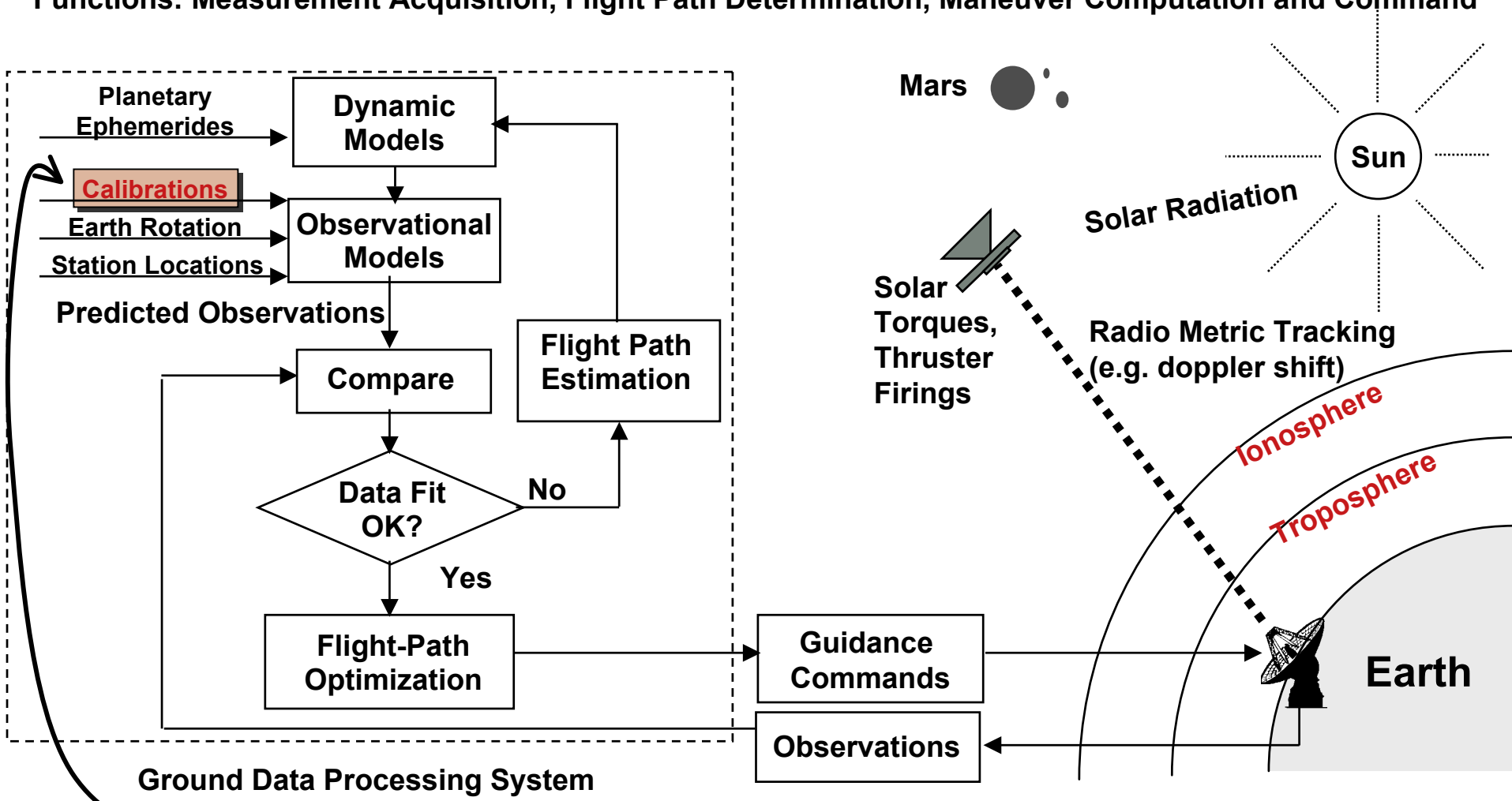
Deep Space Navigation System

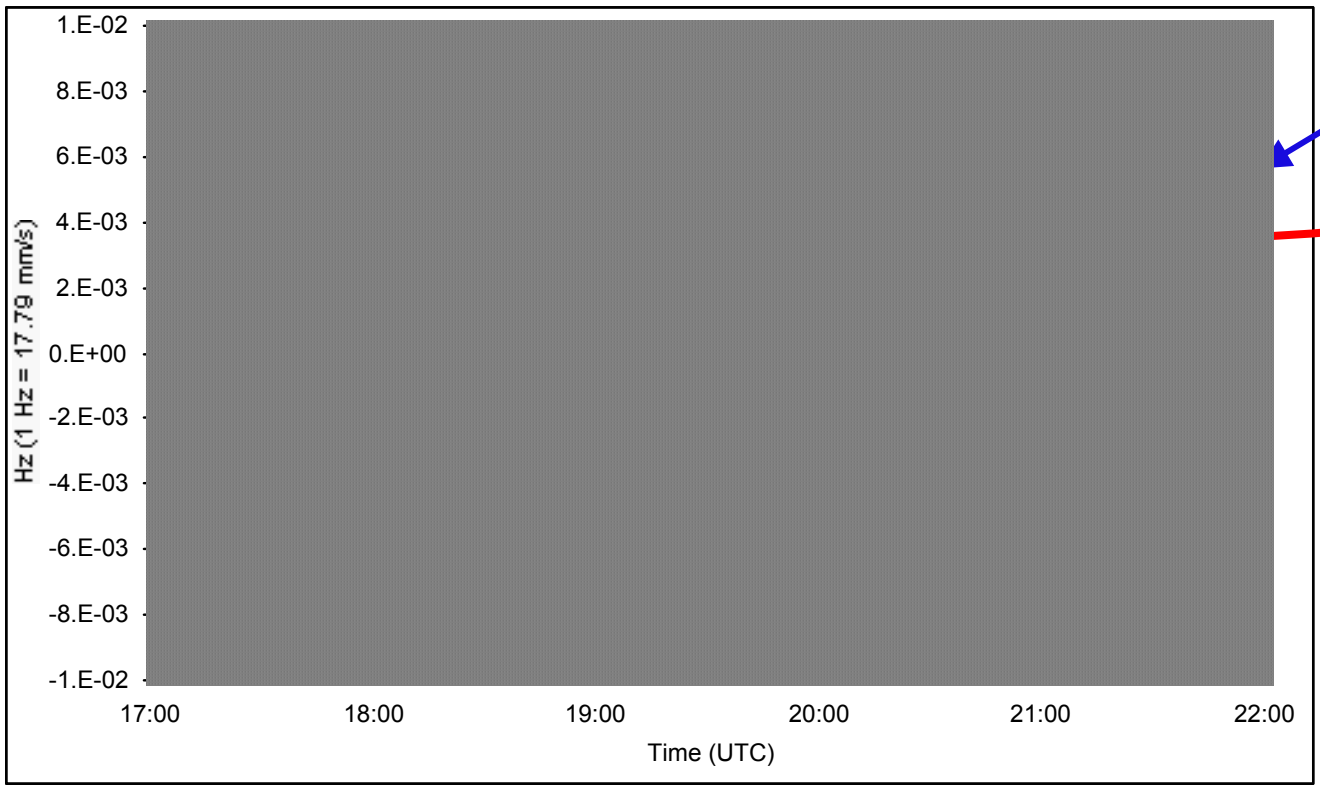
Functions: Measurement Acquisition, Flight Path Determination, Maneuver Computation and Command



NOTE: **Calibrations** must account for ionospheric delays

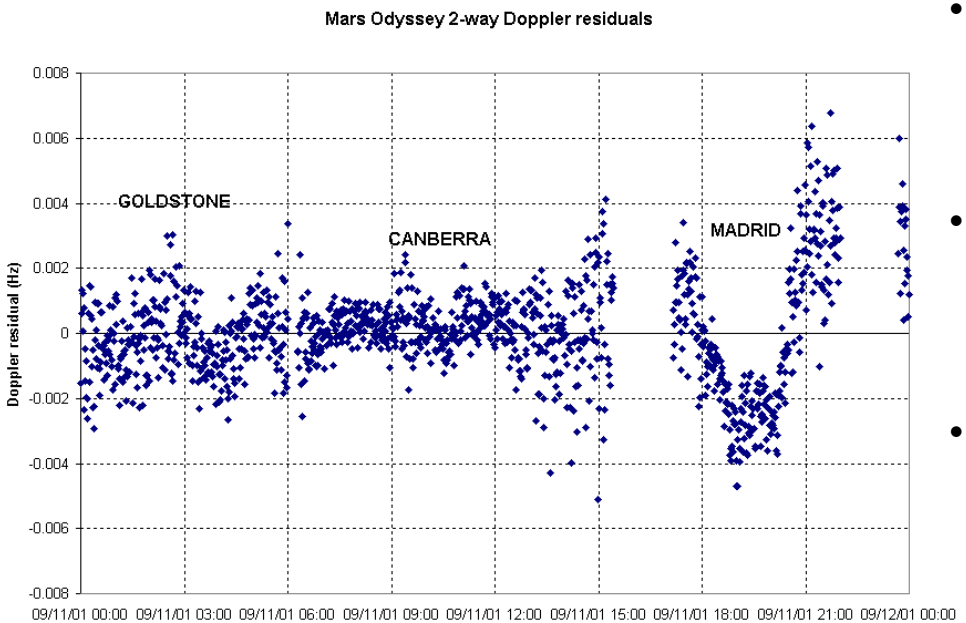
Ionospheric Effect in Mars Odyssey Tracking Data: 'Snakelike' Signature

- Unexplained signature appeared in Mars Odyssey tracking data (2001)
- Signature has ~10 mHz peak-to-peak amplitude in Doppler residuals
  - For well-modeled Doppler, residual scatter is 1-2 mHz (1-sigma)
  - DSMS commitment level is 6 mHz 1-sigma
- Undulations can be abrupt or evolve over 1-2 hours
- Signature not obviously in phase with any known ground, spacecraft activity
- 'Snakelike' signature strongest in Madrid passes, smallest in Canberra passes



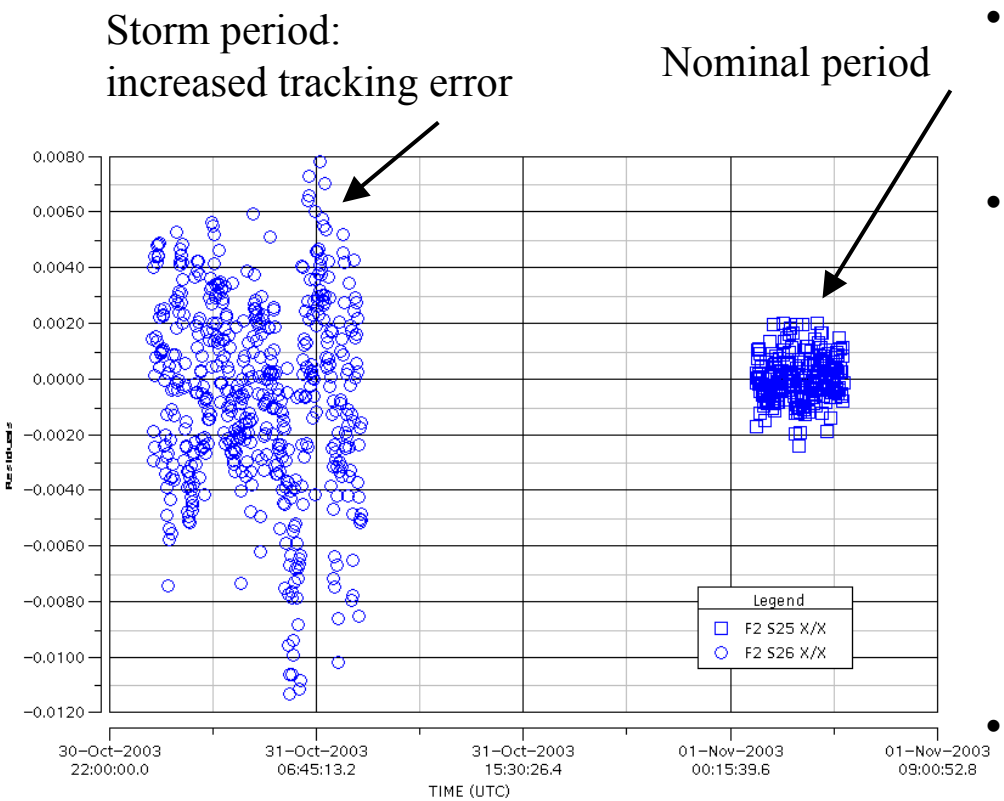
Ideally, these residuals should be a flat straight line

Mars Odyssey Residuals Compared



- Doppler residuals much more pronounced at Madrid, affecting entire pass
- Determined later that inadequately modeled ionosphere was the cause
  - Planetary geometry required low-elevation passes from Madrid
- Negligible improvement from state-of-the-art calibrations applied later
  - Tracking through low-latitude equatorial anomaly from Madrid is challenging
- Significant improvement requires sophisticated “data assimilation” approaches
  - Similar to numerical weather prediction models
  - Research has begun with Global Assimilative Ionosphere Model (GAIM)
  - Much more research needed

Impact of Ionospheric Storms on Spacecraft Tracking



- **Radiometric data acquired for Mars Exploration Rover S/C during Halloween 2003 storms**
- **Using state-of-the-art calibrations, tracking degraded by at least a factor of 5**
  - **Degradation affected entire 8-hour tracking pass**
  - **Several tracking stations were affected (likely)**
  - **All tracking data from storm period was rejected**
- **Geomagnetic storm effects could be critical depending on operational needs for exploration initiative**

LWS Contribution

- Media calibration is currently the largest source of DSN tracking error (primarily the ionosphere and some solar plasma and troposphere)
- LWS will improve scientific understanding of mid-latitude ionospheric storms
  - Tracking sites reside in Madrid, Goldstone, CA and Canberra, Australia
- Geospace ITSP and Ionospheric Imager will develop improved scientific understanding which will be incorporated into real-time capable models
  - Assimilative ionospheric models must be coupled with magnetosphere and thermosphere models and validated with ITSP and Imager
- Validated assimilative models can use existing GPS global ground networks with other real-time data inputs to create operational capability
- Process yields increased accuracy and robustness of radio-metric tracking for unmanned and manned Mars exploration
  - Improved modeling may be critical to reach exploration objectives