Aerothermodynamic Testing Of Aerocapture and Planetary Probe Geometries In Hypersonic Ballistic–Range Environments

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Introduction

- Flight data needed to validate and verify aerothermodynamic design methods

- Not always possible to instrument actual entry vehicles, and dedicated flight experiments are expensive

- Consequently, design methods must be validated against experiments in ground-test facilities
  - Wind tunnels, arcjets, shock tubes/tunnels, ballistic ranges

- No single facility type can reproduce all parameters of full-scale hypersonic atmospheric-entry flight
  - Different facility types complement each other by providing validation data over largest possible parameter space
  - Available flight data helps verify traceability between ground-test and flight conditions
Ballistic-Range Testing

- Ballistic-range uniquely provides opportunity for small-scale flight test
- Hypersonic flight through a quiescent, well characterized atmosphere
- Correct flight enthalpy and Mach number
- Real-gas effects with uncontaminated chemistry
- Broad operational envelope
  - Flight velocity and effective altitude (freestream pressure) are independently variable
  - $V_\infty$ up to 9 km/s ($h_{stag} \approx 40$ MJ/kg)
  - $P_\infty$ from 0.005 atm to 1.0 atm
  - Selectable test atmosphere: Air, CO$_2$, N$_2$, He, Ar, Kr, Xe, etc.

Flight Domain Simulation Capability
NASA-Ames Hypervelocity Free-Flight Facility

Model: 70° Sphere-Cone
Cylindrical Afterbody
(for in-barrel launch stability)

Side View

Front View

3.81 cm
Representative Results

70° Sphere-Cone
V = 3.8 km/s (V_L = 4.5 km/s)
Flight Time = 7.74 ms
P_∞ = 0.658 atm (500 mmHg)

70° Sphere-Cone
V = 3.7 km/s (V_L = 4.5 km/s)
Flight Time = 7.89 ms
P_∞ = 0.75 atm (570 mmHg)

Laminar Zone
Transition Front
Turbulent Zone

\( \dot{q} \) (kW/cm²)

(preliminary)