HiRISE

High Resolution Imaging Science Experiment

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MRO HiRISE Entry, Descent, and Landing (EDL) Imaging

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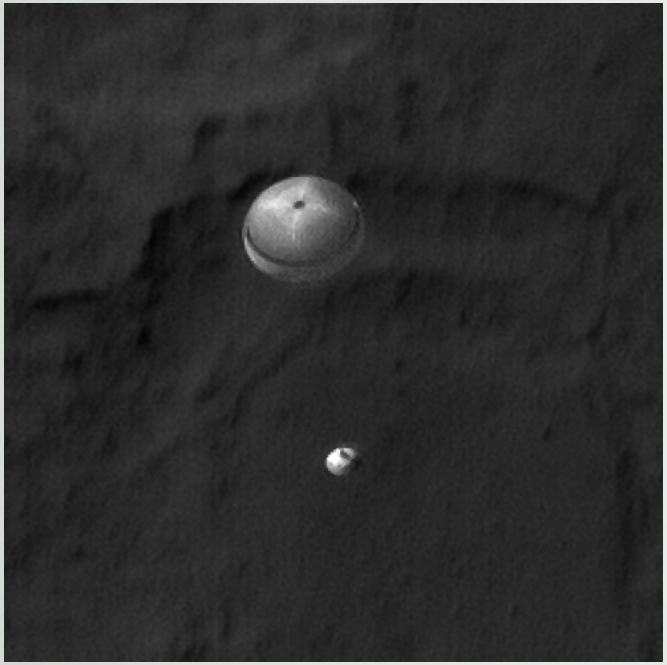

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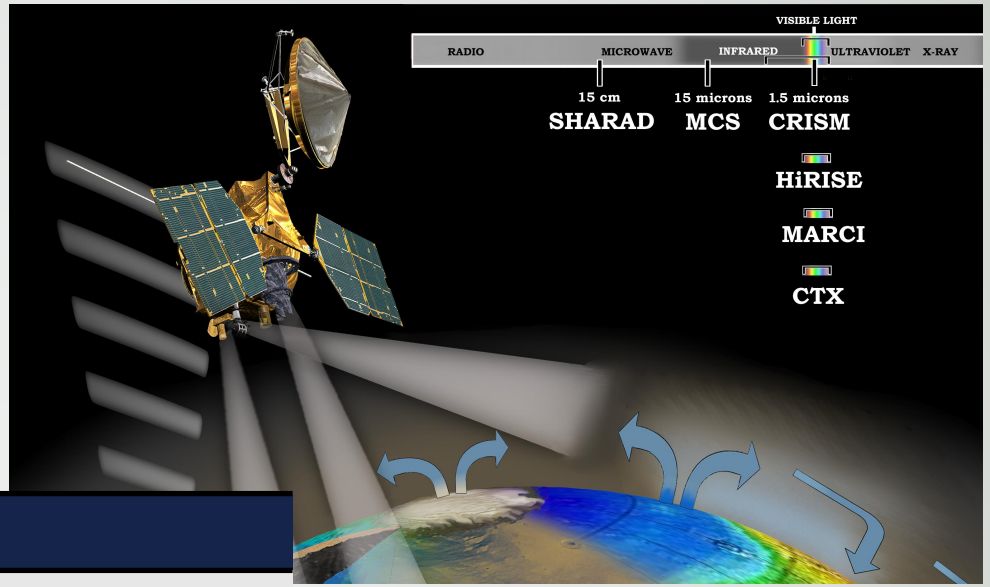
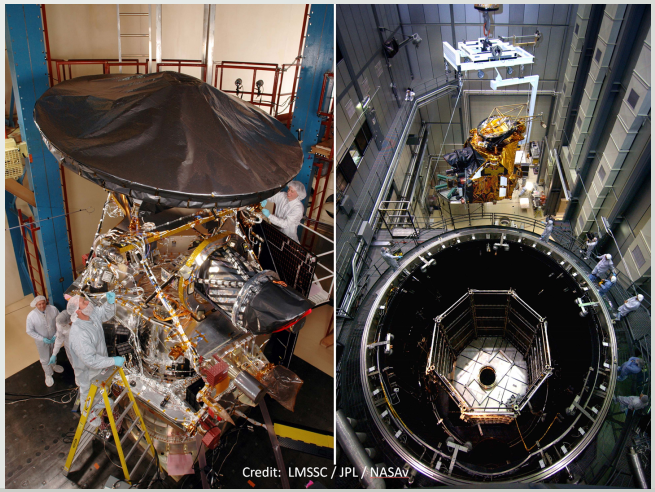
Mars Reconnaissance Orbiter (MRO)

- Launched 2005
- ~300km altitude, sun-synchronous ~3pm LMST orbit
- ~113min orbital period
- ±30° off-nadir rolls
- Built by Lockheed-Martin, managed by JPL



MRO Instruments

HiRISE	High Resolution Imaging Science Experiment	Imager, ~30cm/pix res
CTX	Context Camera	Imager, ~6m/pix res
MARCI	Mars Color Imager	Imager, ~km/pix res
CRISM	Compact Reconnaissance Imaging Spectrometer for Mars	Imaging spectrometer in VNIR, IR
MCS	Mars Climate Sounder	Sounder in thermal IR
SHARAD	Shallow Radar	HF radar, ~10m vertical subsurface res
Electra	telecom package	UHF Relay



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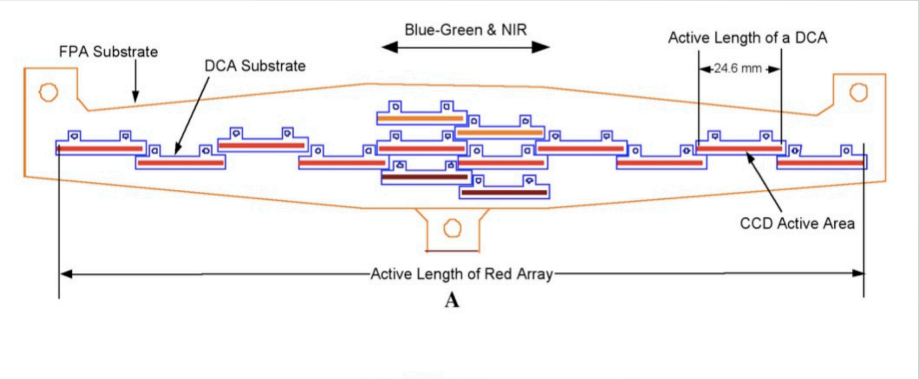
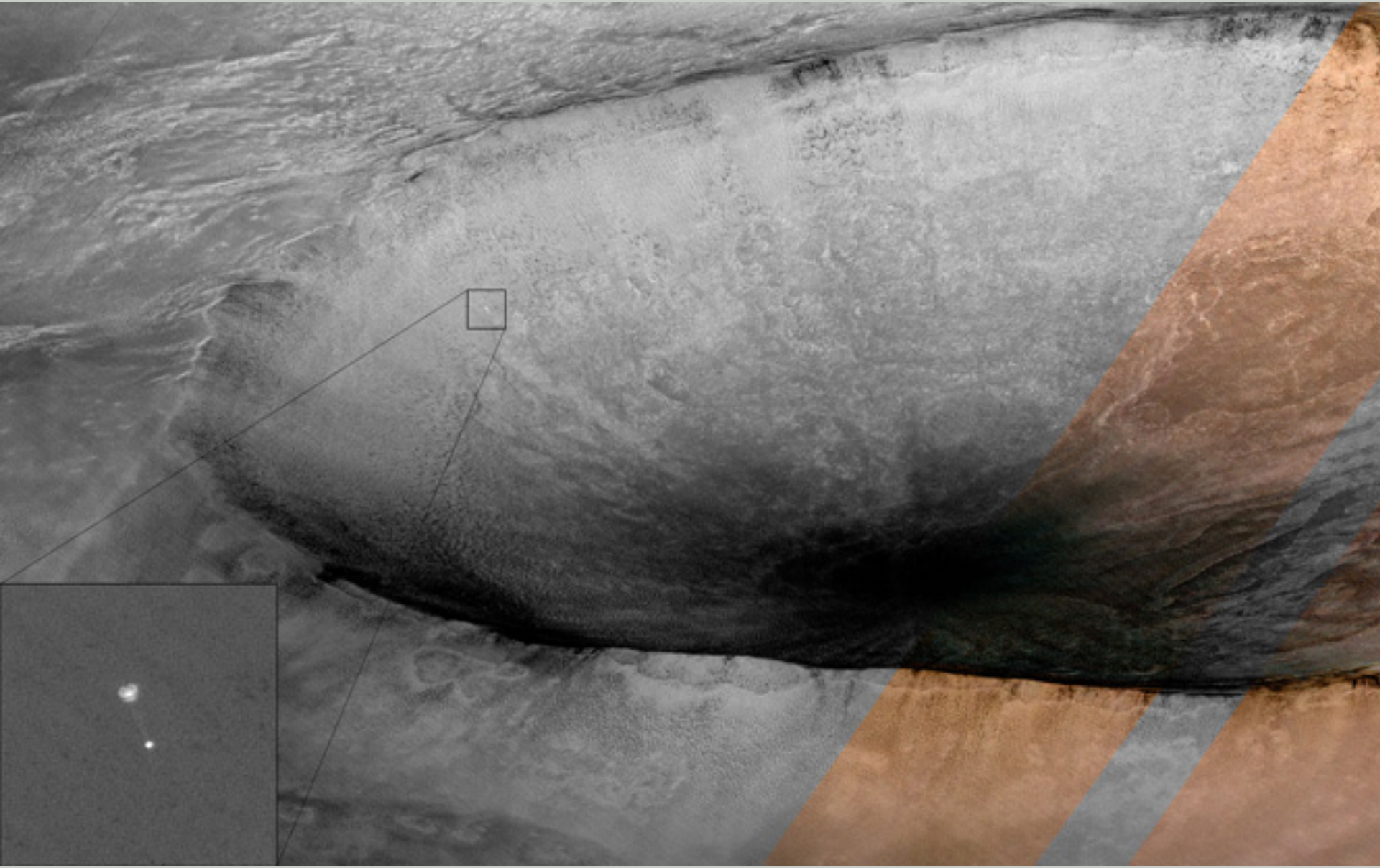
High Resolution Imaging Science Experiment (HiRISE)

- Designed and built by Ball Aerospace
- Operated by University of Arizona Lunar and Planetary Lab, Alfred McEwen, Principal Investigator
- 50cm telescope aperture
- 14-CCD array with 1.0 µrad IFOV
- ~30 cm/pix max resolution
- Pushbroom imager
- Line integration timing matched to orbital ground speed ~3.2 km/s



Phoenix Mars Lander



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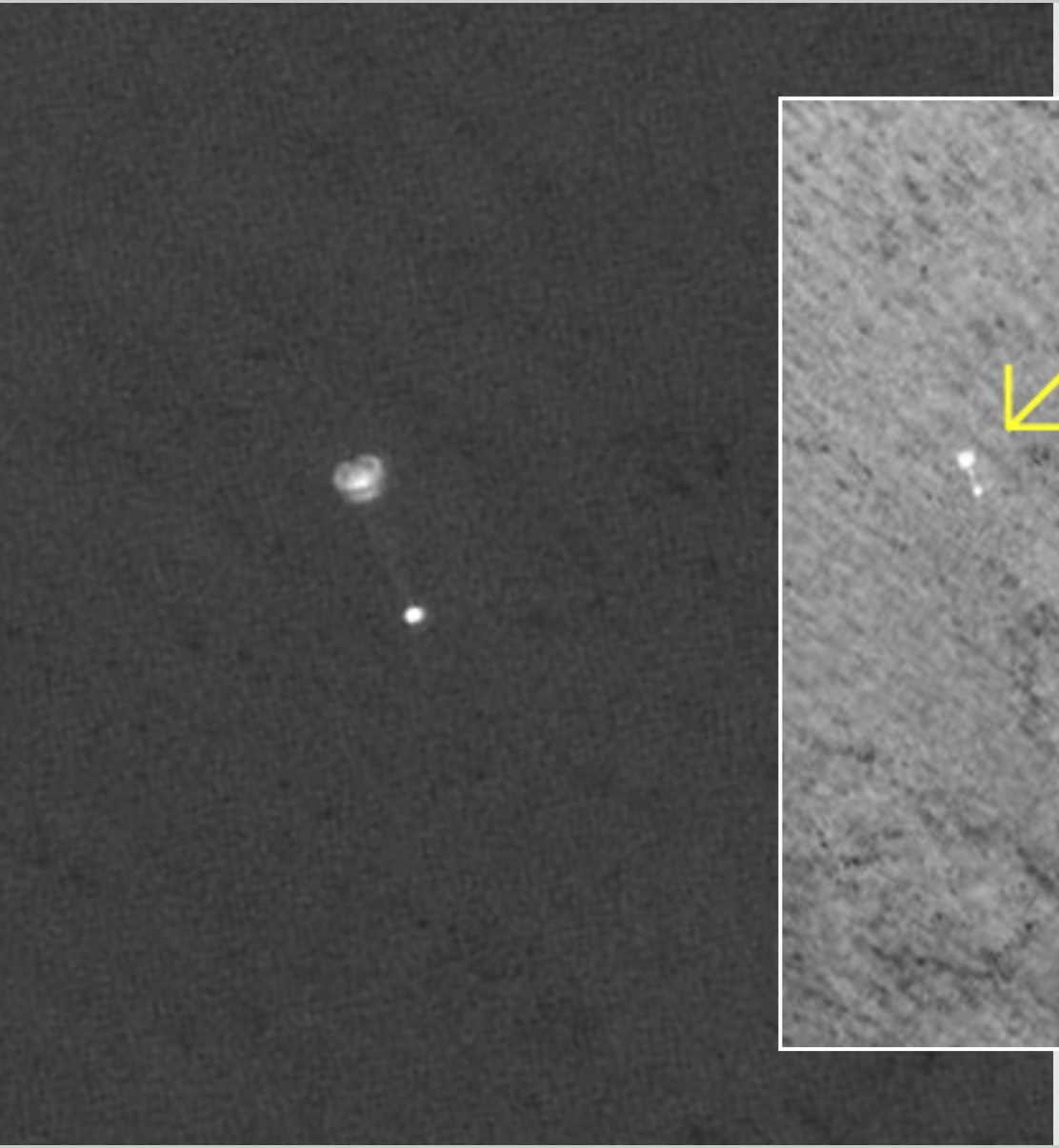
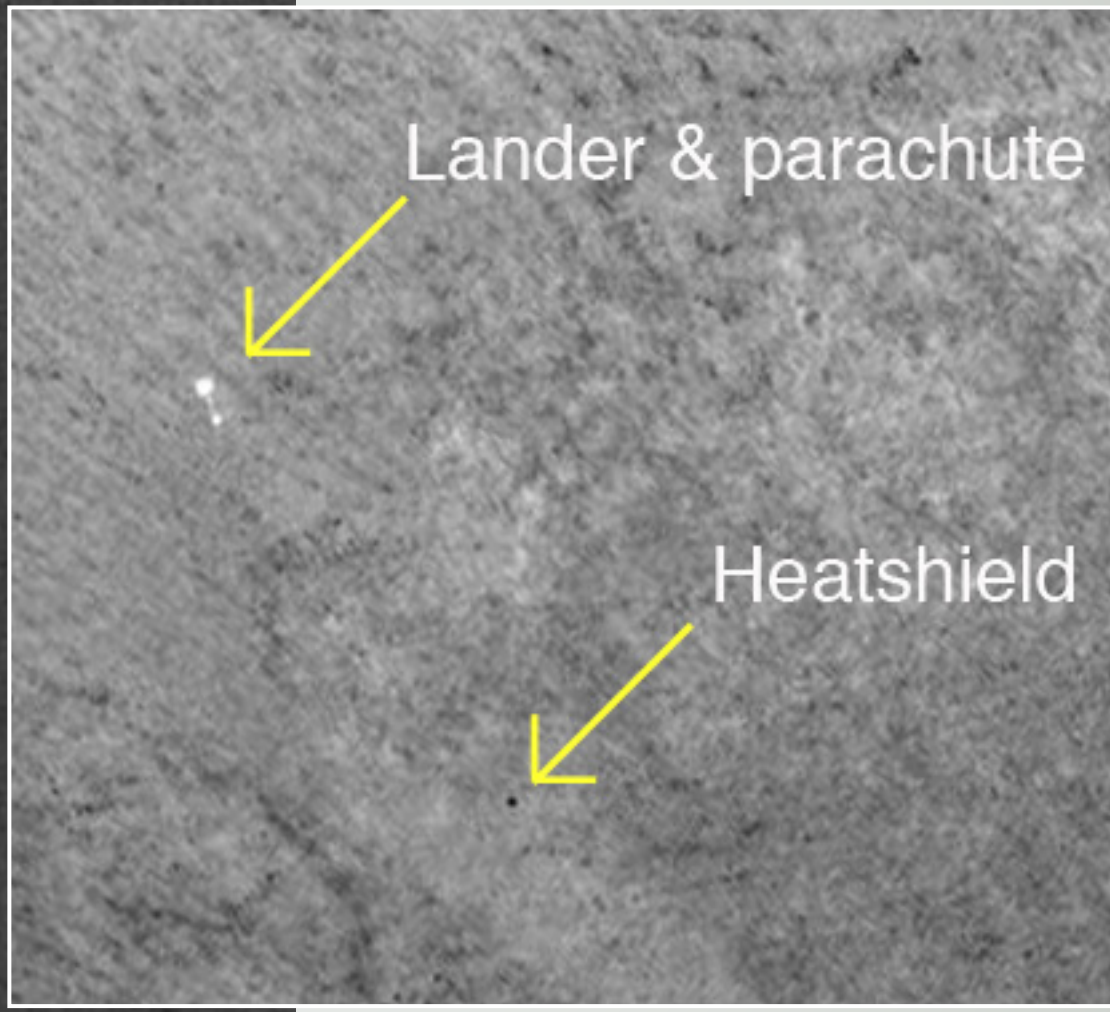
Phoenix Mars Lander





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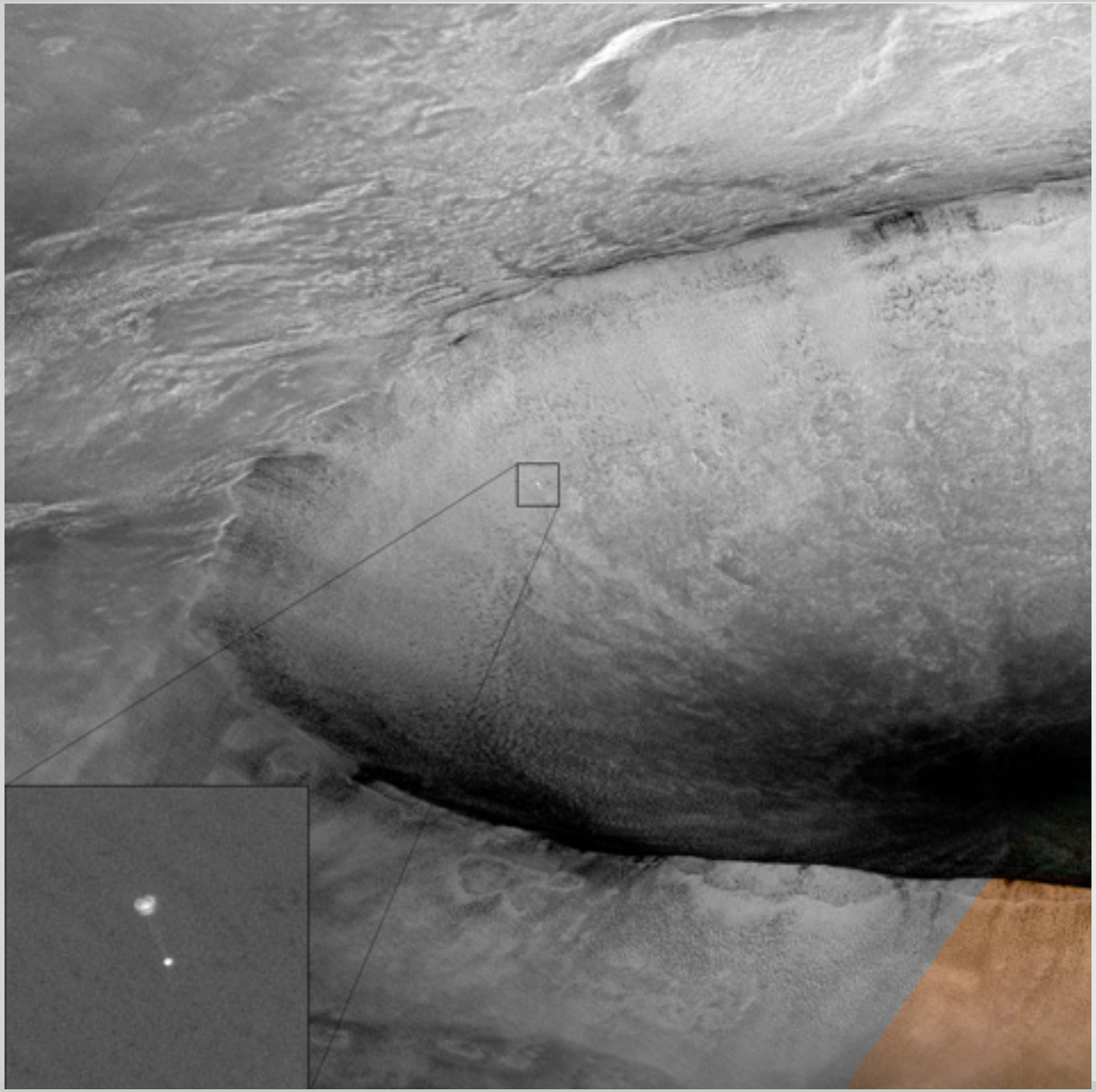
Phoenix Mars Lander



May 25, 2008

MRO altitude: ~310 km
MRO roll angle: large (> 60°)
MRO-PHX distance: 760 km

PHX altitude: ~13 km
PHX parachute: ~10m diameter

Taken 20s after parachute deploy, ~3 mins prior to landing

127000 line image

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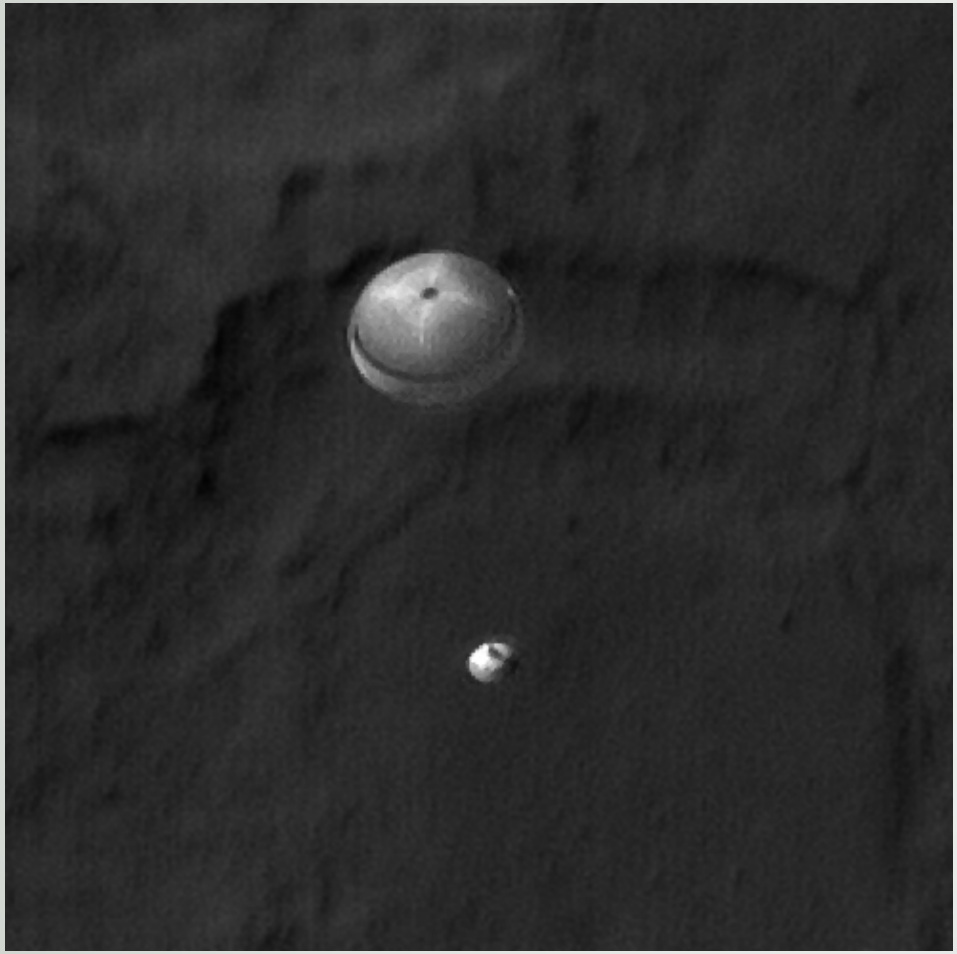
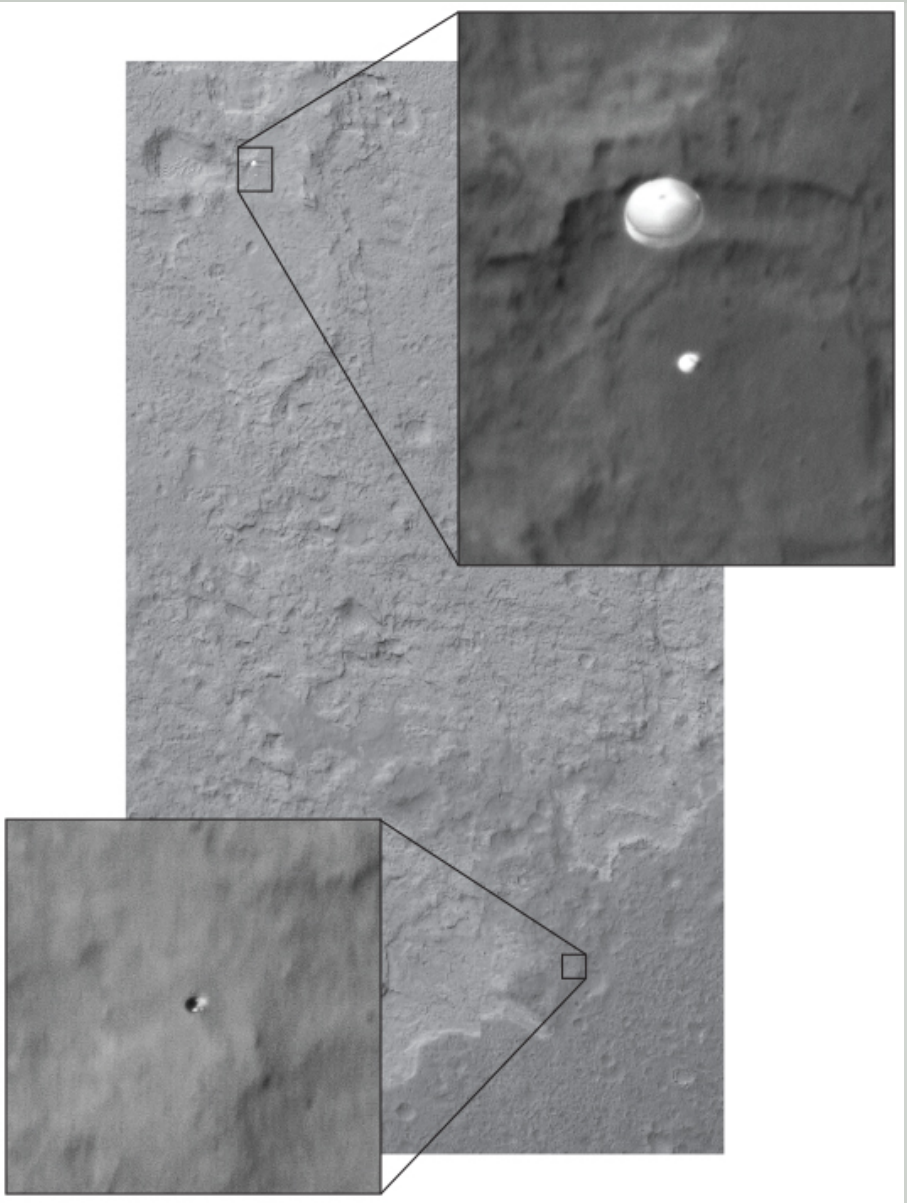
Mars Science Laboratory (MSL)





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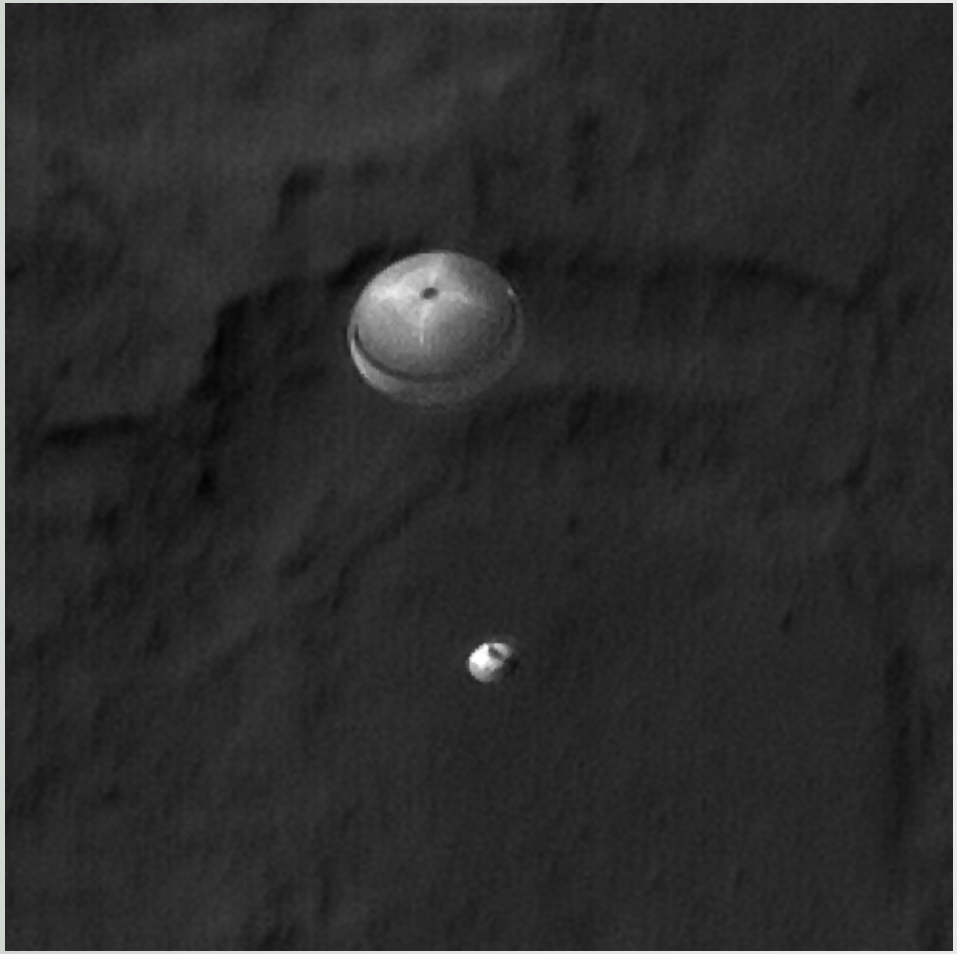
Mars Science Laboratory (MSL)



August 5, 2012

MRO altitude: ~270 km
MRO roll angle: smaller (near typical imaging)
MRO-MSL distance: 340 km

MSL altitude: ~ 7 km
MSL parachute: ~16m diameter

Taken 1 min prior to landing

85000 line image

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InSight Lander imaging attempt

November 26, 2018

MRO altitude: ~270 km
MRO roll angle: large (> 60°)
MRO-InSight distance: 900 km

InSight altitude: ~ 5 km
InSight parachute: ~11m diameter

Taken ~2 min prior to landing

30000 line image

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Spacecraft considerations

Imaging is *not* the primary requirement or concern for MRO EDL support.

- Orbit
  - Phase earlier or later for MRO-target visibility
- Relay support
  - Electra UHF link, nadir pointing
  - Must slew to maintain Electra boresight angle within 30° for EDL and post-EDL
- Power
  - Solar array pointing for acceptable power levels
- Spacecraft slew rate limits
- Instrument sun safety

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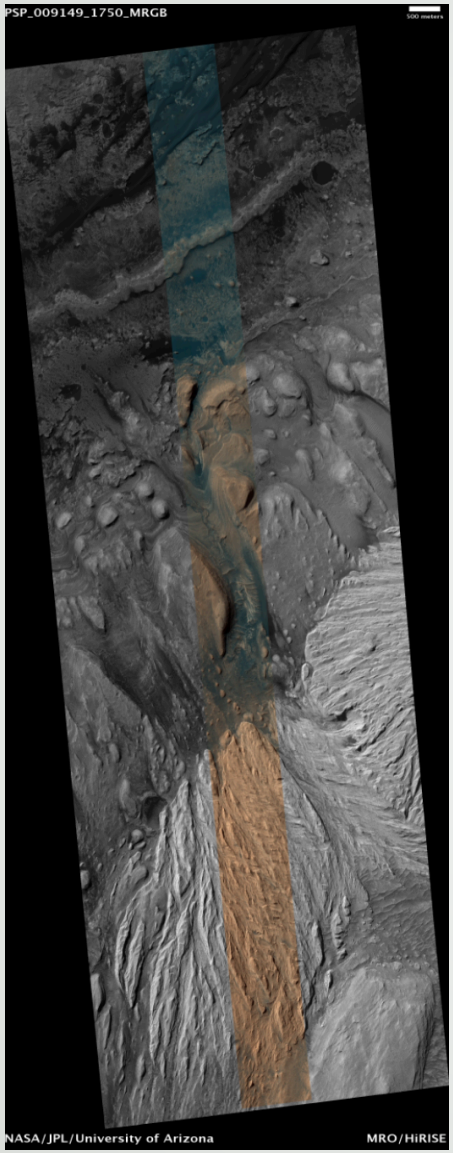
HiRISE considerations

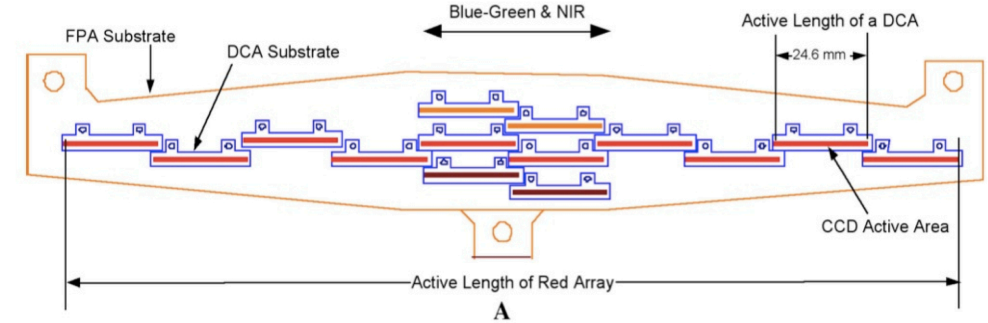
Downtrack sub-satellite (nadir) velocity

Crosstrack direction, 20000 pix max



HiRISE focal plane has:

- 10 Red (550-850nm) CCDs which span full width
- 2 NIR (800-1000nm) CCDs in the center
- 2 BG (400-600nm) CCDs in the center



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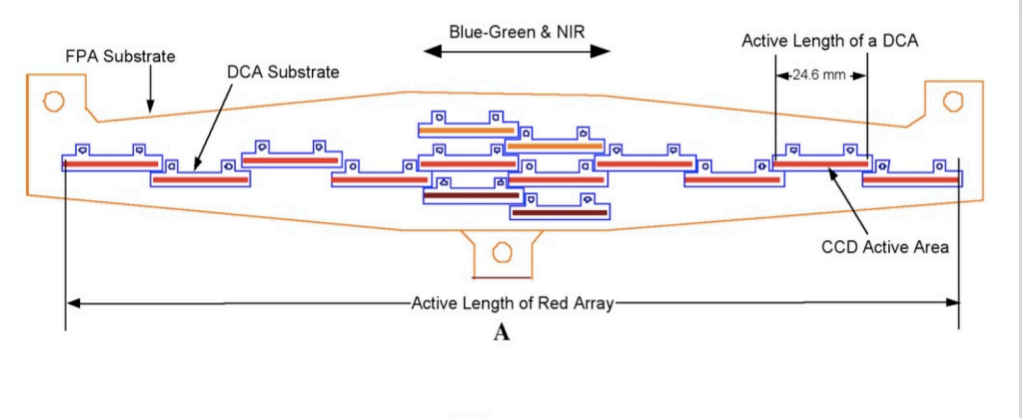
HiRISE considerations

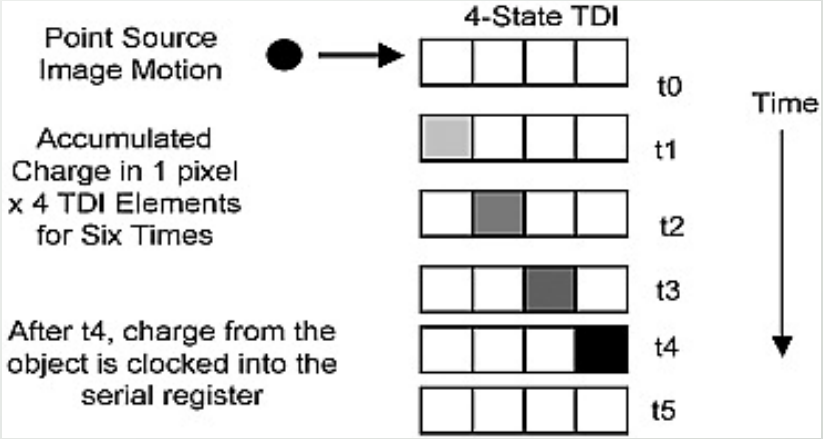
HiRISE is a pushbroom type sensor

- For Mars surface imaging: line integration timing matched to orbital ground speed
- For off-planet imaging: must match line integration timing to spacecraft slew rate



CCD charge transfer Time Delay Integration (TDI) greatly improves SNR

- Motion must be stable
- Motion of target of interest must be in the correct direction



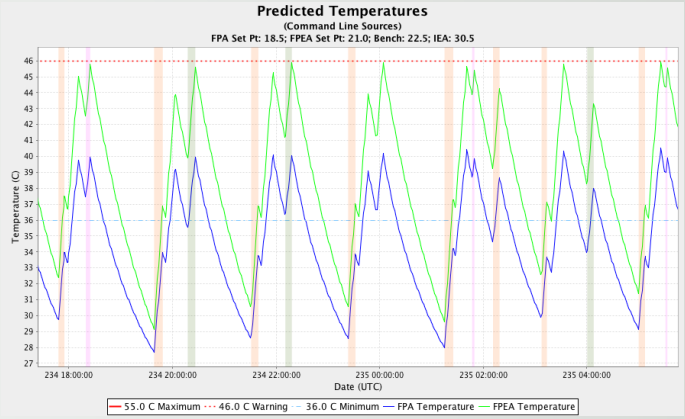
McEwen et al 2007

HiRISE considerations

While a very long, high resolution image would give us the best chance of capturing the entering spacecraft:

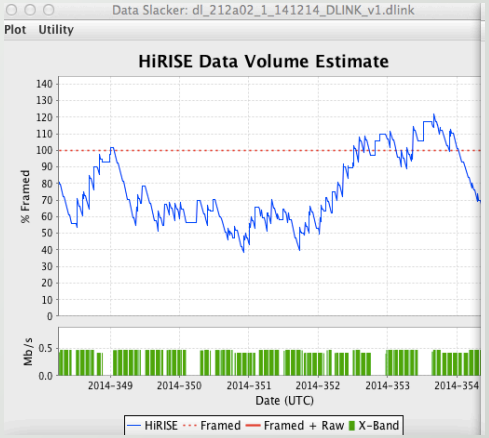
HiRISE is temperature limited

- A long powered-on duration will safe HiRISE
- HiRISE has an ideal temperature range to avoid bit flips (too low) and safing (too high)
- Temperature predictable



HiRISE is data volume limited

- Overflowing the onboard SSR will safe HiRISE
- Reading out data while acquiring from the same CCD will lose data
- No longer a practical concern for a single, compressed image



Planning considerations

- MRO executes observations in two-week cycles
- Planning begins ~3 weeks prior to execution for ~4 weeks of activity

Planning week	Nominal MRO planning cycle	
1	JPL, flight, systems block out relay passes and spacecraft activities for both cycle weeks	
2	Science Operations Teams plan rolled observations for both cycle weeks	
3	Science Operations Teams plan nadir observations for cycle week 1	
4	Science Operations Teams plan nadir observations for cycle week 2	Cycle week 1 executes on board
5		Cycle week 2 executes on board

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5		**Cycle week 2 executes on board**

Nominal process is based on Mars ***surface*** targets

↓

Non-Mars targets require ***special sequence planning*** and ***testing***

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Planning considerations

- EDL imaging activities do not follow the typical MRO planning timeline
- Like other off-Mars imaging opportunities, they are built into special sequences which must undergo rigorous testing before commanding

Phoenix EDL

EDL – 1 month: Identification of imaging opportunity
Rapid iteration of testing, review, commands, image updates

EDL – ~72hrs: final image sequence updates

EDL: May 25, 2008

MSL EDL

EDL – 10 months: Initial assessment

EDL – 9 months: Preliminary tests

Tag-ups, review and testing with placeholder products

EDL – 3 months: Adjust image parameters

EDL– 2 months: Finalize image commands

EDL – 1 month: Rapid iteration of testing, review, commands, image updates

EDL – 72hrs: final image sequence updates

EDL: August 5, 2012

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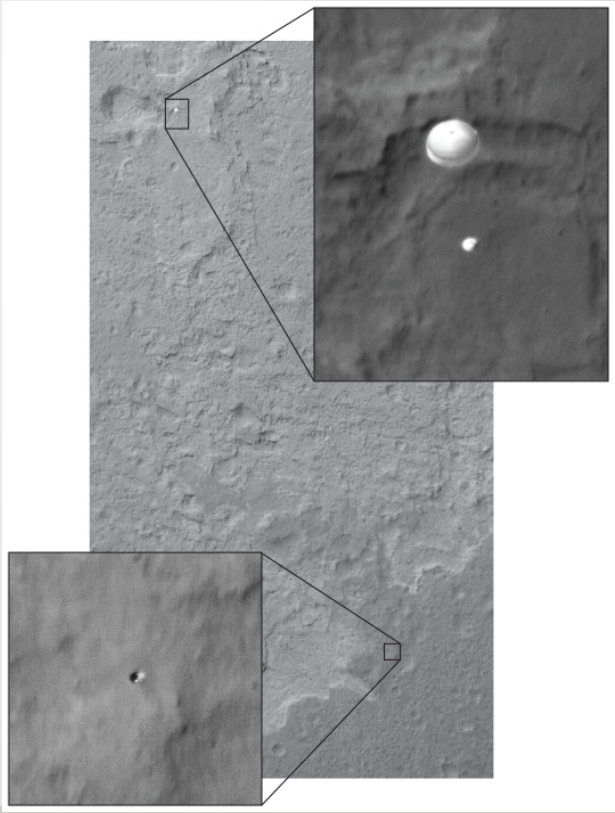
Summary

- HiRISE has completed three very different EDL imaging attempts so far
  - Phoenix EDL: executed as planned, first of its kind
  - MSL EDL: executed as planned, clear image
  - InSight EDL: executed as planned, saturated image
- HiRISE EDL imaging opportunities are driven by MRO support requirements
  - Electra relay is primary consideration
  - Slew capability, sun safety
- HiRISE is optimized for Mars surface, not Mars incoming spacecraft
  - Line time must be matched to steady spacecraft slew rate
  - Slew direction must match TDI lines and be stable
- HiRISE is limited by temperature and data volume



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- Contributors: Nicole Baugh, Uplink Lead; Christian J. Schaller, GDS Lead; Audrie Fennema, Health and Safety Lead

- The University of Arizona is a Hispanic-Serving Institution (HSI)

- The University of Arizona resides on the traditional land of the Tohono O'odham

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