Hub in UK National Wind Tunnel Facility
Primary Goals

• Build large-volume dirty vacuum facility to investigate:
  o Plume ground interaction
  o Plume spacecraft contamination
  o Plume-plume interaction

• Directly Support ESA Exploration for soft landing and comet rendezvous

• Two regimes of interest
  o Hard Vacuum (Lunar landing)
  o Mars Environment
Cross-cutting applications

• Exploration and Robotics
  o Autonomous vehicles: Testing of autonomous vehicles in simulated planetary conditions
  o Robotic manipulators: Testing of sampling devices
  o Dust resilience

• Access to Space
  o Space propulsion systems: Testing of propulsion systems in simulated planetary conditions
  o Clean space environment: The execution of fragmentation studies to understand debris production and its control
Flow field of plume impinging on airless body is complex

As nozzle lowers altitude the flow/shock structures change

Surface topography changes with nozzle stand-off height
ESA ongoing investigation: Mars

- Similitude analysis criterion:
  - Mass flow rate 18.9g/s N2
  - Martian background pressure 6mbar (600 Pa) to be maintained throughout testing

- Vacuum pumps playing greater role.
Design Solution

- Test section volume ~12 m³
- Buffer tank volume ~60 m³
- Conductance pipe volume ~3 m³
- Ultimate vacuum level ~1 Pa (0.01 mbar)
- Time to reach ultimate vacuum level ~3.5 hr
Buffer Tank and Test Chamber
Inside the chamber and external flanges
Mars Scenario Operation

- Pressure control valve on test chamber.
- Capacitance manometer used to meter the opening of butterfly valve to maintain desired pressure in test chamber.
- Three stages of valve operation:
  - **Closed** – vacuum level in test chamber high (low pressure) allowing pressure in test chamber to rise to 600Pa.
  - **Control** – at 600Pa valve begins to open and its rate of opening is metered to maintain target pressure.
  - **Open** – valve fully open, no longer sufficient pressure difference between buffer tank and test chamber to maintain 600Pa.
Simulants: Glass Spheres and Walnut Shells
Heating under vacuum

Macor

Heat exchanger

Heating cord

Nozzle

Gas delivery

Macor

Cartridge heaters
Heat Transfer Measurements

Peek

Aluminium
Dust Resilient Mechanisms

**Dust mitigation technologies**

- **Active**
  - Fluidal
  - Mechanical
  - Electrodynamic (cleaning & shields)

- **Passive**
  - Modified surfaces
  - Mechanical shields/seals
  - Coatings

- **Implicit**
  - Compliant mechanisms
  - Electrodynamic mechanisms

Credit: NASA
Thank you