Radio tracking of Phoenix during its landing on Mars

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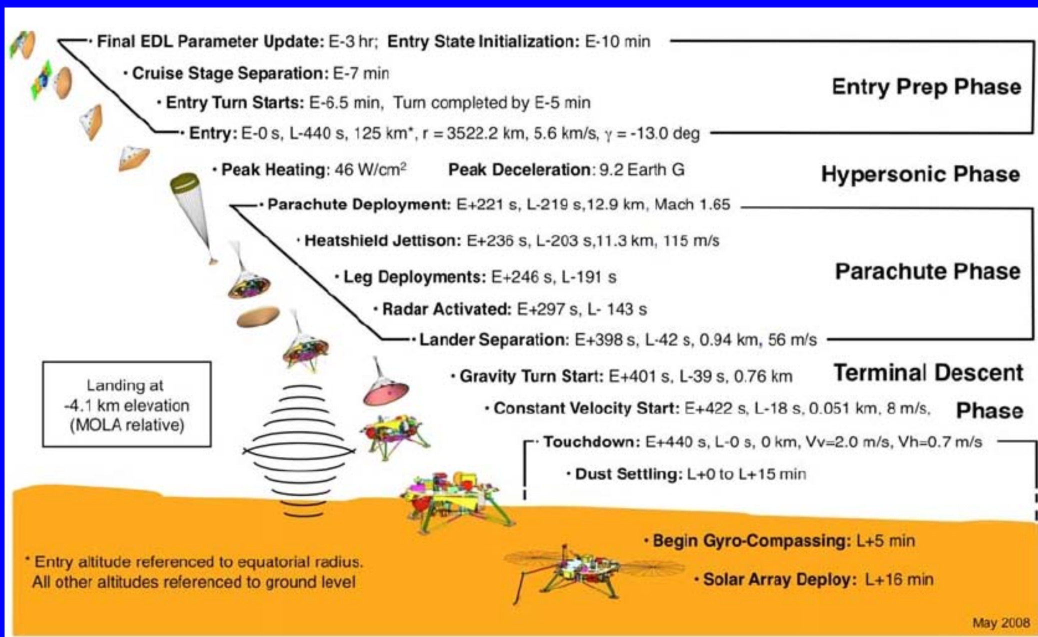
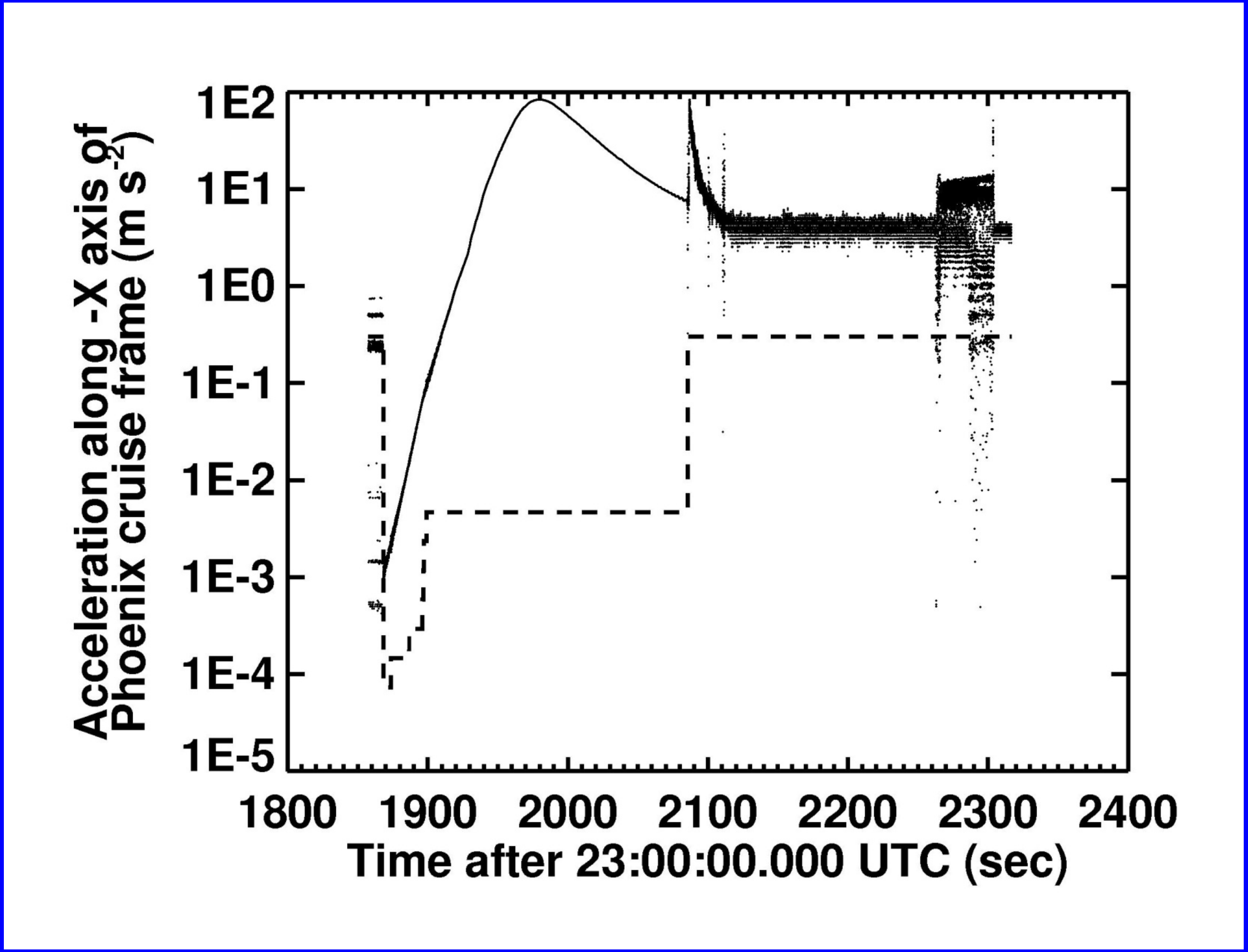
Phoenix atmospheric entry



JPL figure

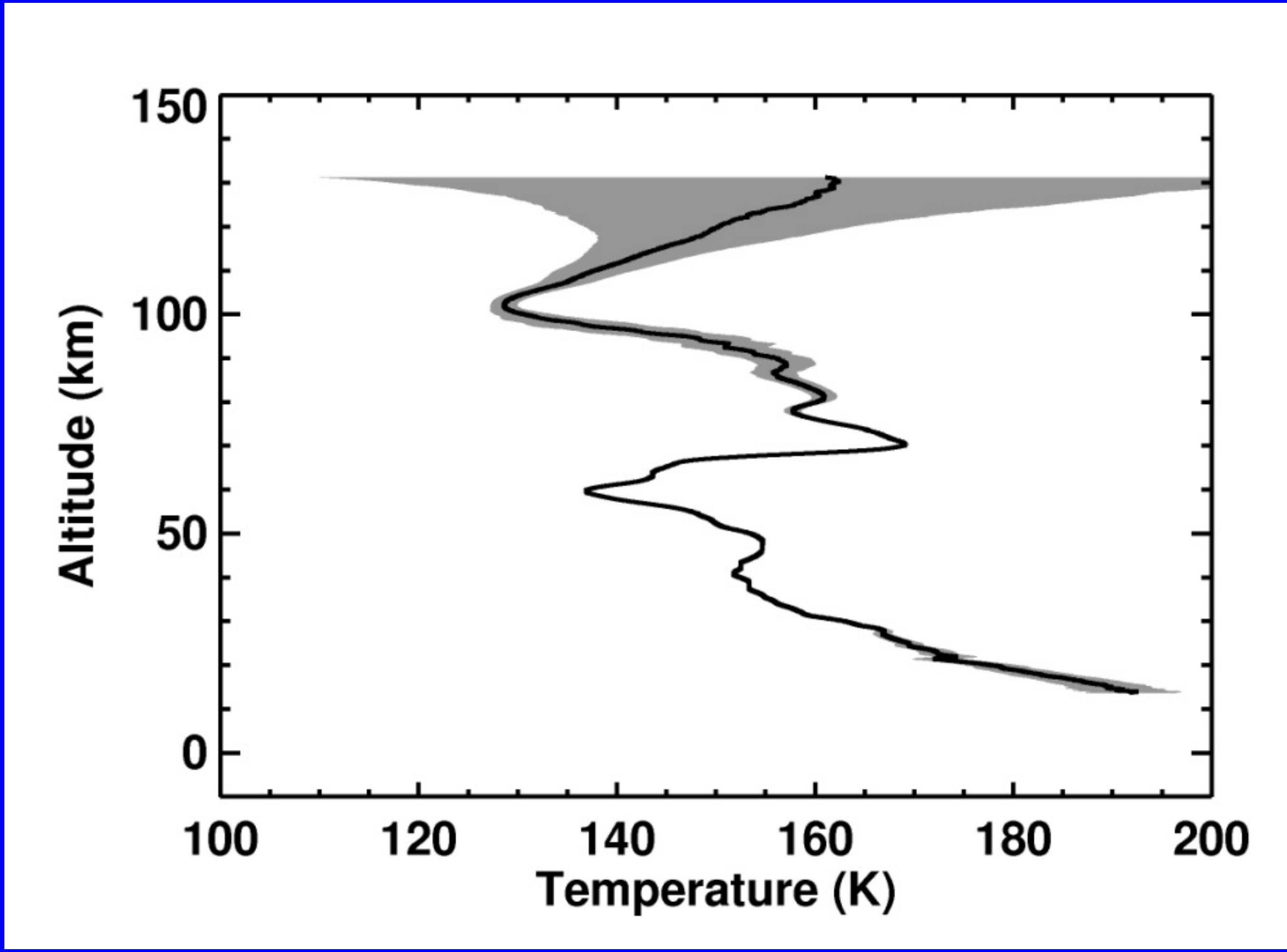
- 25 May 2008
- Landing site at
  - 68.2N, 234.3E
  - -4.1 km (MOLA)
- Ls=77, LST ~16:30
- Ballistic entry with many similarities to Pathfinder and MER
- Accelerometers and gyroscopes on board

Smoothed axial accelerations



Use entry state, equations of motion, and these accelerations to find trajectory

Atmospheric profile



Use trajectory, drag equation, aerodynamics to find density profile, then p and T

Possible alternative

- Many landers have direct-to-Earth comm link during atmospheric entry
- Can such data be used in near-real-time to measure trajectory and atmosphere?
  - Potentially valuable to engineers, to public, and as science
- (Sounds a lot like a Doppler Wind Experiment, but…)

Why bother?

- Independent reconstruction of trajectory
- Rapid results for:
  - Engineers (Where did we land? Nominal?)
  - Public (See results immediately)
  - Science (What are atmospheric conditions?)
- Get results even if lander explodes when reaching ground

Basic approach

- Have entry state, know gravity as function of position
- Need to know vector aerodynamic acceleration at each timestep to find total acceleration and move trajectory forwards in time

- Measure f(t), know line-of-sight velocity as function of time

Detailed approach

Measured: $\underline{v} \cdot \underline{l_0}$

Obvious: $\underline{v_1} = \underline{v_0} + \underline{a}\, dt$

$\underline{a} = \underline{a_{aero}} + \underline{g}$

Re-arrange:

$$\underline{v_1} \cdot \underline{l_0} = \underline{v_0} \cdot \underline{l_0} + \underline{a} \cdot \underline{l_0}\, dt$$

Re-arrange:

$$\underline{a_{aero}} \cdot \underline{l_0} = \frac{1}{dt}\left(\underline{v_1} \cdot \underline{l_0} - \underline{v_0} \cdot \underline{l_0}\right) - \underline{g} \cdot \underline{l_0}$$

Big assumption:

$$\underline{a_{aero}} = -k\underline{v_0}$$

Outcome is expression for <u>a-aero</u> using known quantities

$$\underline{a_{aero}} = \frac{-\underline{v_0}}{\underline{v_0} \cdot \underline{l_0}}\left[\frac{1}{dt}\left(\underline{v_1} \cdot \underline{l_0} - \underline{v_0} \cdot \underline{l_0}\right) - \underline{g} \cdot \underline{l_0}\right]$$

Next steps

- Find f(t) for Phoenix direct-to-Earth link
- See if this technique works
- Compare to results of accelerometer-based reconstruction
- Objective is proof-of-concept, not best possible accuracy
- This may have the potential to be a useful tool supporting many future landers (eg MSL)