Thermodynamic Scaling of Supersonic Retropropulsion Flowfields

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Problem Statement and Motivation
- SRP needed to safely land high ballistic coefficient payloads on Mars
- Flight relevant conditions are hard to simulate in a wind tunnel making existing SRP datasets unreliable (all cold gas Air-Air interactions)
- Modern CFD analysis lacks multi-gas validation datasets
- Existing similarity parameters have questionable ability to account for thermodynamic effects of rocket plume
- Temperature and gas composition variation may help solve this challenge

Flow Topology and Trends
- Most important features include bow shock standoff distance and curvature
- Standoff distance measured from the retro nozzles exit plane to bow shock leading edge
- Stability profile shows the high thrust regime (shown in light blue) where test conditions occur and where flow is hypothesized to be self-similar

Mass Conservation Control Volume Analysis

Parameter Space
- Variated Parameters
  - $M_e$ ranged between 2-3 with $M_e = 2$
  - Jet and freestream gas composition
  - Jet temperature (20-200 deg C)
  - Nozzle outer diameter (1/8" - 3/8")
  - Jet pressure: 90-1300 psi
- Condition
  - $C_{90}$ - $C_{95}$
  - $C_{90}$ - $C_{90}$
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Scale Results
- Data points in grey from outside sources
- Conditions include freestream Mach number 1-7, jet Mach numbers 1-3, Air-Air interactions, unheated

Conclusions
- Linear fit of standoff distance and scaled mass flux ratio independent of varied parameters
- Scaling is consistent with conservation of mass derivation
- Shock shape shown to be self-similar

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Test facility schematic
- Ar, N2, He
- N2, CO2

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