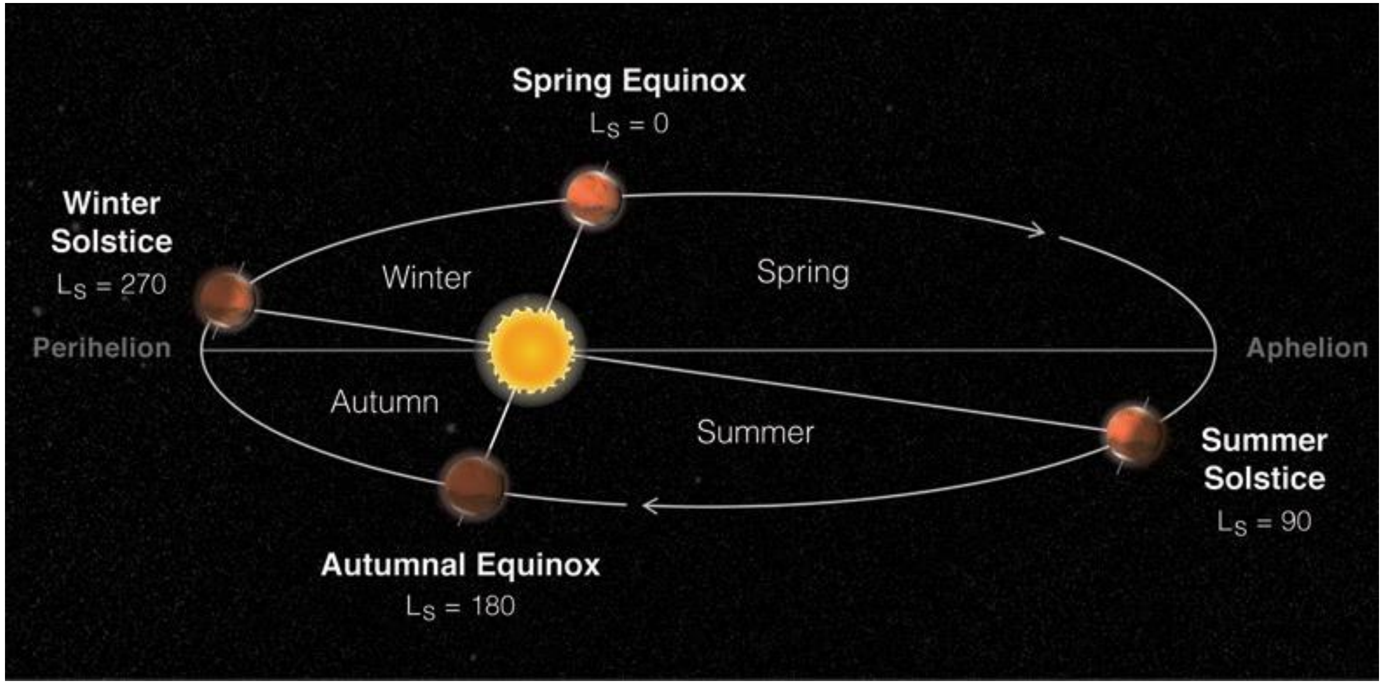
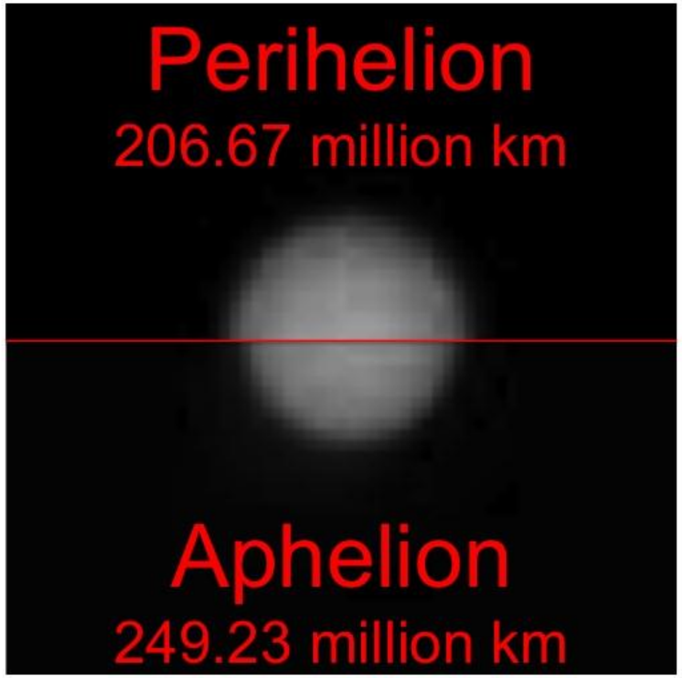
Mars' Orbit

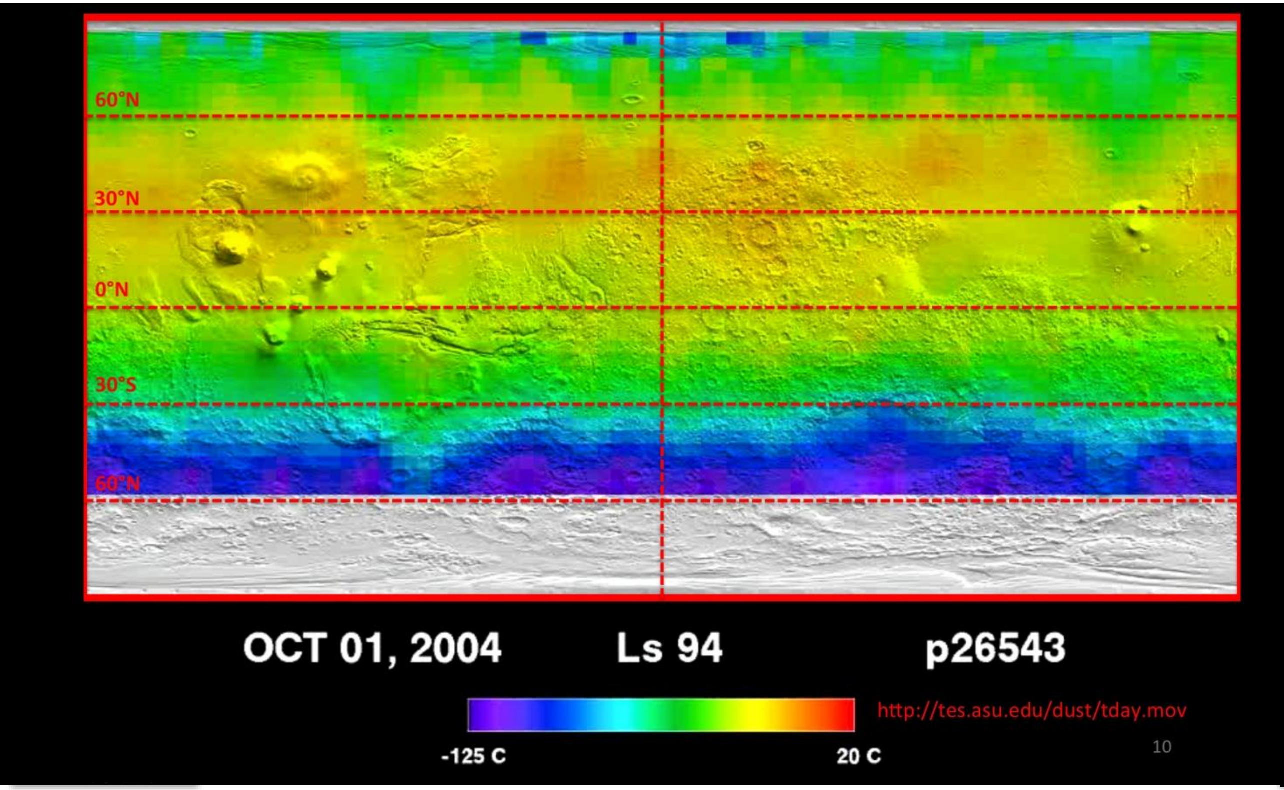




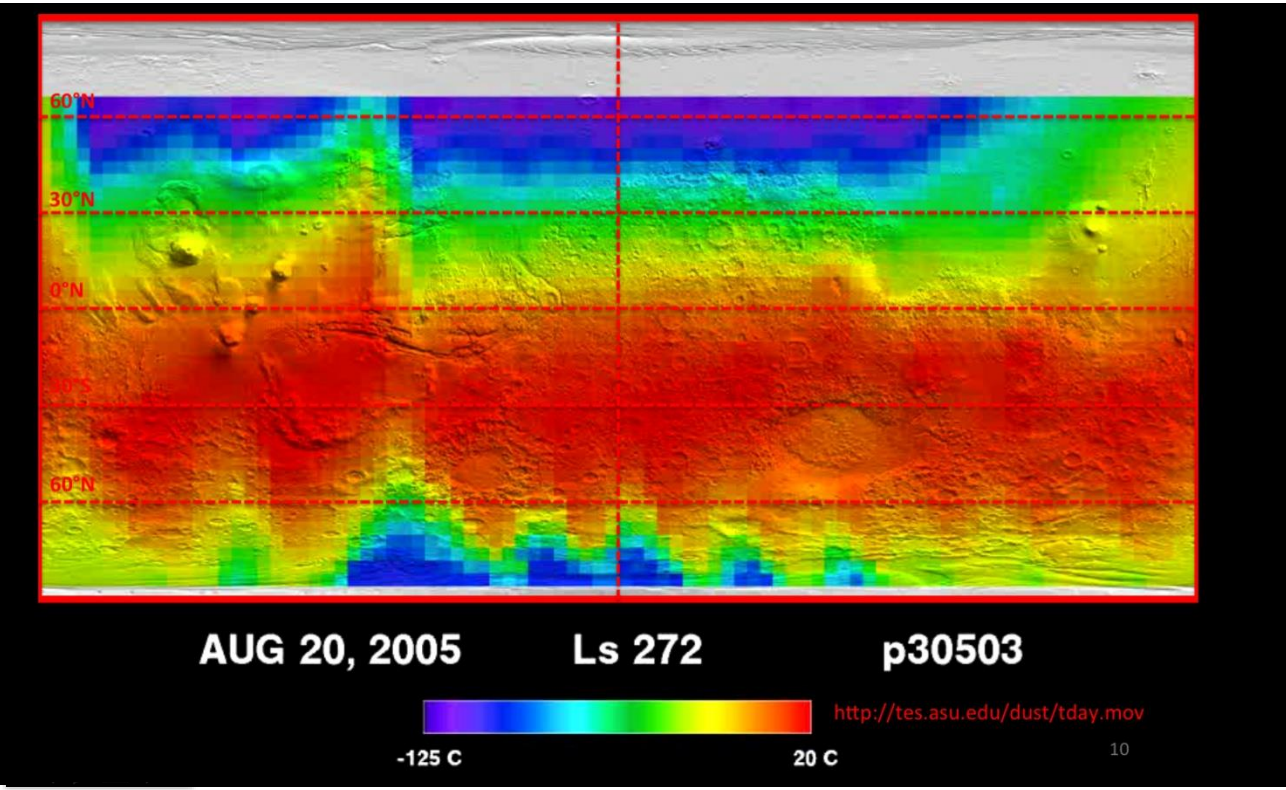
Opportunity Sun Images

Daytime Surface Temperature

Approximate Northern Summer Solstice

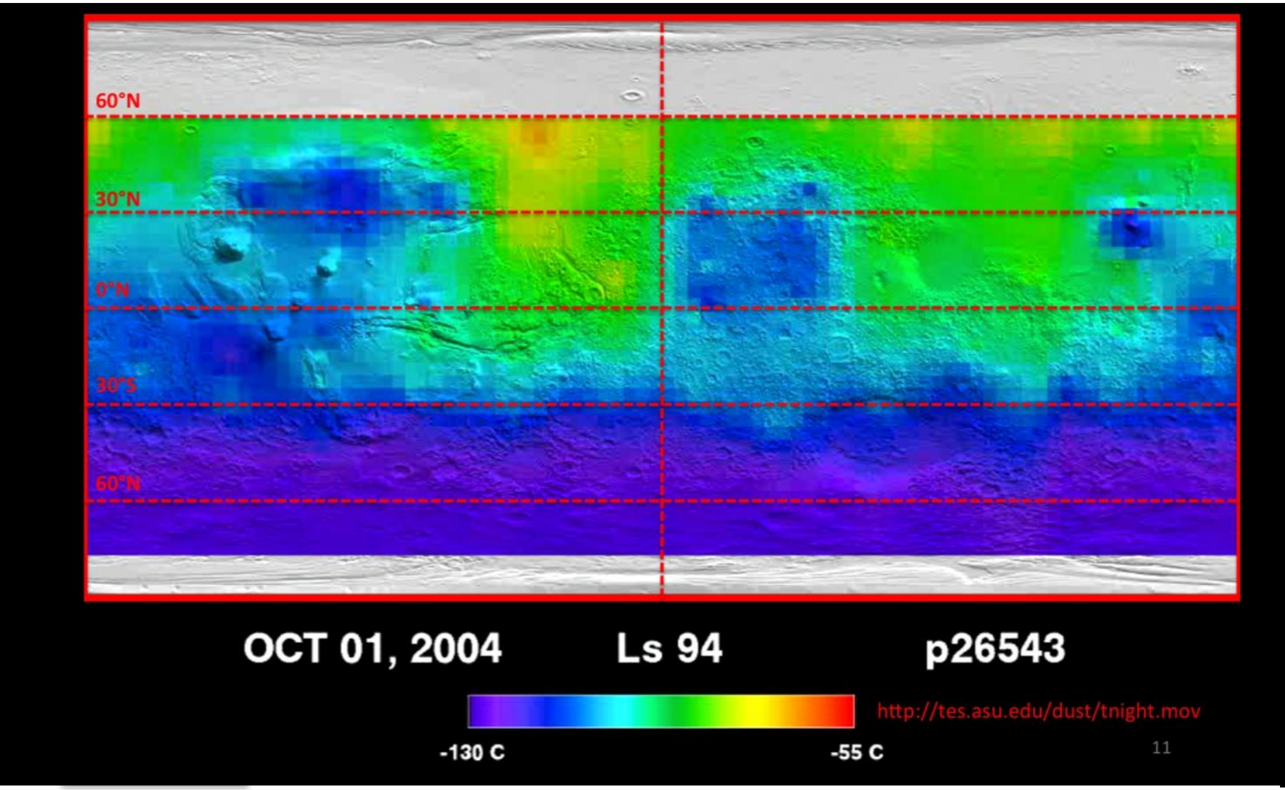


Approximate Northern Winter Solstice

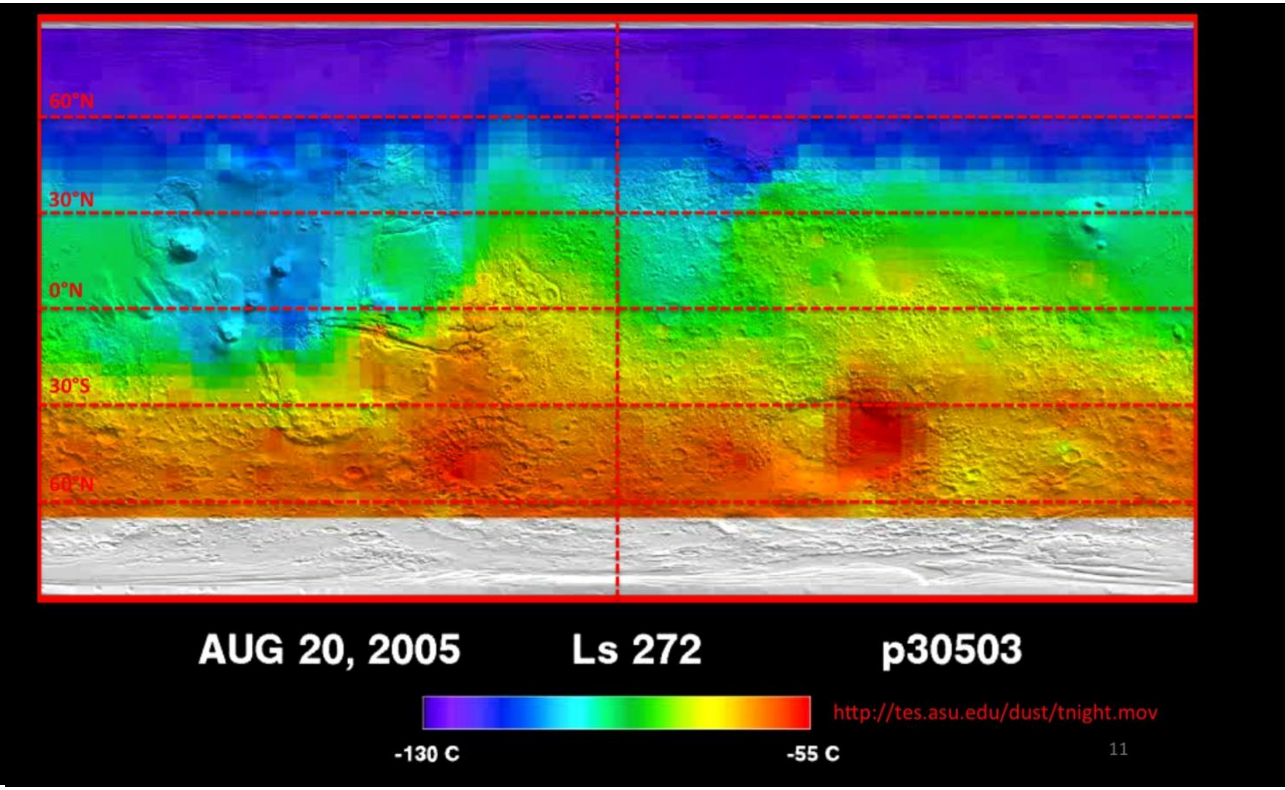


Night Surface Temperature

Approximate Northern Summer Solstice

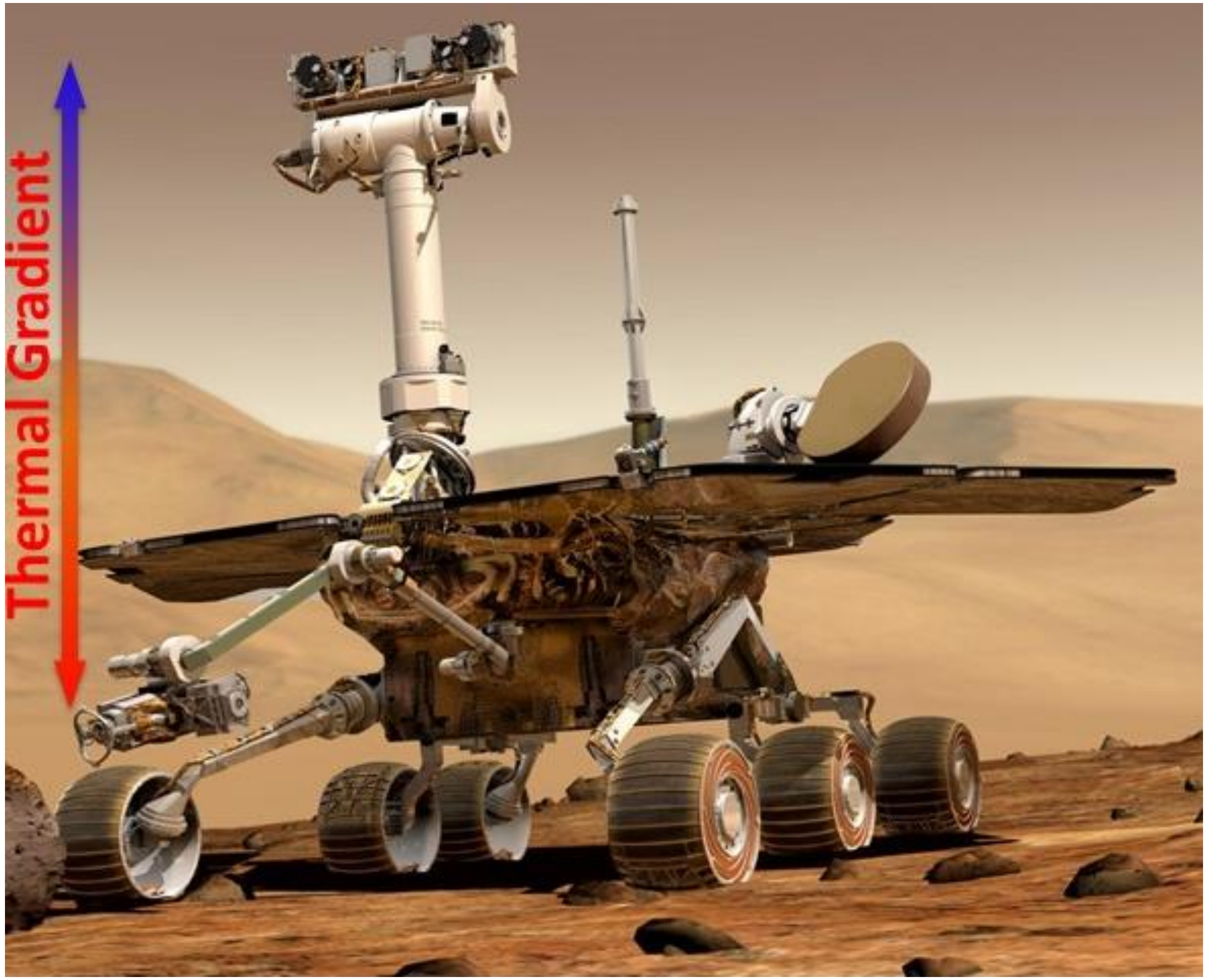


Approximate Northern Winter Solstice



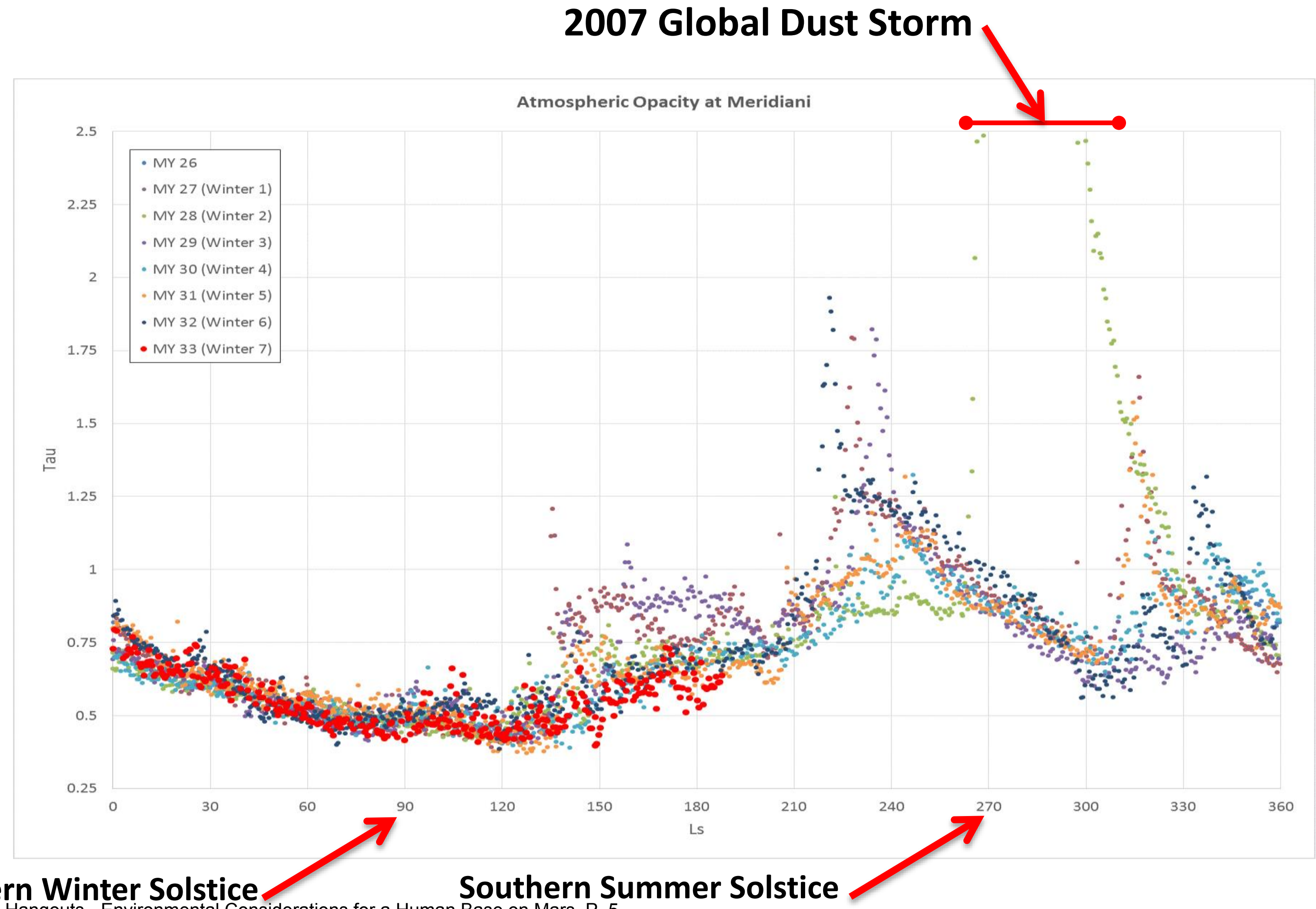
Near Surface Temperature

- Recent data from Opportunity
  - At sunset 5°C temperature drop over 1.3m height difference
  - 2 hours after sunset 10°C drop over 1.3m height different
- Several Mars years of data available from temperature sensors on Spirit, Opportunity, and Curiosity



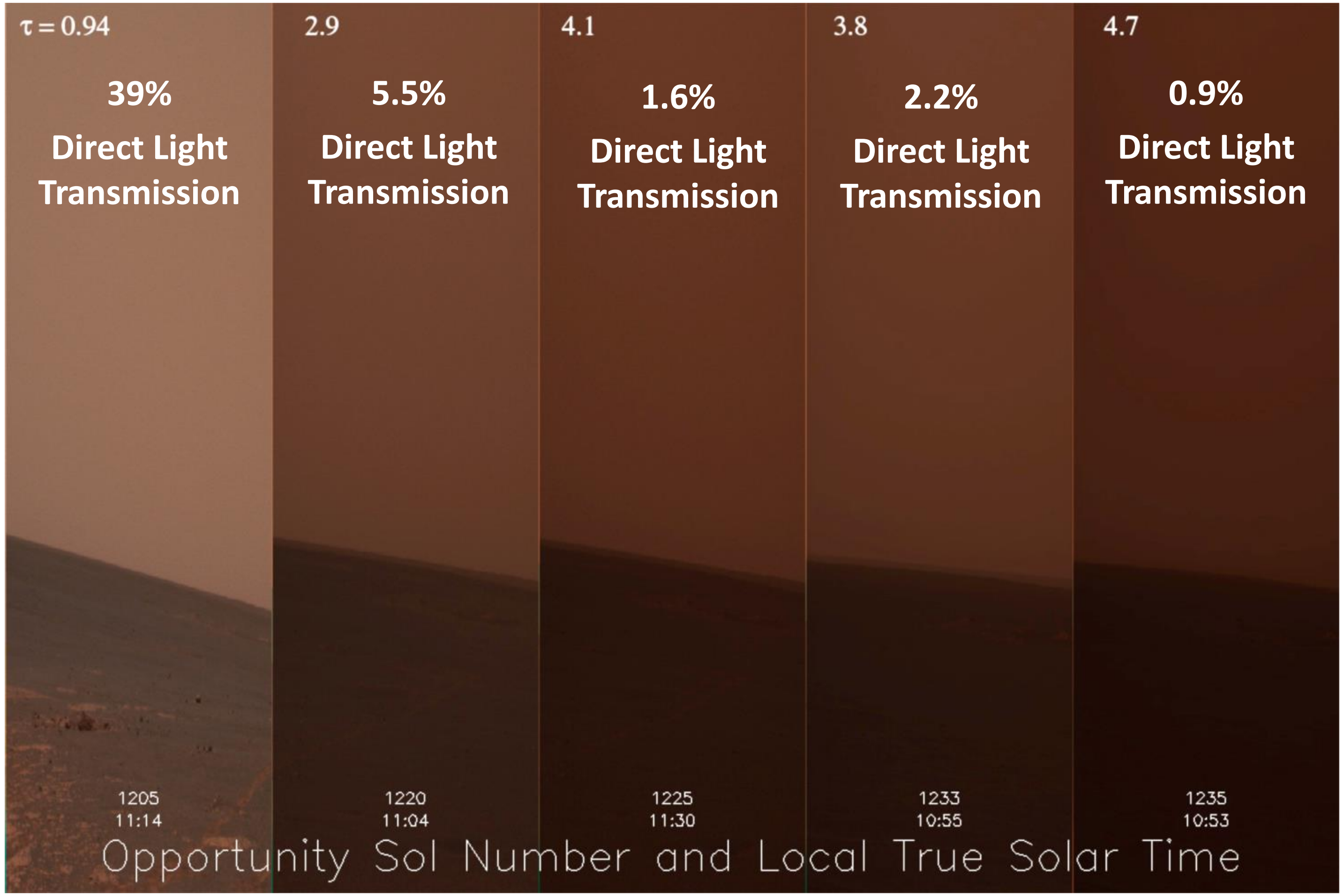
Dust Thermal Effects

- Large amounts of dust in the atmosphere attenuates diurnal temperature changes
- Major storms can decrease average temperatures to levels that require maintenance/survival heating even in summer



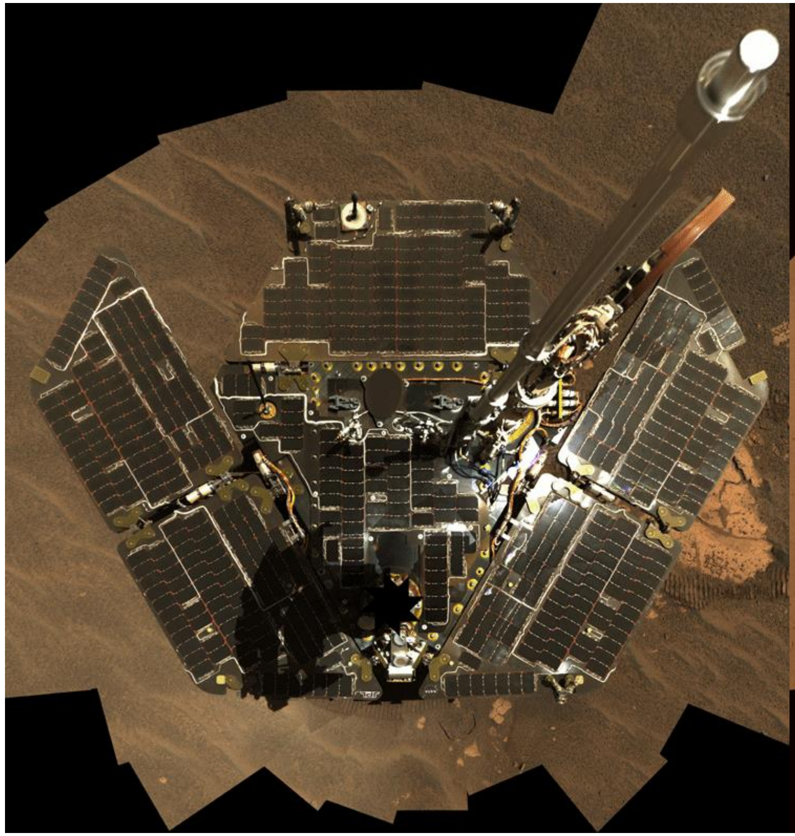
Dust Thermal Effects

- Occur approximately every 3 Mars years
- Storm intensity varies across Martian surface
  - Spirit & Opportunity affected differently
- New models may help predict storm years

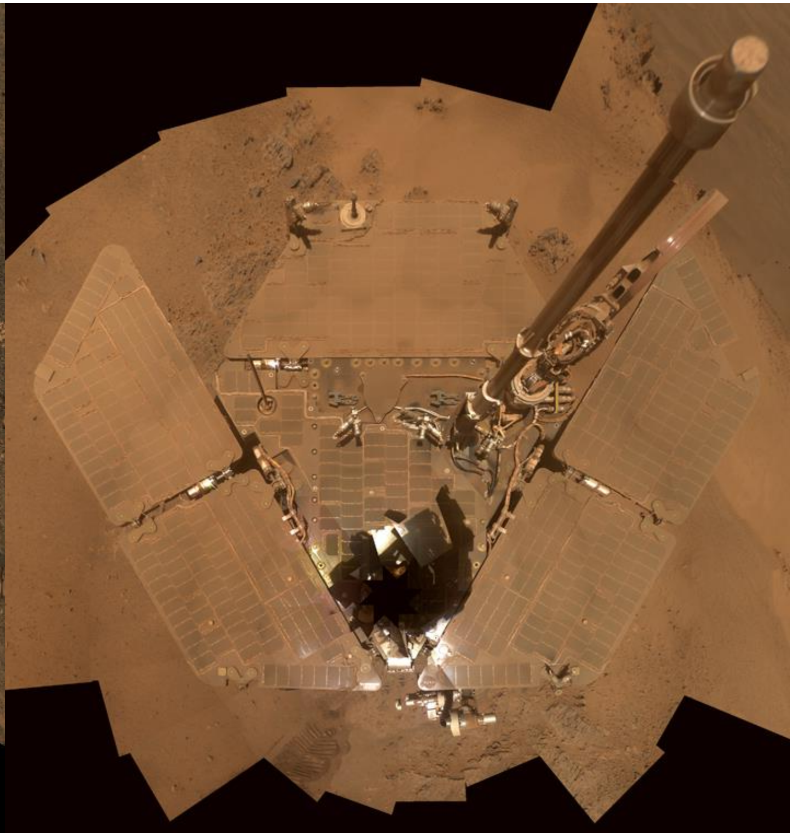


Dust Effects

- Dust settles on surfaces
  - Can be removed by wind or active systems
- Texture, material, and geometry, and vehicle location affect how much dust can be removed



Sol 332 (12/30/04)



Sol 2814 (12/24/11)

Dust Effects

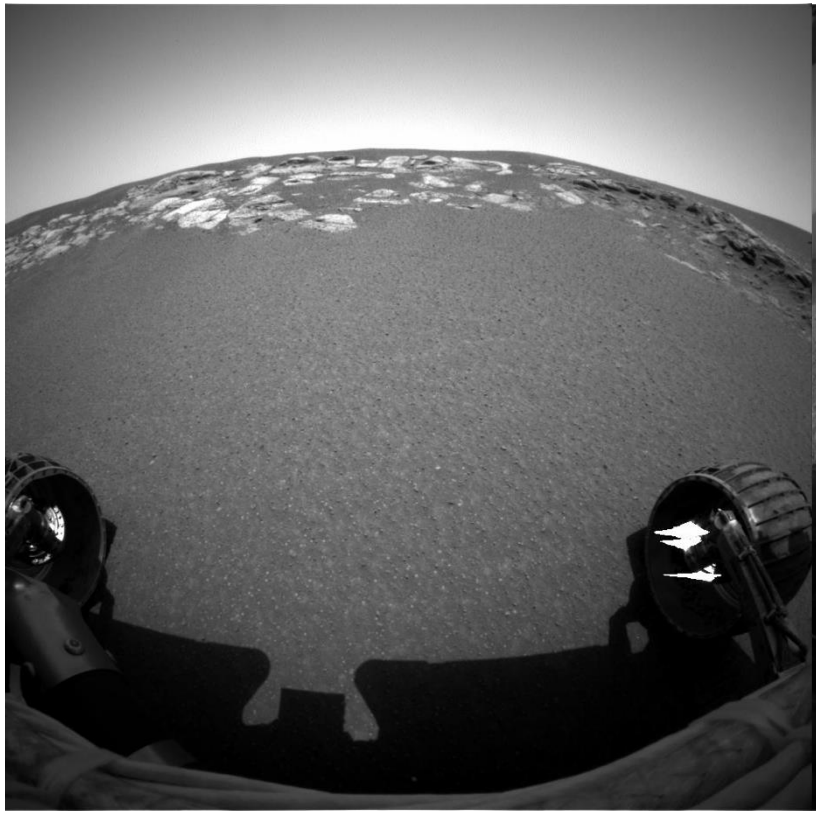
- Dust can be transported across vehicle surfaces by wind or vibration
  - Magnitude of movement affected by tilt of dust covered surface

Sol 4315 (3/14/16)

Dust Effects

Contamination

- Dust sticking to lenses reduces effective resolution which can limit operations
  - Can correct for some contamination
- Static binding to surfaces can render instruments unusable



Sol 16 (2/2/04)

Sol 4408 (6/17/16)

Thermal Effects

Battery Capacity

- Battery capacity is a function of battery temperature
  - Colder batteries hold less charge
  - Up to a 20% change difference between winter and summer

Component Heating Requirements

- Seasonal variation
- Affected by:
  - Surface thermal inertia
  - Height above surface
  - Shadowing
  - Component thermal inertia

Thermal Effects

Mars Arrival Season

Year	Ls	Northern Season	Southern Season	Reference
2001	259	Late Fall	Late Spring	(ODY arrival)*
2004	339	Late Winter	Late Summer	(MERB Landing)
2006	22	Early Spring	Early Fall	(MRO arrival)
2008	76	Late Spring	Late Fall	(PHX landing)
2012	150	Late Summer	Late Winter	(MSL landing)
2014	201	Early Fall	Early Spring	(MAVEN arrival)
2016	245	Late Fall	Late Spring	(ESA EDM landing)
2018	295	Early Winter	Early Summer	(InSIGHT landing)**

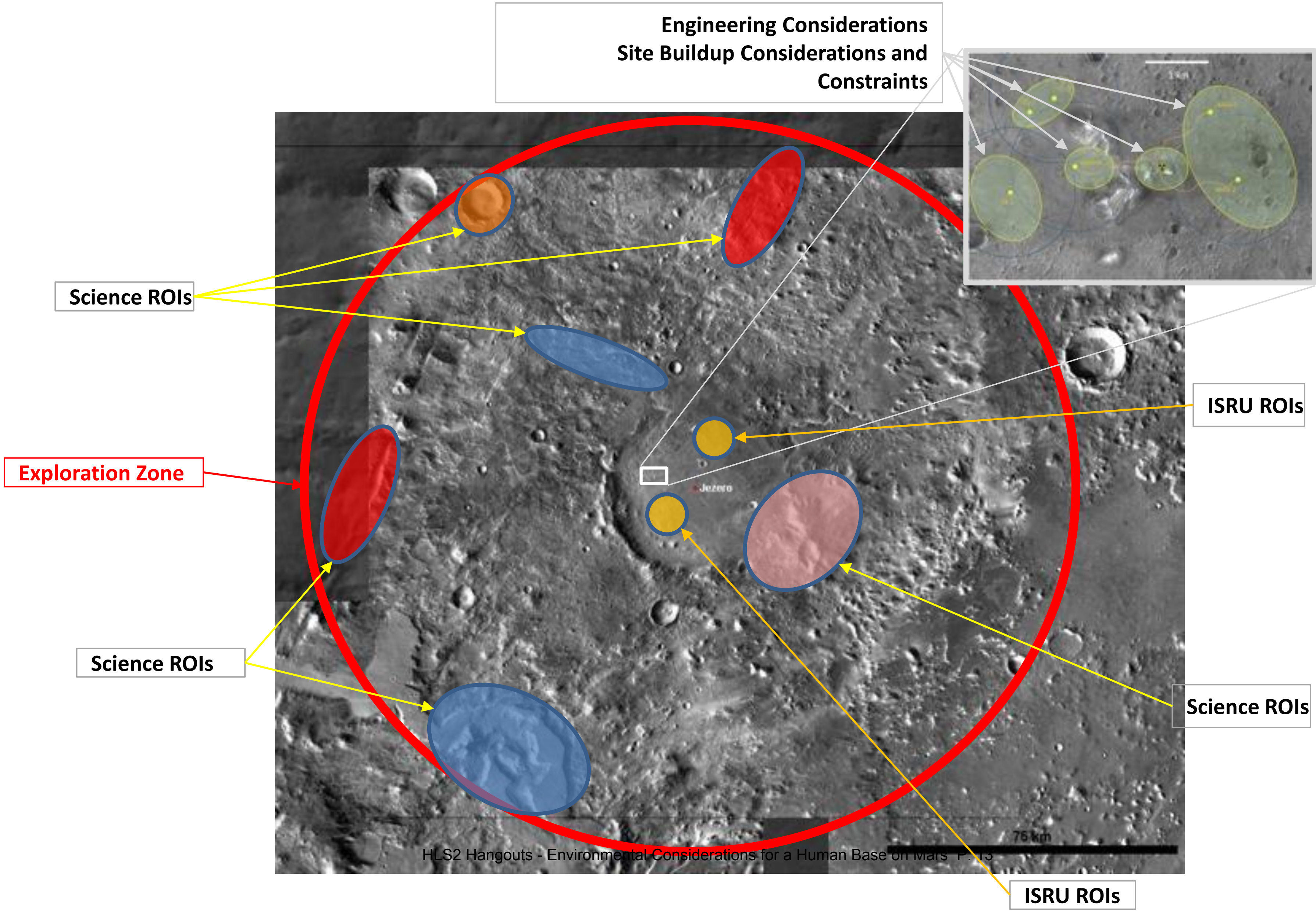
*Global Dust Storm Year

**Global Dust Storm Season (prediction)

The Mars Environment and Its Effects on Human Exploration

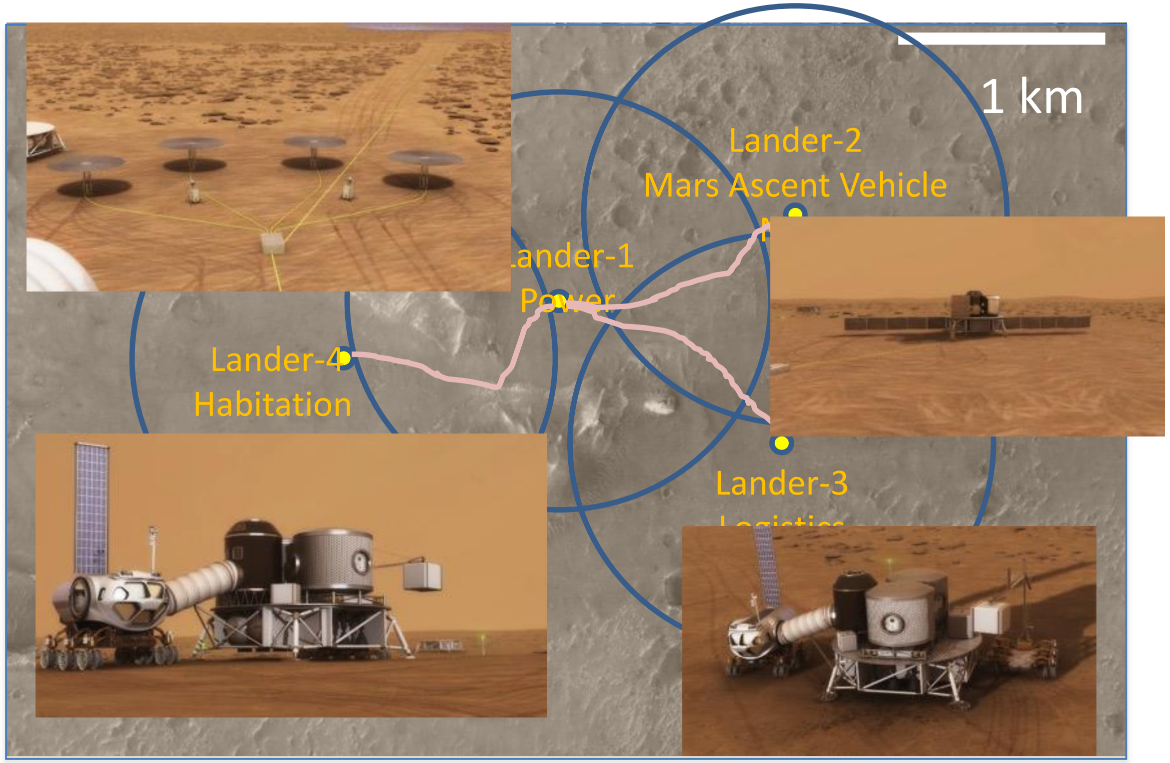
Larry Toups, NASA/Johnson Space Center

Example Mars Surface Field Station and Surrounding Regions of Interest (ROIs) – Jezero Crater



Surface System Elements Needed for the Surface Field Station Emplacement Phase

- **Mars Ascent Vehicle (MAV)**
- **Crew Descent Module**
- **Atmospheric ISRU**
- **Power (4 x 10 kW units)**
- **Robotic Rovers**
  - Special regions
  - Crew support
- **Cargo Off-loading**
- **Habitation**
- **Tunnel**
- **Science payloads**
- **Mobility platform to reposition payloads**
- **Small unpressurized rover (crew)**
- **Small pressurized rover (crew)**
- **Logistics modules**
- **Logistics**
  - Crew consumables
  - Fixed system spares
  - Mobile system spares
  - EVA spares



1 km radius plume ejecta hazard zone (typ)

100 m dia designated landing site

Potential Mars Environment Element Design Drivers

Seasonal changes

- Daylight (at 50 deg N latitude):
  - *~15 hrs (summer solstice)*
  - *~9 hrs (winter solstice)*

Temperature range (extremes)

- Highs > ~20° C
- Lows < ~ -110° C
  - *< −153° C (120 K; −243° F) during the polar night*

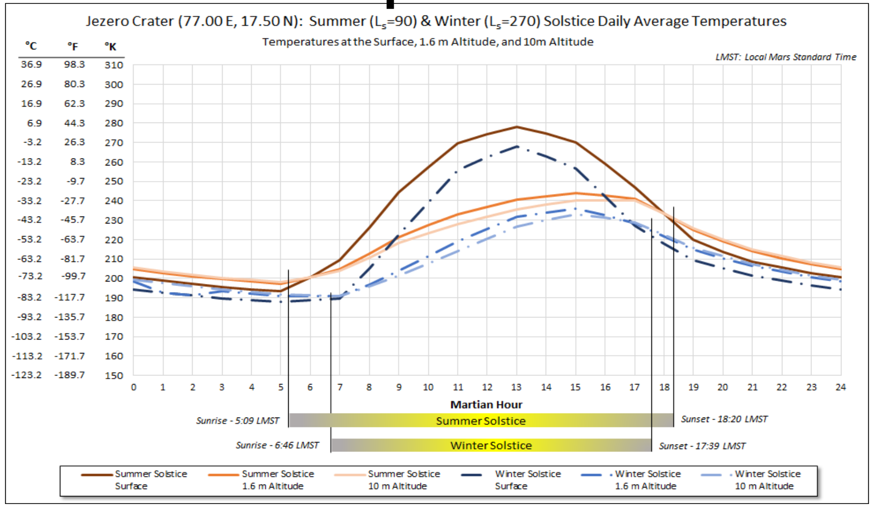
Winds

- Winds: typically < 20 m/s with low dynamic pressure
- Wind speeds measured by Viking landers
  - *Maximum: 30 m/s (60 mph)*
  - *Average: 10 m/s (20 mph)*
- Low atmospheric density (<1% of Earth's) means the wind is not strong as compared to Earth *(hurricane-force winds would "feel like" a slight breeze)*
  - *Periodic Dust Storms*

Temperature and Winds : Jezero Crater

- Several Mars environmental models have been built using remote sensing data gathered from a variety of orbiting spacecraft
- These models are being used to develop site-specific environmental data for use in surface system preliminary concept design
- This slide shows examples of temperature and wind results at Jezero Crater

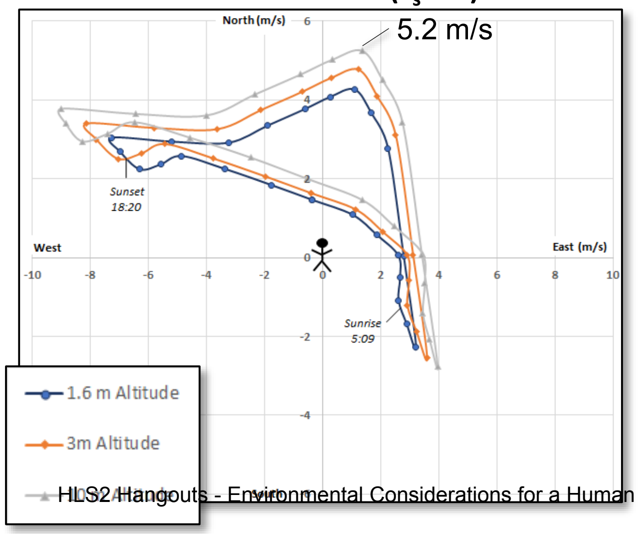
Temperature

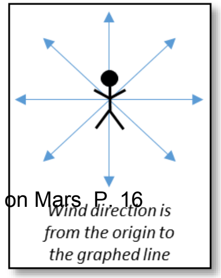


Wind Velocity, Direction @ 1.6 m, 3 m, and 10 m Altitude

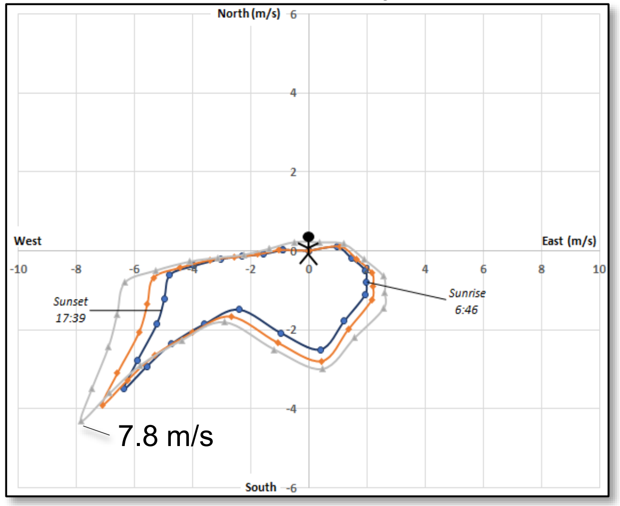
Wind Speed on Mars		Dynamic Pressure (MB)	"Feels like" wind speed on Earth (at STP)	
mph	m/s		m/s	mph
10	4.5	0.2367	0.6	1.4
50	22.4	5.9169	3.0	6.8
67	30.0*	10.6587	4.1	9.1
100	44.7	23.6677	6.1	13.5
150	67.1	53.2523	9.1	20.3
200	89.4	94.6708	12.1	27.1
224	100.0	118.4304	13.5	30.3
447	200.0	473.7216	27.1	60.6
500	223.5	591.6924	30.3	67.7

Summer Solstice (L_s=90)

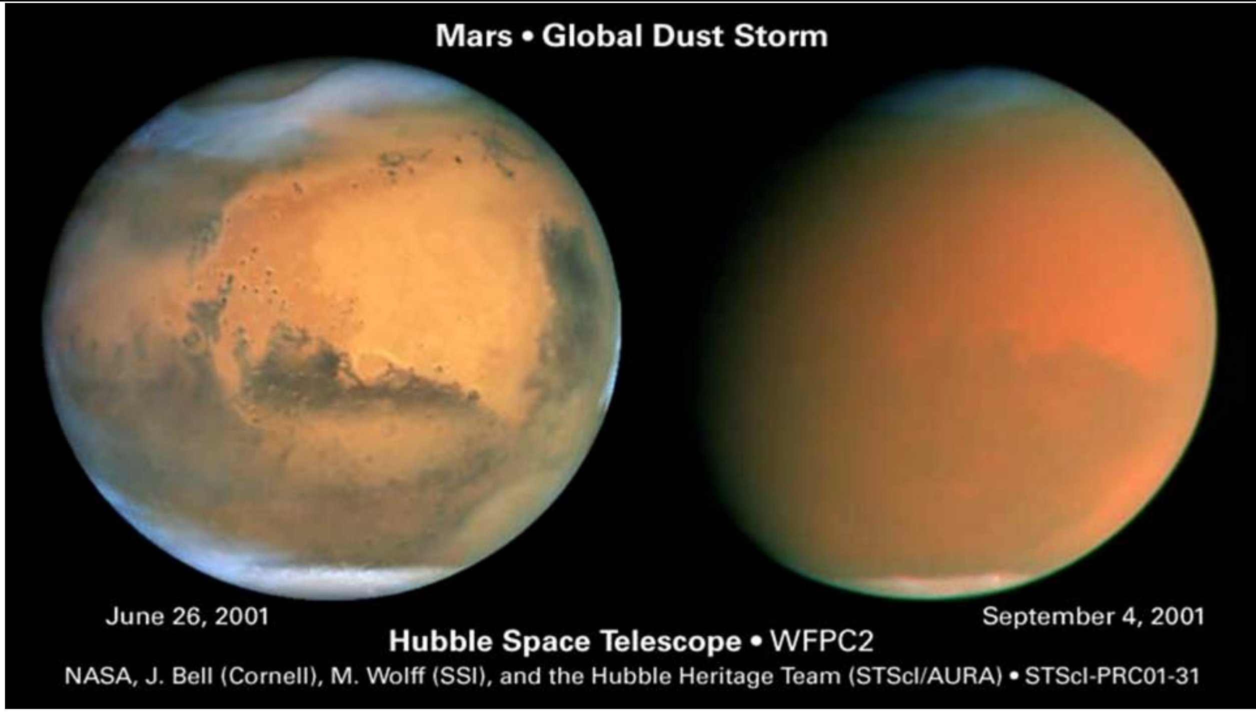




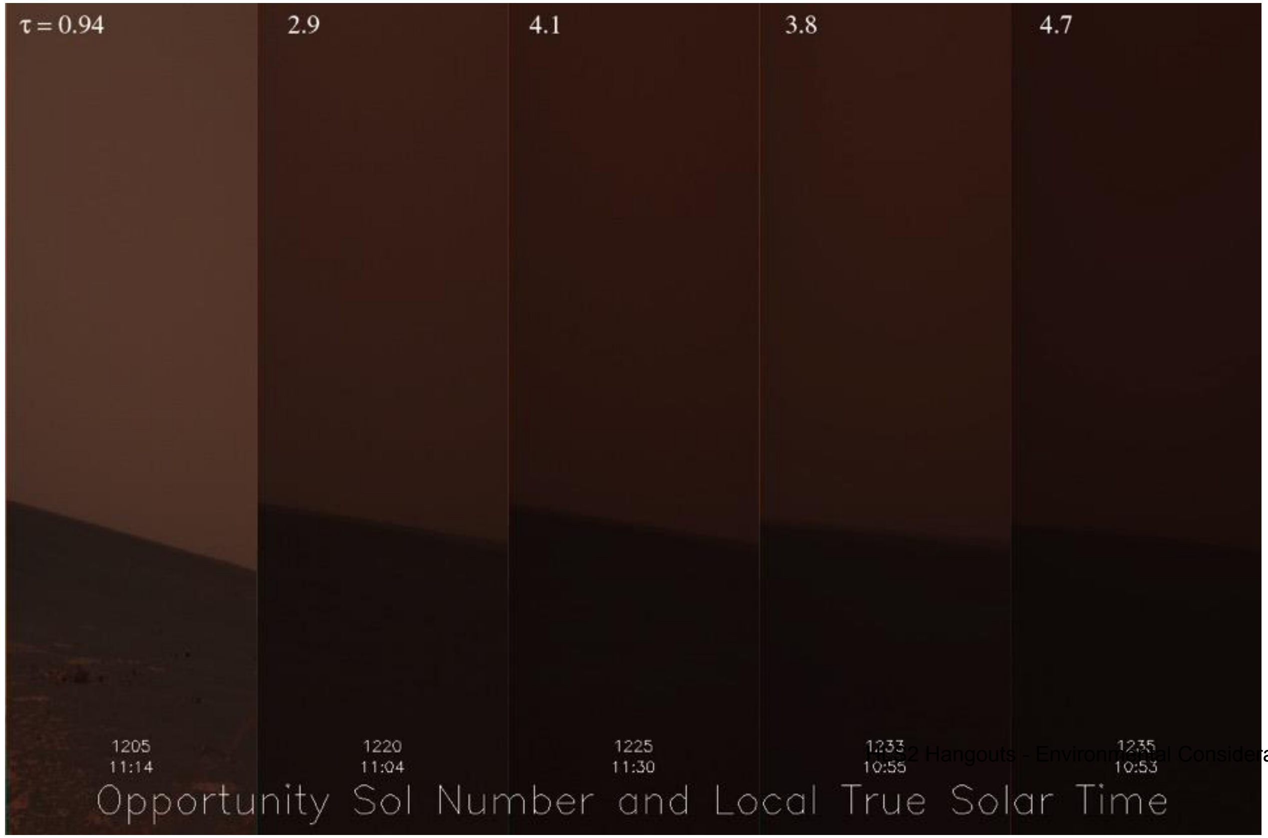
Winter Solstice (L_s=270)



Global Dust Storm



As seen from the surface:



Some Questions to Consider on Element Designs

- **Habitats - How do you build a hab where crew is ingressing potentially multiple times a day, with potentially toxic perchlorates on the suits?**
  - Accumulated dust: Exterior Windows, radiators
  - Abrasion damage: Hatch seals & locking mechanisms
  - Chemical interactions: water processing, food safety
- **Rovers - How are (Pressurized and Unpressurized) Rovers affected by the surface environment?**
  - Accumulated dust: windows, radiators, external batteries (possible overheating)
  - Abrasion damage: moving parts, hatch seals & locking mechanisms
- **Power Systems – Are power systems affected?**
  - Accumulated dust: solar arrays, nuclear power radiators
- **EVA Systems**
  - Abrasion damage: suit fabrics, helmet face shields, EVA tool moving parts
  - Accumulated dust: helmet face shields, boots (tracking into habitat)

Some Questions to Consider on Element Designs

- **If we pursue a site that is further north, potentially for sub-surface ice**
  - Does that affect the efficiencies of solar arrays?
  - Does the thermal environment influence the overall design of the equipment?
- **How do seasonal temperatures and albedo (dust) variations play in?**
- **How do Planetary Protection protocols affect surface systems designs and operations?**
  - Since there could be “critters” that may be part of the natural environment

Some Questions to Consider on Surface Operations

Example: Dust Storm Operations

Since dust storms are a certainty, we need to define what we would/ wouldn't do during a storm

- If solar power: what has to be powered down?
  - *What is the abort criteria to abandon the surface and return to orbit?*
- What's the visibility go/no-go criteria for EVA or rover ops?
  - *Are there knowledge gaps that must be filled to answer this question?*
  - *Is there a niche for tele-robotic rover ops during dust storms?*
- If rover is TBD km from the Habitat when a dust storm hits, should the rover shelter in place or try to return to the Hab?
  - *How will dust storm considerations or storm contingency operations influence the surface rover design?*
- What are the post-storm procedures?
  - *What needs to be checked/cleared of dust?*
- What are the implications for use of optical communications technology?

National Aeronautics and Space Administration

EVA Environments

Overview for Human Landing Site Study
Google Hangout

July 28, 2016

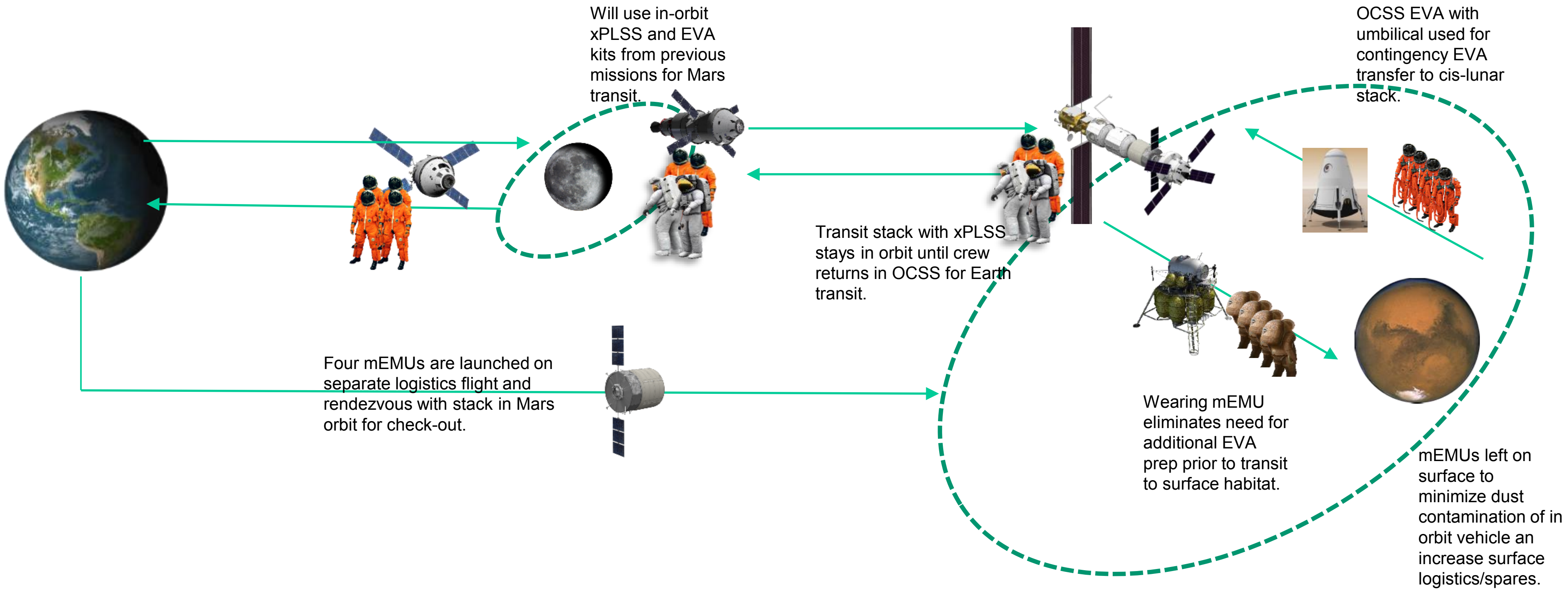
J. Buffington/JSC-XX
R. Blanco/JSC-EC
L. Aitchison/JSC-EC

Planning for EVA

- Extravehicular Activity (EVA) or “spacewalks” brings humans as close to the environment outside a spacecraft as humanly possible
- Two basic questions in EVA System Design:
  - Where are you going?
    - Defines environmental factors affecting design
  - What are you doing?
    - Identifies system mobility and vehicle/tool interfaces
- Unfortunately we have gaps in our understanding, and even with what we do know we see gaps in our technological solutions – no one single EVA Suit design (today) is able to operate in all environments humans might conduct a spacewalk in
- As Human Spaceflight matures towards a Mars Surface Mission, EVA is working to close gaps in knowledge and technology necessary to address significant challenges including the Environment

Extravehicular Activity Management Office

Notional Mars Mission EVA Concept



EVA System Drivers

	ISS	Cis-Lunar Space	Mars Surface
EVA Tasks	• Vehicle assembly and maintenance	• Science • Vehicle maintenance	• Science • Vehicle maintenance
Environment	• Microgravity • Vacuum • Sharp edges from micrometeorite strikes • Relatively constant temperature zones	• Microgravity and $1/6^{th}$-g • Vacuum • Sharp edges from micrometeorite strikes • Loose dust/dirt • Increased radiation exposure	• $3/8^{th}$-g • Non-vacuum • Chemically reactive soil • Loose dirt/dust • Seasonally variable temperatures
EVA Duration	Plan 5 -7h + 30min	Plan 4 - 8h + 1h	Plan 2 – 8h + 1h
EVA Frequency	• Up to 8 per year	• In orbit, 10 per year • Surface, up to 24h per week for <1 yr	• Up to 24h per week for > 1 yr
Maintenance Cycle	• Standard 90/180/360d processing • Focused hardware checks for 2 weeks prior to EVA	• Automated operations for standard processing • In orbit, Focused hardware checks for 1 week prior to EVA • Surface 1h pre/post EVA	• Automated operations for standard processing • Surface 1h pre/post EVA
Re-supply Frequency	10+ cargo flights per year	Up to 2 cargo flights per year	Pre-positioned supplies
Communication Delay	<1 sec	1 -3 sec	3 – 21 min

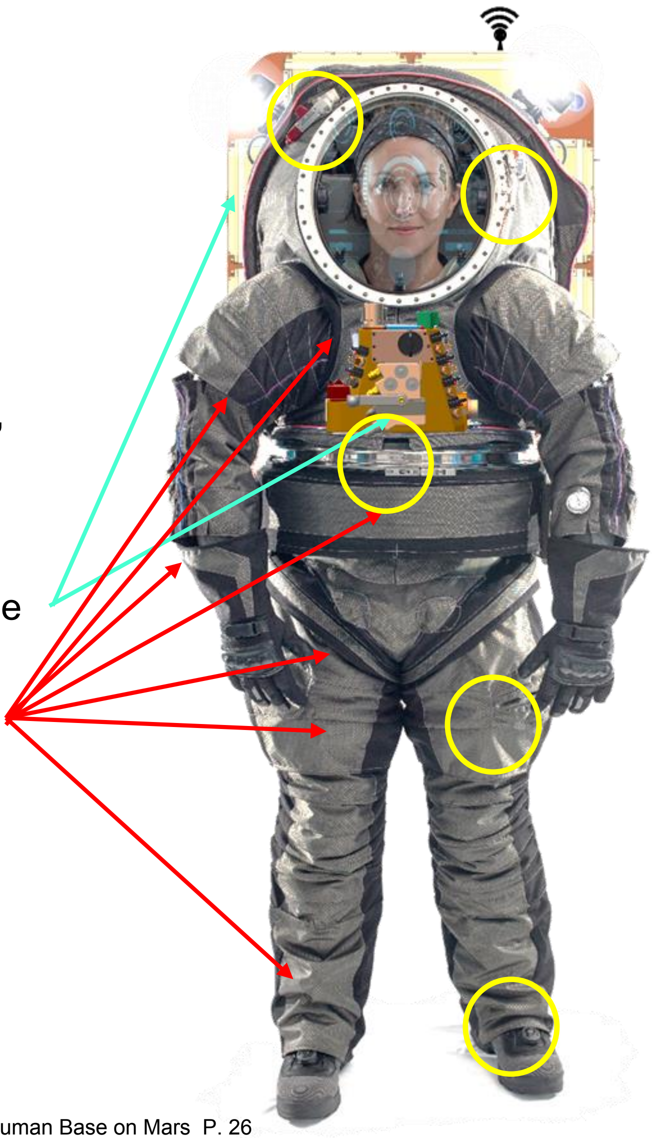
EVA Technology Gaps

- **Dust Tolerant Mechanisms**
- **Textiles for High Abrasion Environments**
- **Thermal Insulation for Non-vacuum Environments**
- **Dust Mitigation Strategy for Remote Habitats**
- **Mass Reduction Strategies**
- **Closed Loop Life Support Systems**

EVA Technology Gaps

Dust Tolerant Mechanisms

- Space suits for planetary exploration will be required to operate nominally in a coarse dirt and fine dust environment for up to 600 hrs with minimal maintenance required.
- Nominal operation is considered less than 10% increase in running torque for bearings, less than 10% increase in actuation torque for disconnects, and less than 2 sccm increase in leakage.
- Key mechanisms in space suits include
  - Quick disconnects for oxygen, water, and power/data lines; gas exhaust ports, relief and purge valves
  - Bearings in the pressure garment arms, legs, and waist
  - Component hard disconnects at the pressure garment wrist, arm, waist thigh, and ankle; and hinges at the pressure garment rear hatch.



Desired Technology Capabilities:

- Mechanisms with quick change-out dust seals
- Mechanisms with active dust repellant properties

EVA Technology Gaps

Textiles for High Abrasion Environments

- NASA needs suit material(s) and systems of layers of materials that are capable of long duration exposure to dust, and abrasive activities that are also flexible so as not to compromise mobility (walking, kneeling, etc.).

Desired Technology Capabilities:

- Self-healing textiles
- Damage sensing textiles
- Manufacturing techniques to minimize dust migration between textile layers
- Textiles or coatings with active dust repellant features
- Textiles or coatings with passive dust repellant features

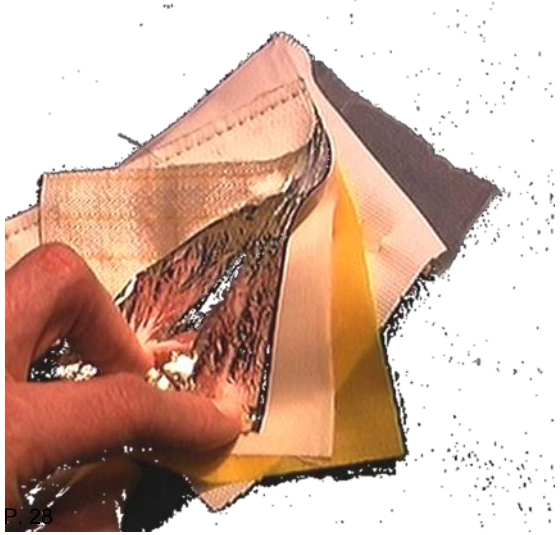
EVA Technology Gaps

Thermal Insulation for Non-Vacuum Environments

- Current space suit insulation technologies rely heavily on the vacuum of the low-earth orbit environment to minimize heat transfer by separation of layers in the space suit material lay-up so that conduction, as well as convection
- However, various exploration destinations, and specifically Mars, exhibit low pressure atmosphere which allows convection to occur

Desired Technology Capabilities:

- Lightweight, flexible, durable, and thin to minimize interference with mobility features of suits (Note: If one or more of the above characteristics is an issue, but could be resolved for space suit application through development, the technology is of interest)
- Adaptable for seasonal variations in temperature



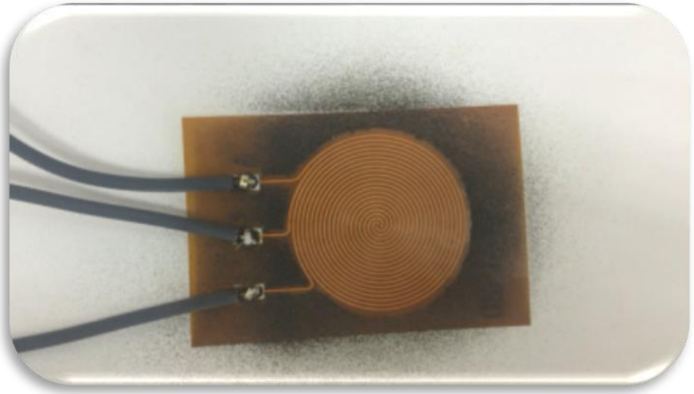
EVA Technology Gaps

Dust Mitigation Strategy for Remote Habitats

- Exclusion of dust from habitable environments is a system level challenge.
- Space suited crewmembers will bring some amount of dust into the habitat following each EVA. In reduced gravity environments fine dust does not quickly settle out of the habitat atmosphere.

Desired Technology Capabilities:

- System to remove/repel dust from space suits
- System to remove and collect dust from the habitat atmosphere
- System to remove and collect dust from habitat surfaces
- System of locks that employ the above to mitigate dust in the habitable volumes



EVA Technology Gaps

Mass Reduction Strategies

- Launch mass from Earth's surface has always been a challenge but introduction of gravity environment for EVA will create greater need for reduced on-back mass.
- Gravity environments will increase the need for finer alignment of EVA suit system CG to optimize mobility and efficiency.

Desired Technology Capabilities:

- Composite lay-ups that meet load requirements (pressure and impact) with minimal mass
- High reliability (low scap rate) methods for fabricating complex composite geometries
- In-situ printing of replacement suit components
- Lightweight bearings

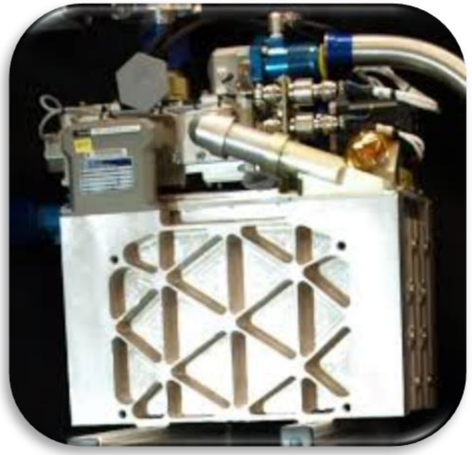
EVA Technology Gaps

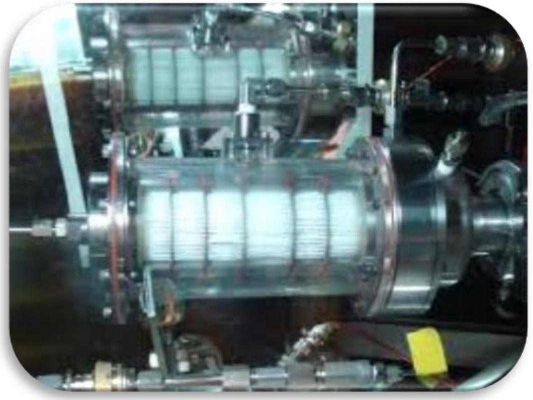
Closed Loop Life Support Systems

- NASA needs EVA CO_2 and H_2O removal system that is low mass, low power, low consumable at the mission architecture level, minimizes exhaust pollutions (for planetary protection considerations), and functions within the Mars CO_2 atmosphere and convective thermal environment.

Desired Technology Capabilities:

- Small package that enables the overall Portable Life Support System (PLSS) volume to be minimized. Current technologies have dimensions 10.5 in x 8in x 6in.
- Remove CO_2 at rates up to 190 g/hr with concentrations <2mmHg
- Accommodate these removal rates for up to 12hrs with 8hrs of autonomous EVA time and potentially 4hrs of prebreathe time.
- Remove H_2O vapor at rates up to 150 g/hr with <75% RH in oxygen carrier gas with trace CO_2





Closing EVA Gaps

- The EVA Community is actively working to collaborate with scientists and engineers across spaceflight
  - Participate in intra-agency technical interchange meetings
    - Human Research Program Annual Workshop
    - EVA Collaboration Workshop
  - Maintain high-level list of technology and knowledge gaps with associated closure plans
    - EVA System Maturation Team
    - NASA Technology Roadmap
  - Partner across Government, Industry, and Academia to strategically target gap areas by priority with emphasis on cross-cutting areas
    - Small Business Innovative Research Program
    - Space Act Agreements
    - Research grants (NSTRF, NAIC, NSBRI, etc.)
  - Publish latest technical developments and research results in relevant publicly accessible forums
    - Conference papers (AIAA, ICES, SAFE, IFAI, SAMPE, etc.)
    - Trade publications
    - NASA Tech Briefs
- Through sharing of knowledge, it is our hope that we are closing the gaps to EVAs on Mars

NASA's Journey to Mars:

EVAs in gravity

Long Way from Home

Mike Fincke, Astronaut Office