The APL Alliances for High-Speed Aerothermal and Propulsion Testing

Gary A. Sullins, Paul J. Waltrup, and G. Richard Garritson

The facilities at the Avery Advanced Technology Development Laboratory (AATDL) have been used to support research in airbreathing propulsion and the development of infrared sensors. Much of the facility development has been done under government contract; up to now, all testing has supported government requirements. To provide industry access to unique government facilities and to reduce the cost to the government by sharing the operation and maintenance costs with industry users, two alliances consisting of government and industry participants have been established: the Alliance for High-Speed Aerothermal Sensor Testing and the Alliance for High-Speed Airbreathing Propulsion Testing. This article describes the alliance concept, the need for establishing such alliances, and their intended goals. A brief description of the AATDL facility and its capabilities is also provided.
(Keywords: Aerothermal testing, APL alliances, Propulsion testing.)

INTRODUCTION

As a not-for-profit research and development division of The Johns Hopkins University (JHU), APL operates in a unique role for the government as a Technical Development Agent for several weapons systems. In this role, APL assists the Navy in system development and provides independent evaluations of contractor designs. Because of this role, APL has a policy prohibiting working directly for industry or competing with industry in response to government requests for proposals (RFPs). This policy is intended to prevent any potential conflict of interest and to avoid jeopardizing the Laboratory's function of providing unbiased support to the government. As a result, nearly all work at APL is done under federal government contract.

The Avery Advanced Technology Development Laboratory (AATDL), formerly the Propulsion Research Laboratory, is a fully automated test facility capable of supporting large-scale airbreathing engine tests as well as aerothermal sensor tests at supersonic and hypersonic speeds. The AATDL was built under Navy contract, and much of the past research conducted there was sponsored by the Navy. The Air Force has sponsored much of the recent propulsion research. Frequently, these programs are insufficient to support a facility for the entire year; thus, parts of it remain inactive for some period. This time can be used to perform facility refurbishments, but often personnel must be temporarily reassigned to other tasks. Such reassignment carries a risk that personnel will not be available when the facility is reactivated. Finding additional customers for the facility will help keep key personnel in place. Furthermore, sharing the operations and maintenance cost with other customers will reduce the cost to the government. Therefore, APL has begun actively pursuing new customers for the facility through two alliances: the Alliance for High-Speed Aerothermal Sensor Testing and the Alliance for High-Speed Airbreathing Propulsion Testing.

In the 5 years prior to the establishment of the alliances, APL had rejected requests from industry to perform various wind tunnel tests at the AATDL facility to avoid the appearance of a conflict of interest. Even in cases where a conflict clearly did not exist, there was no convenient mechanism for receiving funds from industry. The only available mechanism was for the company to return money to their government customer, who in turn would send it to the Navy's Space and Naval Warfare Systems Command (SPAWAR) through a Military Interagency Purchase Requisition (MIPR). SPAWAR would then enter the funding in the APL contract.

From the customer's point of view, the MIPR process means loss of control, because the customer no longer controls the funds. The government sponsor, meanwhile, has the added burden of receiving the money and transferring it to SPAWAR. The process is more complicated for non-Navy sponsors. Therefore, a mechanism was needed that (1) allowed APL to work with industry while avoiding even the appearance of a conflict of interest, and (2) provided a mechanism for APL to receive funds directly from industry for use of the facility.

THE ALLIANCES

Several approaches to these goals were investigated, including establishing consortia, alliances, a center of excellence, teaming with industry, and working through grants. Establishing alliances among APL, industry, and government was chosen. The Alliance for High-Speed Aerothermal Sensor Testing was established first, with the Alliance for High-Speed Airbreathing Propulsion Testing established after that. The alliances were approved *a priori* by the appropriate Navy Program Offices. Membership in an alliance is free and provides the opportunity to use the APL test facility pertinent to that alliance. Joining and maintaining alliance membership imposes no financial or contractual obligations. Members pay usage fees for testing, which is performed under individual contracts. In addition, members are invited to occasional open house events at APL and receive periodic newsletters. Some engineering evaluation may be provided but must be approved on a case-by-case basis. Although membership in an alliance is free, industrial participants must join before using the facilities for testing.

The alliance concept potentially benefits several groups: industrial and academic participants receive equal access, on a "first-come, first-served" basis, to unique government facilities and to DoD-developed expertise; the Navy is assured that the facility is available for future needs at reduced yearly operational and maintenance costs; other government agencies receive the benefit of national investments in facilities and technology; and APL can receive continued support for the facilities.

Membership

Membership is open to any agency with a potential need or an interest in aerothermal or propulsion testing. Invitations to join the Alliance for High-Speed Aerothermal Sensor Testing have been extended to all DoD contractors currently participating in defense programs utilizing infrared (IR) sensors and to government agencies with sensor programs. Members to date include APL; the STANDARD Missile Program Office; Gencorp Aerojet; Aerotherm Corporation; United Technologies Pratt & Whitney; Busek Company, Inc.; Hughes Missile Systems Corporation; and Wright Laboratories Flight Dynamics Directorate.

Likewise, invitations to join the Alliance for High-Speed Airbreathing Propulsion Testing have been extended to all DoD contractors currently participating in defense programs utilizing advanced airbreathing propulsion concepts and to government agencies with interests in high-speed airbreathing propulsion. Members to date include APL, the Office of Naval Research, United Technologies Pratt & Whitney, Kaiser Marquart, Rockwell International, Atlantic Research Corporation, United Technologies Research Center, and the University of Michigan.

Both alliances are still in the early stages. No testing has been done under the alliance structure, although three companies have expressed interest. In two cases, estimates for testing were requested to support sensor work upon the award of a government contract. The third contractor has expressed interest in performing propulsion research.

High-Speed Aerothermal Sensor Test Facility

The Laboratory established the High-Speed Aerothermal Sensor Test Facility (Figs. 1 and 2) in the 1980s to support the development of IR sensors and sensor windows. The facility uses high-pressure, high-temperature air and a supersonic supply nozzle to simulate high-speed flight. Flight conditions of Mach 4

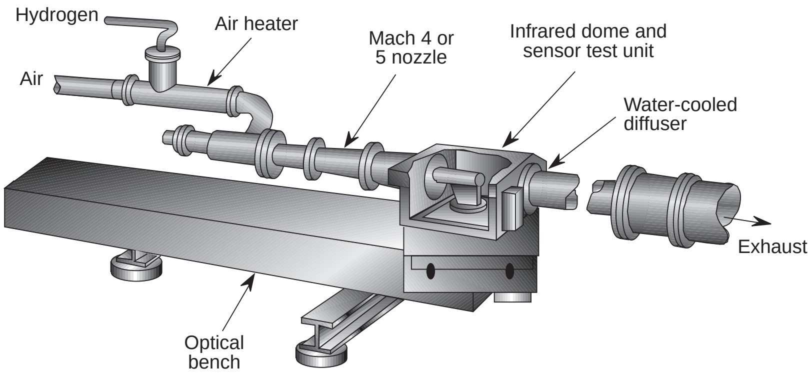


Figure 1. Schematic of the High-Speed Aerothermal Sensor Test Facility.

or Mach 5 can be duplicated. For materials testing, heating rates can be produced to simulate much higher flight speeds. Achievable heating rates and the simulated flight speed and altitude are shown in Fig. 3.

Unique attributes of this facility include long run times (up to 90 s), which allow thermal equilibrium to be reached for aerothermal testing; two filters installed upstream of the facility, which prevent particles greater than 1 μm from reaching sensor windows; and computer control of the facility gases (air and hydrogen), which allows very steady conditions to be maintained or allows the conditions to be preprogrammed to vary, simulating a vehicle trajectory.

The facility can be secured for performing tests on classified programs (up to the secret level). Also, APL's unique role with the government permits protection of industrial proprietary information.

Use of the facility to date has been almost entirely for the development of IR sensor windows for the U.S. Navy. Tests in this facility have defined the aerothermal heating conditions to which uncooled and actively cooled IR windows will be exposed, and several prototype windows have been evaluated for survivability under these conditions. Reliable methods for attaching windows to missile bodies have been developed and proved; deployable covers have been demonstrated through heat soak exposures and ejection into the airstream. Cooling concepts have been developed, and their effect on the optical signal has been documented. Testing of an operational IR seeker in a realistic, flight-like environment has led to design improvements and significant risk reduction prior to flight testing.

In addition to the Navy sensor work, some testing has been done for the U.S. Air Force. A heat exchanger for high-speed inlet testing was investigated, and leading-edge materials for a freejet engine were tested.

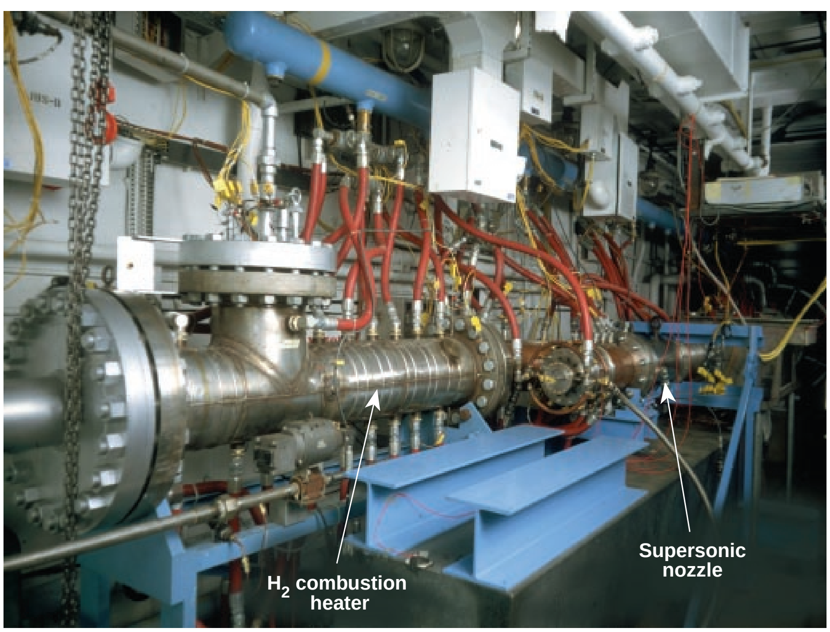


Figure 2. Photograph of the High-Speed Aerothermal Sensor Test Facility.

High-Speed Airbreathing Propulsion Test Facilities

Airbreathing propulsion research has been ongoing for over 35 years at the AATDL. Facilities are available to develop and test various engine components (inlets, combustors, fuel injectors, and nozzles), either separately or fully integrated as an engine.

Some components (for example, inlets and fuel injectors) can be tested with unheated air; however, others require heated air. Heating can be done using a hydrogen-fueled combustion heater (with oxygen replenishment) to achieve temperatures up to 4000°R. Steady-state conditions can be produced for 10–90 s with heated air or for several minutes with cold air. A storage bed heater also is

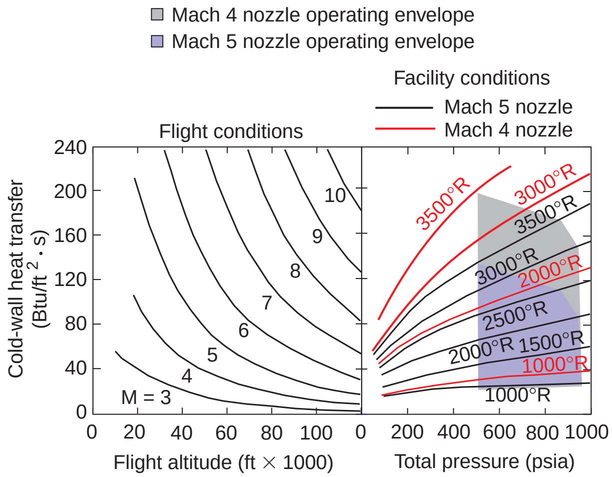


Figure 3. Conditions simulated by the High-Speed Aerothermal Sensor Test Facility for a 2.8-in.-dia. hemispherical dome. The shaded area indicates the facility envelope.

available to produce temperatures to 2200°R for several minutes.

A supersonic wind tunnel was recently brought on-line to perform freejet engine tests (Fig. 4). High-pressure (up to 1000 psia), high-temperature (up to 4000°R) air can be delivered through one of three existing supersonic nozzles (M = 4, 6, or 7). This tunnel can produce simulated flight conditions up to Mach 7 at altitudes up to 130,000 ft (Fig. 5).

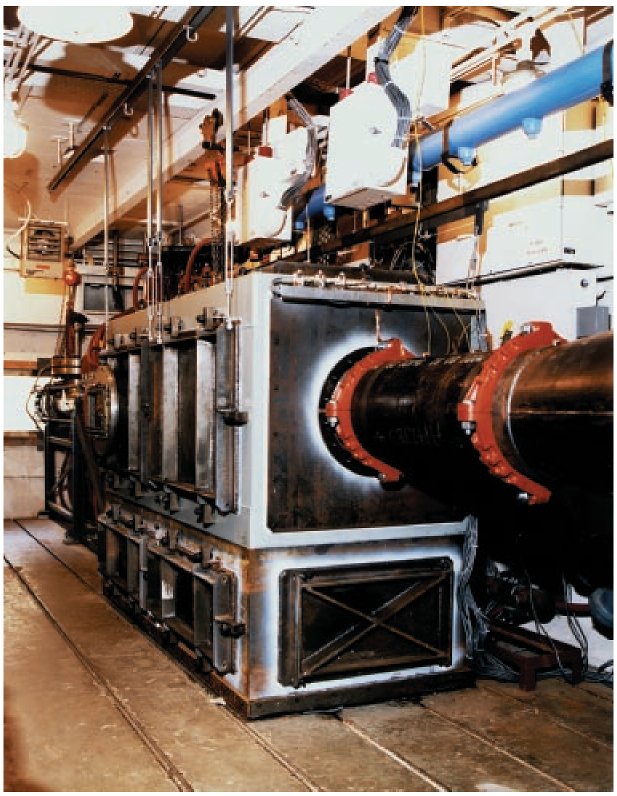


Figure 4. Supersonic wind tunnel capable of performing Mach 4–7 freejet engine tests.

A small-scale, bench-top facility is also available for hands-on, unheated aerodynamic tests. Recently performed tests have evaluated inlet starting, shear layer mixing, and small-scale turbojet engine nozzle performance.

The AATDL has computer-driven controls to maximize the number of conditions achievable in a short time. The facility and test cell controls are digitally operated and can be programmed to provide a number of test points or to simulate a given trajectory's enthalpy and altitude variation during a test. More than 400 instrumentation channels are available per test cell to record various measurements. Both fixed and portable data acquisition systems can be used; the portable systems have scan rates up to 500 kHz. Data can be stored on a variety of electronic media, and up to 30 channels of data can be displayed in real time during a test. Flow visualization includes schlieren images (both still photographs and video), thermal imaging video, and standard and high-speed video and photographs (6000 frames/s).

CONCLUSIONS

In response to interest generated by DoD contractors for use of the APL High-Speed Airbreathing Propulsion and Aerothermal Sensor Test Facilities, and recognizing that the facilities are periodically idle, APL has developed a mechanism to allow industry to use these government-established facilities, while still maintaining our trusted agent relationship with government sponsors. The mechanism established is through the Alliance for High-Speed Aerothermal Sensor Testing and the Alliance for High-Speed Airbreathing Propulsion Testing. These alliances have been endorsed by APL's Navy sponsors, and membership is open to all U.S. industrial, academic, and government organizations.

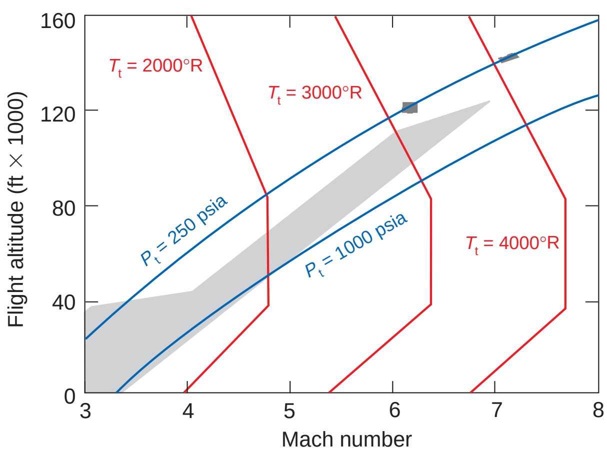
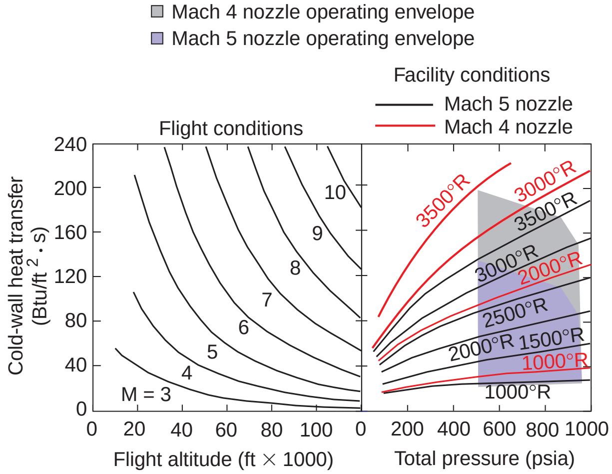


Figure 5. Freejet test capabilities with vitiated air heating (P_t = stagnation pressure; T_t = stagnation temperature).



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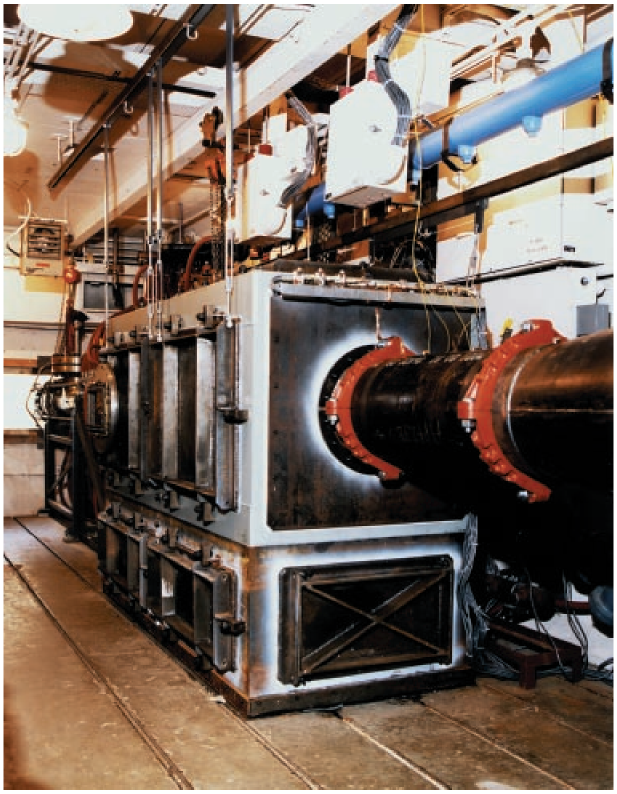

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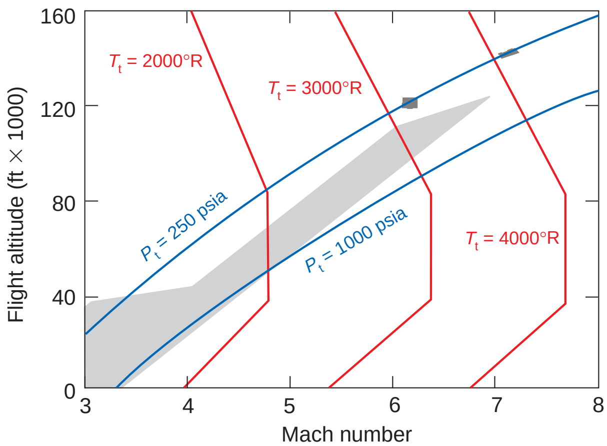

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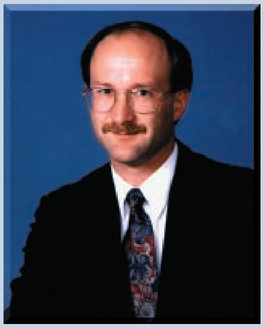
THE AUTHORS



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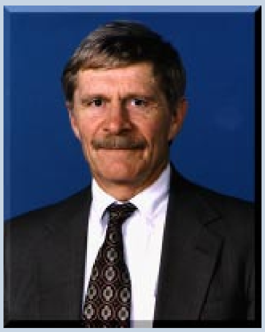

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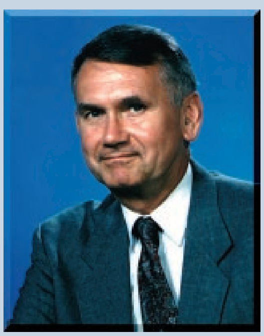

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