Deep Space Navigation System

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

Ground Data Processing System

- Planetary Ephemerides
- Earth Rotation
- Station Locations
- Predicted Observations
- Dynamic Models
- Observational Models
- Compare
- Flight Path Estimation
- Data Fit OK?
- No
- Yes
- Flight-Path Optimization
- Guidance Commands
- Observations

Calibrations must account for ionospheric delays

NOTE: Calibrations must account for ionospheric delays
• 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
• 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