Current/Future TT&C at NASA

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Mars Exploration Program

2001 - 2012
- Mars Odyssey
- Mars Express (ESA)
- Mars Reconnaissance Orbiter
- Mars Exploration Rovers
- Phoenix
- Mars Science Laboratory

2013
- MAVEN
- ExoMars/TGO 2016 (ESA)
- InSight

Future Mars Missions
- ESA Collaborations
- Mars Orbiter
- ExoMars 2016 EDM (ESA)
- ExoMars 2018 Rover/Lander (ESA)
Mars Mission Plans

- NASA MAVEN – 2013
  - Mars Atmosphere and Volatile EvolutioN. Investigate the physics, chemistry, and dynamics of the upper atmosphere, the effects of solar wind and radiation, and the escape of volatiles to space
  - Partnership between the PI (UC Boulder), NASA/GSFC as the mission center, and Lockheed Martin as the spacecraft system contractor and carries Single String Electra relay payload
- NASA INSIGHT – 2016
  - Re-flight of the Phoenix Lander with MAVEN Avionics; Planned as Relay only mission using CE-505 Radio
- ESA Trace Gas Orbiter (TGO) – 2016
  - Search for evidence of methane and other atmospheric gases that could be signs of active biological or geological processes.
  - NASA provides Orbiter Electra Radio payload
- ESA TGO Entry, Descent, and Landing Demonstrator Module (EDM) – 2016
  - ESA TGO delivers the EDM to the surface of Mars, to demonstrate key technologies for landing on Mars.
- ESA ExoMars Rover + Lander – 2018
  - Search for evidence of extant and extinct life featuring a deep drill up to 2 m to collect samples; Lander contains scientific instruments to investigate the Martian environment.
  - Two flight elements: Roscosmos built Lander delivers ESA Rover to the surface
- NASA Mars 2020 Rover
  - Science Rover based upon proven guided MSL Entry, Descent, and Landing Technology
Current Project Status

- MAVEN:
  - On schedule to launch this Fall 2013
  - Now in Environments Testing in Denver

- MSL:
  - Analyzing first drilled rock materials in Yellowknife Bay;

- MRO:
  - Detecting new areas of Recurring Slope Lineae (RSLs), e.g., in Valles Marineris
  - SHARAD returning to operations

- ODY:
  - Successful transition to Side B
  - Continuing to fill gores in THEMIS coverage
  - Drifting to later local times

- MEX:
  - Finished period of good radar coverage (periapsis in the dark)

- MER-B:
  - Finishing Cape York survey
  - Preparing to start move to Solander Point

- INSIGHT
  - Project enters Phase C in Fall 2013
Mars Network Relay Performance

- Curiosity is returning large amounts of science data via an international network of Mars relay orbiters
  - Over 132 Gigabits of data returned through Sol 238
  - Averaging over 1/2 Gb/sol, well above MSL project requirements

- **MRO:**
  - High performance relay based on new Electra UHF Transceiver capabilities
    - Adaptive Data Rate (ADR)
    - Operations over Multiple Frequencies
    - Higher Data Rates ... up to 2 mbps

- **ODY:**
  - Real-time data return during MSL EDL
  - Continues to serve as the workhorse relay orbiter for Opportunity

- **MEX:**
  - Tracking of MSL carrier during EDL
  - Backup relay asset for Curiosity surface ops – conducting monthly demonstration relay passes to verify MSL-MEX telemetry and command functions

All Passes Through Sol 238

<table>
<thead>
<tr>
<th></th>
<th>ODY</th>
<th>MRO</th>
<th>Total</th>
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<tbody>
<tr>
<td>Total # Passes</td>
<td>438</td>
<td>425</td>
<td>863</td>
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<tr>
<td>Total Data Return (Gb)</td>
<td>32.5</td>
<td>99.8</td>
<td>132.3</td>
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<td>Average # Passes/sol</td>
<td>1.84</td>
<td>1.79</td>
<td>3.63</td>
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<td>Average Return Data Vol/Sol (Mb)</td>
<td>136.68</td>
<td>419.31</td>
<td>555.99</td>
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<tr>
<td>Average Return Data Vol/Pass (Mb)</td>
<td>74.27</td>
<td>234.81</td>
<td>309.08</td>
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Over 500 Mb/sol average
MSL data return

TTC-2013 10 – 12 Sept. ESA-ESOC
Future Mars Comm. Challenges

- ExoMars TGO 2016 is crucial to the continuation of Mars Network
  - Consider Existing Mars Orbiter ages by 2020
    - ODY 20
    - MRO 15
    - MAVEN 8
- Agency cross-support through CCSDS standards will continue to enable missions
  - After EDL, 4-SOL TGO EDM mission will be solely supported by NASA orbiters
  - CCSDS Optical Comm. WG begins in Fall 2013
- Near and Longer Term Challenges
  - InSight and MSL will be in close proximity – Separate Relay overflights will be allocated
  - Internetworking – Using Delay Tolerant Networking (DTN)
    - Data Rate Goal is ¾ Gbit/sec at minimum Mars Distance .4 AU (Factor 10x greater than Ka-band capability on MRO)
    - Spacecraft Optical Terminal of comparable mass & power as MRO Ka-band system
Possible Comm System Improvements

- **5m Deployable Spacecraft Antenna**
  - Factor of 2.8 over today

- **High Power S/C Transmitter**
  - 180W

- **Advanced Coding & Compression**
  - Factor of 5 over today

- **Ka-Band Deployment on all Assets**
  - Factor of 4 enabled by Next Gen DSN

- **Next Gen DSN (array equivalent to 7 34m Antennas)**
  - Factor of 7 over today

- **Next Gen DSN (array equivalent to 3 34m Antennas)**
  - Factor of 3 over today

**Current Spacecraft and DSN**
- (SC: 100W, X-band, 3m antenna, std coding  DSN: 34m antenna)
“Garden of Interplanetary Delights” - 2025

- Dedicated Mars Relays
- Mars Local Network
- Operational Optical Stations
- DSN Arraying
- Lunar Relays
- Lunar Local Network
- Human Missions
- Cat A Missions
- Formation Fliers and Primitive Body Missions
- Outer Planets Missions
- Point-to-point RF links
- Point-to-point Optical links