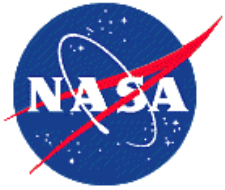




Monitoring Space Weather for Mars Science Laboratory, on approach to Mars

Martin Ratliff
Jet Propulsion Laboratory,
California Institute of Technology
27 September 2012

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SWx for MSL, on approach to Mars

Assertion 1: Operations during bad space weather carry an increased risk of Safe-mode entry (or worse).

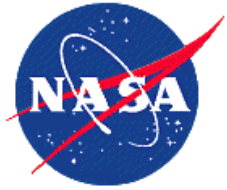
Assertion 2: Only near Earth do we know the space weather well enough to set quantitative criteria for including SWx in operations decisions.



SWx for MSL, on approach to Mars

Assertion 3: For locations not near Earth, we can, at best, infer the space weather conditions and the forecast well enough to **qualitatively** factor SWx into operations decisions.

This is appropriate only at certain times in some missions, when the benefit might overcome the drawbacks of subjective criteria and SWx false alarms.



SWx for MSL, on approach to Mars

When do we need to monitor SWx?

MSL's Entry, Descent, and Landing (EDL) sequence is completely autonomous, and orbital mechanics dictates when it will happen, so
no need to look at SWx for EDL . . .



SWx for MSL, on approach to Mars

...except for EDL anomaly resolution
(but that wasn't needed either).



<http://www.youtube.com/watch?v=wnG-rFFpP8A>



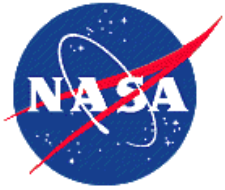
SWx for MSL, on approach to Mars

SWx monitoring at launch?

YES;

LV and S/C need to perform critical operations
in a timely manner, so...

**Don't launch into a large
solar energetic particle event.**



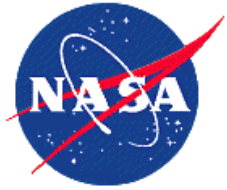
SWx for MSL, on approach to Mars

SWx monitoring during cruise?

No need;

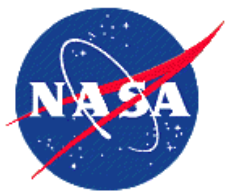
S/C is designed to handle a lot of radiation,
and handle it autonomously.

If it sees more than it can handle, Safe mode
helps it ride out the storm.



SWx for MSL, on approach to Mars

But it takes time to recover from Safe mode,
and time is precious when a critical
operation such as EDL is imminent...



SWx for MSL, on approach to Mars

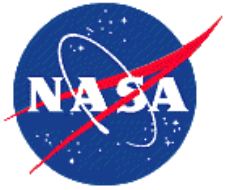




SWx for MSL, on approach to Mars

Hence we want to avoid operations that carry a relatively higher risk of taking the s/c into safe mode.

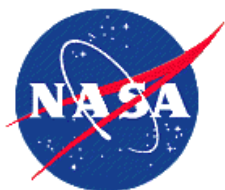
Remember Assertion 1: Operations during bad space weather carry an increased risk of Safe-mode entry (or worse).



SWx for MSL, on approach to Mars

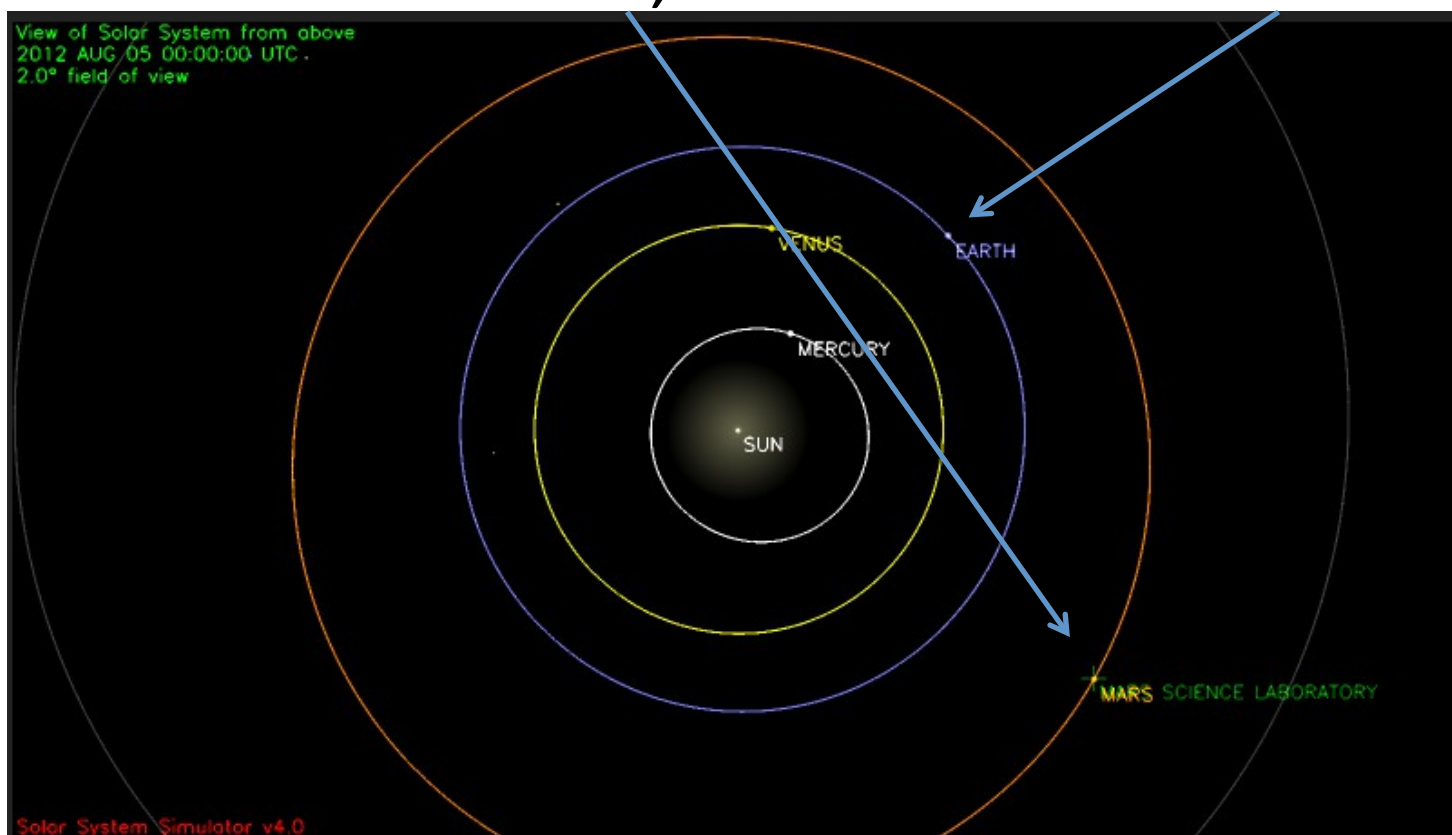
SWx monitoring began about 2 weeks prior
to EDL.

For maneuvers and data uploads
just prior to EDL,
solar energetic particle (SEP) events will
increase the risk of safe-mode entry.



SWx for MSL, on approach to Mars

How do we determine and forecast SWx there at Mars, when we are here?



Simulation from <http://space.jpl.nasa.gov/>



SWx for MSL, on approach to Mars

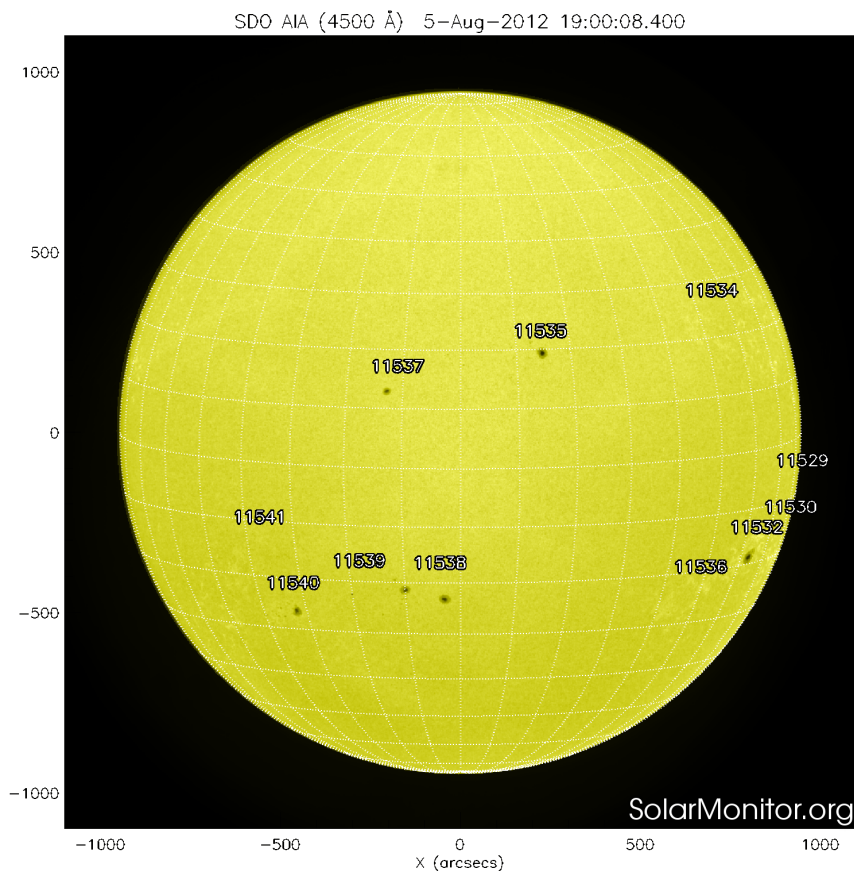
Fuzzy criteria for postponing flight ops and data uploads due to weather:

- a SEP event at Mars may be imminent (look at flare probability);
- a SEP event may be in progress at Mars (flare and CME sightings);
- a SEP event of unknown severity is in progress (un-calibrated HEND in-situ data).



SWx for MSL, on approach to Mars

Use regions' flare probabilities to get flare probability relevant to Mars. (SWPC solar synoptic analysis; off-menu product)



NOAA/SWPC gives a low probability of X-class flares from regions we can see from Earth (which is also what happens to matter most for Mars right now).

Flare Event Probabilities for next 24 hrs:

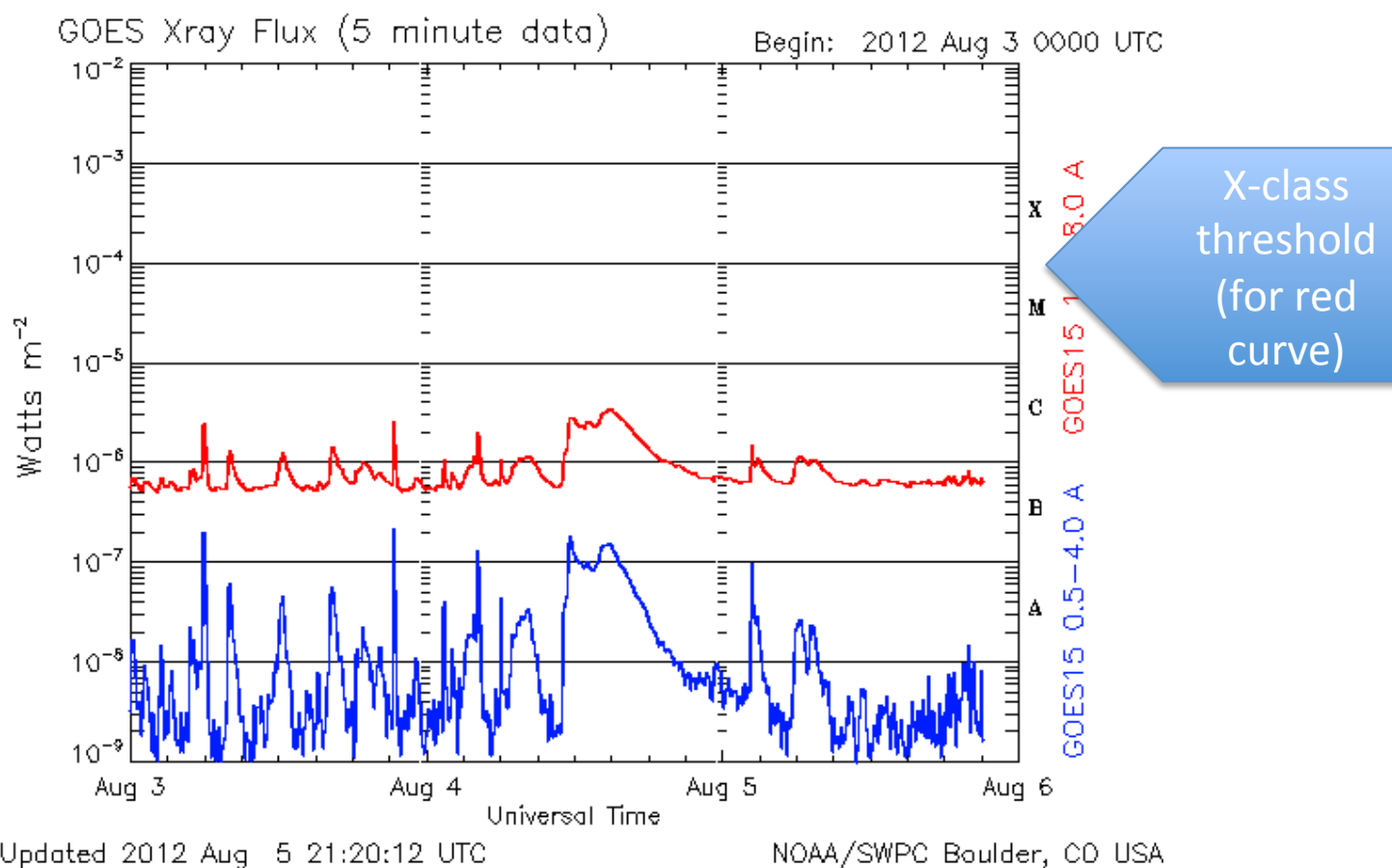
Class M 15%

Class X 1%



SWx for MSL, on approach to Mars

Watch for flare alerts, note peak values and locations.

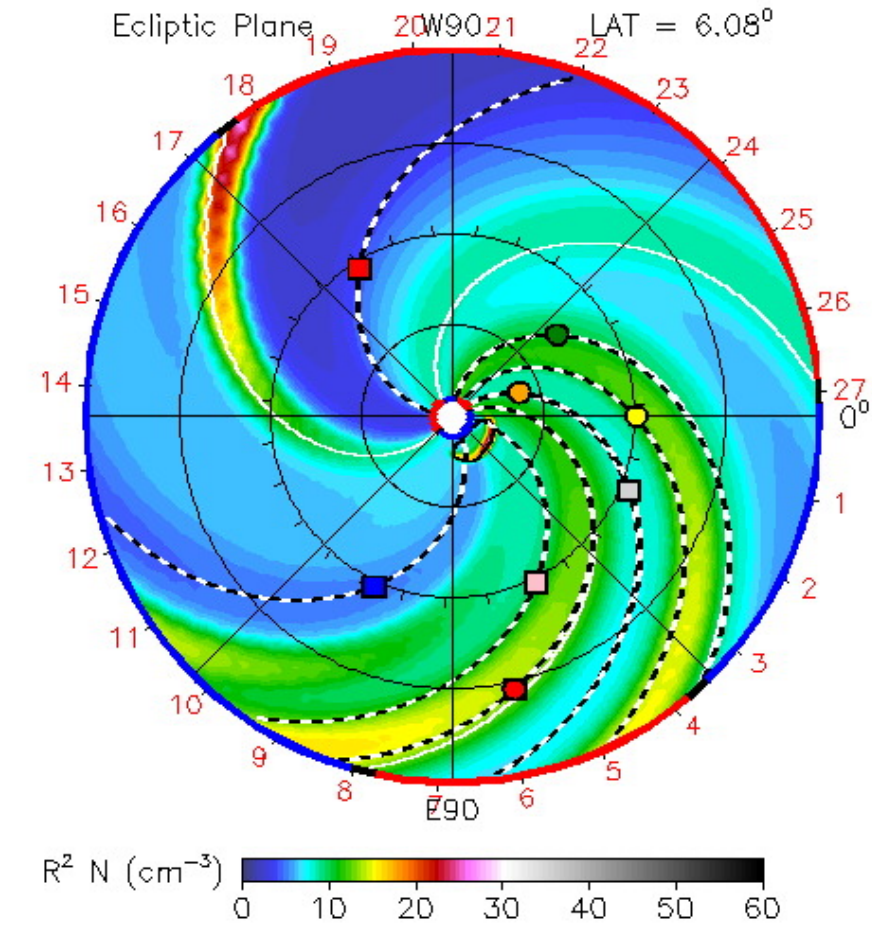




SWx for MSL, on approach to Mars

2012-08-05T06:00

- Earth
- Mars
- Mercury
- Venus
- Stereo_B



ENUL-2.7 lowres-2126-a3b1f WSA_V2.2 GONG-2126 [ccmc/wsafr-ld/256x](http://ccmc.gsfc.nasa.gov)

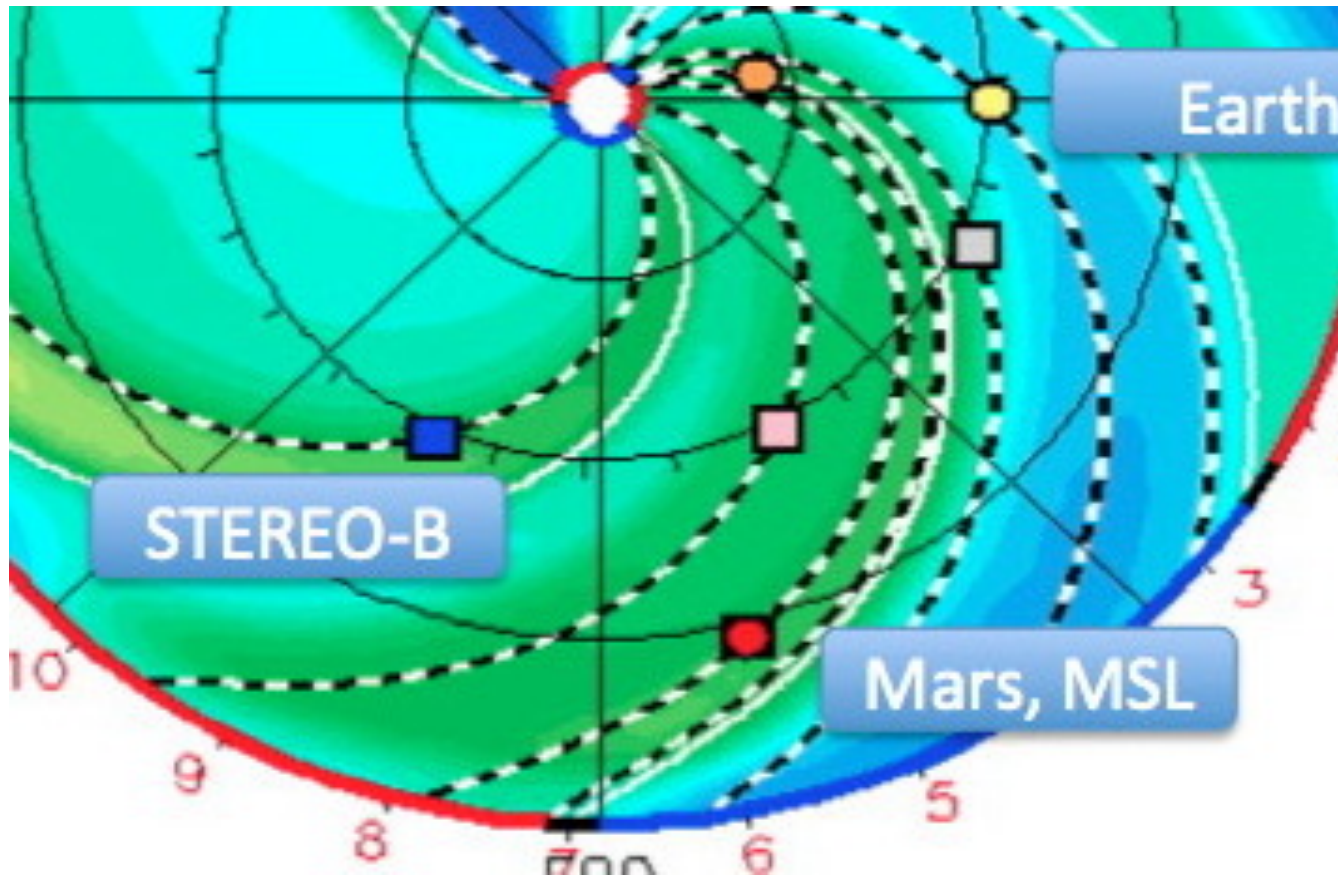
Watch for CME sightings.

<http://swrc.gsfc.nasa.gov/main/iSWACygnetsreamer-CME-03-Aug.gif>



SWx for MSL, on approach to Mars

“Interpolate” from SEP conditions at Earth and Stereo-B.

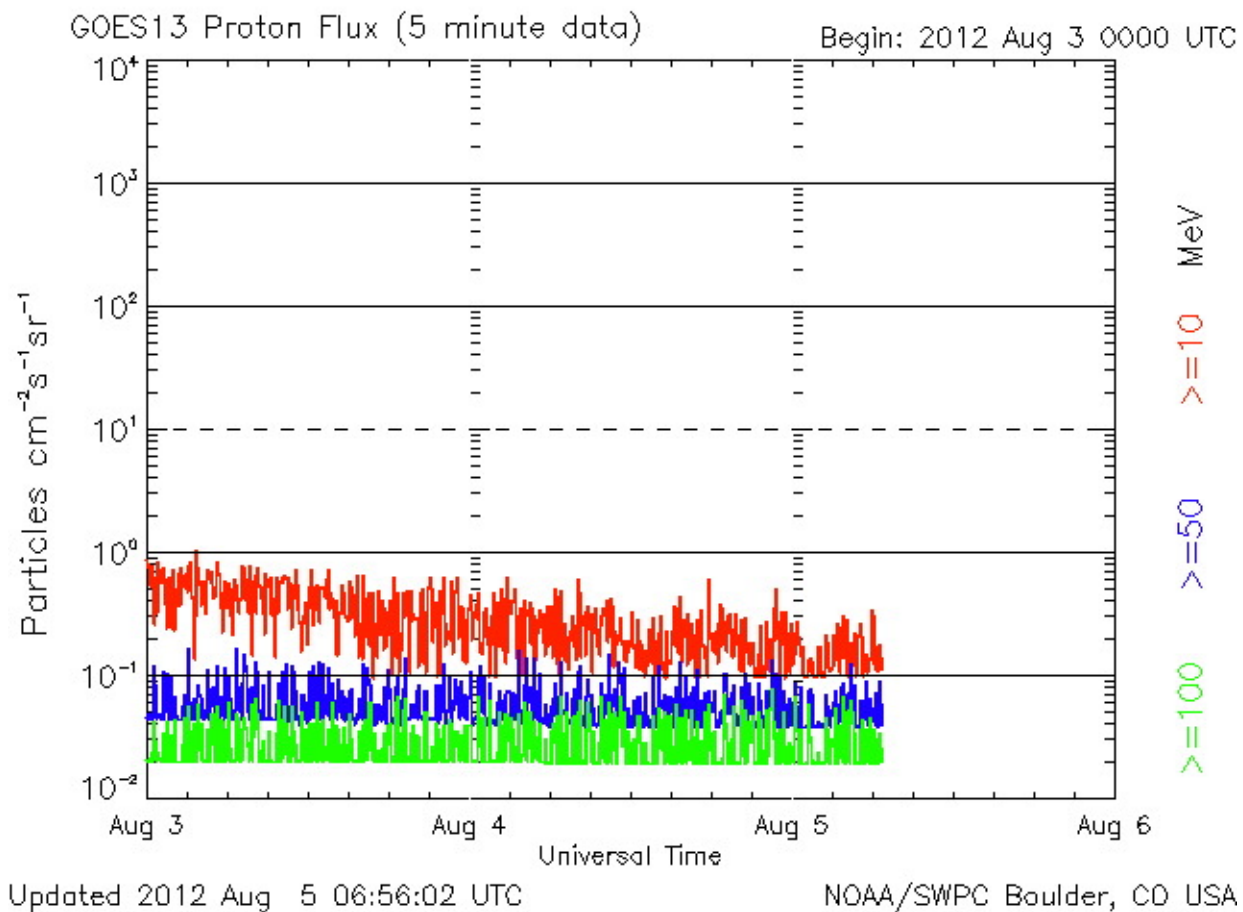


http://www.swpc.noaa.gov/rt_plots/pro_3d.html



SWx for MSL, on approach to Mars

SEP conditions at Earth, from GOES.

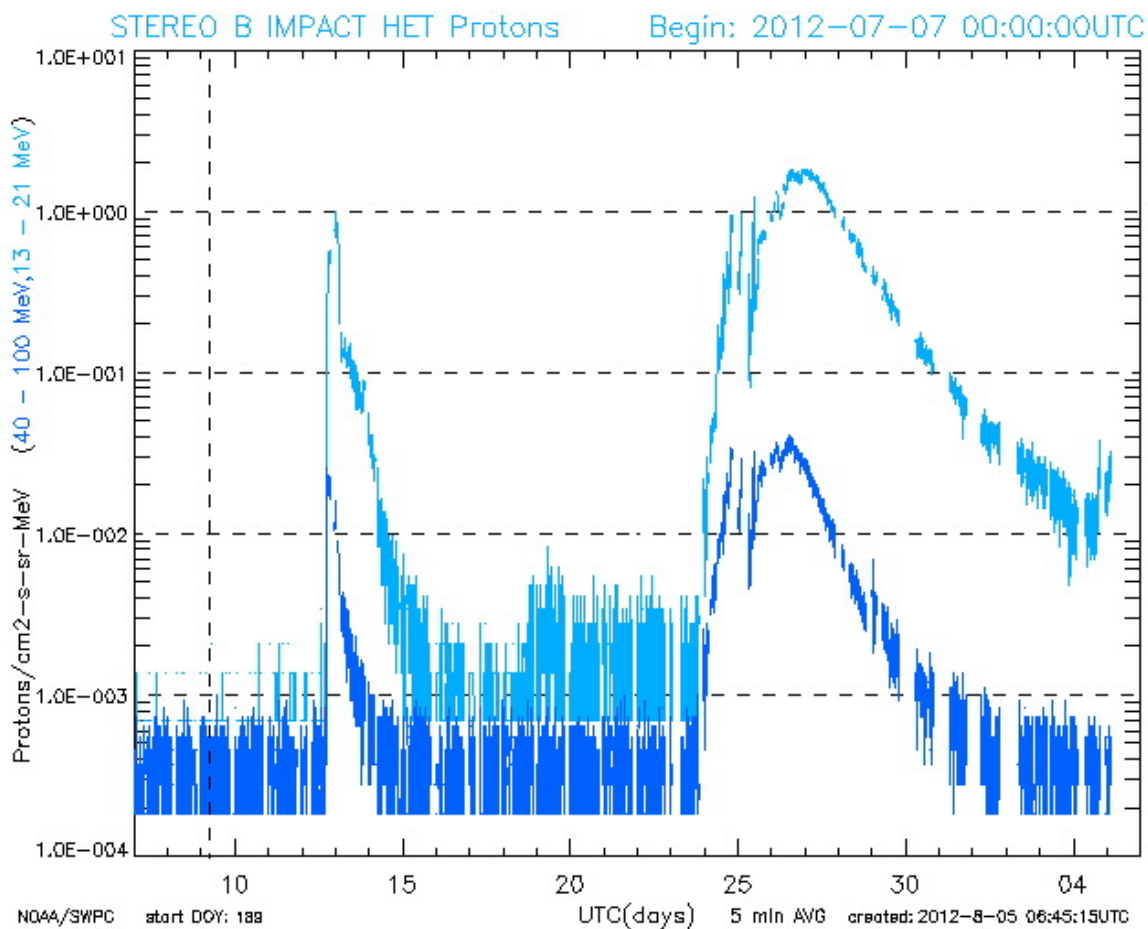


http://www.swpc.noaa.gov/rt_plots/pro_3d.html



SWx for MSL, on approach to Mars

SEP conditions from STEREO-B.



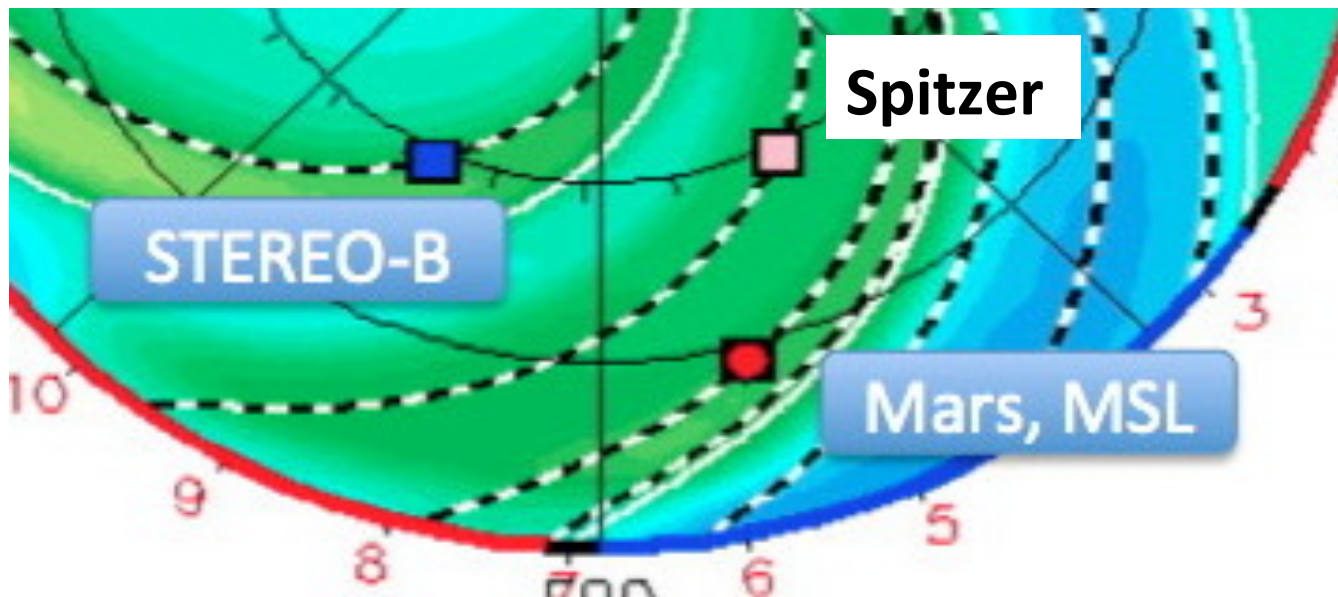
http://www.swpc.noaa.gov/stereo/impact_het_B_30d_w.html



SWx for MSL, on approach to Mars

On one occasion, I requested and received housekeeping telemetry from Spitzer, showing memory SEU counts.

**No change in count-rate,
so
no evidence of SEP flux.**



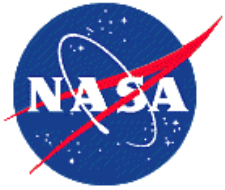


SWx for MSL, on approach to Mars

In-situ monitor of high-energy protons: High Energy Neutron Detector (HEND) on Odyssey s/c orbiting Mars.



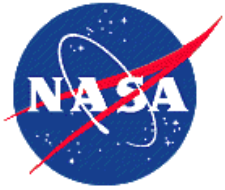
<http://mars.jpl.nasa.gov/odyssey/mission/overview/>



SWx for MSL, on approach to Mars

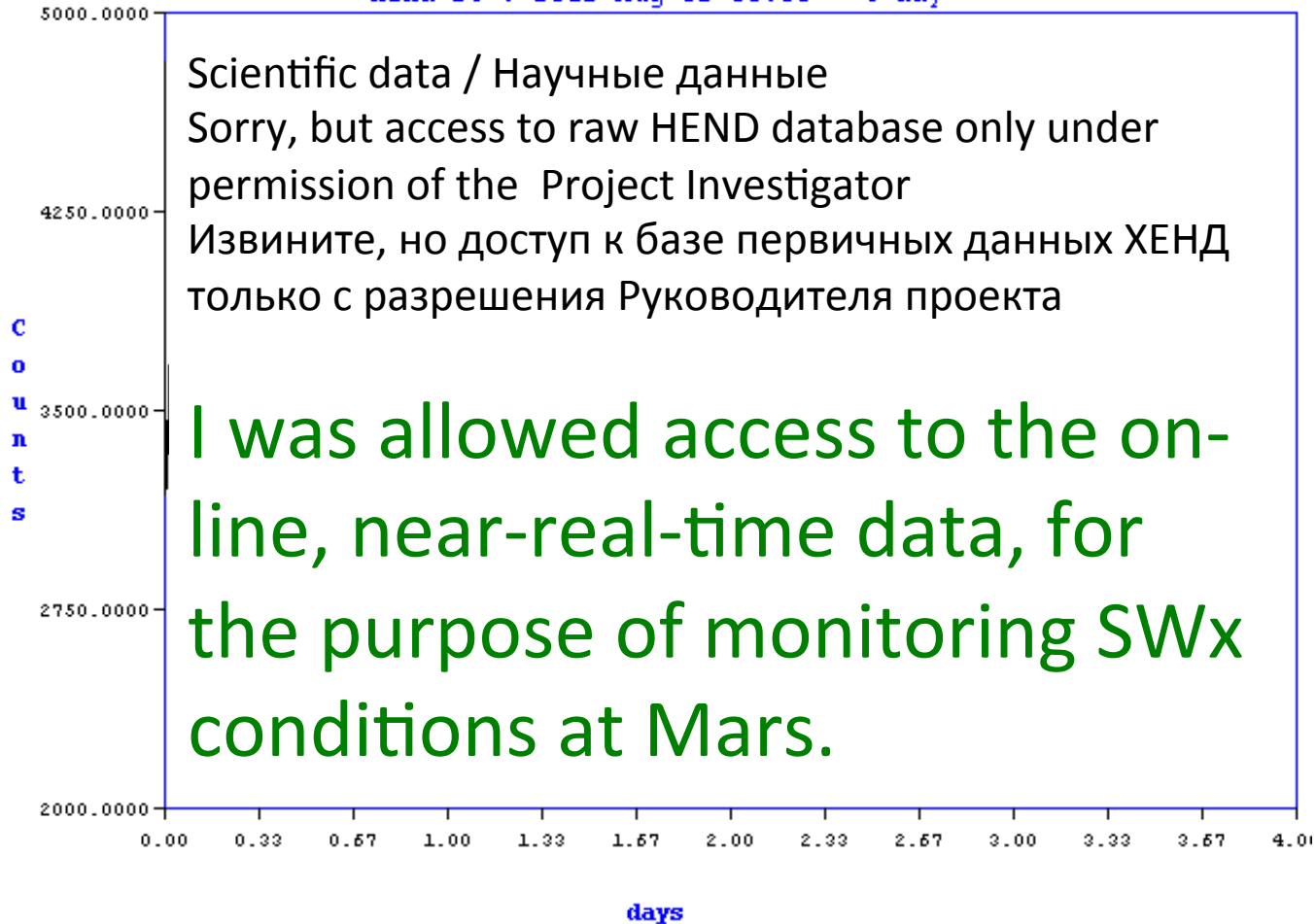
HEND:

- developed at the Institute for Space Research (ИКИ, anglicized to IKI) in Moscow, Russia. (Dr. Igor Mitrofanov);
- detects epithermal, resonance, and fast neutrons;
- sees high-energy protons, but is **NOT CALIBRATED FOR THEM!**



SWx for MSL, on approach to Mars

hend s6 : 2012 Aug 02 00:00 + 4 day



Energetic particle flux at Mars is at background level.
(This is what MSL wanted to see.)



SWx for MSL, on approach to Mars

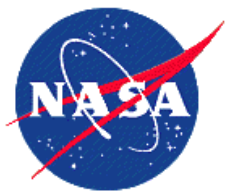
Sample: Last slide of the last MSL SWx report, at
EDL minus 8 hrs:

SUMMARY:

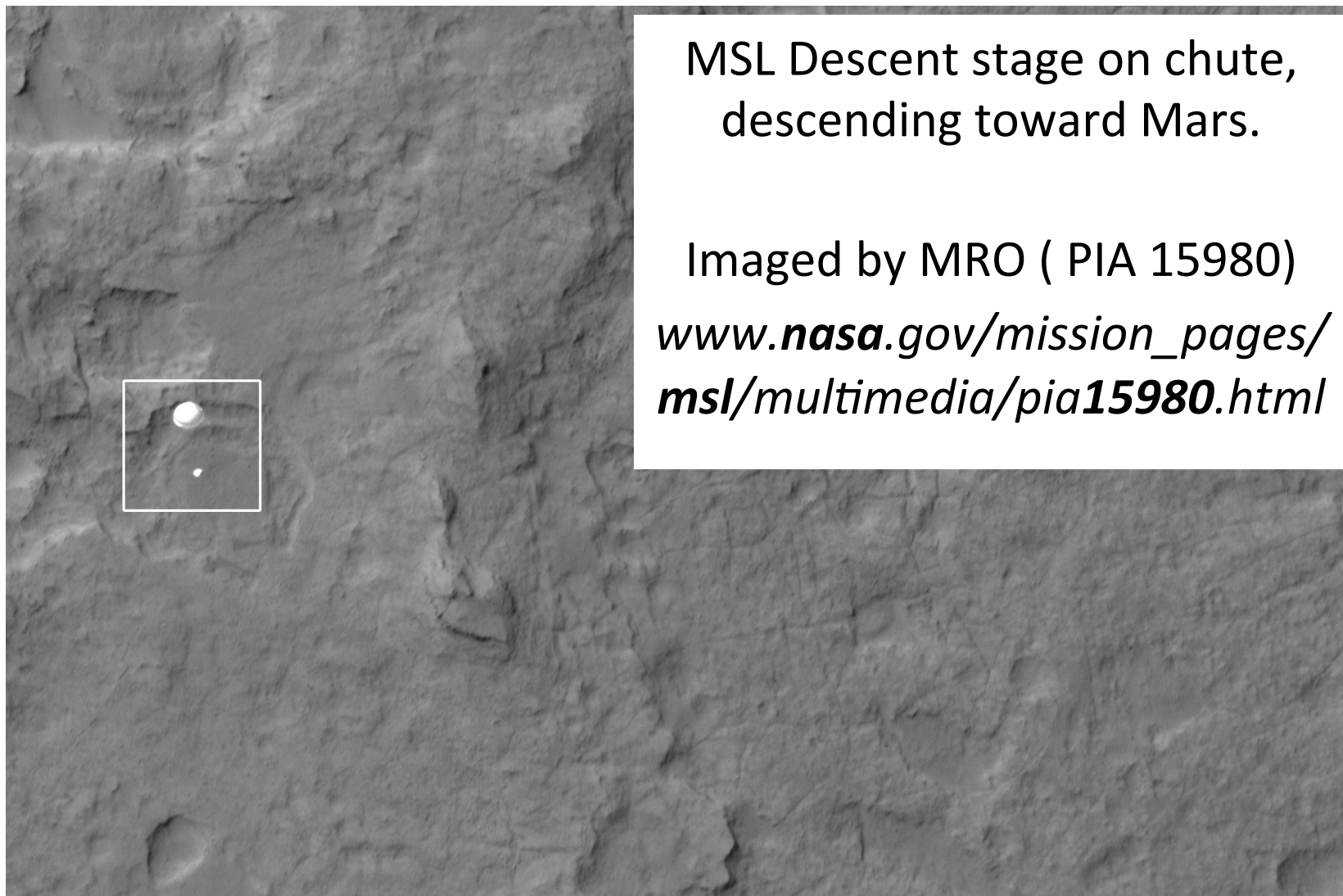
We currently have a background radiation level at Mars.

Some chance of a small to moderate Solar Energetic Particle event (SEP event) at Mars, through EDL.

Low (near zero) chance of a large SEP event.



SWx for MSL, on approach to Mars

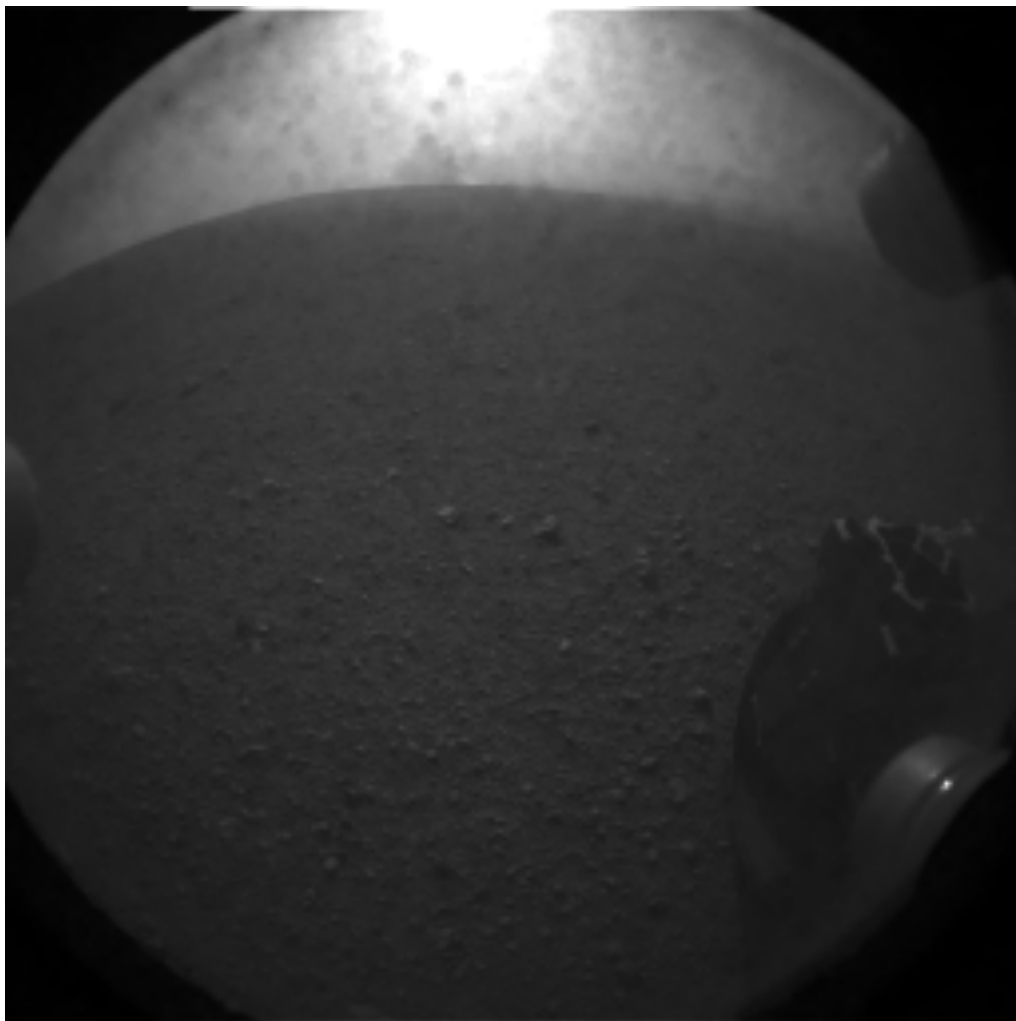


MSL Descent stage on chute,
descending toward Mars.

Imaged by MRO (PIA 15980)
[www.nasa.gov/mission_pages/
msl/multimedia/pia15980.html](http://www.nasa.gov/mission_pages/msl/multimedia/pia15980.html)



SWx for MSL, on approach to Mars



First MSL image
from Mars.

[http://
photojournal.jpl.nasa.gov/
catalog/?
IDNumber=PIA15971](http://photojournal.jpl.nasa.gov/catalog/?IDNumber=PIA15971)



SWx for MSL, on approach to Mars



Summit of Mt.
Sharp, 16 km
distant.
(telephoto
camera on MSL)

[http://www.nasa.gov/
681384main_PIA16104r_ma
lin03m100focus_raw.png](http://www.nasa.gov/681384main_PIA16104r_malin03m100focus_raw.png)