"You are required to assist on the Atmospheric Structure Reconstruction using the Beagle 2 Entry, Descent, and Landing Accelerometer"

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Accelerometers - Why?

- Know trajectory
  - position
  - speed
  - acceleration
- Know atmospheric structure
  - density
  - pressure
  - temperature

Examples

- Viking and Pioneer Venus defined the "standard atmospheres"

- Galileo, Mars Pathfinder

- Beagle 2 and Huygens

- Aerobraking and Aerocapture

Spacecraft Trajectory

- Know initial position and velocity
- Know acceleration during entry as a function of time
- Then integrate!
- Frame issues
- Spacecraft attitude
- Landing site position, radar altimetry near landing, Doppler shift of descent telemetry are possible constraints

Atmospheric Density

$$\rho C_D A V^2 = -2ma$$

- A and m known from design
- V and a known from trajectory
- C_D is a nightmare
- Solve for density at each point along the trajectory
- Hence $\rho(z)$ …
  vertical profile may stretch over some horizontal distance
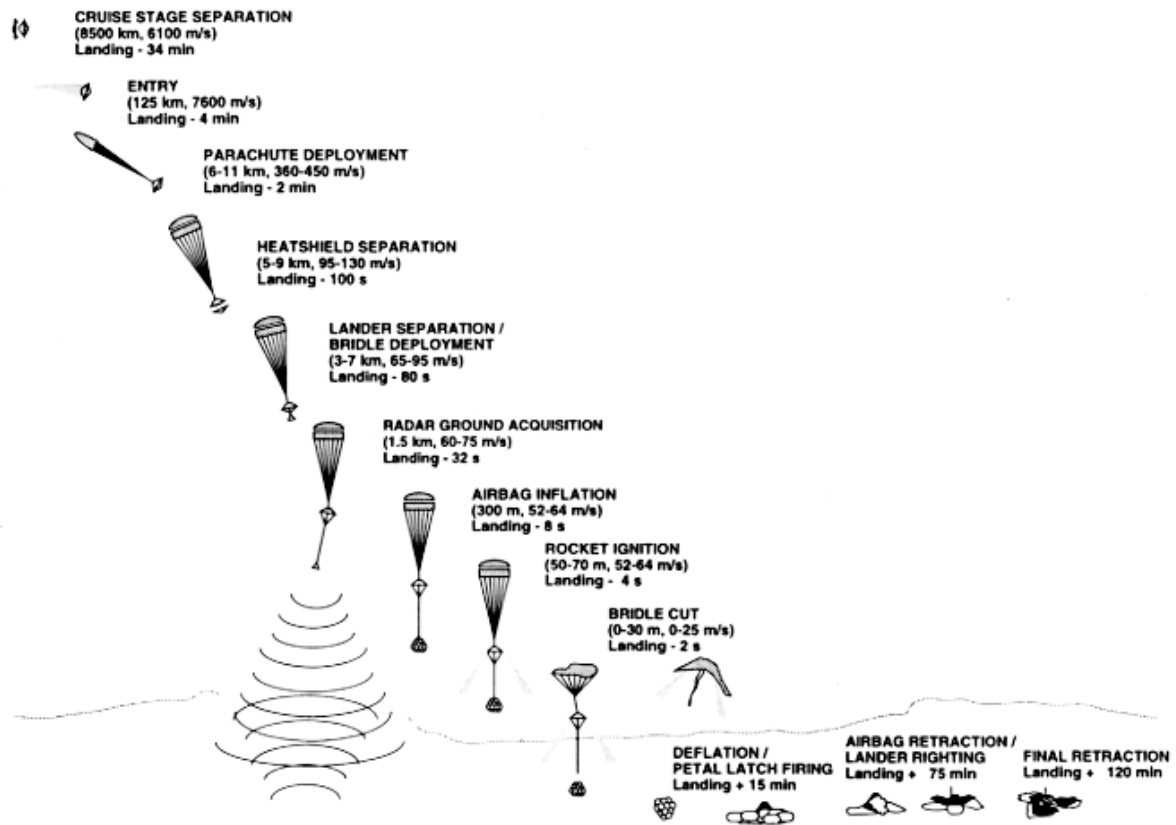
Atmospheric Pressure and Temperature

$$\frac{dp}{dh} = -\rho g$$

$$pm_m = \rho RT$$

- Integrate density to get pressure
- Constant of integration?
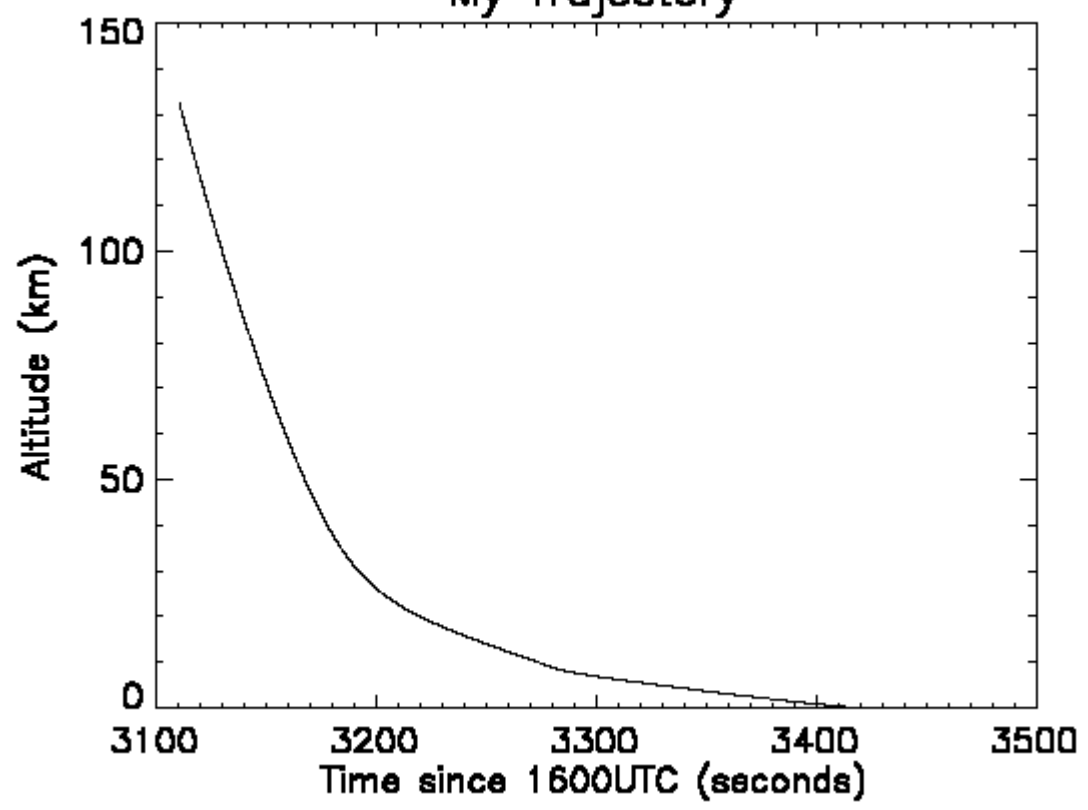- Solve equation of state, such as ideal gas law for temperature

Can I Make It Work?

- Beagle 2 is aerodynamically similar to Mars Pathfinder

- Mars Pathfinder accelerometer data is publicly accessible

- Trajectory and density, pressure, and temperature from Mars Pathfinder are also publicly accessible
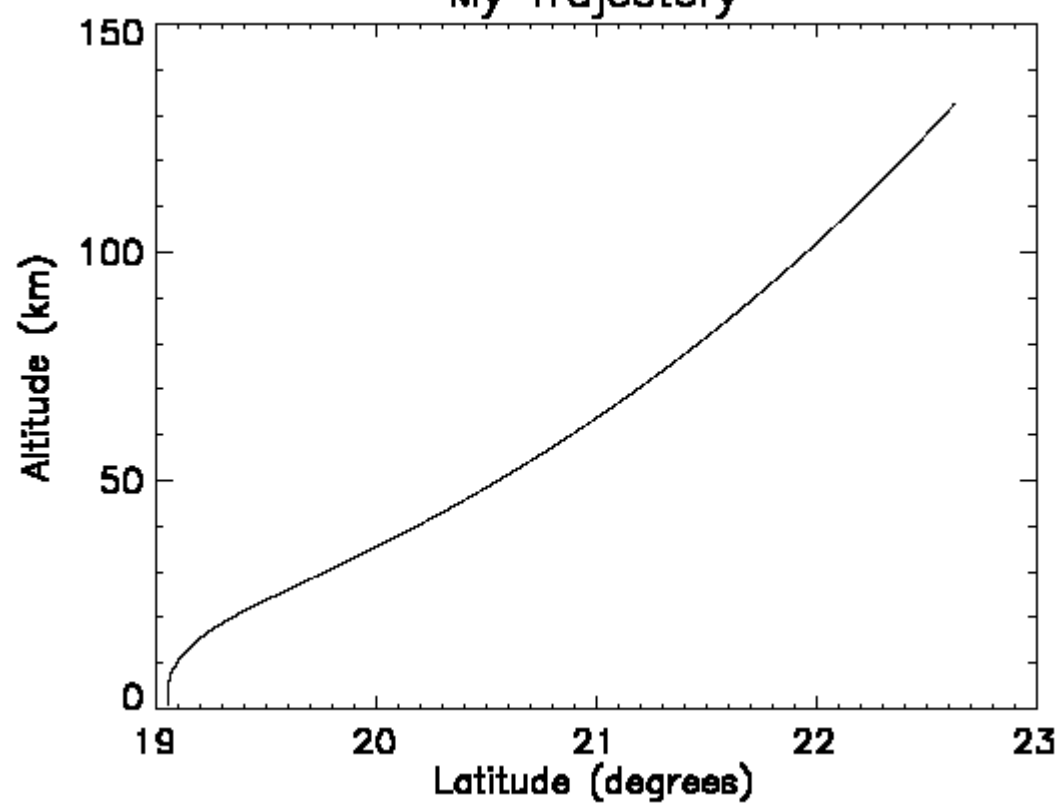
- Download and compare results!

CRUISE STAGE SEPARATION
(8500 km, 6100 m/s)
Landing - 34 min

ENTRY
(125 km, 7600 m/s)
Landing - 4 min

PARACHUTE DEPLOYMENT
(6-11 km, 360-450 m/s)
Landing - 2 min

HEATSHIELD SEPARATION
(5-9 km, 95-130 m/s)
Landing - 100 s

**LANDER SEPARATION /
BRIDLE DEPLOYMENT**
(3-7 km, 65-95 m/s)
Landing - 80 s

RADAR GROUND ACQUISITION
(1.5 km, 60-75 m/s)
Landing - 32 s

AIRBAG INFLATION
(300 m, 52-64 m/s)
Landing - 8 s

ROCKET IGNITION
(50-70 m, 52-64 m/s)
Landing - 4 s

BRIDLE CUT
(0-30 m, 0-25 m/s)
Landing - 2 s

**DEFLATION /
PETAL LATCH FIRING**
Landing + 15 min

**AIRBAG RETRACTION /
LANDER RIGHTING**
Landing + 75 min

FINAL RETRACTION
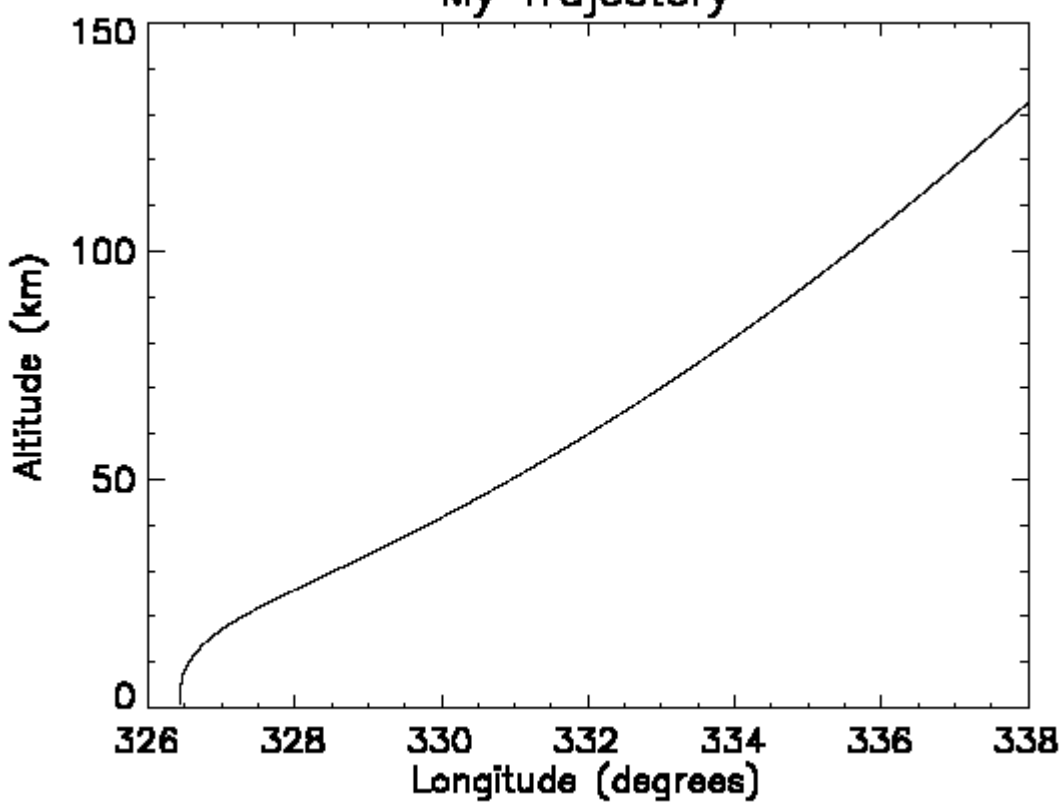Landing + 120 min

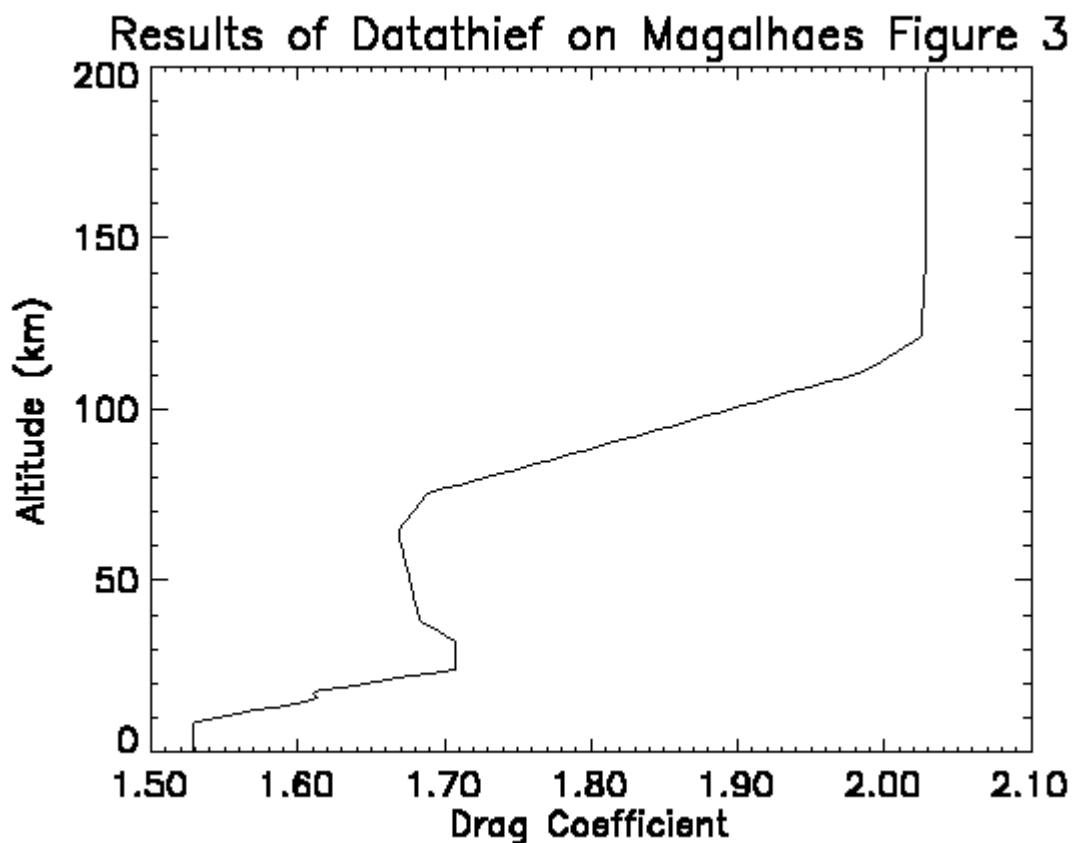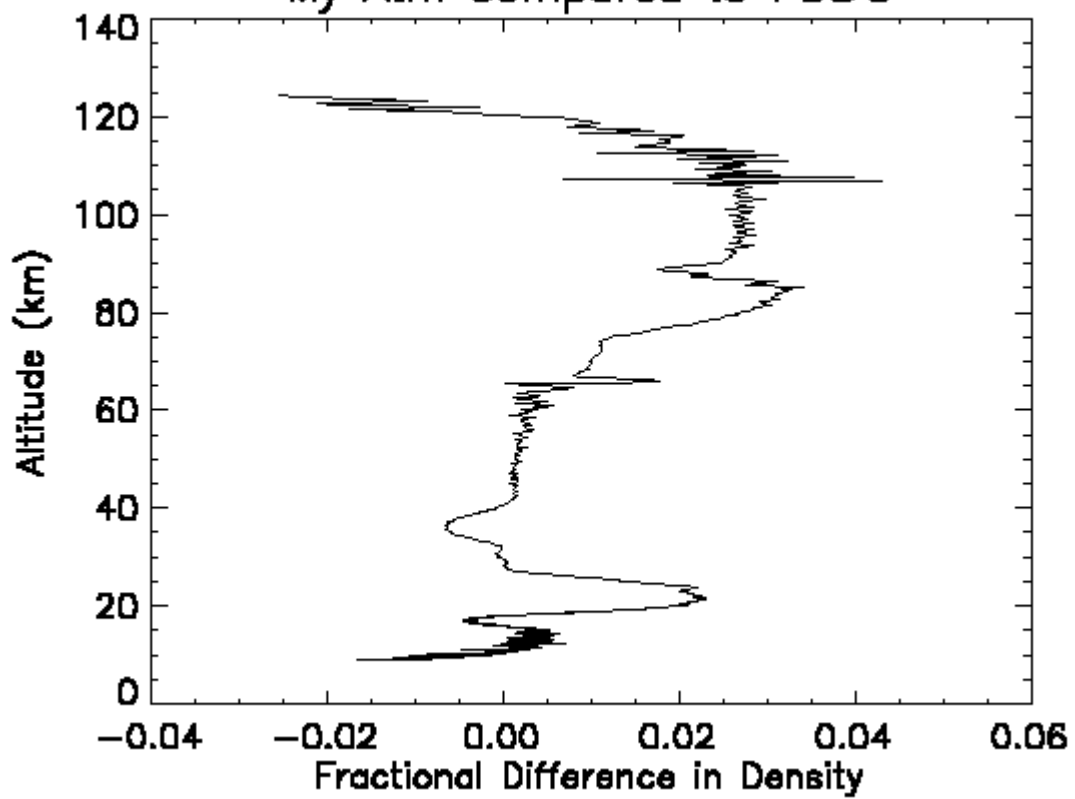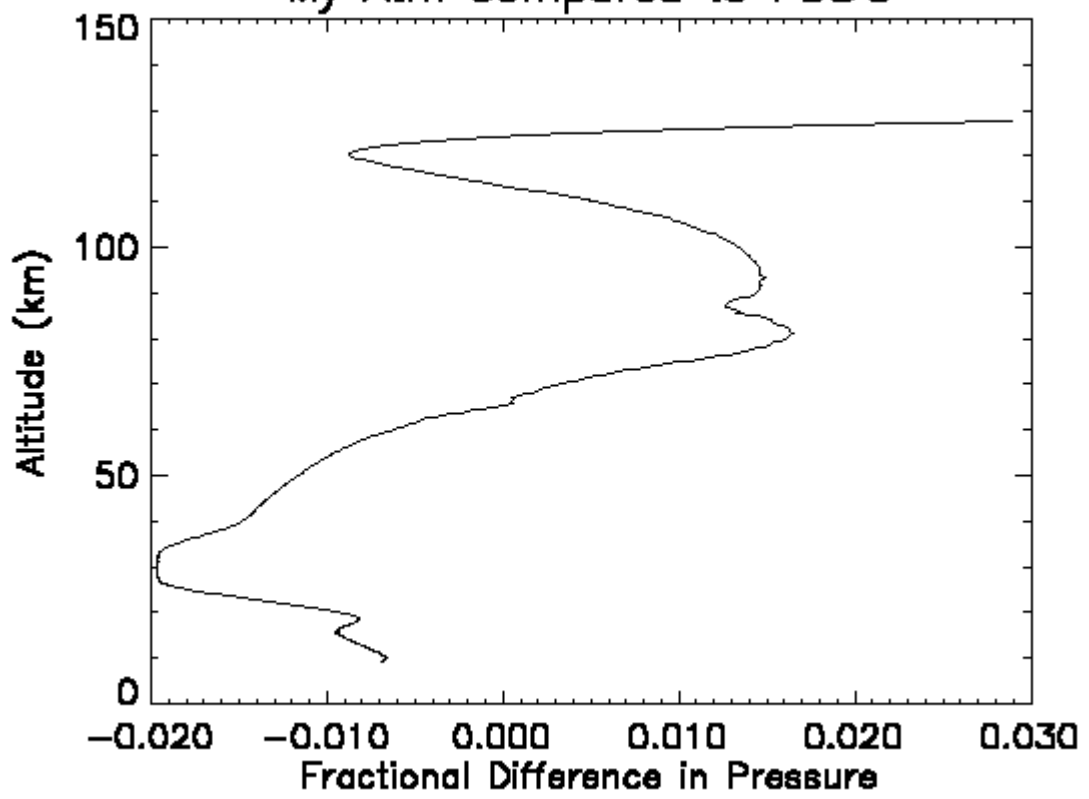*Mars Pathfinder entry, descent and landing*

My Trajectory

My Trajectory

My Trajectory

Detailed Aerodynamic Database, created at great expense on the world's shiniest computers

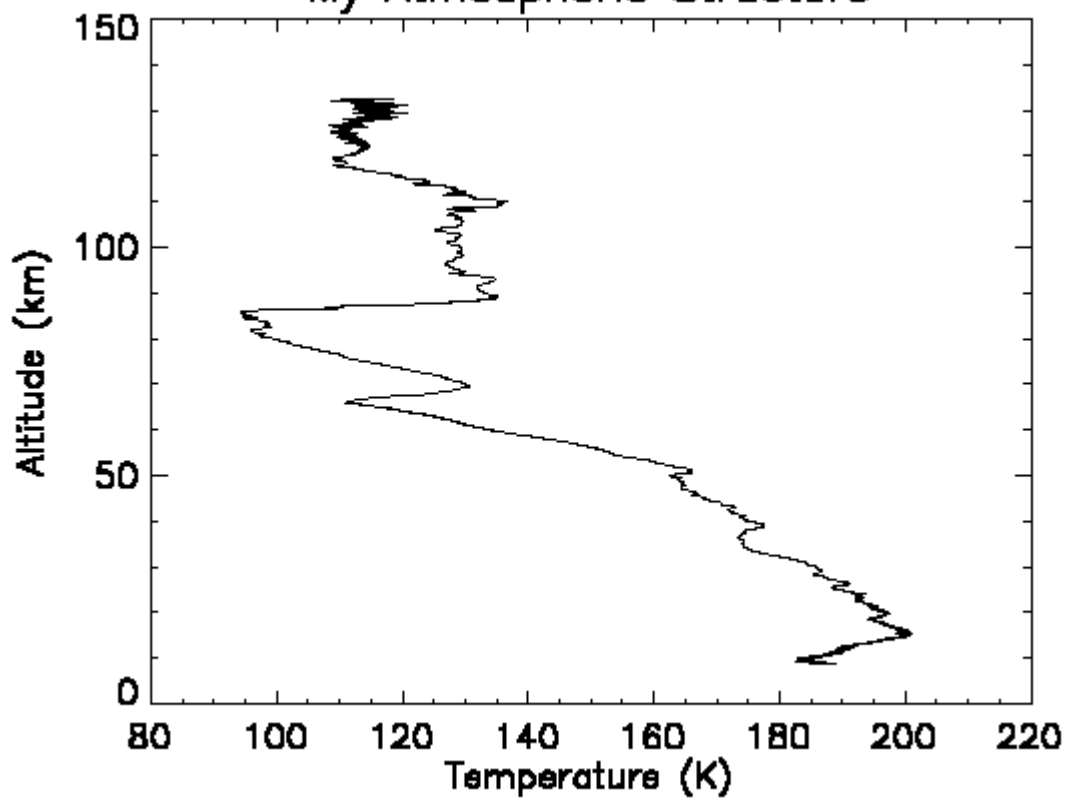Results of Datathief on Magalhaes Figure 3
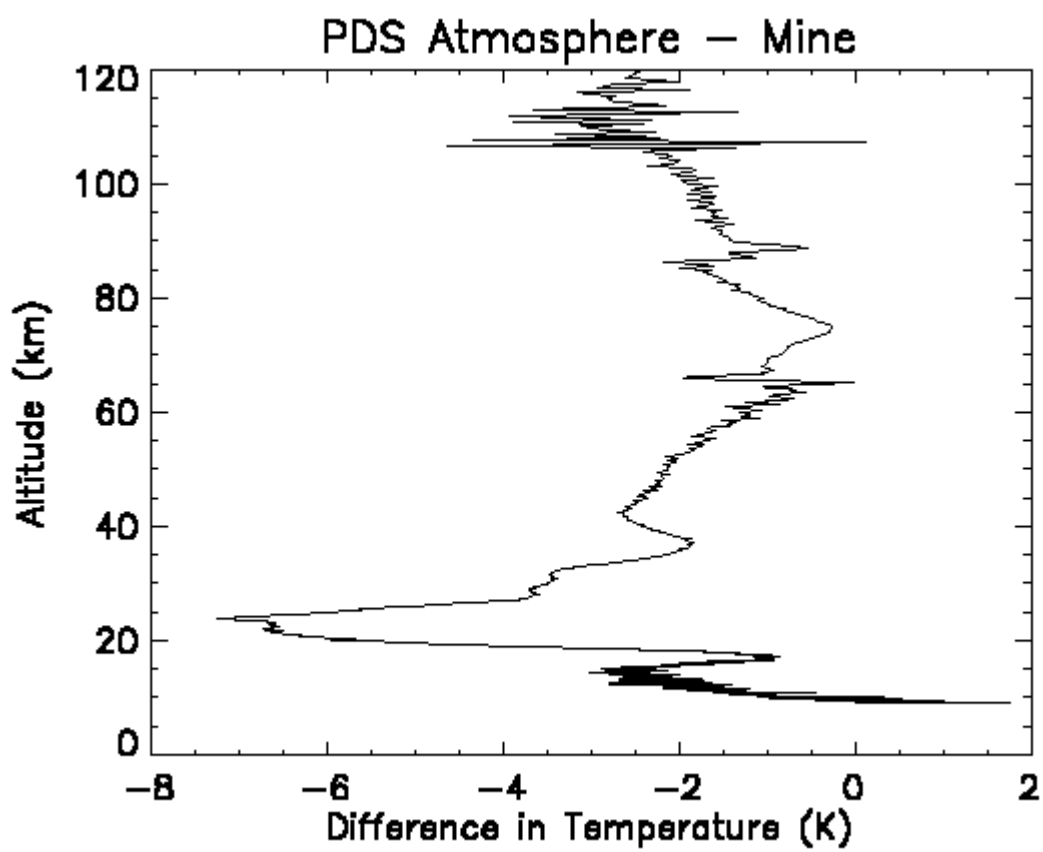
My Atm compared to PDS's
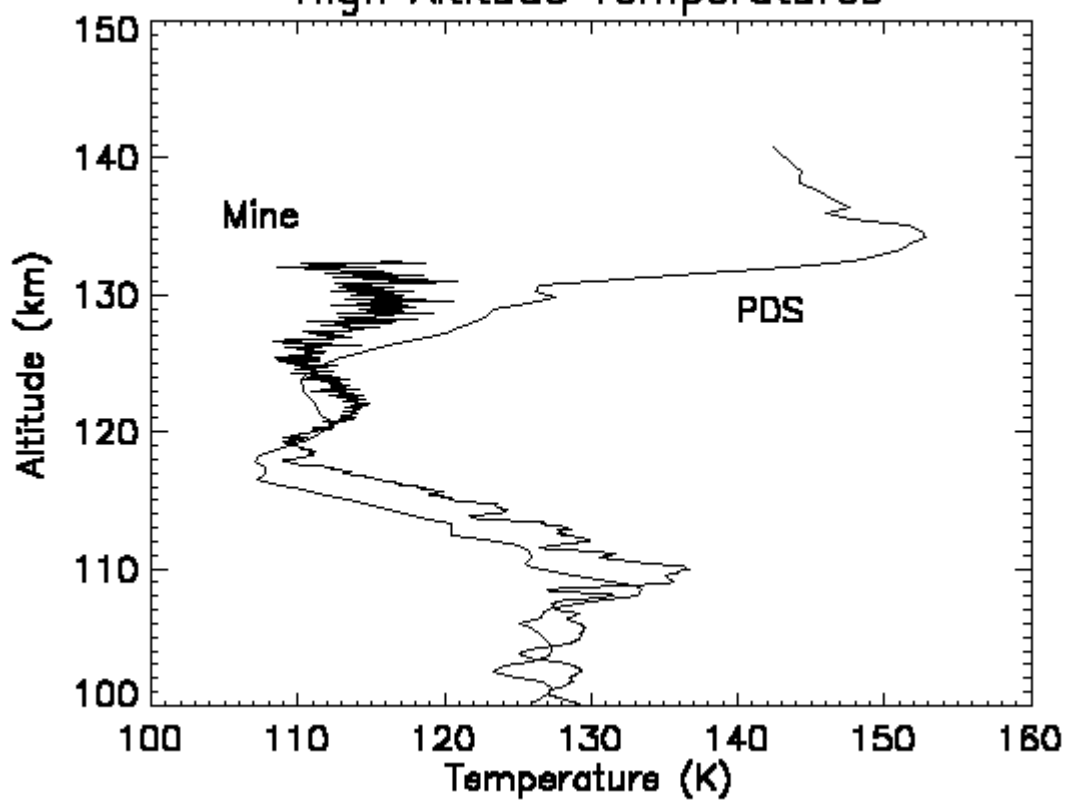
My Atm compared to PDS's

My Atmospheric Structure

PDS Atmosphere − Mine

High Altitude Temperatures

Now What?

- Effects of uncertainties in initial conditions
- Effects of uncertainties in aerodynamic properties
- Instrument digitisation, sampling, and systematic offset
- Effect of atmosphere of landed position (and landing ellipse)

Future Work for Someone

- Understanding all my archived results and computer programs

- Formal error analysis of my solution

- Specific studies of Beagle 2 - likely entry conditions and instruments

- Getting aerodynamic database out of Martin-Baker's clutches