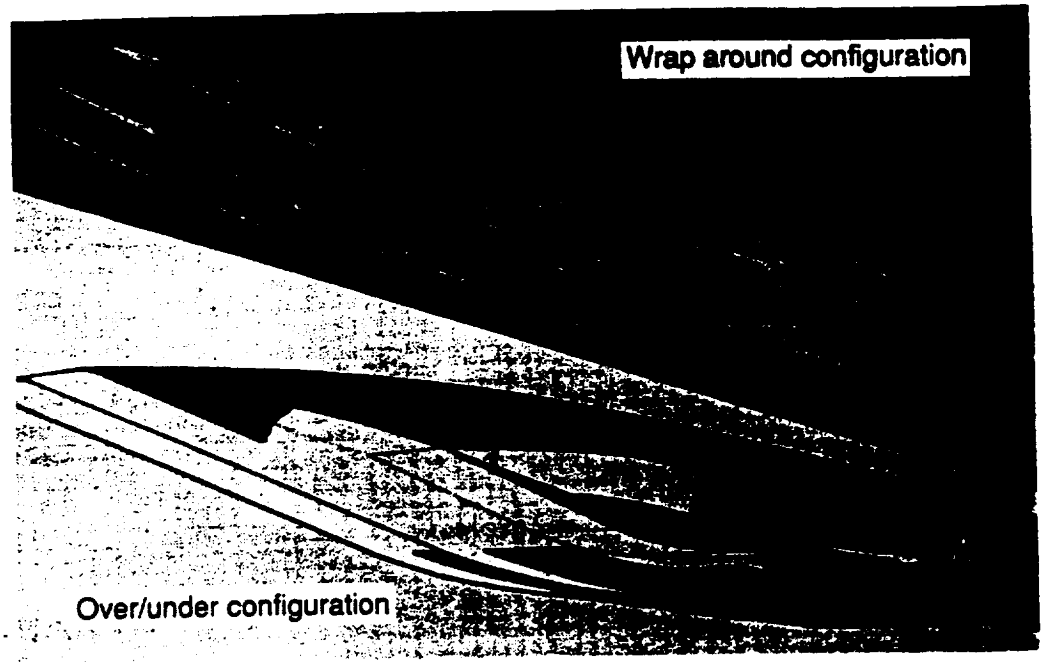


Figure 5.- Turboramjet Mach 5 propulsion system

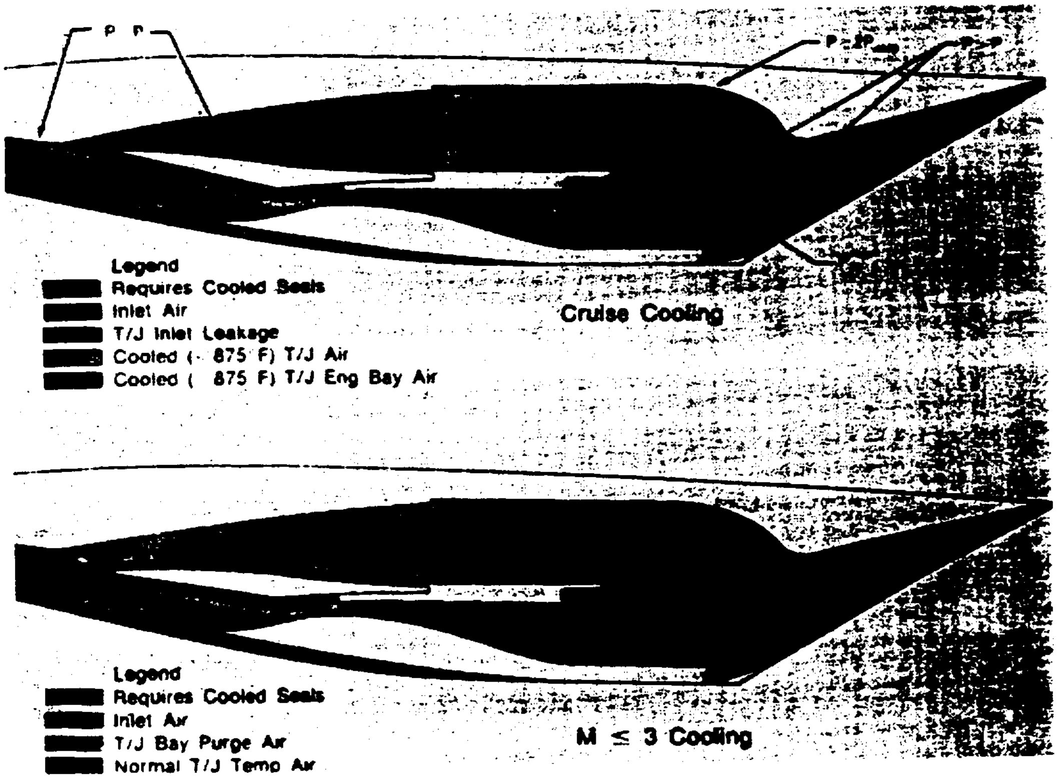


Figure 6.- Separate turbojet/ramjet engine concept

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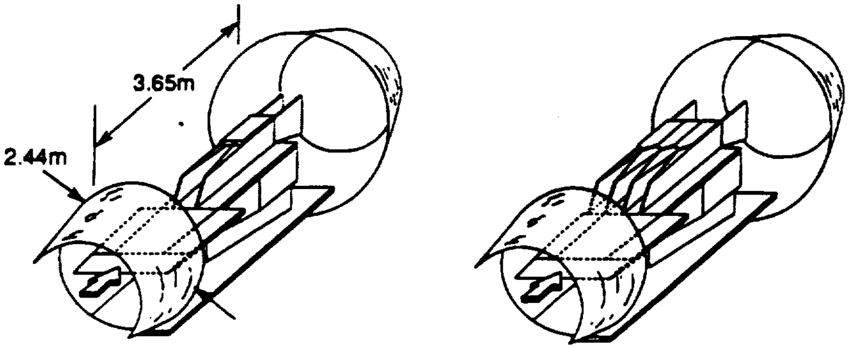
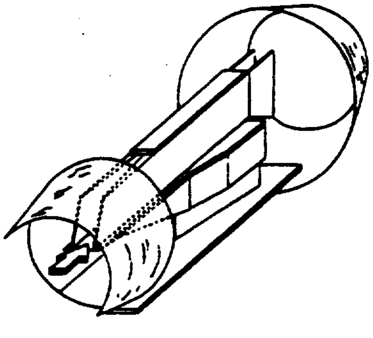
Figure 7.- Langley Parametric Engine



(a) Subscale scramjet mounted on forebody

(b) Multiple subscale modules mounted on forebody



(c) Larger scale scramjet

Figure 8.- Scramjet tests planned for the 2.44-meter HTT

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