Plansee / JPL / Ceramatec TIM Introductory Comments 26 Jan 2016

Background Charts Borrowed from:

Entry, Descent, and Landing:

Seven Minutes of Terror

Presentation fo the Los Angeles Section of the American Society of Mechanical Engineers

Carl S. Guernsey
Jet Propulsion Laboratory
California Institute of Technology

November 20, 2008

A Short History of Mars Landings

aka

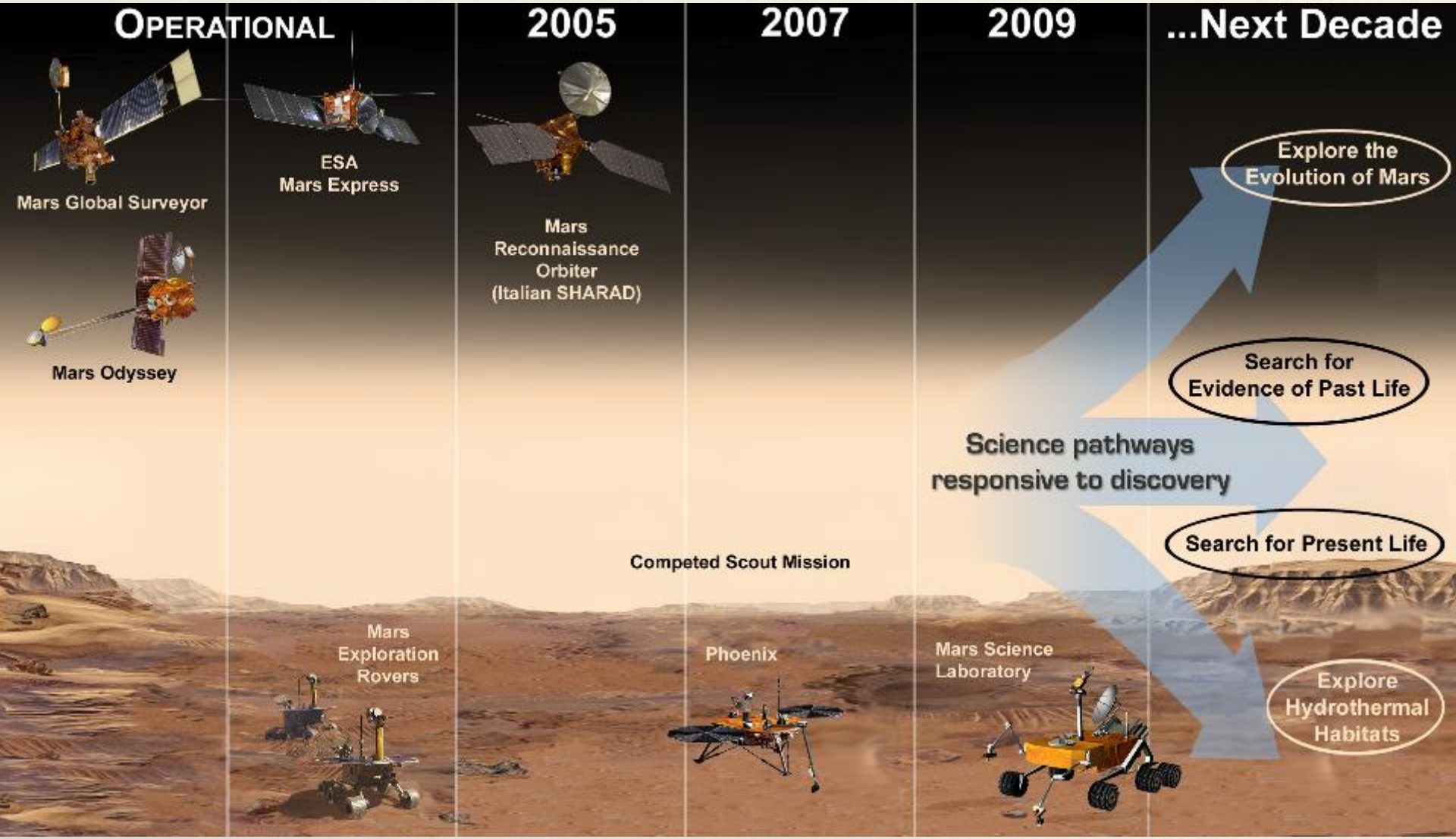
"Dare Mighty Things!"

Just getting to Mars is Hard

The international community has sent 27 orbiters, 12 landers, & 2 probes, totaling 41 attempts to gain an understanding of Mars.

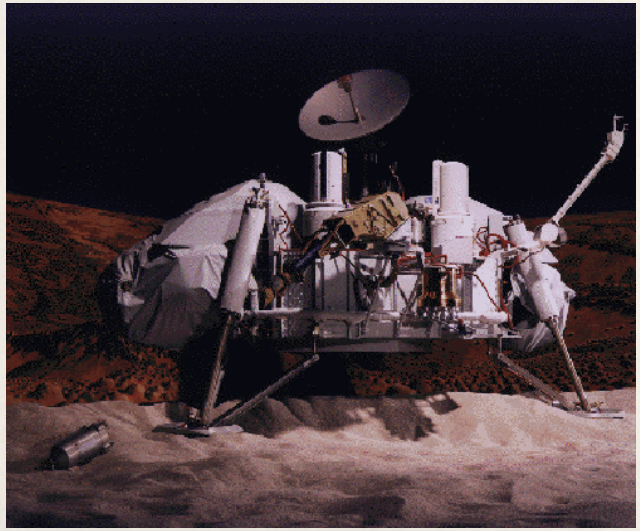
63% of the time, Mars has won!

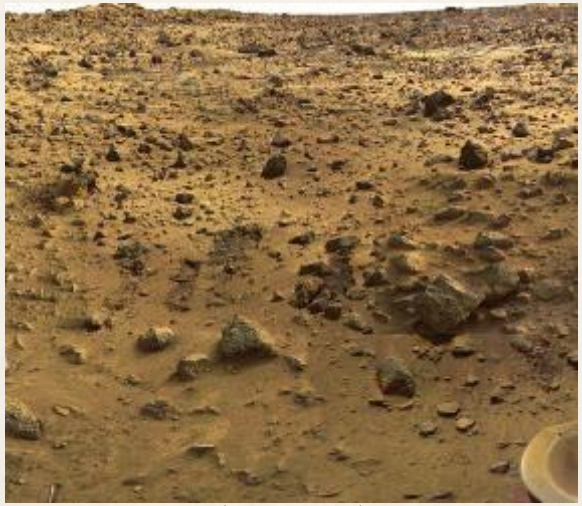
NASA's Mars Exploration Program



Strategy: Follow the water, assess habitability, potentially return a sample, prepare for humans.

Viking





Viking Lander 1

Viking Lander 2

~600kg RTG powered lander with robotic arm (~90kg science payload)

Entered atmosphere after being carried into orbit by an orbiter vehicle

Propulsive terminal descent using continuously throttle able engines

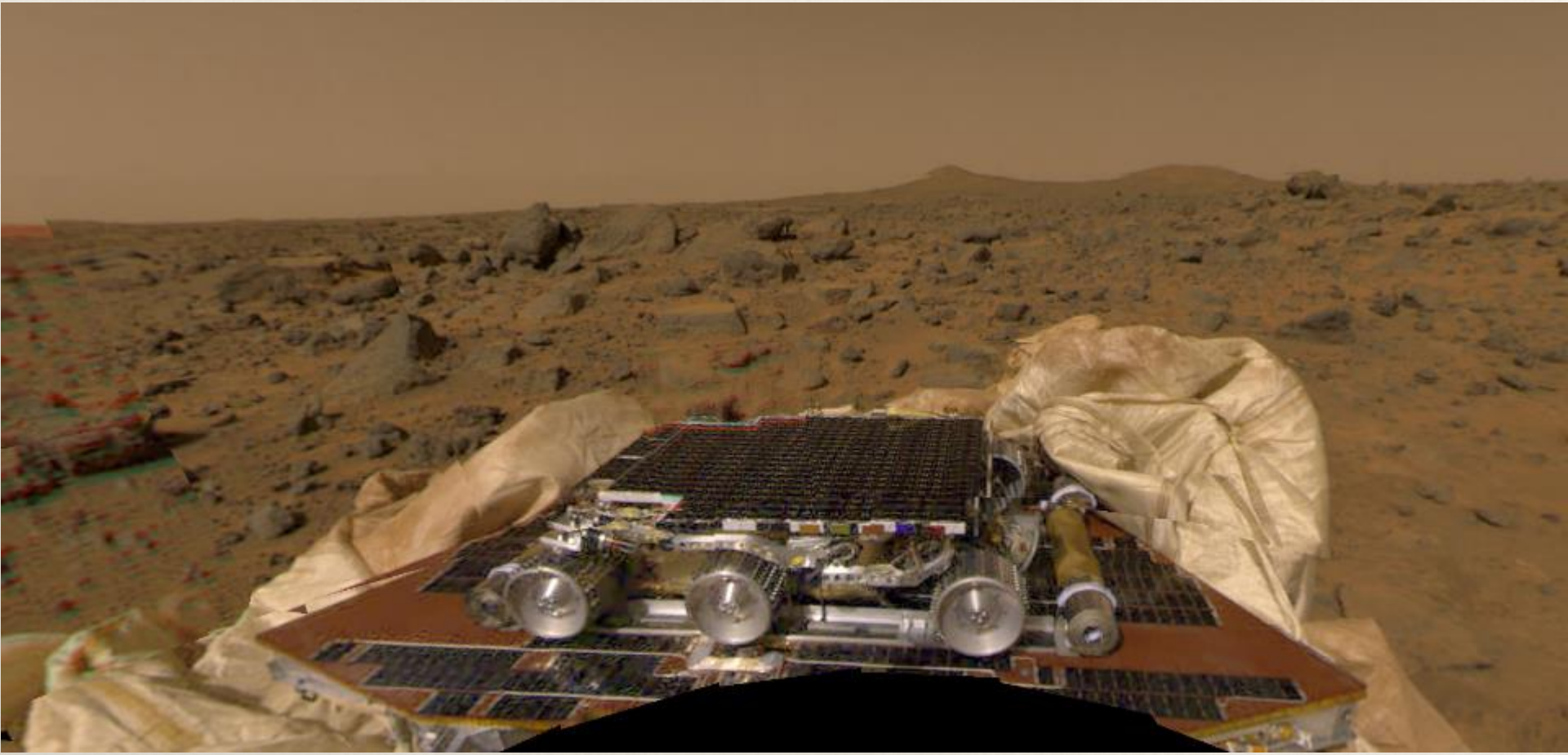
Landed July 20, 1976 and September 3, 1976

Cost was in the $ B's

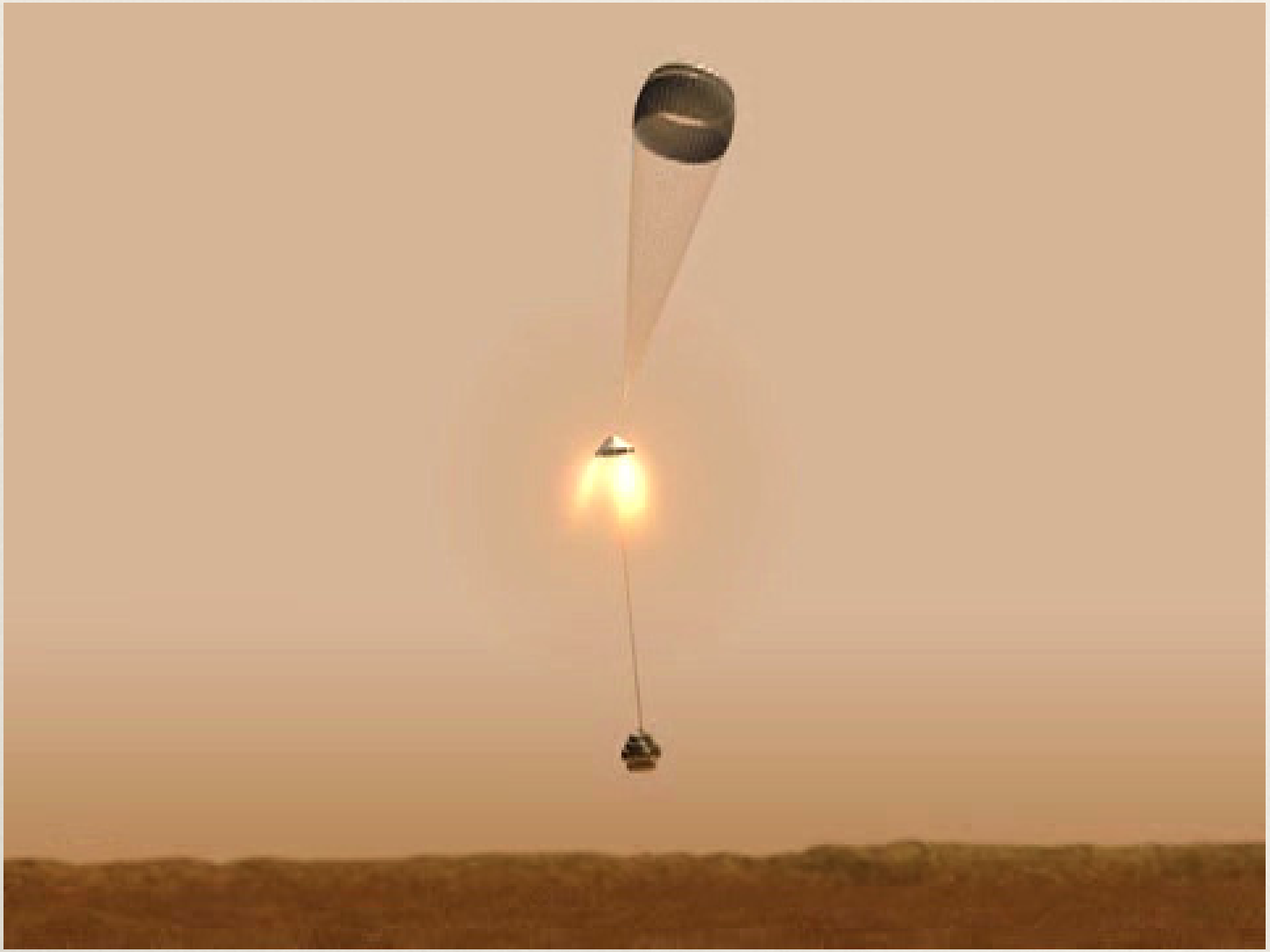
It was to be nearly 20 years before we returned to the surface of Mars…

Mars Pathfinder (MPF) - July 4, 1997

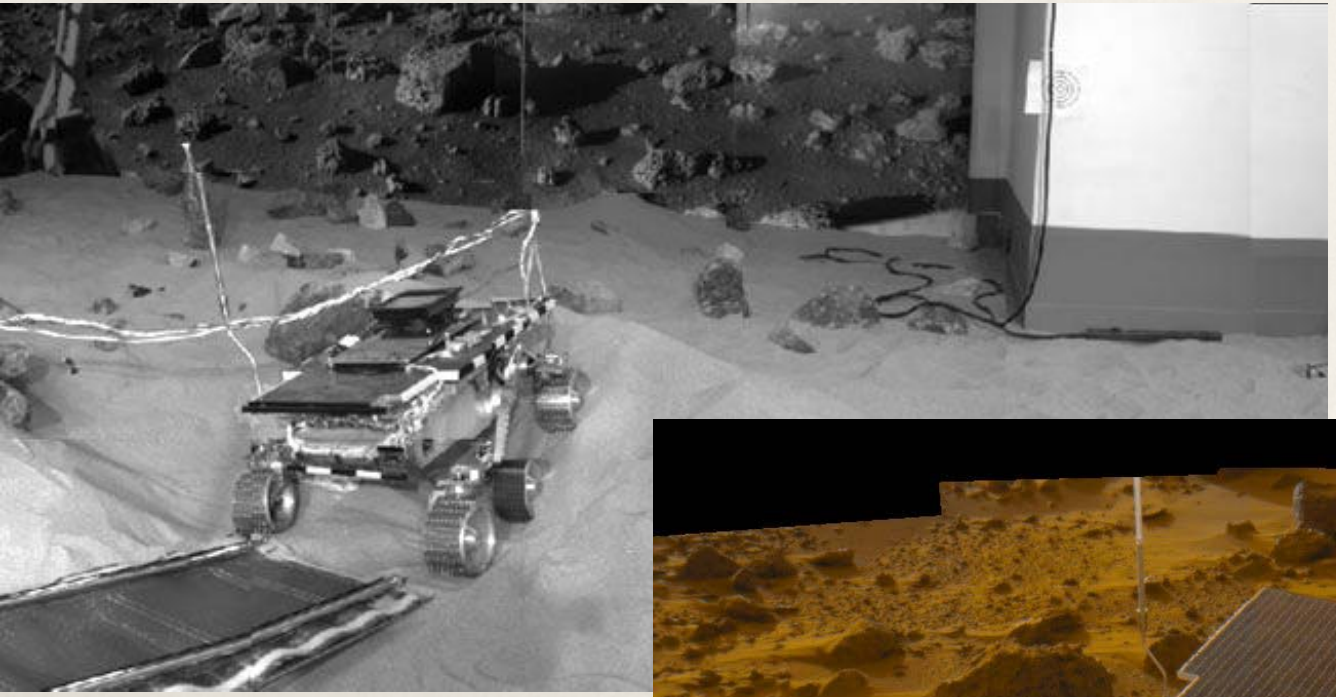
First attempt at a “Faster, Better, Cheaper approach to landing on Mars with the use of air bags to cushion the lander at impact

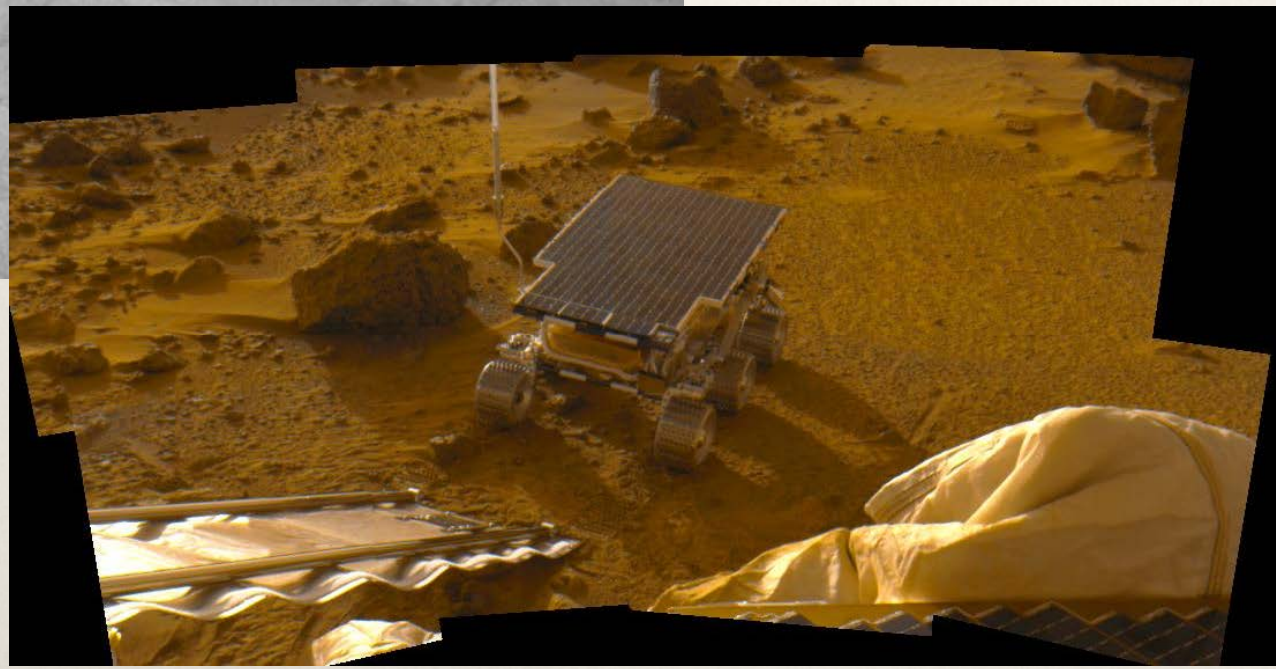


Mars Pathfinder EDL



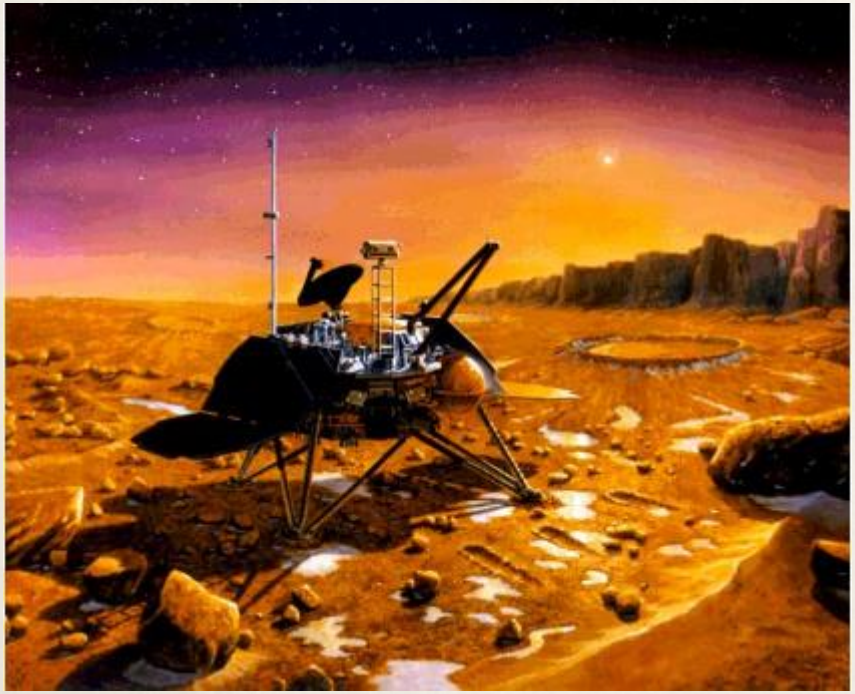
Sojourner Operations
Just like on Earth…well not really





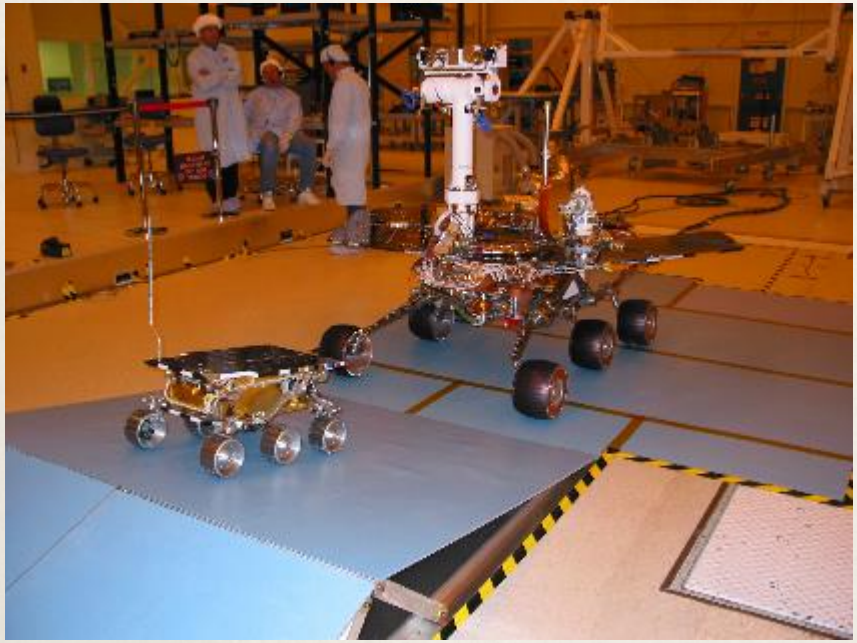
Mars Polar Lander (MPL)

* Attempt to continue the “Faster, Better, Cheaper” approach to landing on Mars
  * Propulsive terminal descent using pulse width modulation of descent engines
* Vanished during entry in Dec 1999
  * Numerous issues were found which might have caused the failure
* Begat the next two NASA missions to land on Mars:
  * Mars Exploration Rovers
    * MPF “build to print” - NOT
  * Phoenix
    * Based on MPL sister ship mothballed in 2000



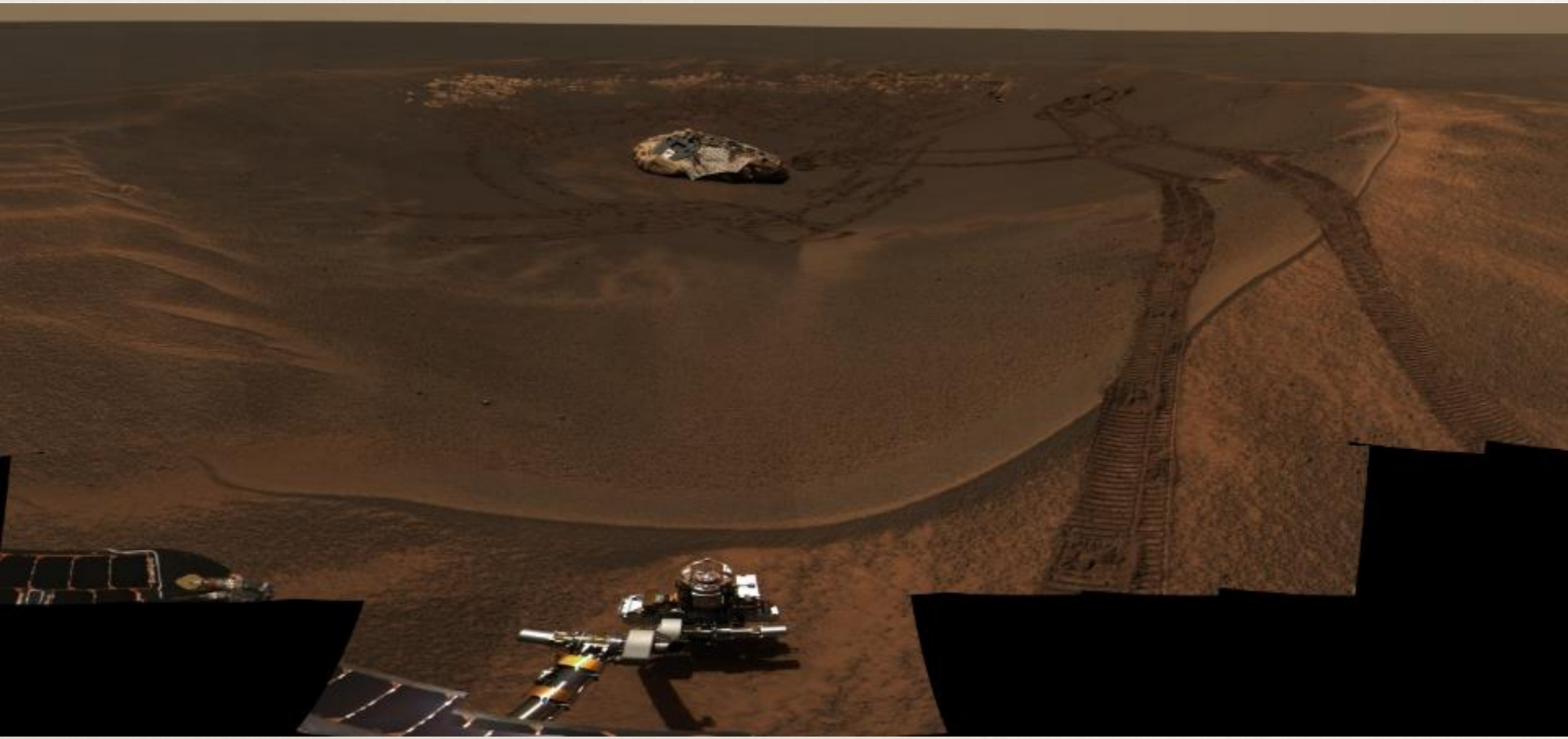
Mars Exploration Landers (MER)

* Launched as a high-priority mission in 2000 as part of the Mars Exploration Program's attempt to recover from the loss of MPL
* Intent was to use as much heritage from Mars Pathfinder as possible to reduce risk and enable an aggressive schedule
  * Solid rockets for deceleration
  * Air bags protect lander
* Unlike MPF and MPL, two vehicles were built and flown to provide redundancy against random failures
  * First time since Voyager that this approach to redundancy was used



MPF Rover Meets MER Rover

MER - Roving on Mars



~~Five~~ **TWELVE** years and still going!!!

Phoenix

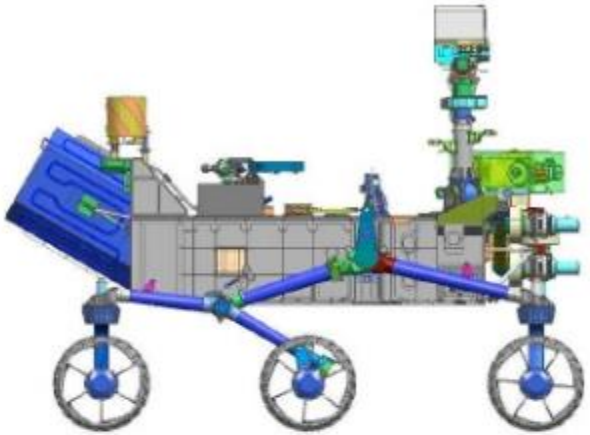
* Like it's namesake, Phoenix has risen from the ashes of MPL and successfully landed on Mars this year
  * Team had to address all issues identified in the course of the MPL failure investigation
  * There was also an extensive effort to search for other problems which might be found in the heritage hardware
* It appears likely that the very rocket engines used to produce a soft touchdown may have given us our first look at water just below the surface
* As the most recent arrival at the Red Planet it has some of the finest outreach video

MSL

* Mars Science Laboratory (MSL) was launched in 2011
* Very large rover with an extensive array of science instruments
* Unique “sky crane” landing architecture to be described later
* For the first time since Viking, uses propulsive terminal descent with continuously throttle able engines
* M2020 is a direct descendant!

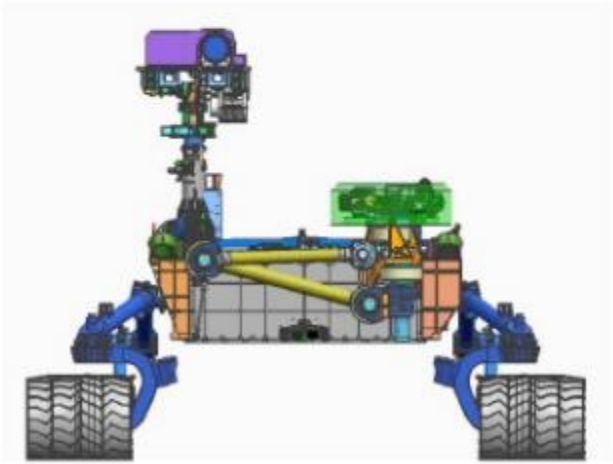
Mars Science Lander (and M2020)

MSL is Big!

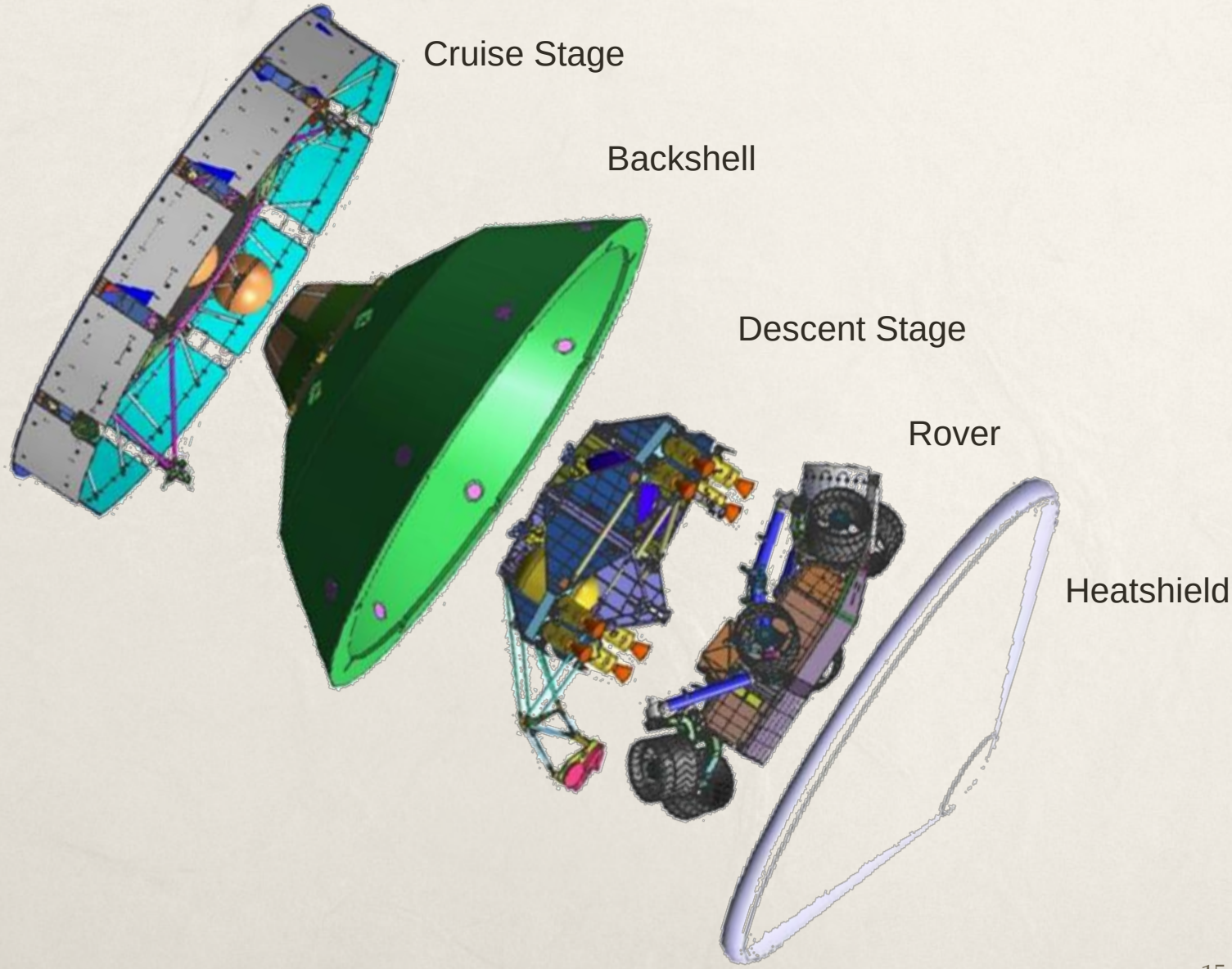


JPL 2009 MSL Rover

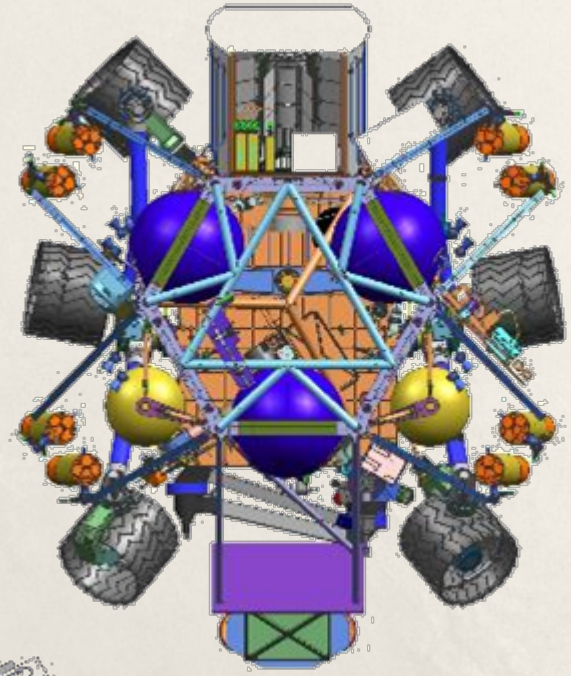
2005 MINI Cooper S

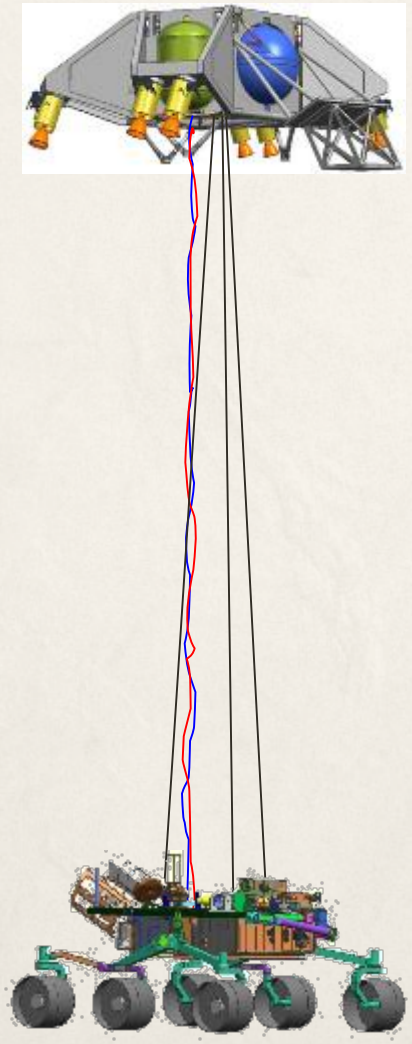


MSL Separated View



Descent Stage with Stowed Rover



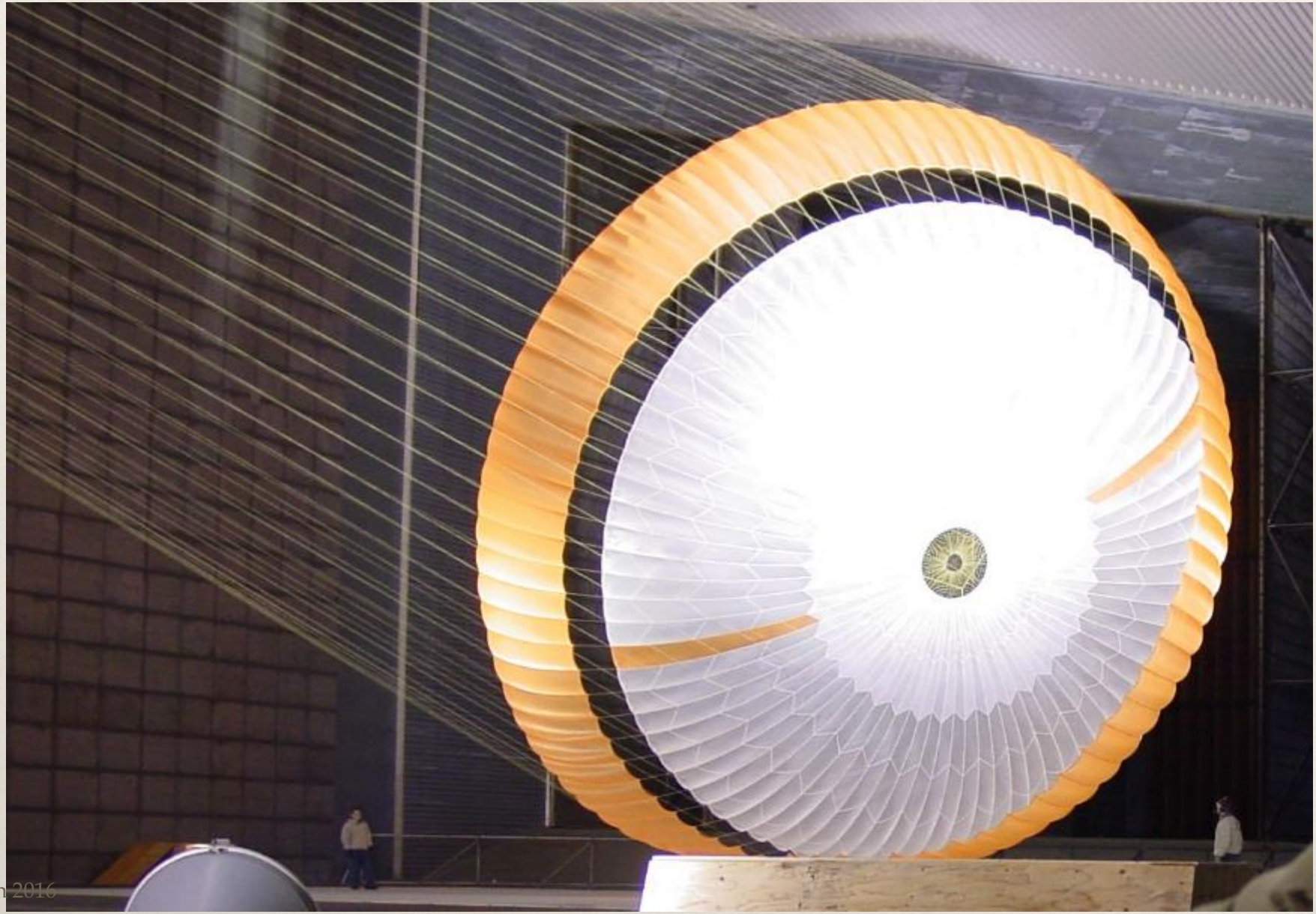


Not latest configuration. Shown for reference only.

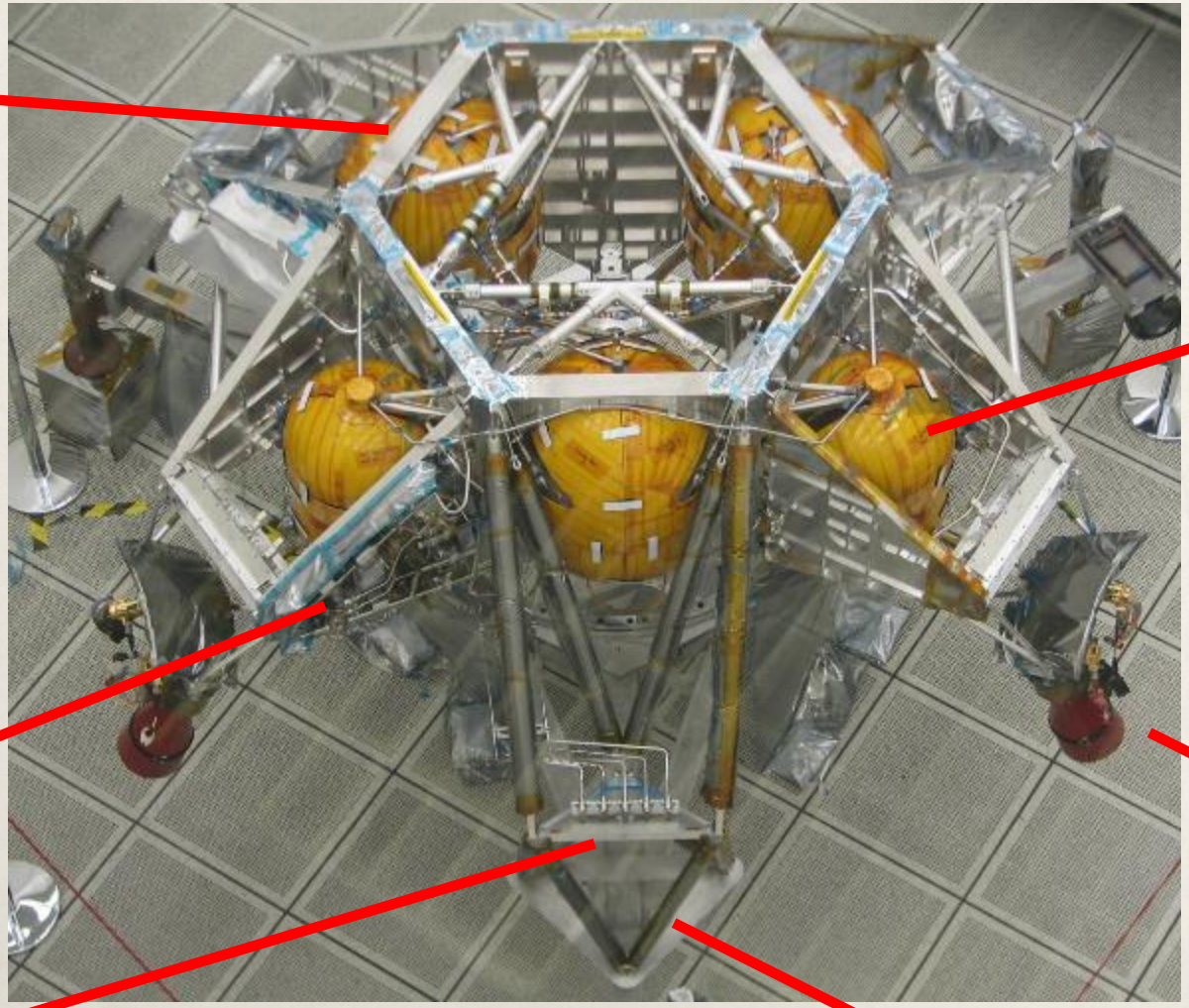
Aeroshell “Fit Check” (11/07)

Flight Aeroshell

Parachute Development Testing



Descent Stage
Prop Integration complete September 2008



Mars 2020

* Primary mission is to collect and “cache” samples of Martian rock for potential retreival and return to Earth by subsequent missions
* To limit costs, maximum use is made of the MSL heritage design.
* Additional payloads, including MOXIE, were selected as part of the Anouncement of Opportunity process managed out of NASA hedquarters

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C. Graves, *DTU (Coll.)*

M. de la Torre Juarez, *JPL (Coll.)*

Michael Hecht (MIT), PI
J. Mellstrom, Project Manager

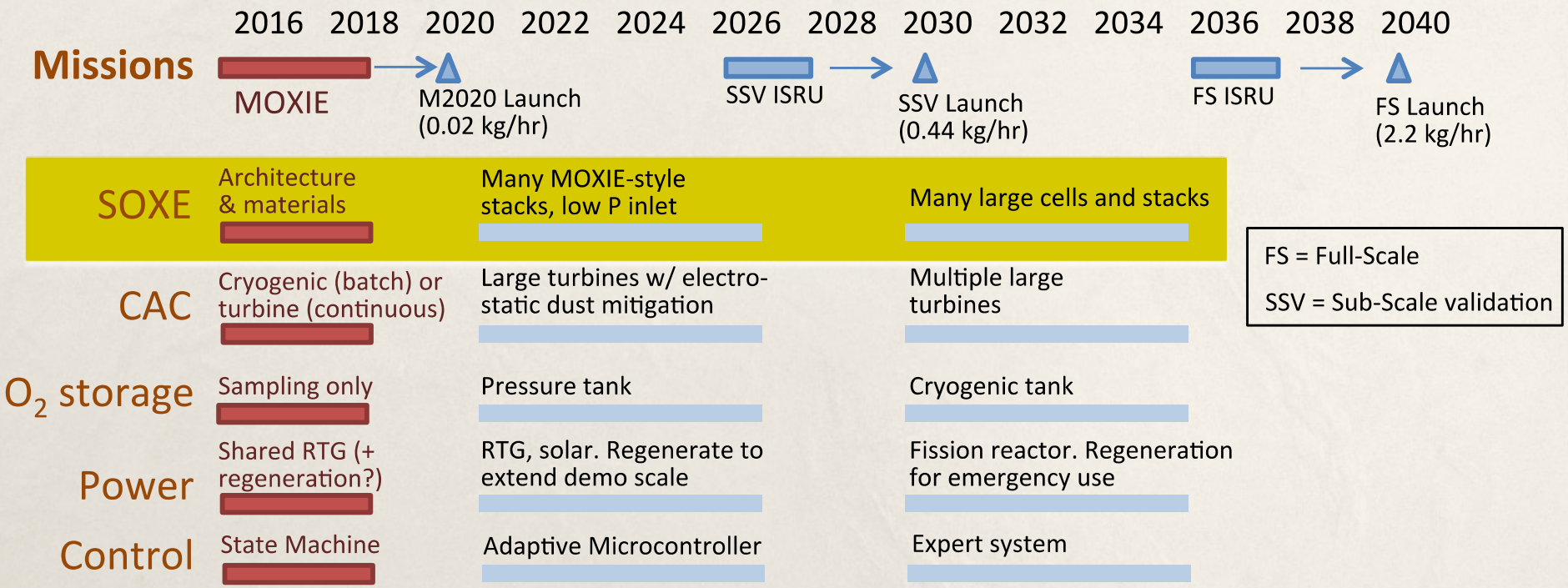
MOXIE

The Mars Oxygen ISRU Experiment

Not your usual instrument

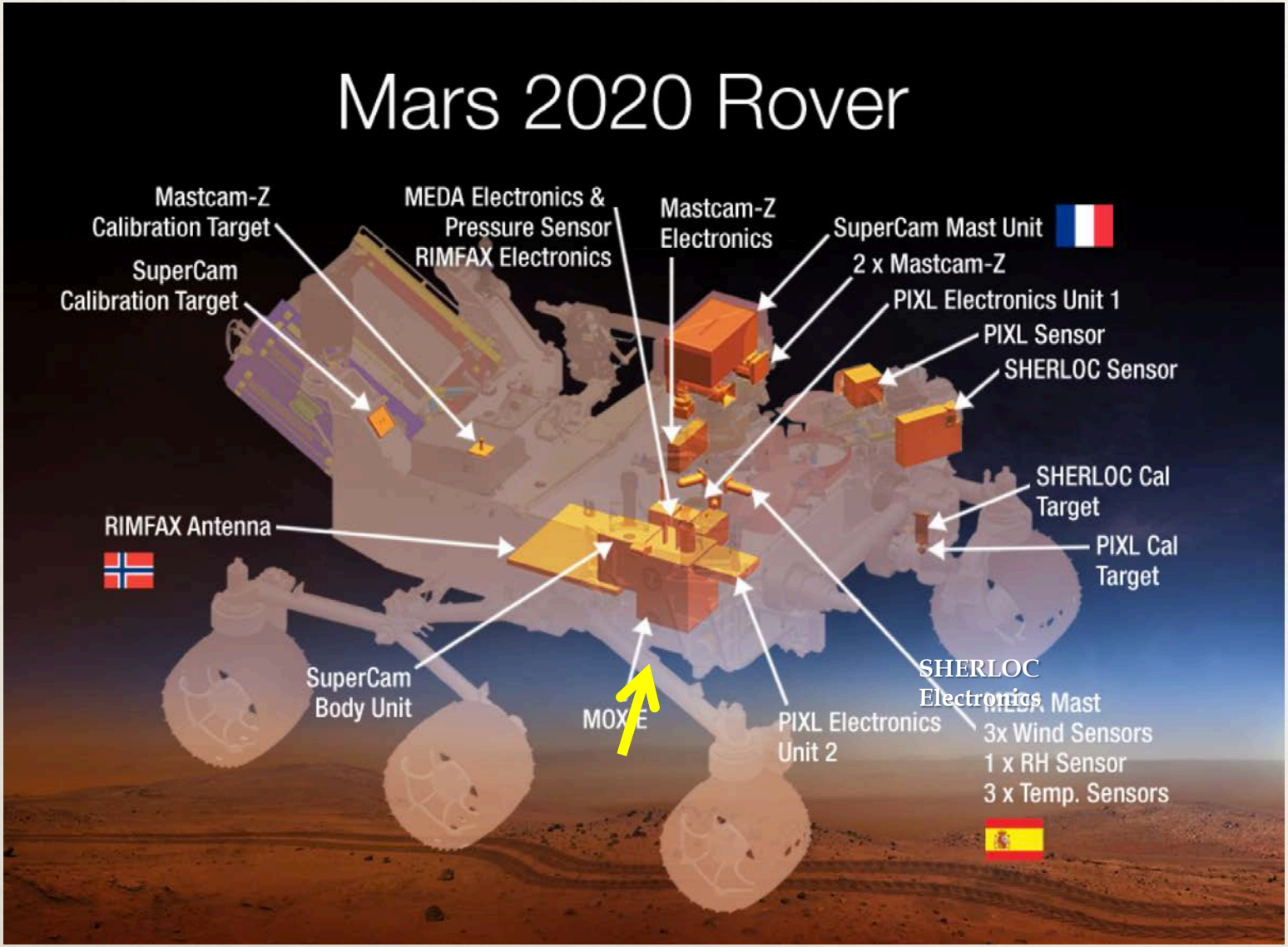
* Sponsored by NASA Human Exploration and Operations Mission Directorate (HEOMD) & Space Technology Mission Directorate (STMD) – Last unfulfilled objective of Mars Surveyor 2001 Lander!
* MOXIE itself is the subject of the experiment – how well does it run under various conditions, how does it degrade, etc.
* Long-term goal: Eliminate need to take LOx to Mars for return trip. May also be used to generate oxygen for breathing.
* Top level requirements
  * Requirements have been a subject of much debate. Current goals inclue 15 operational cycles on Mars, ≥ 4 g/hr O_2 production at end of life, and > 99.6 % O_2 purity
  * Demonstrate resilience with respect to dust and other environmental challenges: identify "unk-unks"
  * Return knowledge of performance parameters that are critical to the design of a full-scale system

NASA ISRU Roadmap
(at time of MOXIE selection)

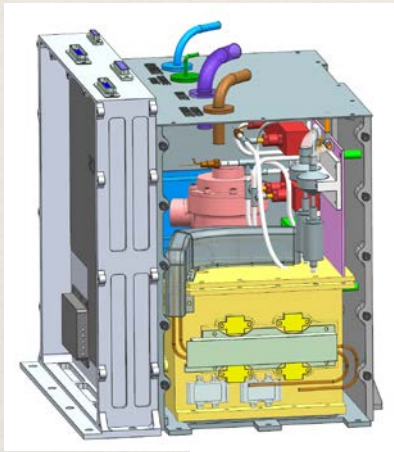


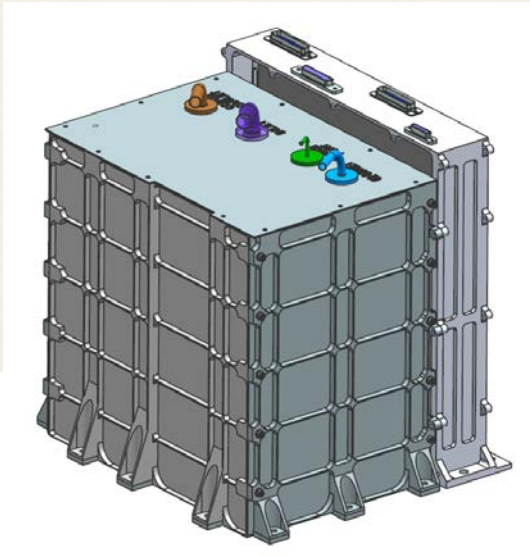
MOXIE has replaced cryogenic acquisition with a scroll pump and added a microcontroller

MARS 2020 Payload

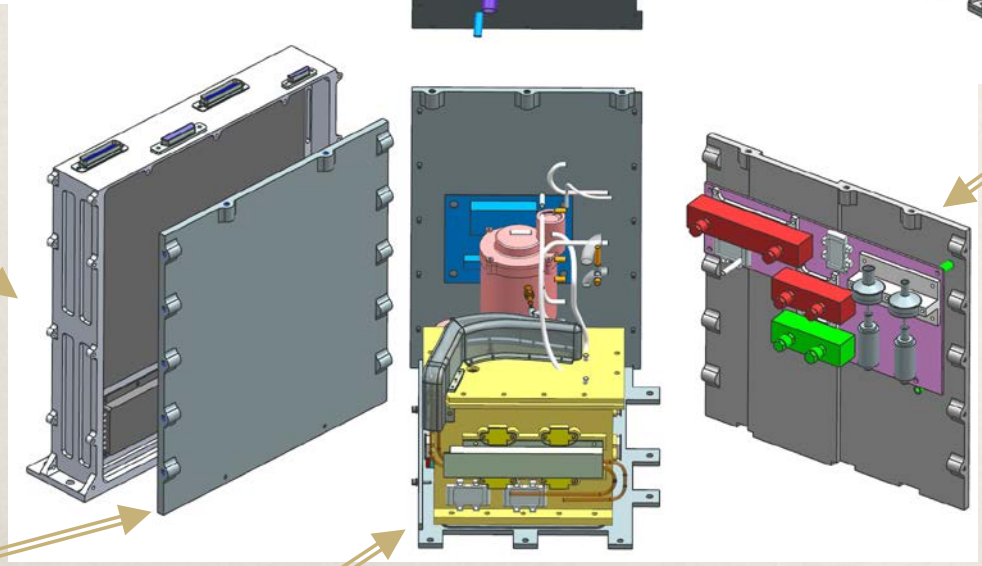


MOXIE





Inlet Panel



Sensor Panel

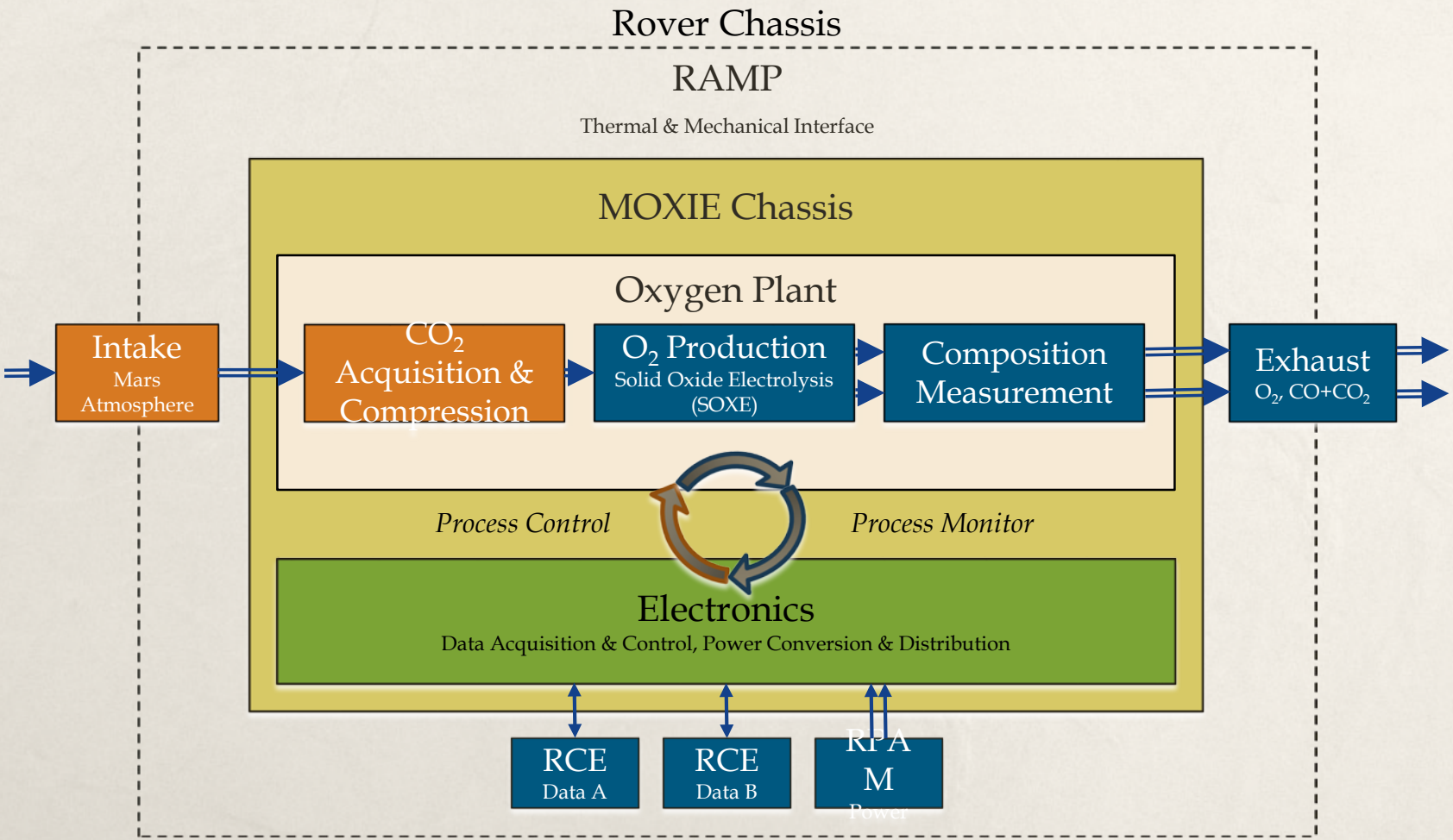
ELX Box

ELX Panel

Base Plate

MOXIE Functional Block Diagram

Mars 2020 Project



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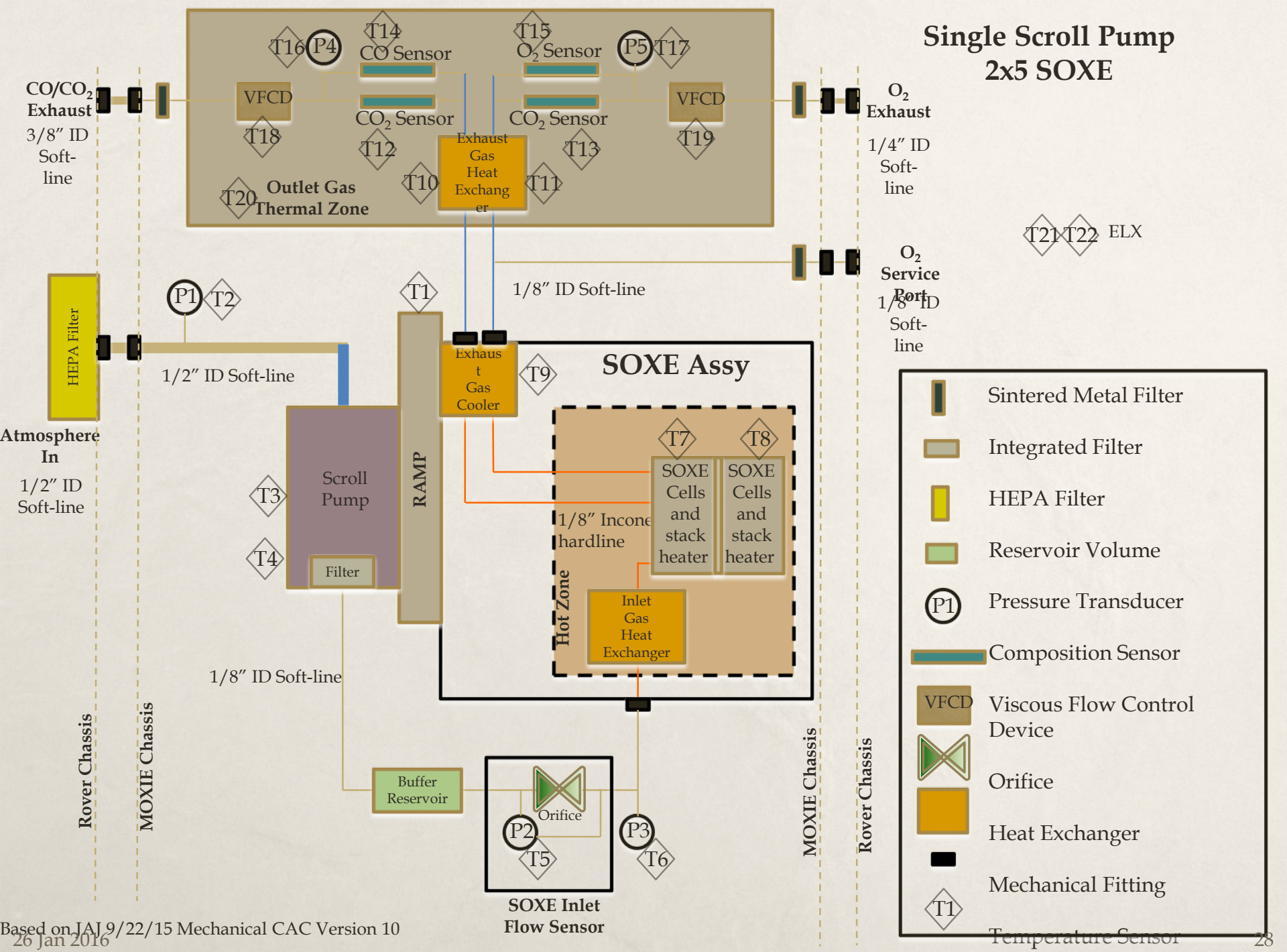
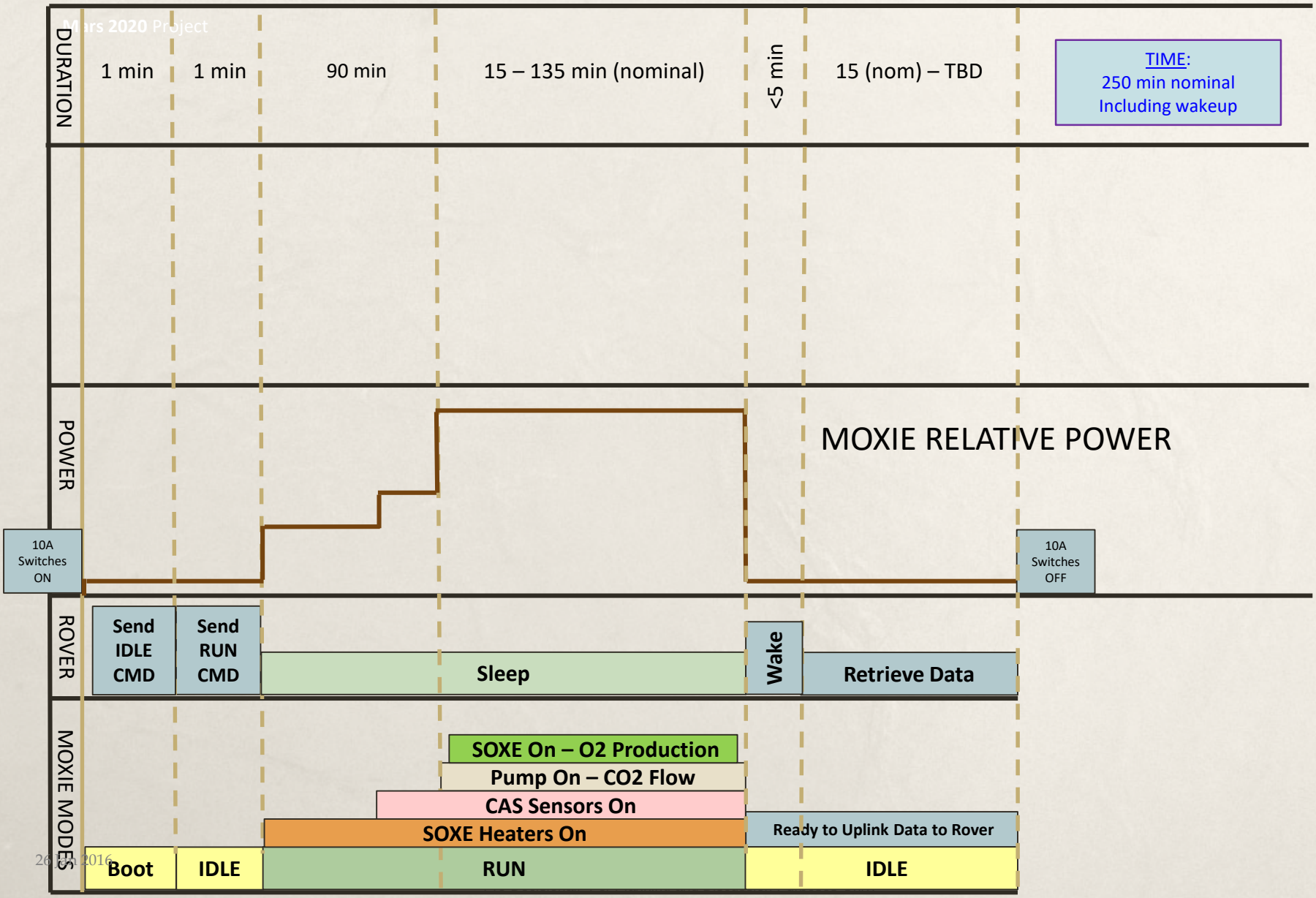
Single Scroll Pump 2x5 SOXE



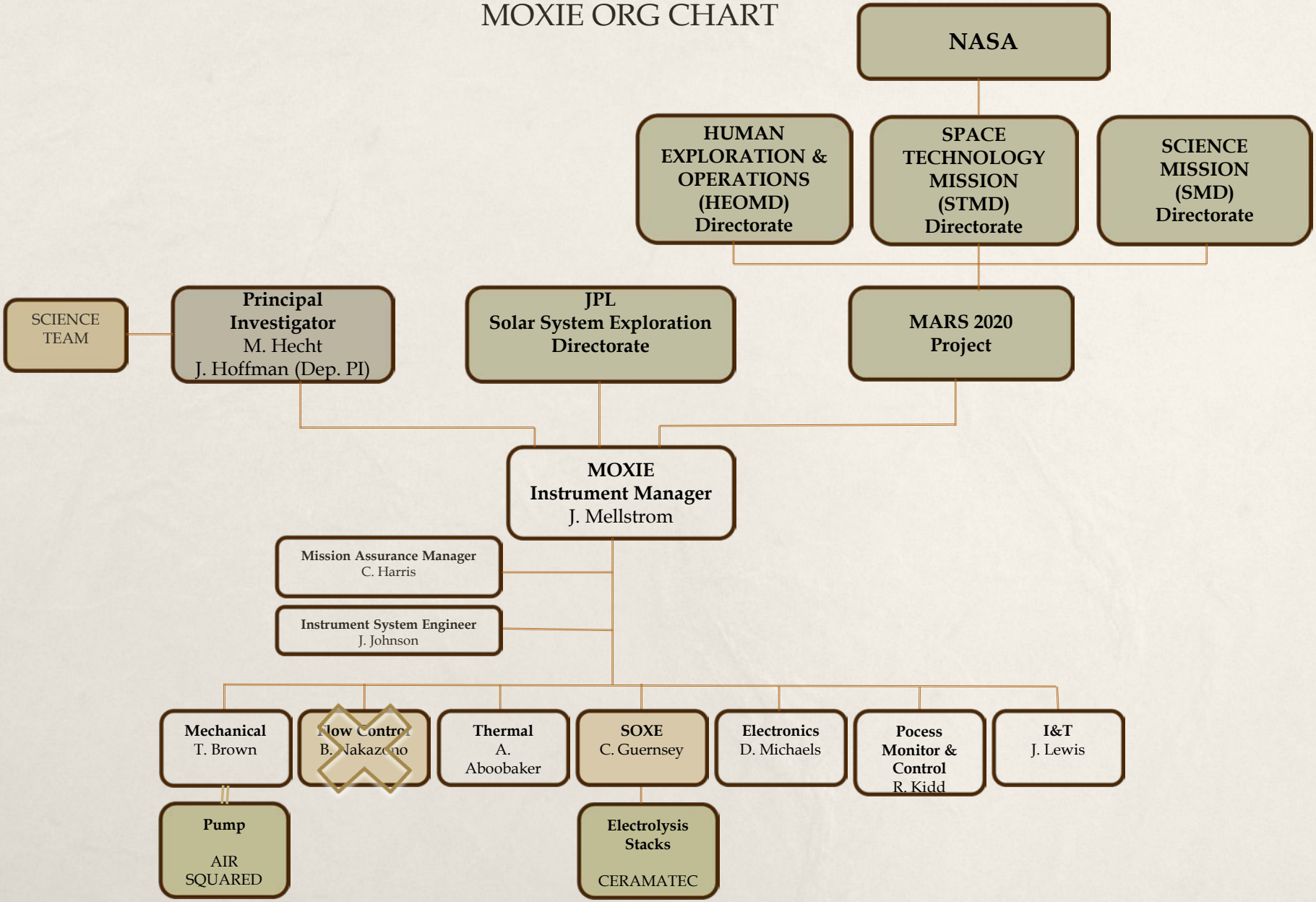
Based on JAJ 9/22/15 Mechanical CAC Version 10

MOXIE STATES (nominal case)

Version 2 (11/29/2015-znc)



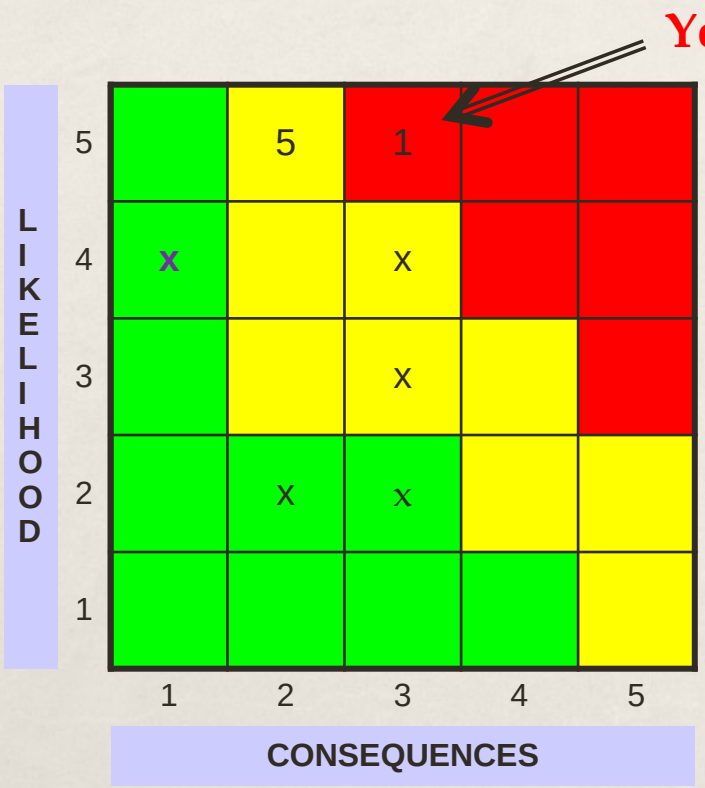
MOXIE ORG CHART



Key Partnerships

* Ceramatec, Inc.
  * Ceramatec's capability to produce a rugged, field-tested SOXE was a strength in the proposal
  * Lead engineer Joe Hartvigsen is a MOXIE Co-Investigator
  * Plansee is the most significant subcontractor to Ceramatec in terms of both cost and criticallity
* MIT
  * Investigation Team Leadership, combining SMD and HEOMD experience
  * Laboratory capability in SOXE technology, key for characterization
* Air Squared
  * Provides the scroll pump for atmosphere acquisition and compression

MOXIE Top Implementation Risk



Trend	Risk ID	Approach	M/I/P	Risk Title
⇨	1	M	I	SOXE Maturation
⇨	5	M	I	Accommodations – Mass & Volume

Likelihood	
5	Almost Certain
4	More Likely Than Not
3	Significant Likelihood
2	Unlikely
1	Very Unlikely

Consequences	
5	Overrun Budget and Contingency
4	Consume All Contingency
3	Significant Reduction In Contingency
2	Small Reduction In Contingency
1	Minimal Reduction in Contingency

Description:

- Electrolysis stack performance needs to be characterized.
  - Uncharacterized behavior in dry CO_2
  - Uncharacterized cycle performance
- Inter-cell hermetic seals are not typical to stack construction
- Stack packaging and manifolding design is very immature
- Realizable conversion rates and the process control necessary to prevent carbon formation on cathode must be developed
- Not all the technical challenges for SOXE maturation are known at this time

Mitigation Plan:

- Over $1M above proposed A/B resources are being applied to SOXE, for packaging and thermal design.
- Ceramatec to develop the plan to achieve TRL-6 prior to PDR – Reviewed with Ceramatec on 1/7/2014. Two pass design/fab/test cycle planned.

SOXIE

* SOXE is the centerpiece of MOXIE
  * It's the key technology that will feed forward into the NASA roadmap for Human Exploration (Mars and beyond)
  * It is the most challenging and most exciting component of MOXIE
  * As a team Ceramatec and JPL need to:
    * Perform to a concrete and executable plan
    * Meet programmatic constraints (e.g. schedule & budget)
    * Actively manage risks
    * Make the resources available to deliver on commitments
* The interconnects provided by Plansee are absolutely critical to the SOXE effort
  * Long lead time or changes
  * SOXE performance critically dependent on issues such as flatness, permeability, and integrity of braze joints

JPL Objectives

* Gain an understanding of Plansee processes and process controls
  * Are there issues associated with producing "flight qualified" hardware that differ from requirements Plansee normally has to deal with?
    * Rick Paynter is the hardware quality assurance manager for the M2020 project.
    * Mike Knopp is the Materials and Process Lead for the M2020 project
* Understand the plans for qualification of key processes
  * Braze joints may be of particular concern due to potential loading under flight vibration and/or thermal environments
    * We have observed flaws in braze joints delivered during first phase of development
  * Recent experiences on Insight show that past (non-flight) experience can be misleading when producing flight hardware.