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Communications Technologies for Planetary Science Missions

Chad Edwards

**Jet Propulsion Laboratory
California Institute of Technology**

March 6, 2013

Today's State of the Art



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- **Mars Reconnaissance Orbiter**
 - HiRISE (30 cm/pixel)
 - CRISM (18 m/pixel x 544 wavelength channels)
- **Telecom Specs**
 - 3 m HGA
 - X-band 100 W TWTA
 - Ka-band 35 W TWTA
- **Downlink Performance @ Max Earth-Mars Range (to DSN 34 m)**
 - X: 0.6 Mb/s
 - Ka: 0.5 Mb/s



Curiosity During EDL



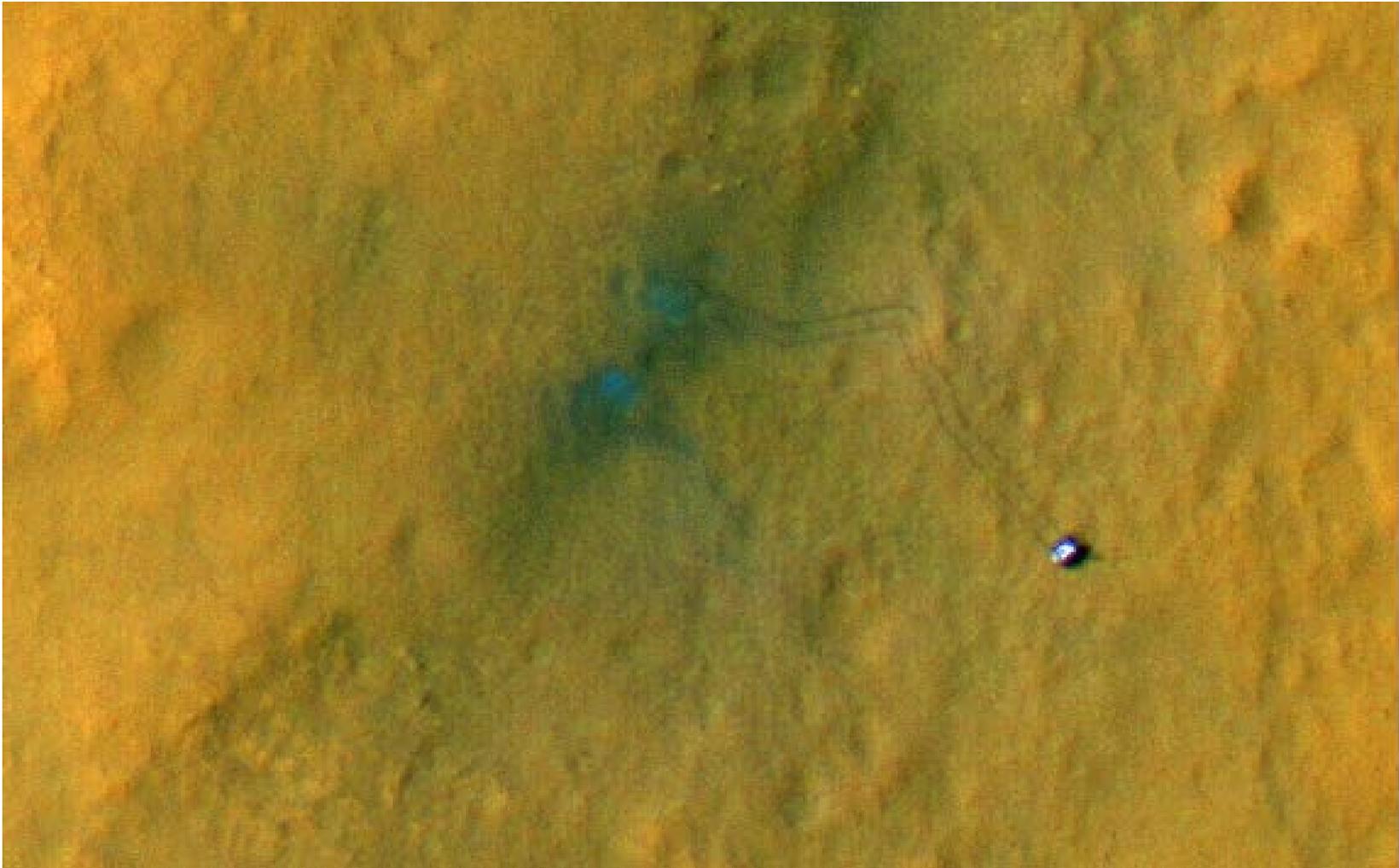
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Curiosity Roving @ Gale Crater



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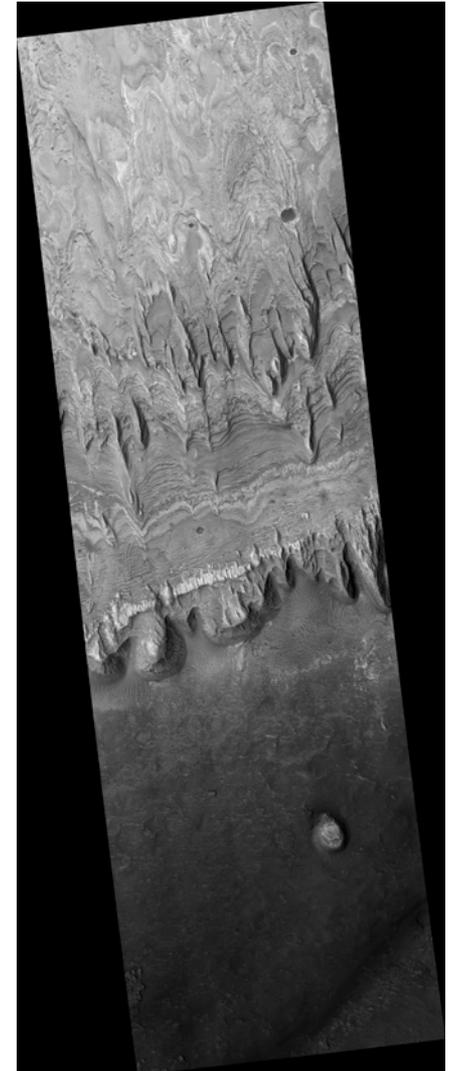
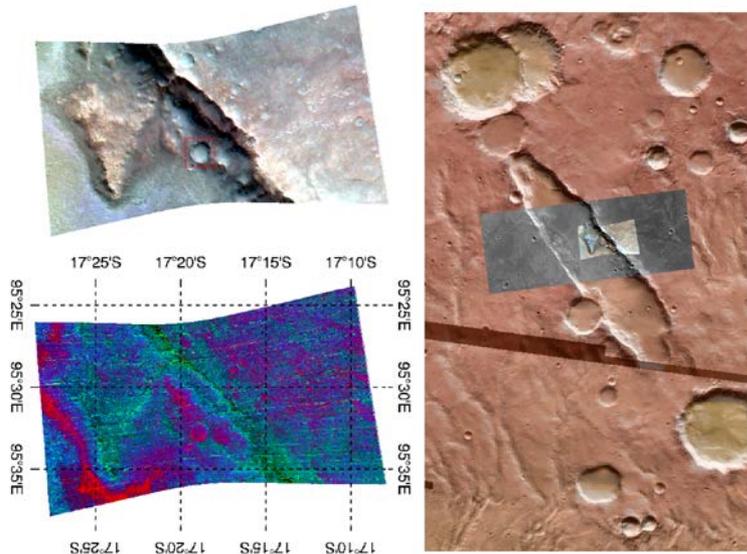


MRO Data Return



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- To date, MRO has returned over 187 Terabits of data – *more than all other planetary missions combined*
- Nonetheless, the MRO communications link still fundamentally limits hi-res mapping of Mars
 - More than 7 yrs after launch, MRO has only imaged ~2% of Mars at full HiRISE resolution



Pathways to Higher Performance: Ka-band

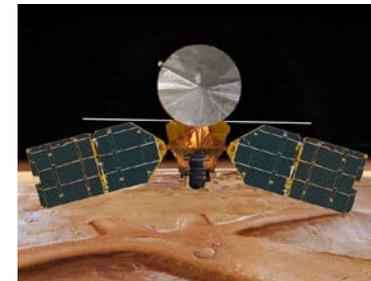


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- **Ka-band (32 GHz) offers significant advantages over X-band (8 GHz)**
 - Higher frequency -> higher antenna gain
 - Overall ~4-6 dB advantage over X-band, after accounting for Ka-band atmospheric effects, antenna efficiencies, circuit losses
 - Increased spectrum allocation (500 MHz) enables higher downlink rates (X-band limited to ~6 Mb/s for Mars applications due to spectral constraints)
- **Key technology elements are mature**
 - 200 W Ka TWTA (50% efficiency, <3 kg mass)
 - 3 m HGA (flight demonstrated on MRO)
 - DSN 34m receive capability (operational)
- **MRO re-flight w/ 200 W TWTA would enable ~3 Mb/s @ 2.5 AU**
 - Scales as $1/R^2$ up to **100 Mb/s @ 0.4 AU** (minimum Earth-Mars distance)



L3 Communications 32 GHz 200 W TWT



MRO 3m High Gain Antenna



DSN 34m Beam Waveguide Antennas

Pathways to Higher Performance: Optical



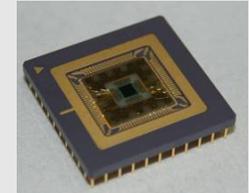
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- **Optical communication offers potential for further growth in downlink capability**
 - 250 Mb/s downlink to 12 m optical ground station from 0.4 AU
 - 28 kg/75 W flight system
- **Key challenges**
 - Acquisition and tracking for very narrow ($<10 \mu\text{rad}$) beams
 - Atmospheric effects for ground-based facilities
 - High efficiency for photon-starved links

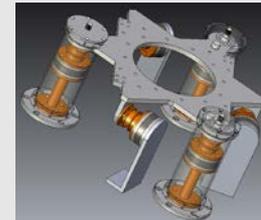
Flight Systems



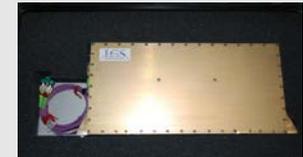
22 cm Gregorian Telescope



Single-Photon Detector

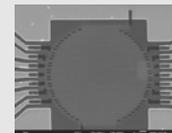


Disturbance Rejection Platform



Space-Qualified 1550 nm Fiber Laser

Ground Systems



Superconducting Nanowire Detector



5.1-m Palomar Telescope (Downlink)



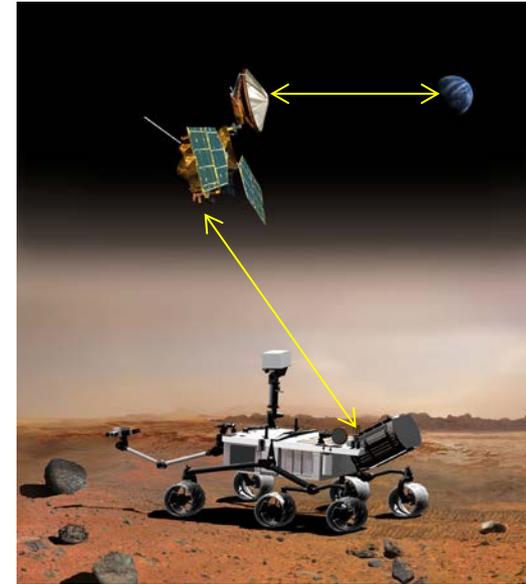
1-m Table Mtn Telescope (Uplink)

Pathways to Higher Performance: Proximity Links



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- **Relay communications can offer greatly increased data return from mass/power/volume-constrained *in situ* landers and rovers**
 - Curiosity is returning 1/2-Gbit per sol from Gale Crater via UHF relays through ODY and MRO
- **Electra software-defined radio provides flexible relay services**
 - Adaptive Data Rate capability maximizes data return over high-variable comm channel
- **Future growth paths**
 - Migration to high-frequency directional RF link
 - Optical proximity links



MRO Electra UHF Transceiver