Mars Network - A Telecommunications and Navigation Infrastructure for Mars Exploration

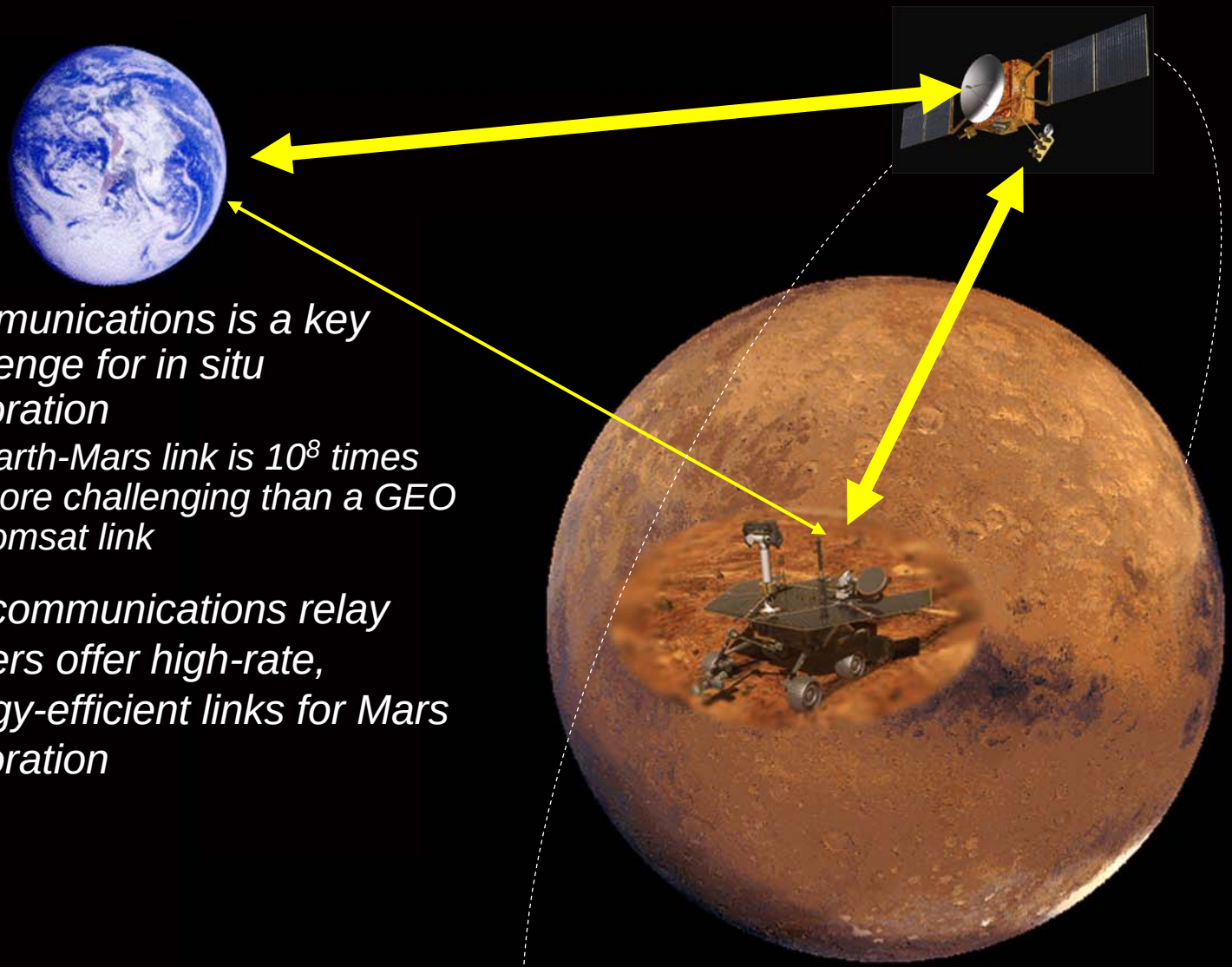
Chad Edwards

Chief Telecommunications Engineer, Mars Exploration Program

Jet Propulsion Laboratory, California Institute of Technology

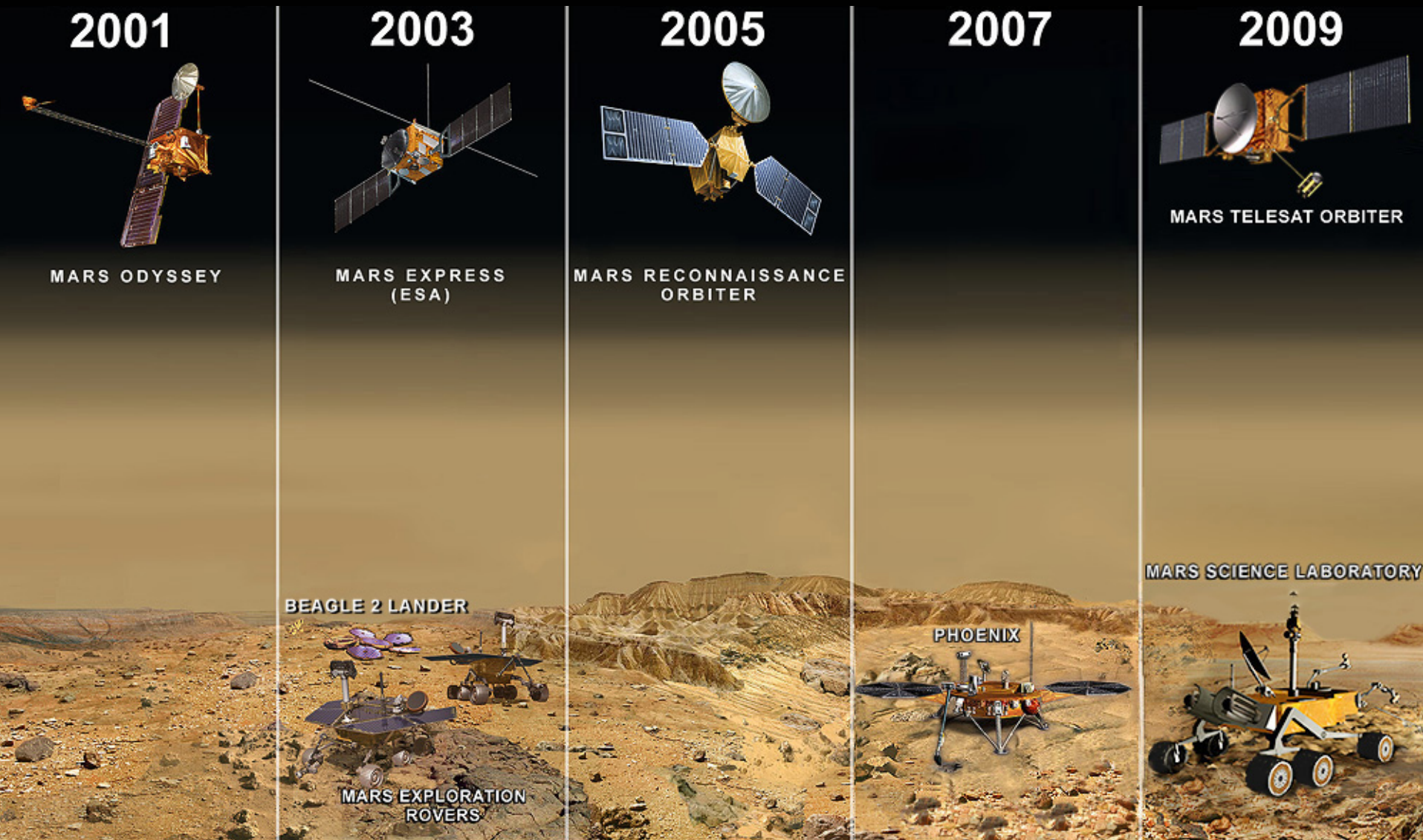
June 15, 2005

Mars Telecommunications Overview



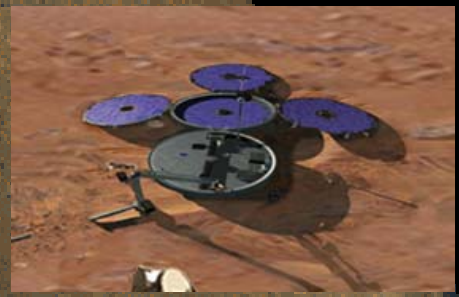
- *Communications is a key challenge for in situ exploration*
  - *Earth-Mars link is 10^8 times more challenging than a GEO comsat link*
- *Telecommunications relay orbiters offer high-rate, energy-efficient links for Mars exploration*

A Decade of Mars Exploration



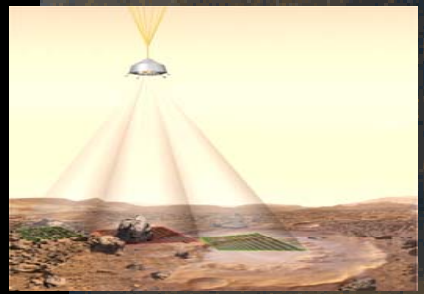
Program Drivers on Telecommunications Infrastructure

Increased Science Data Return for MSL-Class Landers

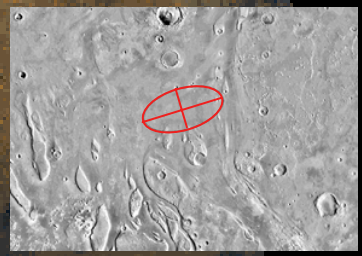


Enabling Energy-efficient Relay for Scout-class Missions

Public Engagement - Creating a Virtual Presence at Mars



Robust Capture of Critical Event Tracking and Telemetry

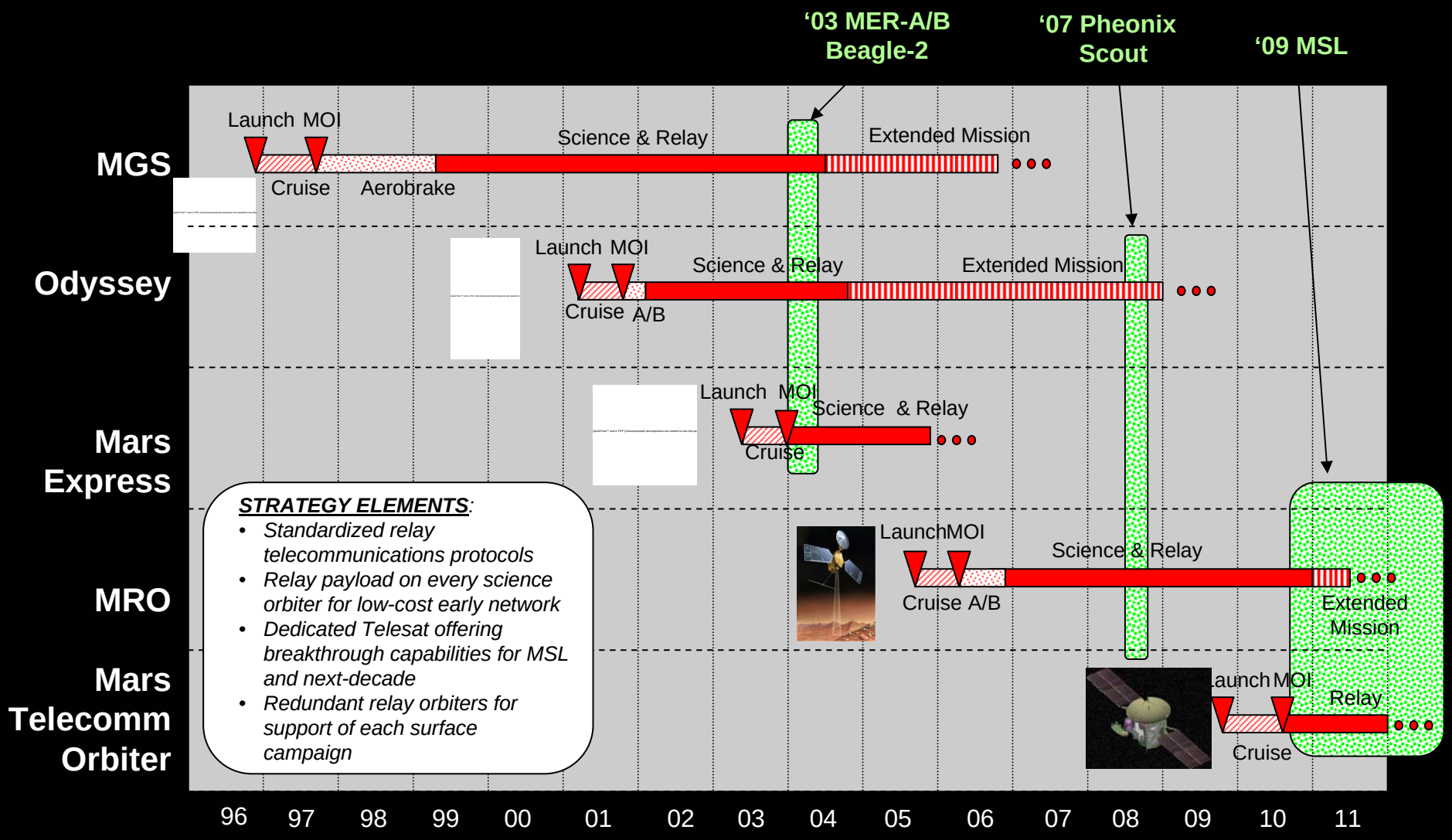


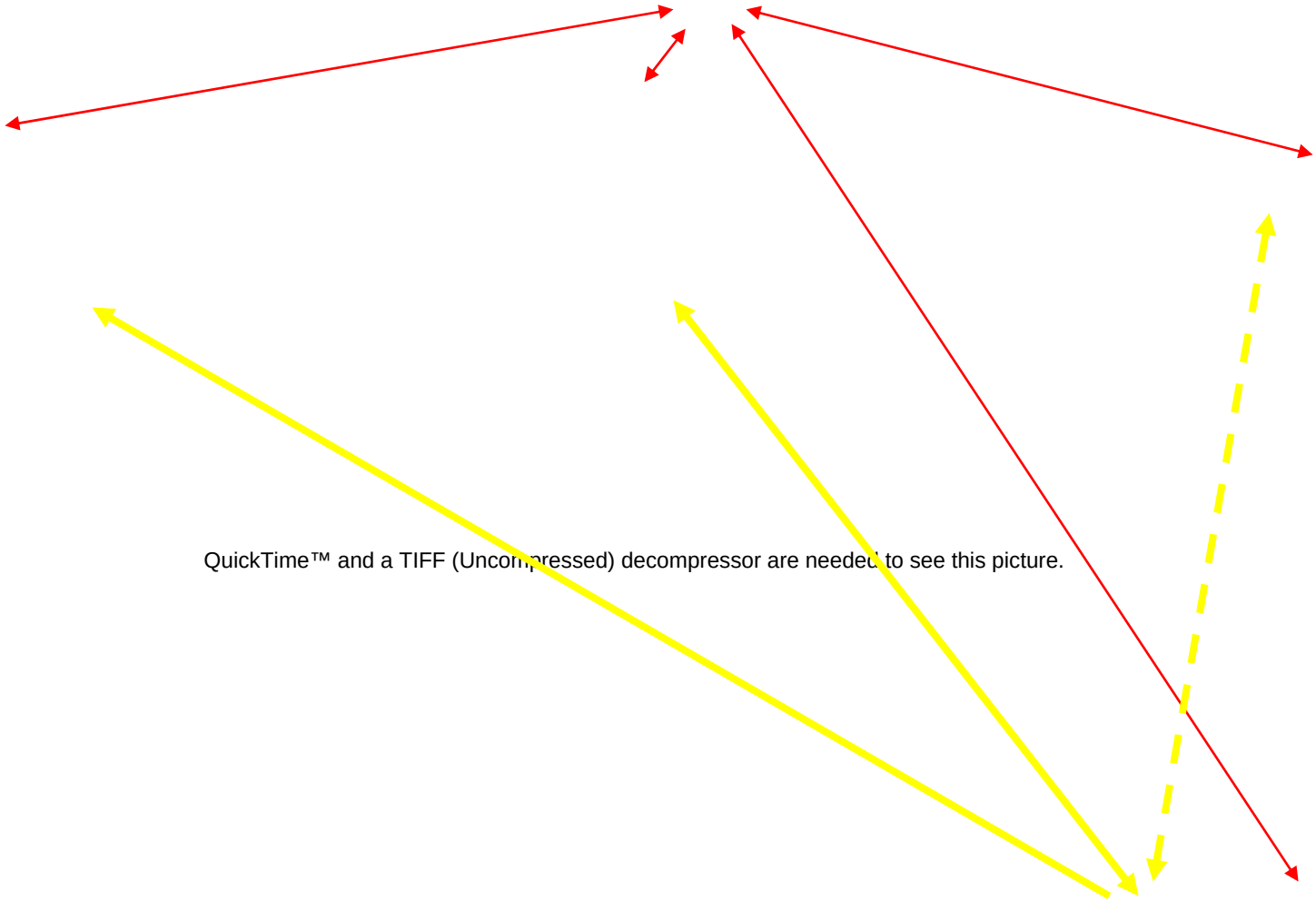
Precision in situ Navigation and Positioning

QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

Increased Comm Contact for Complex Surface Operations

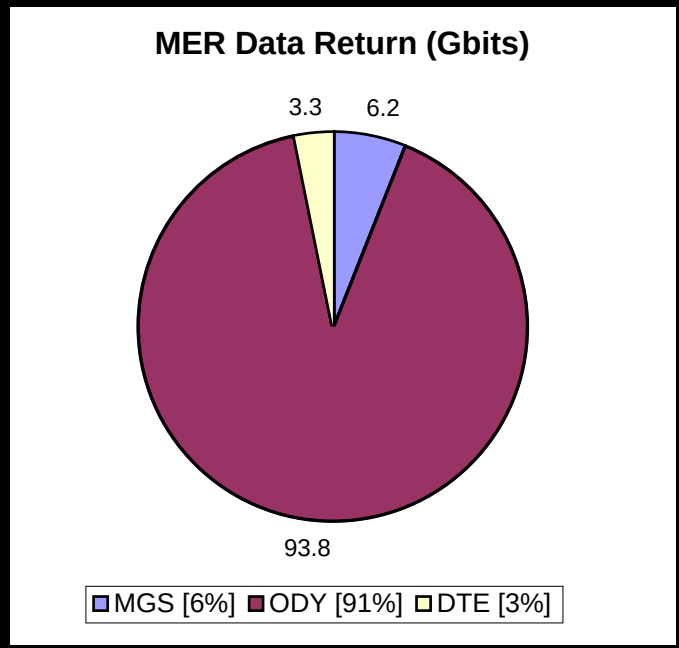
Mars Network Evolution

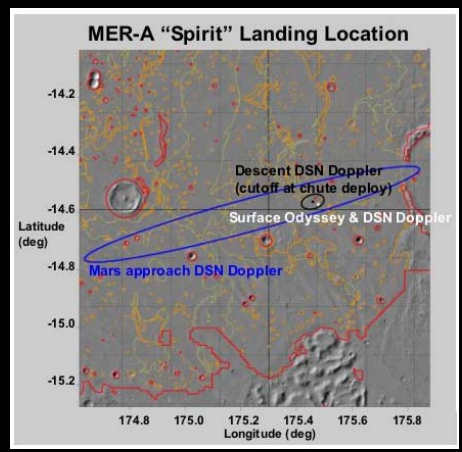



QuickTime™ and a TIFF (Uncompressed) decompressor are needed to see this picture.

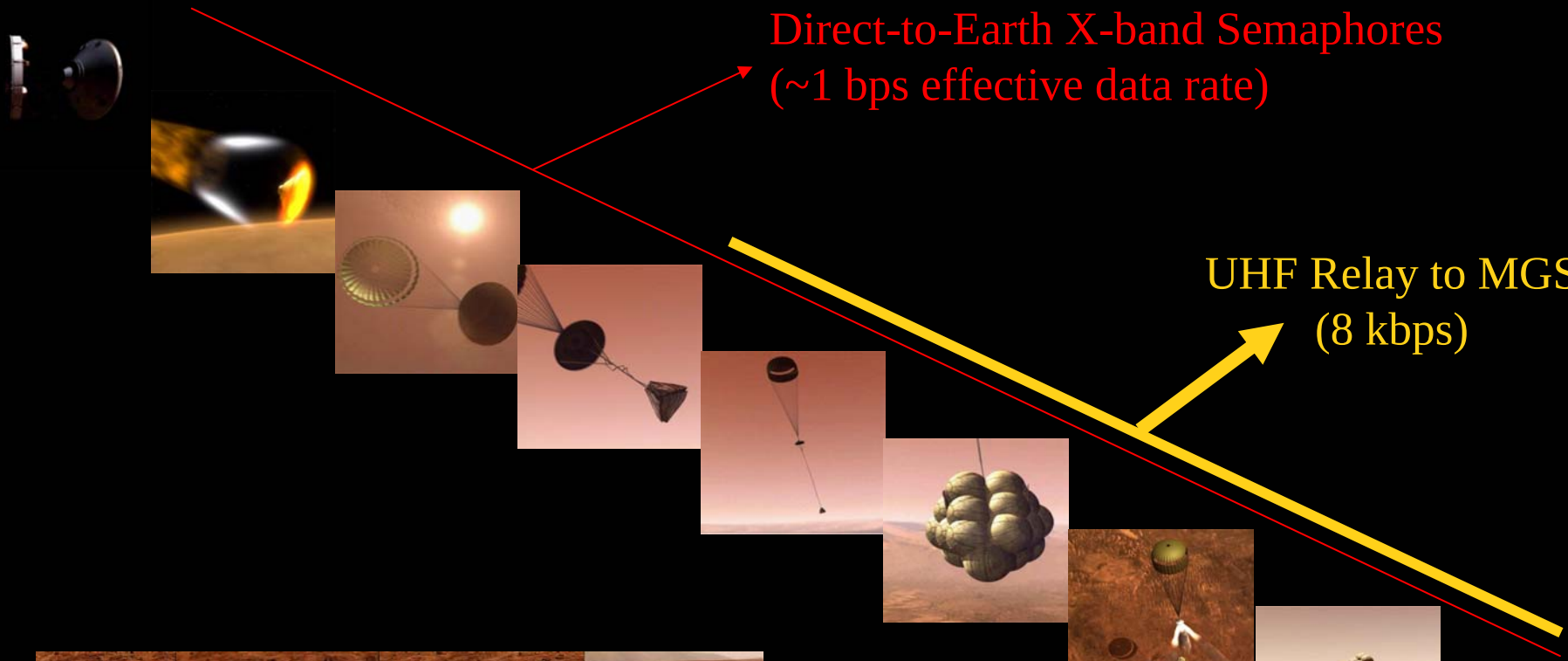
Spirit & Opportunity Surface Ops

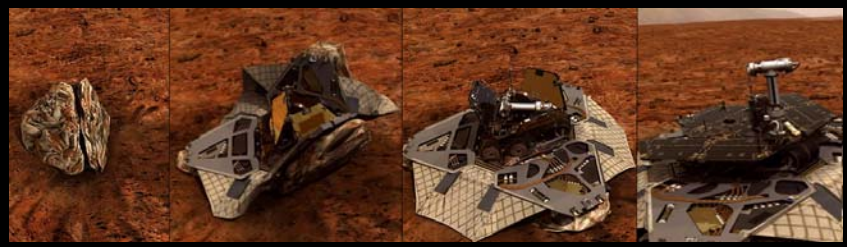
- **As of March 9, 2005, over 100 Gbits of MER data have been returned via UHF relays through Odyssey and MGS**
  - 97% of total MER data return
- **New CCSDS Proximity-1 space communications protocol**
  - Provides for reliable, gap-free relay link
  - Establishes international standard for relay services
- **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





MER Entry, Descent and Landing





Critical Deployments

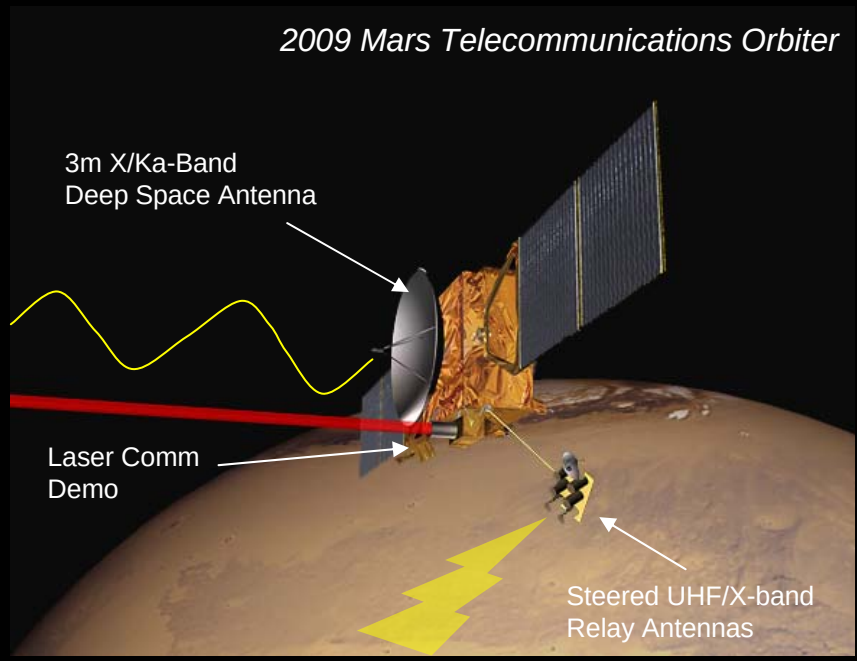
UHF Relay
to ODY

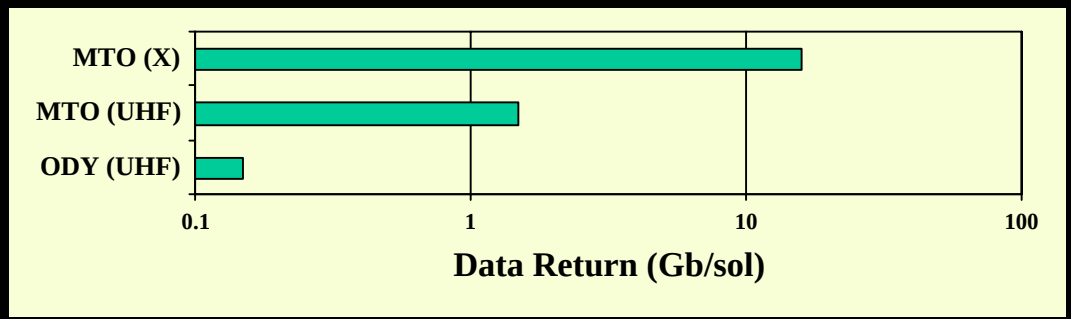
Network Evolution: Mars Reconnaissance Orbiter

- **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



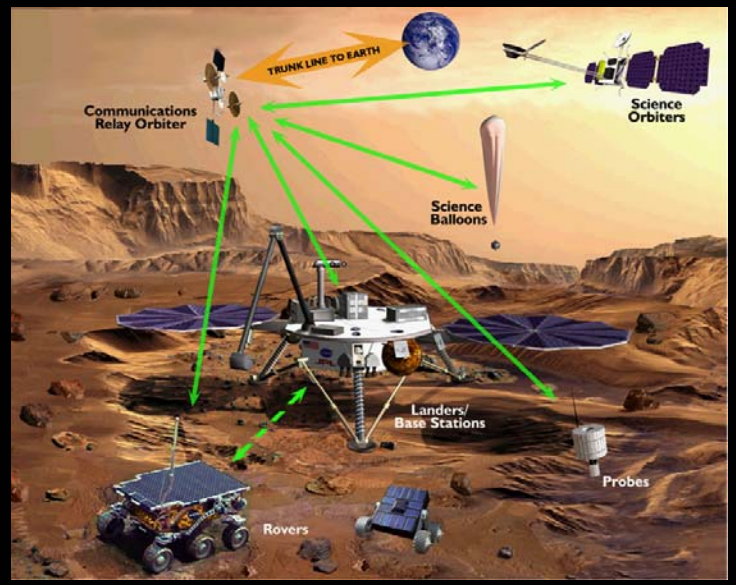


Electra Proximity Link Payload

- **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**

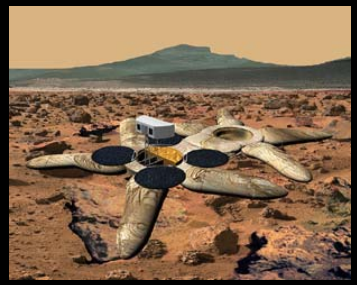
Communications Protocols

- **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

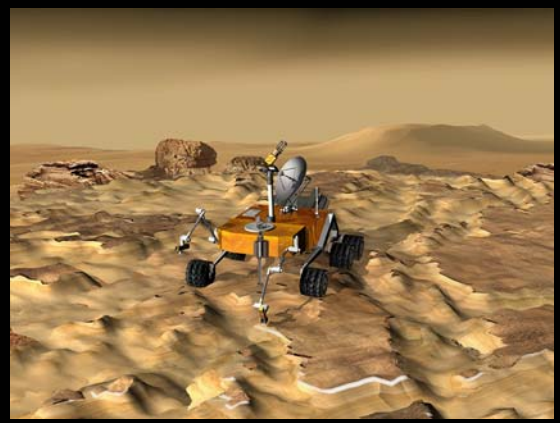


- **Full documentation at http://www.ccsds.org**

Next Decade and Beyond…



QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

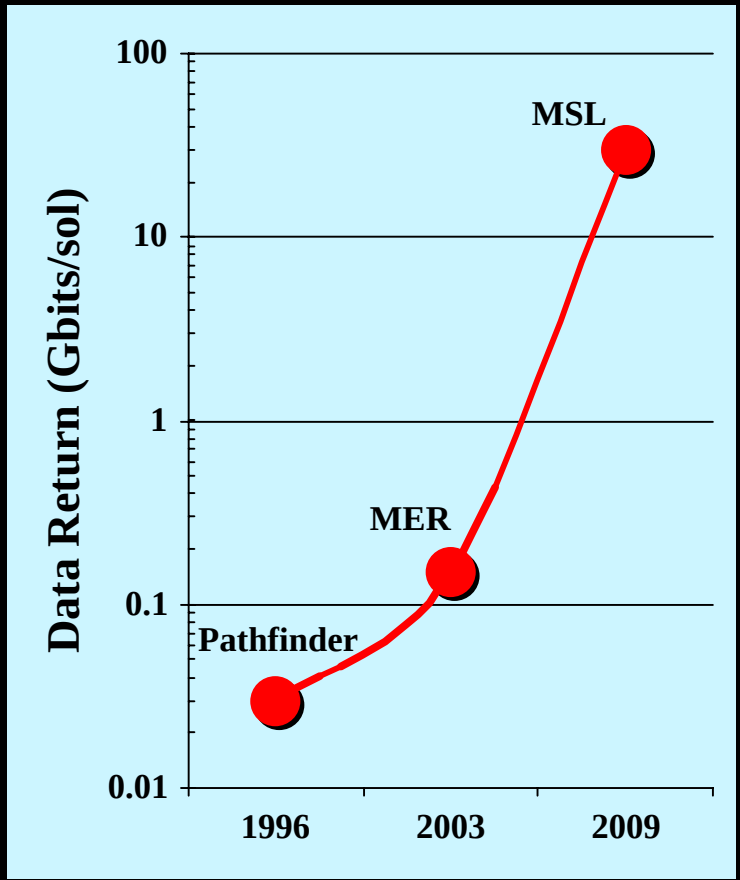


QuickTime™ and a TIFF (Uncompressed) decompressor are needed to see this picture.

QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

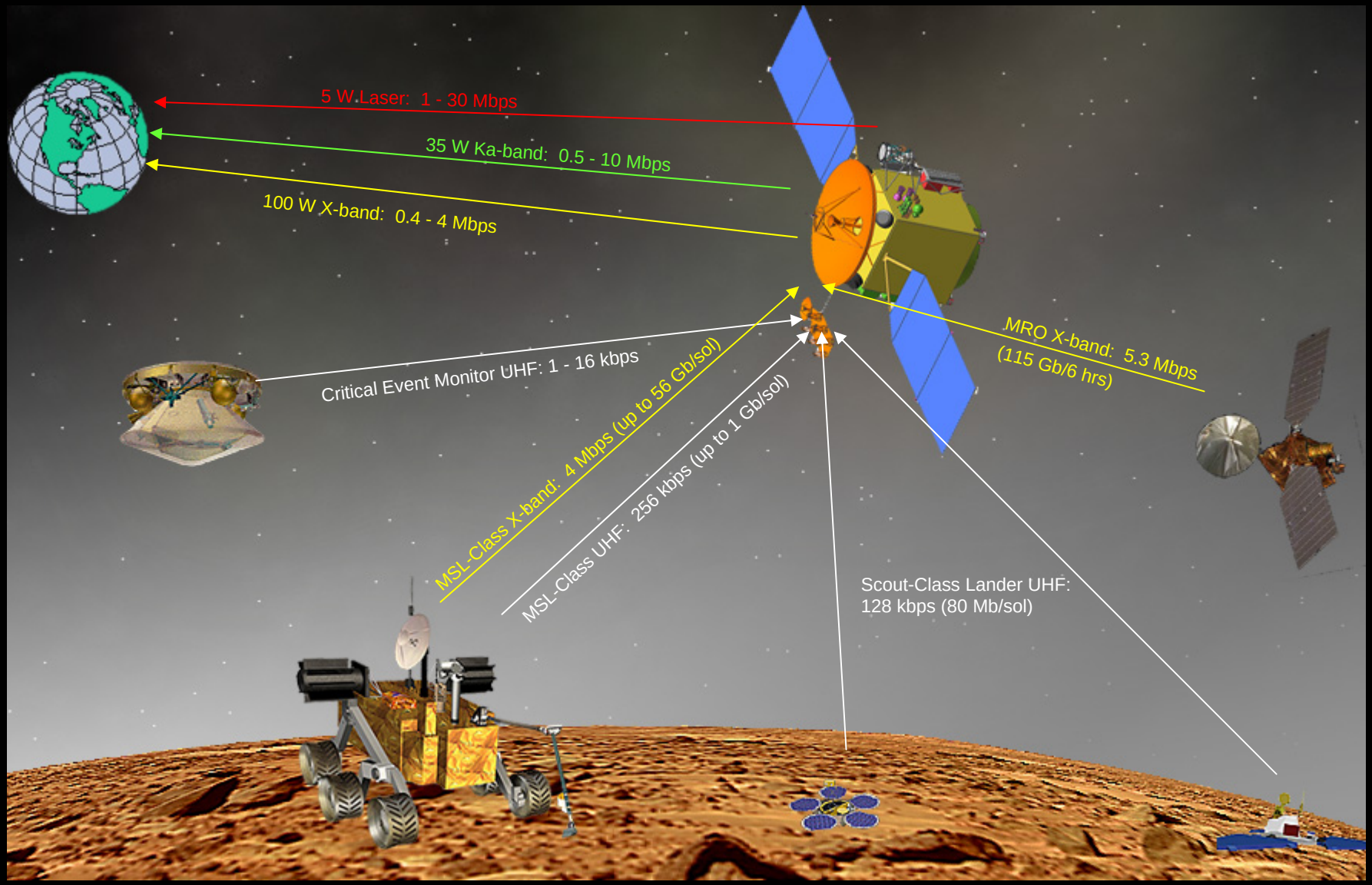
Summary

- **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



MTO Coverage

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