Mars Exploration Program Telecommunications Strategy

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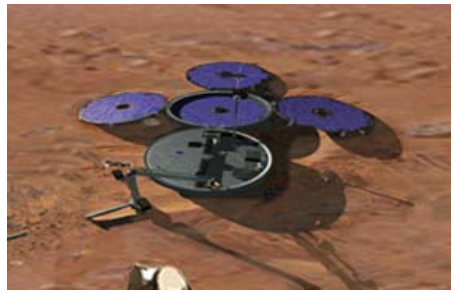
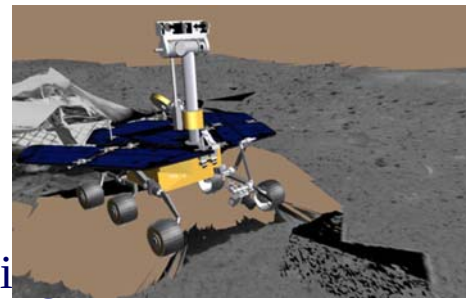
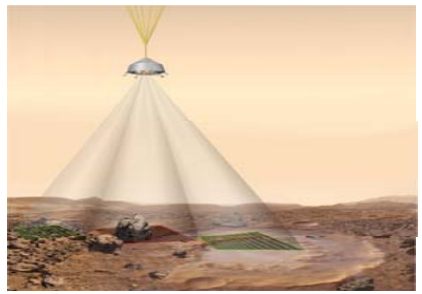
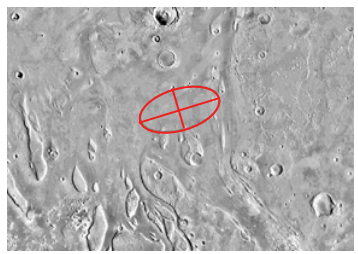
MEP Telecommunication Needs

- **Increased data return**
  - Augment comm bandwidth for high spatial/spectral/temporal resolution instruments
- **Energy efficiency**
  - Enable small, low-cost mission concepts
- **Connectivity**
  - Support interactive, *in situ* ops
- **Critical event telemetry**
  - Capture engineering telemetry duri high-risk mission phases
- **Radio-based navigation**
  - Utilize radio metric observables on comm links for *in situ* nav



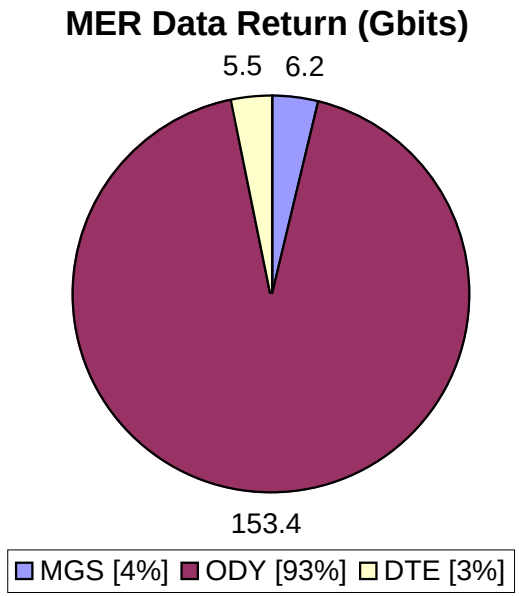


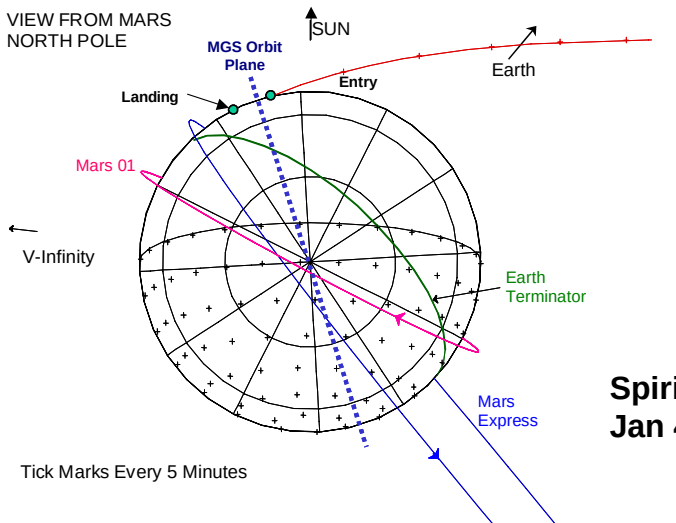




Relay Telecommunications Support to Spirit and Opportunity

- **The MER mission has demonstrated the benefits of relay communications for Mars surface exploration**
  - Mars Exploration Rovers have returned 165 Gb of data
    - 97% of MER data return has come via the ODY and MGS UHF relay paths
  - UHF also offered high-rate critical event comm during EDL
    - 8 kbps relay to MGS vs. 1 bps link to Earth





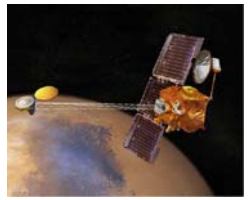
Spirit Arrival: Jan 4, 2004

MEP Telecom Study Objectives

The Mars Program Director has commissioned a study of the Mars program telecommunications strategy, in light of the cancellation of MTO:

- **Telecommunications drivers in the MEP,** including coordination with the Mars Exploration Program Analysis Group (MEPAG) Subgroup on next decade planning
- **Telecommunications needs derived from current mission requirements,** namely Phoenix and Mars Science Laboratory (MSL), and related telecommunications support scenarios through the period identified.
- **Options** on meeting the requirements of scientific return and command/telemetry, **including use of foreign and domestic assets currently at Mars.** Options must include anomalous entry of MRO, i.e. loss of mission, incorrect orbit, etc.
- **Options for orbit configuration** for MRO after the primary science phase. This should include orbit options, science impacts if instruments are operating, fuel and life-time consequences of orbit and/or plane changes, coverage comparisons for entry/decent/landing and surface communications, etc.
- Quantitative analysis of the **robustness and resource requirements** for communications infrastructure options
- **Recommendations** for this and the next decade's telecommunications infrastructure

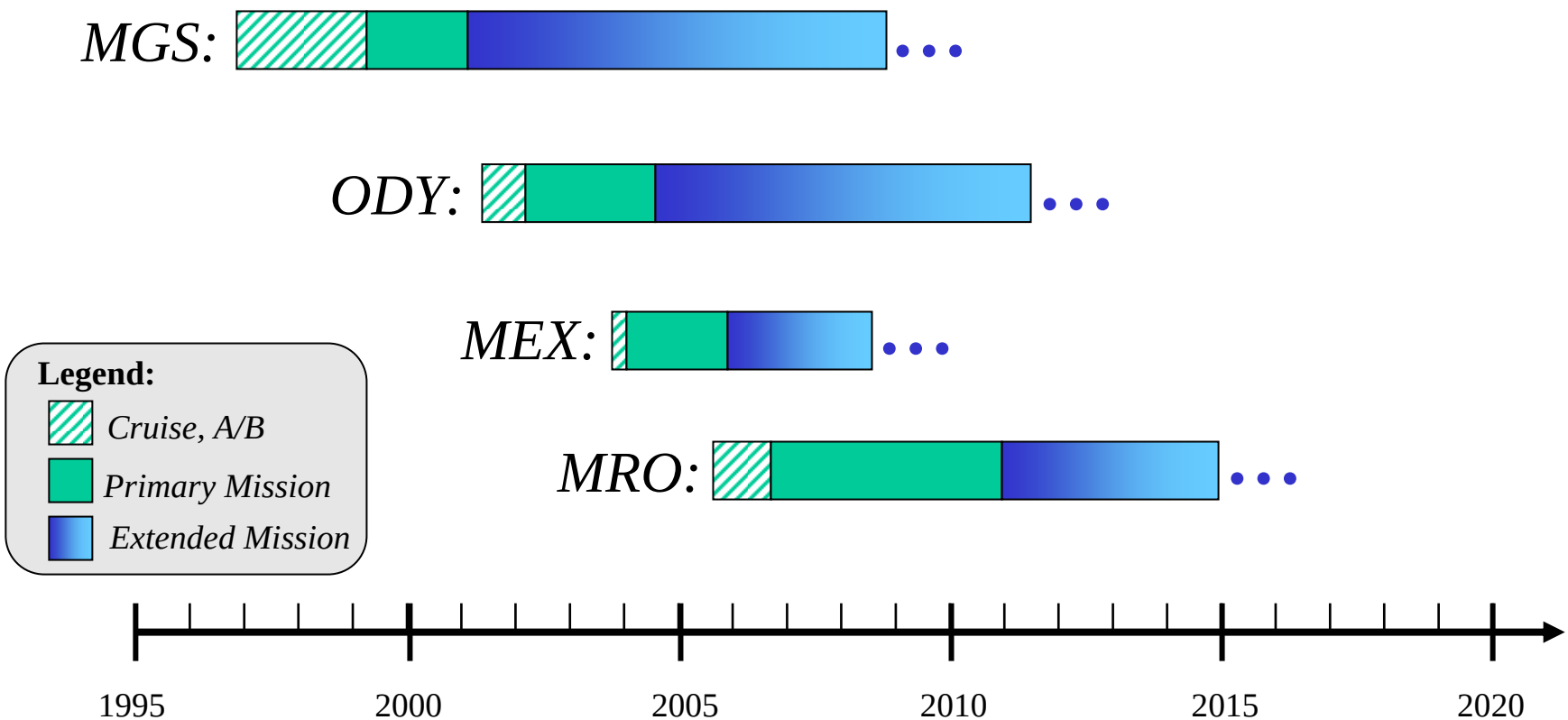
Mars Relay Network Orbiter Comparison



	Mars Global Surveyor	Mars Odyssey	Mars Express	Mars Reconnaissnace Orbiter
Agency:	NASA	NASA	ESA	NASA
Launch:	Nov. 8, 1996	April 7, 2001	June 2, 2003	Aug, 12, 2005
Mars Orbit Insertion:	Sep. 11, 1997	Oct. 24, 2001	Dec. 24, 2003	Mar, 2006
Orbit Characteristics:	~400 km circular sun-synch ~2 PM asc node 93 deg inclination	~400 km circular sun-synch ~5 AM asc node 93 deg inclination	250 x 10,142 km elliptical non-sun-synch 86.3 deg inclination	255 x 320 km sun-synch ~3 PM asc node 93 deg inclination
UHF Radio:	Mars Relay (CNES)	CE-505	Melacom	Electra
Link Protocol:	Mars Balloon Relay (MBR)	CCSDS Proximity-1	CCSDS Proximity-1	CCSDS Proximity-1
Forward Link:				
- *Frequency*	437.1 MHz	437.1 MHz	437.1	435-450
- *Data Rates*	n/a (MBR tones only)	8 kbps	2, 8 kbps	1,2,4, É , 1024 kbps
- *Coding*	n/a	uncoded	uncoded	uncoded or 7,1/2
Return Link:				
- *Frequency*	401.528711 MHz	401.585625 MHz	401.585625 MHz	390-405
- *Data Rates*	8, 128 kbps	8, 32, 128, 256 kbps	2,4, É ,128 kbps	1,2,4, É , 1024 kbps
- *Coding*	(7,1/2) Convolutional	(7,1/2) Convolutional	(7,1/2) Convolutional	(7,1/2) Convolutional

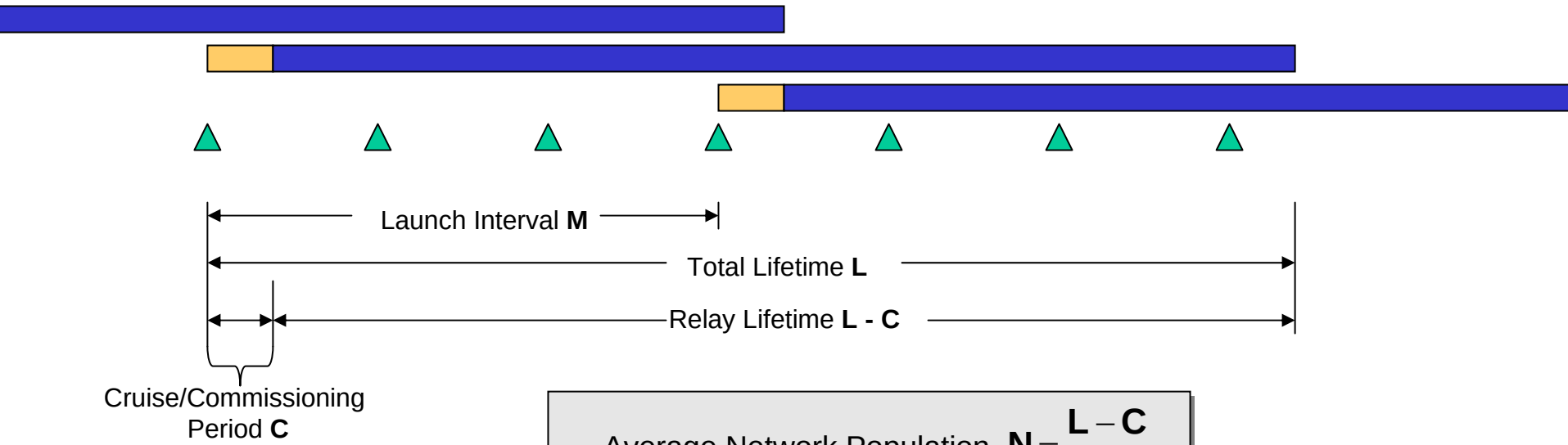
Relay Infrastructure Robustness

- **Existing set of orbiters provides robust coverage through current decade, but will require replenishment in the second decade**



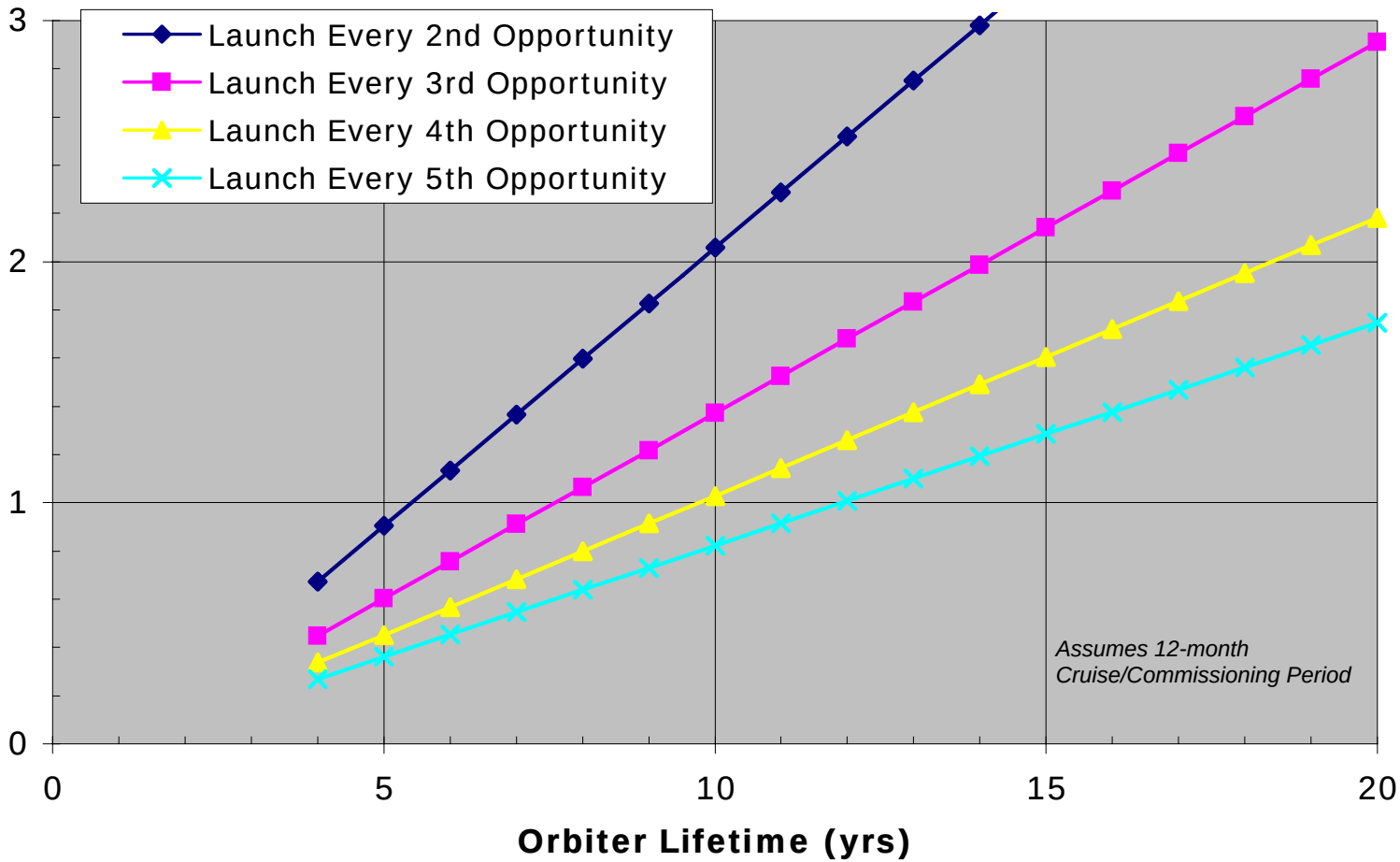
2nd-Decade Relay Planning

- **A robust infrastructure strategy would maintain a *nominal* population of at least 2 orbiters over time**
  - Avoids single-point failure for relay-dependent missions
- **Relay network occupancy will be a function of *lifetime* and *launch rate***



Average Network Population $\mathbf{N} = \dfrac{\mathbf{L} - \mathbf{C}}{\mathbf{M}}$

Relay Network Population



2nd-Decade Mission Concepts: Key Telecom Challenges

	AFL	Mid-Rovers	Geophysical Network	MSR
Number of assets	1	2	~4	Lander, Rover, MAV, OSC, ERV
Critical Events	Complex EDL	• Multiple, complex EDLs • Few weeks separation	• Multiple, low-complexity EDLs • All within ~1 sol	• Complex EDL • MAV Ascent • OSC Rendezvous • TEI
Telecom System Characteristics	MSL-class • UHF relay • X-band DTE/DFE (LGA?)	Redundant Electra-Lite (UHF-only)	• UHF-only • Highly constrained mass/energy • High-g landing	• Lander: UHF/X • Rover: UHF-only • MAV: constrained mass/energy
Data Volume Rqmts	MSL-class (250-1000 Mb/sol)	MER/MSL class (50-1000 Mb/sol)	40-50 Mb/sol (donÕ need daily contact)	MER-class (50-250 Mb/sol)
Surface Ops Concept	Complex ops w/ mobility	Complex ops w/ mobility	Simple static landers (weekly command load)	Short duration, complex surface ops

Legend		
Less challenging	◄——►	More challenging

Preliminary Architecture Comments

Initial architecture assessment based on nominal 10-year lifetime for each relay orbiter:

Redundant MRO/ODY support for MSL

'11/'13 Orbiter represents single-string relay for '16, '18, '20 opportunities

'22 Orbiter establishes core 3rd-decade relay infrastructure

2009	2011	2013	2016	2018	2020	2022	2024	2026
MSL	Scout	Science Orbiter + Telecom	Mid-rovers (2)	Scout	Geophysics Network	Science Orbiter + Telecom	MSR Orbiter + ERV	MSR Mobile Lander
	or	or	or			or		
	Science Orbiter + Telecom	Scout	AFL			Scout		

'01 ODY

'05 MRO

'11 Orbiter can support '13 Scout

Aging single-string relay support for '22 Scout

'MSR Orbiter can support MSR lander

'11 Sci/Telecom Orbiter

'13 Sci/Telecom Orbiter

'24 MSR Orbiter

'22 Sci/Telecom Orbiter

Program should place high priority in achieving >10 yrs operational lifetime from MRO, providing significant improvement in 2nd-decade relay robustness