

Hypersonic test facilities:

Hypersonic ground test requirements:

- A) Potential civilian requirements:
- Planetary exploration.
 - Access to space.
 - Hypersonic transport/cruise.

Vehicle shapes are different for each mission.

Requirements of test facilities:

1. Test a model of a sufficient scale.
 - Re_x effect simulation.
 - Turbulence/ transition simulation.
2. Sufficient run times.
 - Has influence on instrument response time.
 - Unsteady phenomena like flow separation, wave interactions must be stabilized.
 - Internal flows take longer time to attain steady state—engine operability etc.
 - Thermal soak should be sufficient to study heat transfer related issues.
3. Sufficient dynamic pressure.
 - Sensors need sufficient density to respond.
 - Signal to noise ratio should be small.
 - Preferred dynamic pressure approx. 0.9 atm. Generally available is 0.2 to 0.3 atm. or lower.
 - There should be a nominal boundary b/n performance improvement and thermal survival.

4. Quality freestream.

- Should be uniform.
- Free of contamination.
- Should have the right turbulence level.

5. Quiet tunnels.

- No vibrations and interferences.
- Wall boundary layers preferably laminar unless required.
Smooth internal surfaces.

B) Potential military requirements:

1. Access to space.

- ✓ Space control.
- ✓ Satellite protection and denial.
- ✓ Space based weapons: space based lasers and certain weapons launched from space for *kinetic kill* and penetration of extremely hard and buried targets.

2. Missiles.

- Major munitions in the present day warfare.
- Missile with war head must be stable in its trajectory.
- Wave drag must be minimum. Makes counter measures difficult.
- Should have an optimum TPS and a good range.
- Sensors on missiles susceptible to shocks, heating and contaminants. Require sensor protection/cooling.
- These have to be tested all-up before deployment in a real mission.

3. Interceptor testing:

- ✓ Sensors and control surfaces should be very efficacious to sense and catch prey.

- ✓ Control testing demands higher test duration.
- ✓ Interceptor testing requires higher dynamic pressure as the interception occurs at relatively lower altitude.

Principles of Hypersonic Ground Testing:

Different hypersonic flow regimes:

- i. Low hypersonic regime: Mach 5 to 10.
- ii. Hypervelocity regimes: Reacting mixture of gases.
- iii. Rarefied hypersonic flows.
- iv. Requisite turbulence level.

All these can't be simulated in one facility.

Hypersonic ground testing themes:

- i. Duplication: All the aspects of the flight environment are matched in the test environment—which is seldom achieved.
- ii. Replication: Temperature, Pressure, Velocity and Chemical composition of the test medium match the flight medium. Achievable but difficult some times.
- iii. Simulation: Only some important parameters are reproduced in the ground test, such as Non-dimensional parameters (Reynolds no., enthalpy etc.).

Reasons for short fall of flight duplication:

- a. Freestream non-uniformity over a wide range of conditions.
- b. Lack of equilibrium due to small/short test times.
- c. Flow contamination from facility surfaces because of erosion.
- d. Acoustic and enthalpy fluctuations affecting B.L. transition.
- e. Incorrect surface roughness and scaling effects.
- f. Motion of the model.

- g. Interference from model mounts and tunnel walls.
- h. Simulation of high enthalpy and high speed.
- i. Condensation and liquefaction threshold. (Ref. to TV diagram for water showing liquid and vapor phases.)