Mars Network -
A Telecommunications and Navigation Infrastructure for Mars Exploration

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Mars Telecommunications Overview

- Communications is a key challenge for in situ exploration
  - Earth-Mars link is $10^8$ times more challenging than a GEO comsat link

- Telecommunications relay orbiters offer high-rate, energy-efficient links for Mars exploration
A Decade of Mars Exploration

2001: Mars Odyssey
2003: Mars Express (ESA)
2005: Mars Reconnaissance Orbiter
2007: Mars Science Laboratory
2009: Mars Telesat Orbiter
Program Drivers on Telecommunications Infrastructure

- Increased Science Data Return for MSL-Class Landers
- Enabling Energy-efficient Relay for Scout-class Missions
- Robust Capture of Critical Event Tracking and Telemetry
- Public Engagement - Creating a Virtual Presence at Mars
- Precision in situ Navigation and Positioning
- Increased Comm Contact for Complex Surface Operations
**Mars Network Evolution**

**STRATEGY ELEMENTS:**
- Standardized relay telecommunications protocols
- Relay payload on every science orbiter for low-cost early network
- Dedicated Telesat offering breakthrough capabilities for MSL and next-decade
- Redundant relay orbiters for support of each surface campaign

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**Timeline:**
- **Launch MOI**
- **Science & Relay**
- **Extended Mission**

**Orbiters:**
- **MGS**
- **Odyssey**
- **Mars Express**
- **MRO**
- **Mars Telecomm Orbiter**

**Dates:**
- '03 MER-A/B
- Beagle-2
- '07 Phoenix Scout
- '09 MSL
QuickTime™ and a TIFF (Uncompressed) decompressor are needed to see this picture.
As of March 9, 2005, over 100 Gbits of MER data have been returned via UHF relays through Odyssey and MGS – 97% of total MER data return

New CCSDS Proximity-1 space communications protocol
– Provides for reliable, gap-free relay link
– Establishes international standard for relay services

Successful MER - Mars Express relay demonstration
– Validates NASA-ESA interoperability
– Establishes an international relay infrastructure

In situ positioning based on UHF doppler tracking
– < 30 m (3-sigma) MER position determination using 2-way coherent UHF tracking measurements on Odyssey
Direct-to-Earth X-band Semaphores
(~1 bps effective data rate)

Critical Deployments

UHF Relay to MGS
(8 kbps)

UHF Relay to ODY
Network Evolution: Mars Reconnaissance Orbiter

• Launch in 2005
• Low altitude science orbiter
• Electra UHF Transceiver
  – Standardized CCSDS Prox-1 Protocol
  – Flight-reprogrammable
  – Frequency-agile
  – Improved coding and modulation
• High-performance DTE link
  – X-band primary (3m, 100W)
  – Ka-band demo (3m, 35W)
• Initial use of CCSDS File Delivery Protocol (CFDP)
  – End-to-end data accountability
Network Evolution:
Mars Telecommunications Orbiter

• High-altitude telesat orbit
  – Increased contact time, critical event coverage

• High-performance relay links
  – Electra Proximity Link Payload
  – Addition of X-band (8.4 GHz) receive capability for high-rate directional relay links
  – 15 dBi steered UHF antenna; 50 cm steered X-band MGA

• Multiple DTE links
  – X/Ka-band prime
  – Optical comm demo
Electra Proximity Link Payload

- Standardized communications protocols
- Multiple proximity link services
  - Command (forward)
  - Telemetry (return)
  - Radio metrics
  - Timing
- Flight-reprogrammable “software radio” architecture
- Frequency-agile for multi-link environment
Communications Protocols

- **CCSDS Proximity-1 Space Link Protocol**
  - Provides international standards for the physical and data link layers for Mars proximity communications
  - First implemented on Mars Odyssey followed by Beagle2, Mars Express, MER A/B; will be used by MRO, Phoenix, MTO, and MSL
  - Key for achieving interoperability among multiple Mars landers and orbiters

- **CCSDS File Delivery Protocol (CFDP)**
  - Provides reliable and complete end-to-end file delivery
  - Addresses unique aspects of deep space communications
    - Long RTLT
    - Intermittent connectivity
    - High BER links
    - Multi-hop store-and-forward relays
    - Custody transfer to minimize onboard storage rqmts

- **Full documentation at** [http://www.ccsds.org](http://www.ccsds.org)
Next Decade and Beyond…
Summary

• The sustained exploration of Mars drives the need for an orbital telecommunications infrastructure
  – Increased data return and contact time
  – Robust critical event coverage
  – Energy-efficient relay
  – In situ navigation

• Key strategies
  – Improved DTE performance
  – Relay capability on every Mars science orbiter
  – Reprogrammable Electra proximity link radio
  – Standardized comm protocols
  – Dedicated Telesat to provide breakthrough capability
Backup
MTO Telecommunications Capability

- **Scout-Class Lander UHF**: 128 kbps (80 Mb/sol)
- **Critical Event Monitor UHF**: 1 - 16 kbps
- **MSL-Class X-band**: 4 Mbps (up to 56 Gb/sol)
- **MSL-Class UHF**: 256 kbps (up to 1 Gb/sol)
- **MRO X-band**: 5.3 Mbps (115 Gb/6 hrs)
- **100 W X-band**: 0.4 - 4 Mbps
- **35 W Ka-band**: 0.5 - 10 Mbps
- **5 W Laser**: 1 - 30 Mbps
- **100 W X-band**: 0.4 - 4 Mbps
- **Critical Event Monitor UHF**: 1 - 16 kbps
- **MSL-Class UHF**: 256 kbps (up to 1 Gb/sol)
- **Scout-Class Lander UHF**: 128 kbps (80 Mb/sol)

- **Laser**: 1 - 30 Mbps
MTO Coverage

- High telesat altitude provides greatly improved coverage for critical events and for extended surface contacts.