

### AT A GLANCE

#### What is it?

The Naval Research Laboratory (NRL) Hypersonic Wind Tunnel is a long-duration mid-size aerodynamics test facility capable of real-time altitude and speed variation. The range spans sea level to over 30km and Mach 1.5 to 5+ in a 12" x 12" x 24" test section.

#### How does it work?

Pressurized air is stored in stagnation tanks, then forced through a convergent-divergent planar nozzle where it reaches a sonic condition at the throat. The flow then expands to supersonic speeds in the test section at the desired density, altitude, and Mach number (see blue-red contour at top right). The test section Mach number is a function of the area ratio between the test section and the nozzle throat, which is controllable *in real time*.

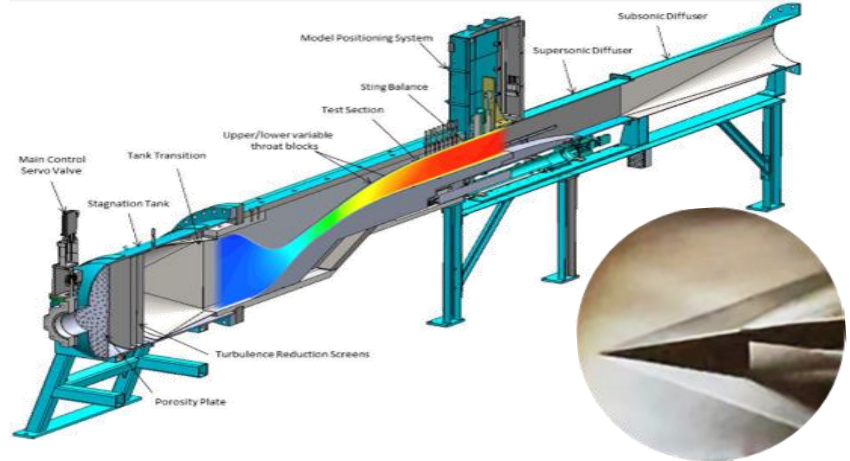
#### What will it accomplish?

The NRL Hypersonic Wind Tunnel offers the unique capability of varying flight conditions – the Mach number, Reynold's number, density altitude, and dynamic pressure *simultaneously* and *in real time*. This capability enables continuous aerodynamic testing along a flight *path* as opposed to a discrete *point* flight condition.

The NRL tunnel offers *low cost* operation and rapid test turnaround. Recharging the air tanks from empty takes less than 90 min.

#### Point of Contact

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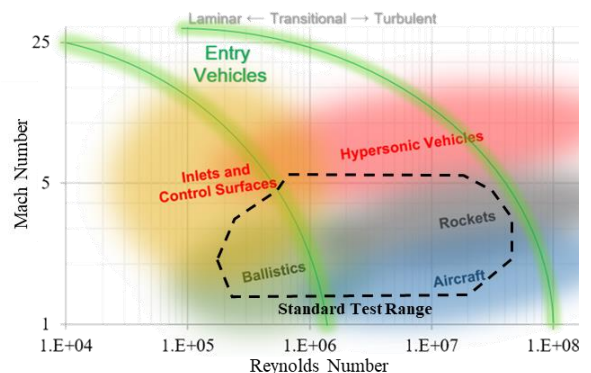
*The NRL Hypersonic Wind Tunnel Cutaway with Centerline Mach Number Contour*

Hypersonic wind tunnel testing presents many challenges for scientists and engineers who aim to recreate realistic flight conditions in an observable test apparatus. Chief among the complications of ground testing is matching the aerodynamic conditions with inexpensive and rapid-turnaround testing. Housed in the Hypersonic Aerodynamics & Propulsion Laboratory at the Naval Center for Space Technology, the facility is equipped with advanced diagnostics for flow visualization and model measurements of pressure, temperature, forces, and moments. The modular test-section allows for easily customizable window mounts and supports wall-mounted and sting-mounted models based on research needs.

A key feature of this facility is the ability to adjust the Mach number in real-time between Mach 1.5 and Mach 5+. Coupled with the adjustable stagnation pressure, full flight path simulation is possible in a *single run*. Equivalent altitude spans 0 to 30km+ with dynamic pressure variation from 50 to 300kPa+, and Reynolds numbers from  $10^6$  to  $10^8$ .

### Test Capabilities

The adjacent figure illustrates operational regimes for various flight vehicles ranging from ballistics to rocketry. The NRL tunnel offers overlapping performance into each category as shown in the dashed region. The test duration reaches as high as 75s depending on Mach and Reynolds numbers.



*Flight Regimes Achievable in the NRL Tunnel*

Planned diagnostics include a six-degree-of-freedom force and moment balance, temperature- and pressure-sensitive paints, IR thermal imaging, Shadowgraph and Schlieren imaging, Particle Image Velocimetry, Molecular Tagging Velocimetry, Stereoscopic Digital Image Correlation, and Planar Laser-Induced Fluorescence.