Abstract #1666

English

The latest from MOXIE

Essential subsystems of the Mars Oxygen ISRU Experiment (MOXIE) on NASA's Mars 2020 mission have passed their Critical Design Review, and the project is beginning a flight build stage that will culminate in delivery of flight hardware in late 2018. Also being delivered to the MOXIE Science Team is an Engineering Model, equivalent in form, fit, and function to the flight hardware, that will support Mars 2020 mission operations and subsequent extensions of the MOXIE flight demonstration (for example, tests of long duration operation). As a scale model of a future oxygen production facility on Mars, MOXIE will generate a minimum of 6 g/hr high purity oxygen from the Martian atmosphere in at least 15 separate runs, sampling different environmental conditions on Mars, in the 2.5 years following landing of the Mars 2020 rover in February, 2021. The presentation will review the MOXIE scroll pump for CO_2 collection and compression, the solid oxide electrolysis system and its packaging for CO_2 conversion to O_2, the monitoring and control subsystem, and the expectations for operation on Mars.

French

No abstract title in French

No French resume

Author(s) and Co-Author(s)

Dr. Michael H Hecht
(UnknownTitle)
MIT Haystack Observatory

N/A The MOXIE Team
(UnknownTitle)
MIT Haystack Observatory

Profile of Dr. Michael Hecht

General

Email(s): mhecht@haystack.mit.edu
Position:

Preferred Language: [Language not defined]

Addresses

Business

Home

Biographies

Biography submitted with the abstract

Michael Hecht is the Associate Director for Research Management at the MIT Haystack Observatory, and Principal Investigator for the MOXIE payload on NASA's Mars 2020 Rover mission. Previously, he was a Senior Research Scientist at JPL, where he served as PI and Instrument Manager for the MECA instrument on the Phoenix Mars Scout mission, a soil analysis suite for investigating wet chemistry, microscopy, and thermophysical properties, which was originally developed in support of the human exploration.

Biography in the user profile

Collaborators

Author(s) and Presenter(s)

Author(s):

Dr. Michael H Hecht

[Unknown Title]
MIT Haystack Observatory

N/A The MOXIE Team
[Unknown Title]
MIT Haystack Observatory

Presenter(s):

Dr. Michael H Hecht
[Unknown Title]
MIT Haystack Observatory

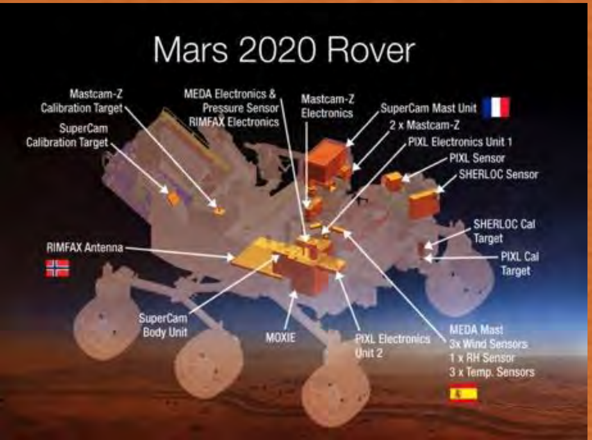
Jet Propulsion Laboratory
California Institute of Technology

J. Mellstrom , Project Manager

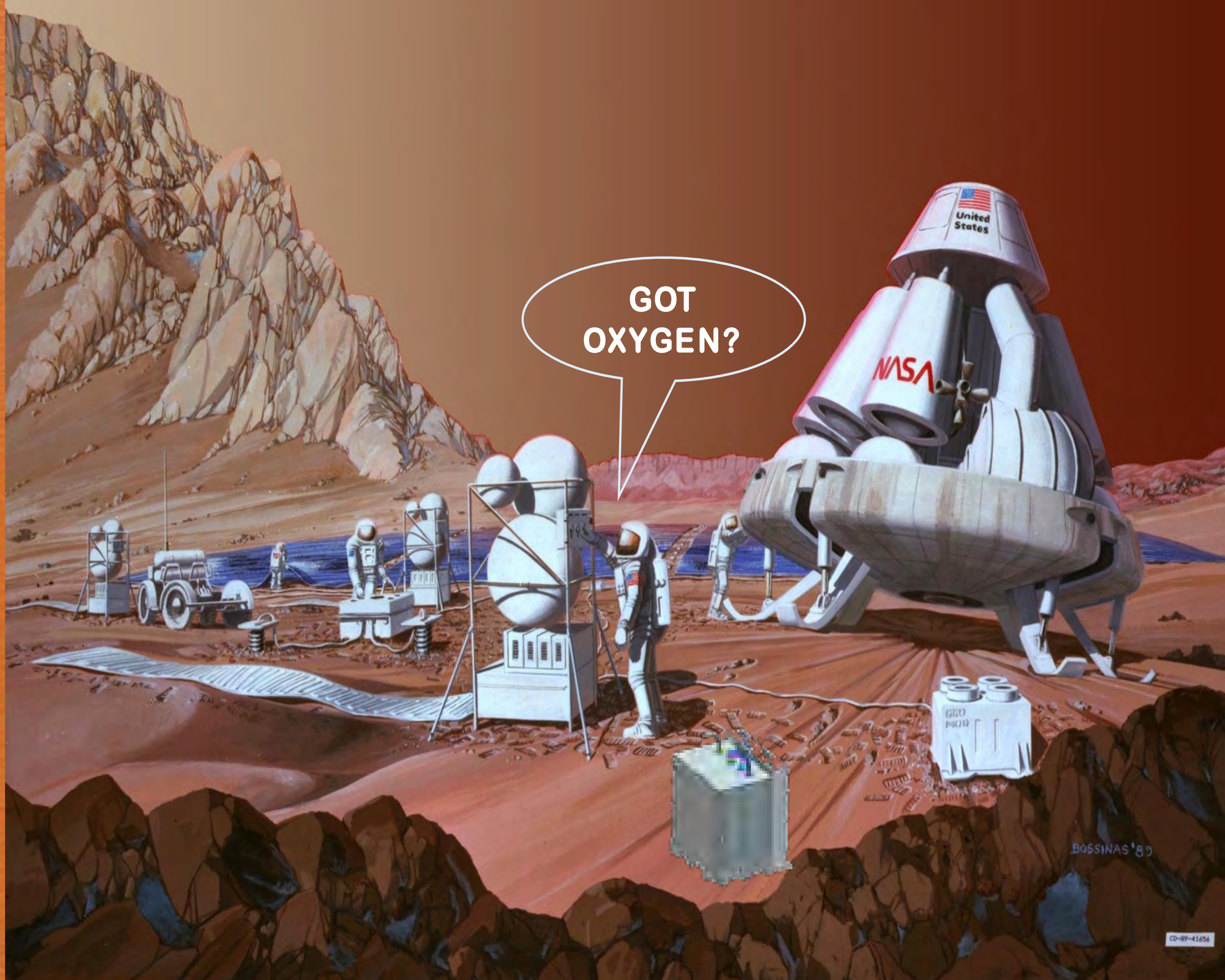
HAYSTACK OBSERVATORY

The latest from MOXIE

Michael Hecht &
The MOXIE Team

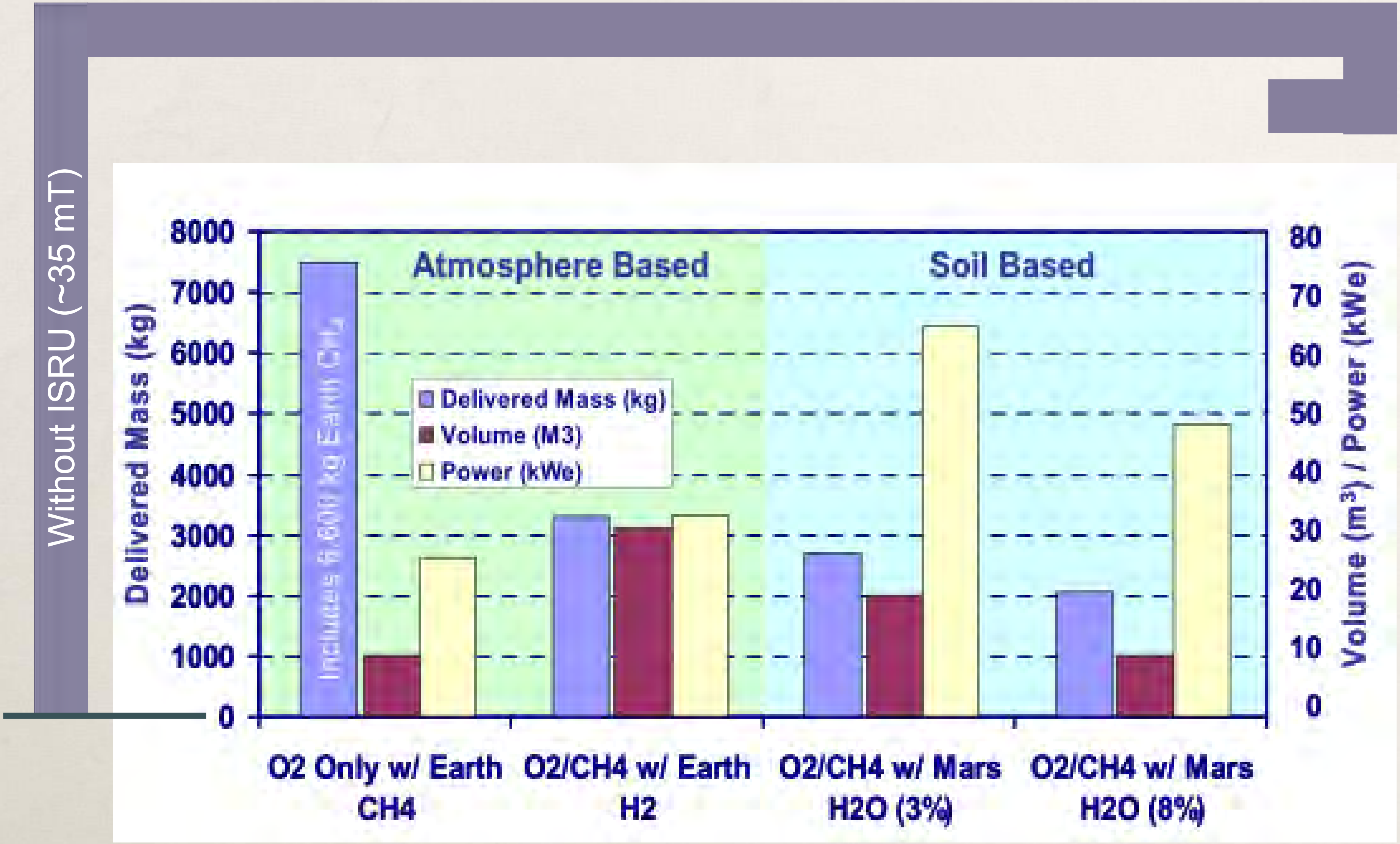


MOXIE
Mars Oxygen
ISRU Experiment



ISRU & the human Mars mission

MOXIE
Mars Oxygen ISRU Experiment

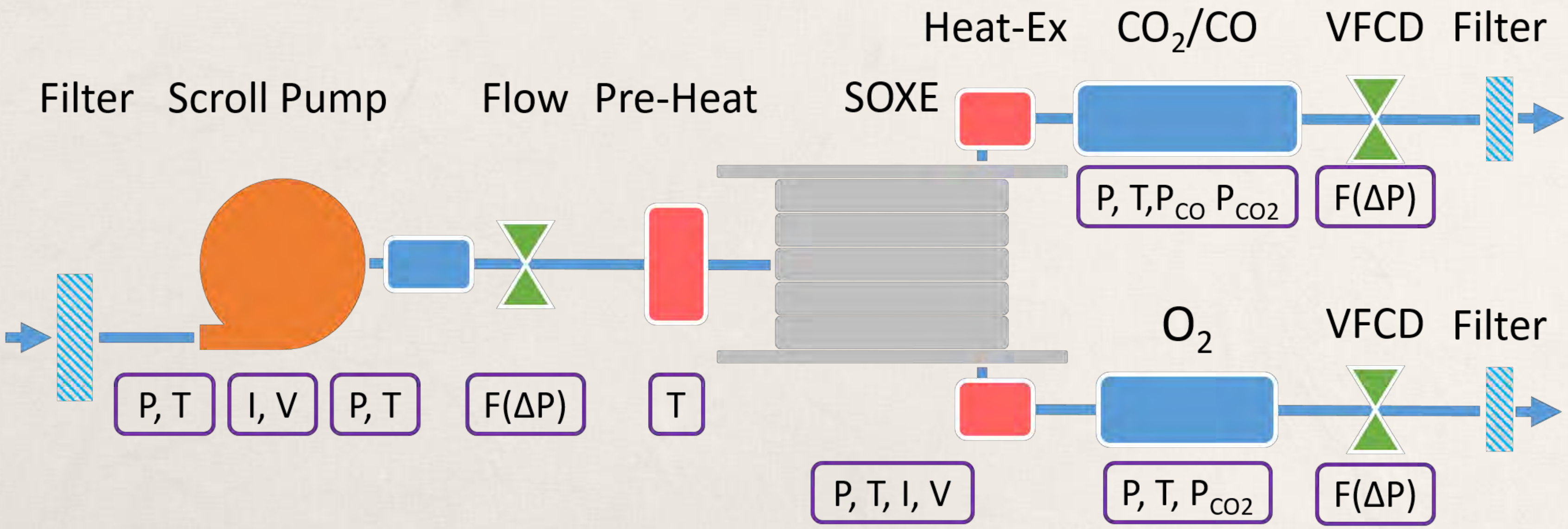


Drake (2009)

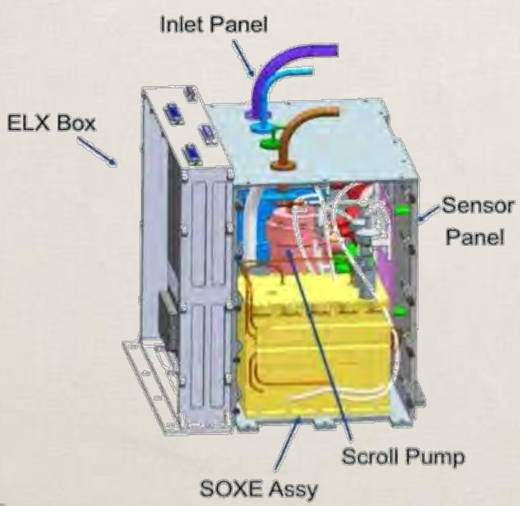
MARS

How does it work?

MOXIE
Mars Oxygen ISRU Experiment

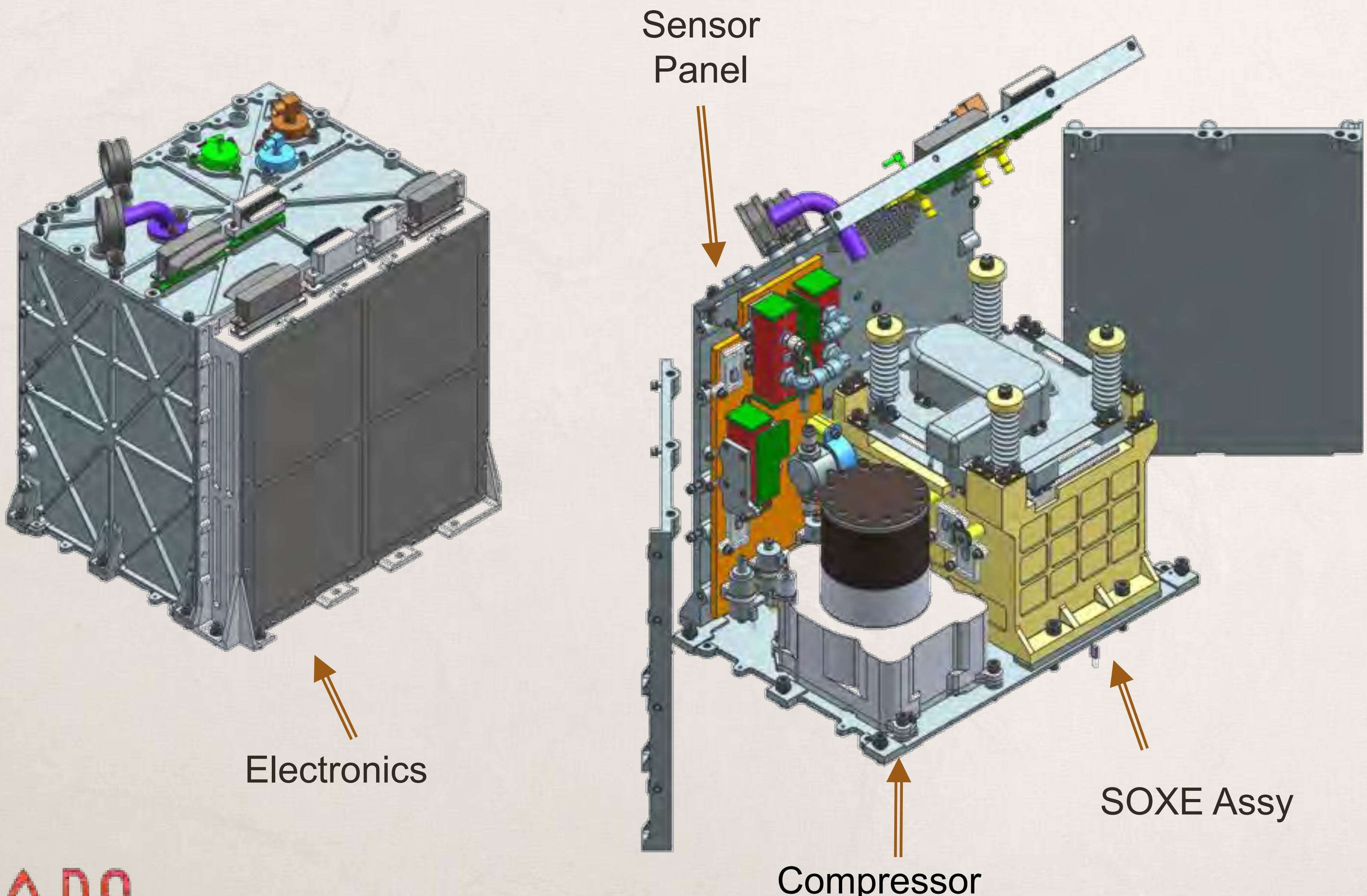


Meyen (2015)



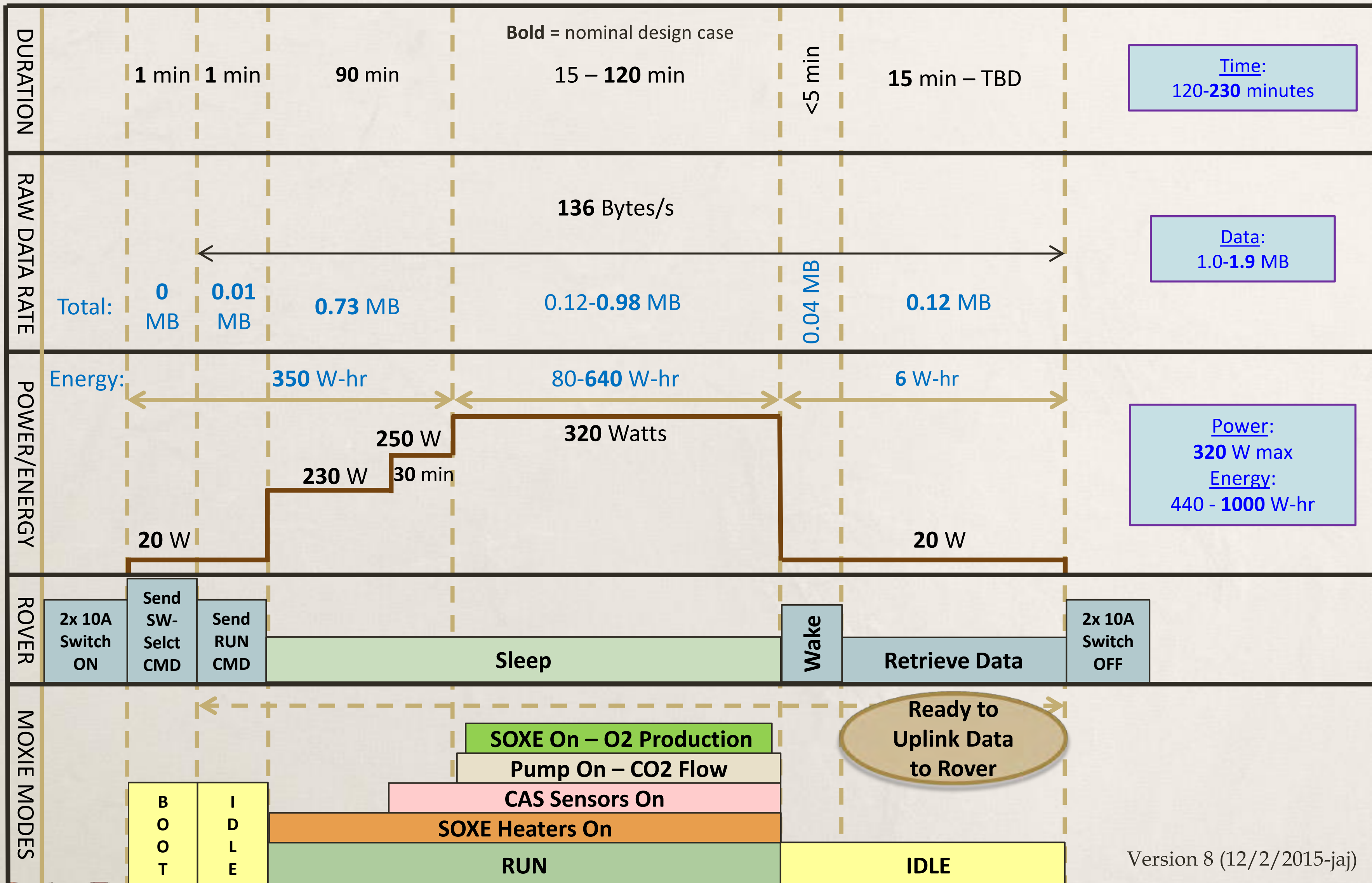
MARS

How does it all go together?



A day in the Life

Mars Oxygen ISRU Experiment



Version 8 (12/2/2015-jaj)

Formal Requirements

Requirement	Goal	Threshold
Oxygen Production Rate	8 g/hr at 5 Torr, 0ºC.	6 g/hr at 5 Torr, 0ºC.
Oxygen Purity	99.6%	98%
Number of Cycles	20	10

System Performance

- O_2 production – >1g/hr per cell (10 cells)
- Operational Cycle – >45 cycles w/ no failures
- O_2 purity – All recent stacks exceed 99.9%
- Limited by:
  - Inlet flow (pump capacity, gas density at landing site)
  - Available power (4A limit, equiv. to 12 g/hr)
  - SOXE capability (10 cells, 22.7 cm^2/cell)

Making O_2 with SOXE

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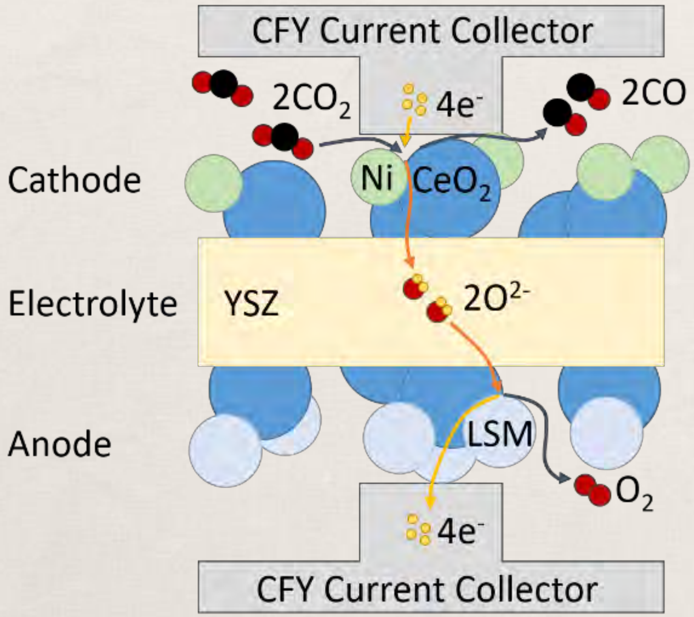
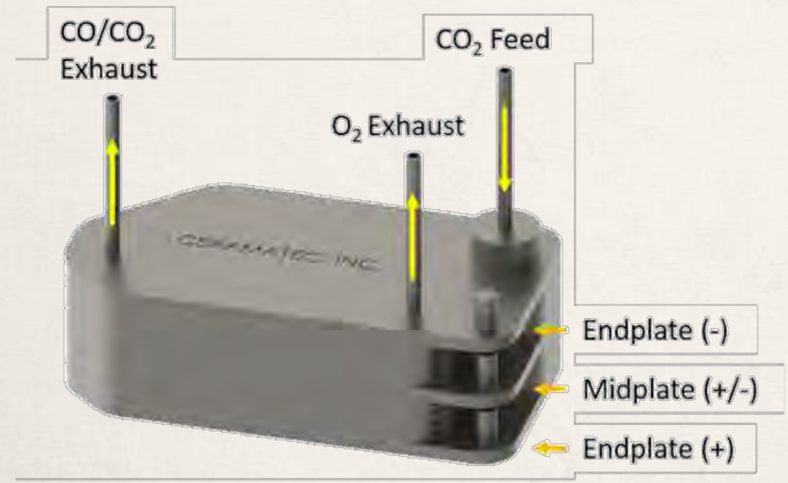
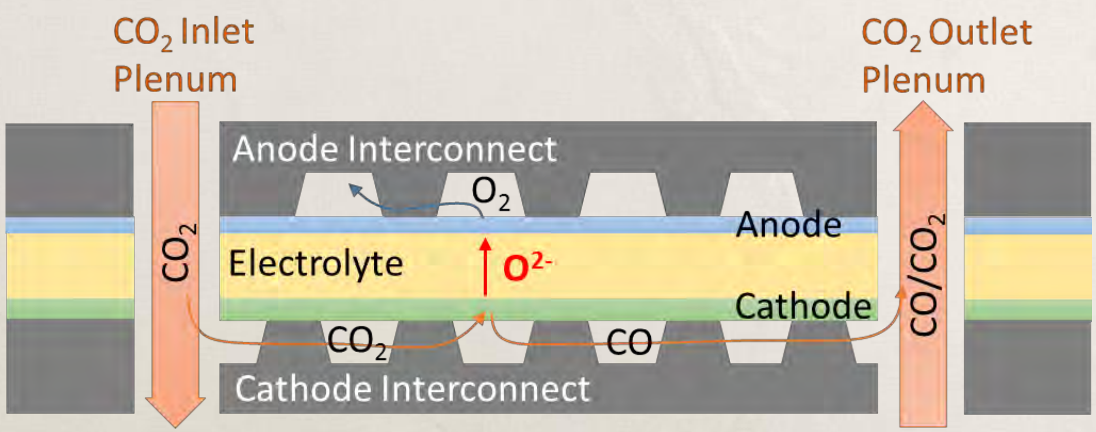
Mars Oxygen ISRU Experiment

CERAMATEC







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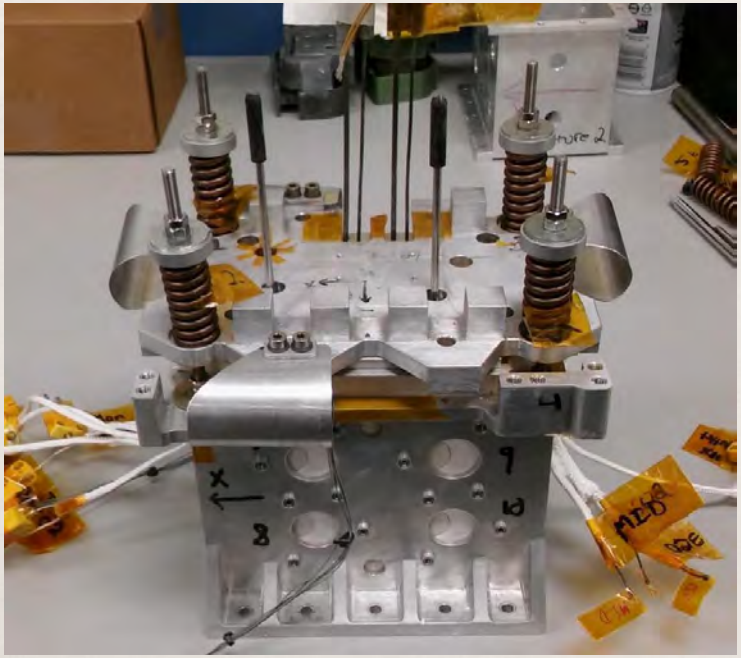
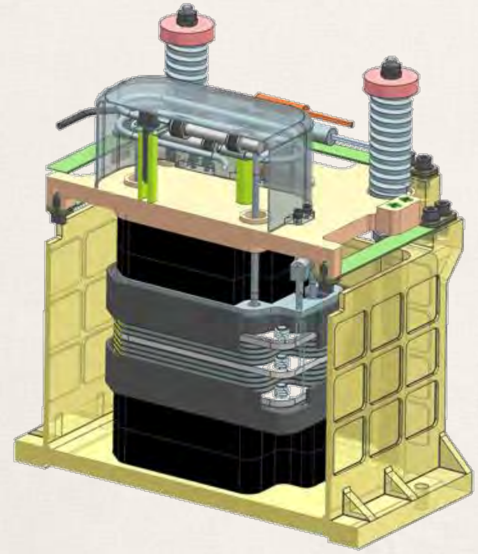
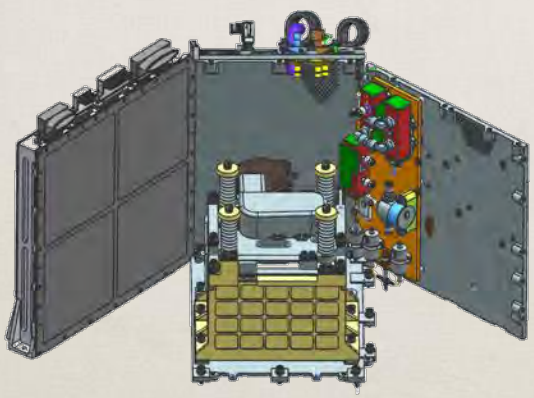
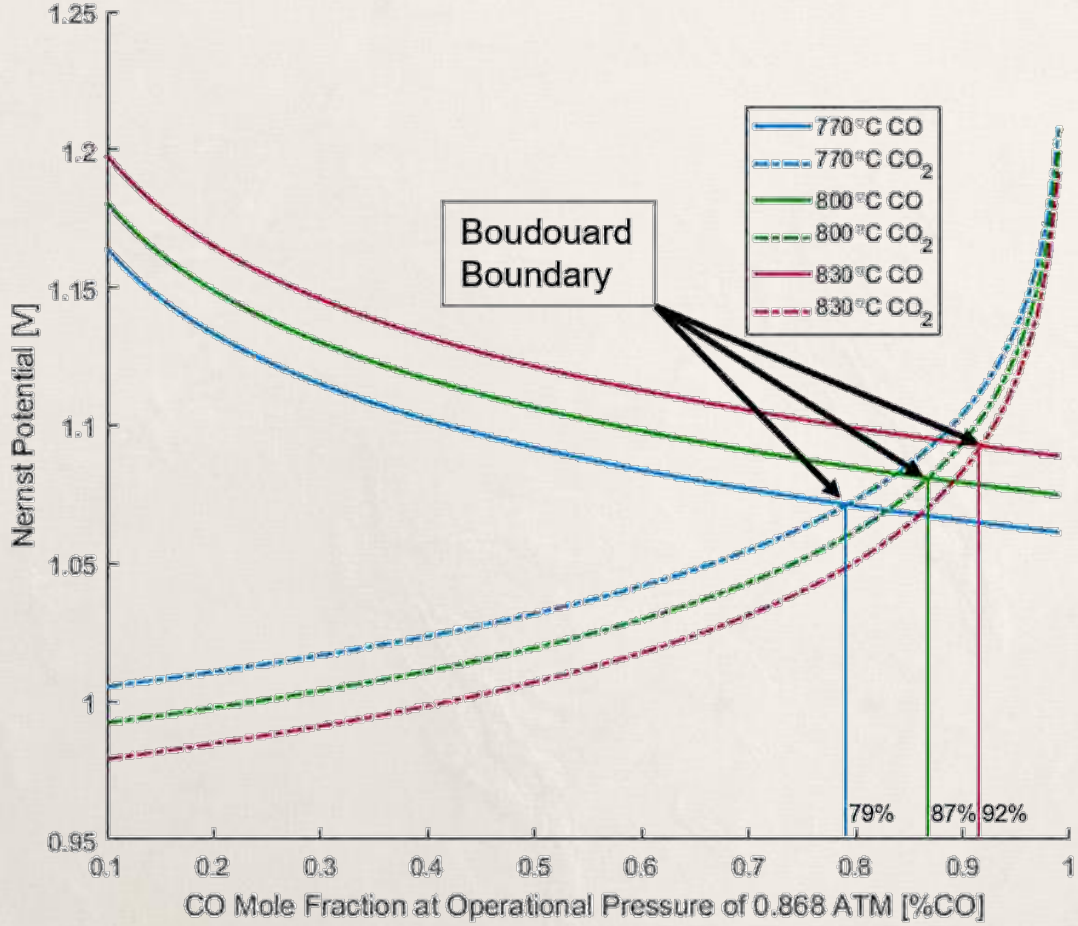
SOXE Assembly



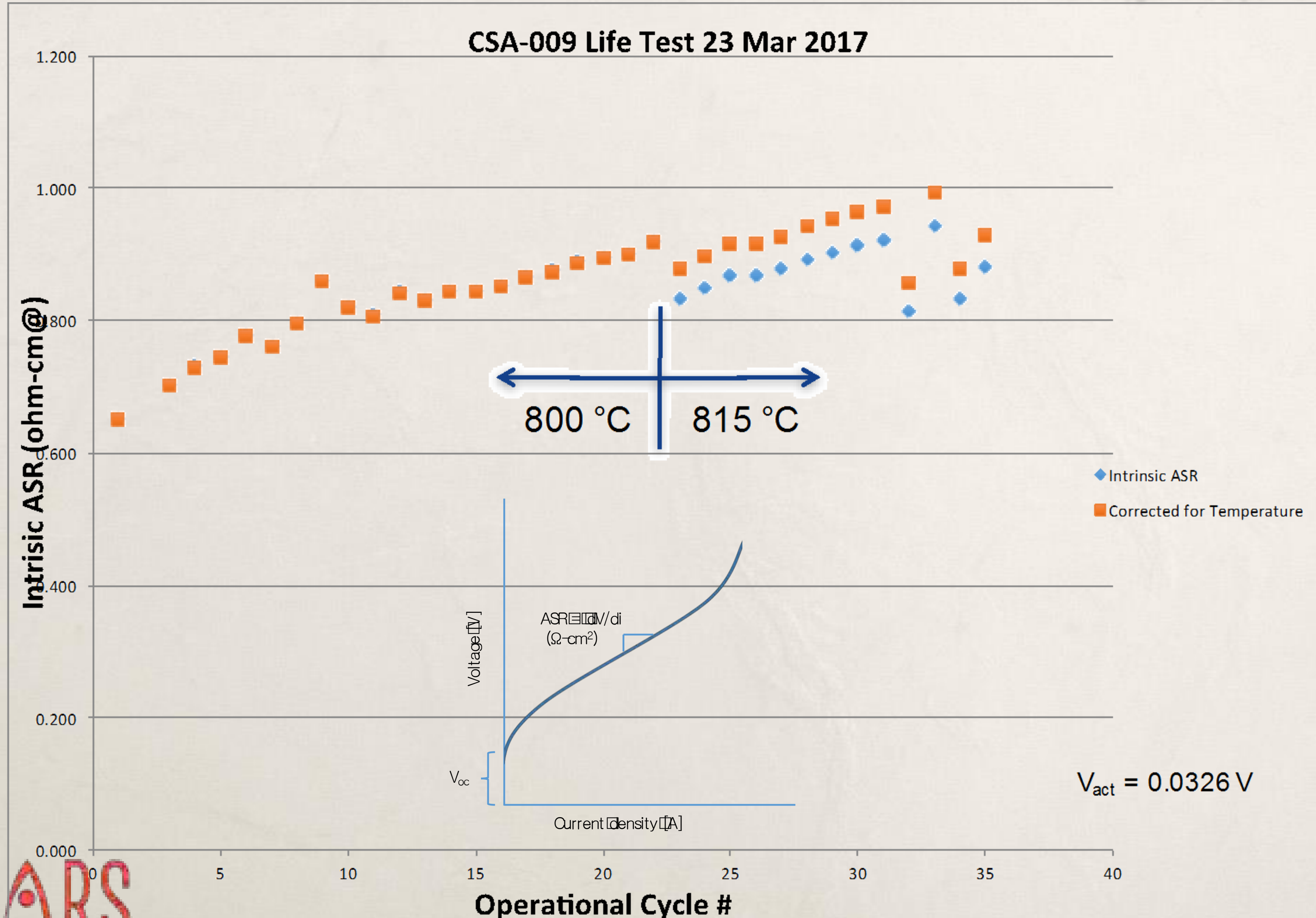




Boudouard and Ni Oxidation Limits



ASR resilience to cycling



CO_2 compression strategy

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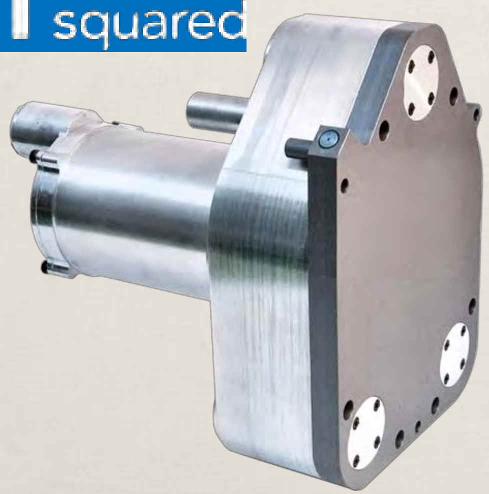
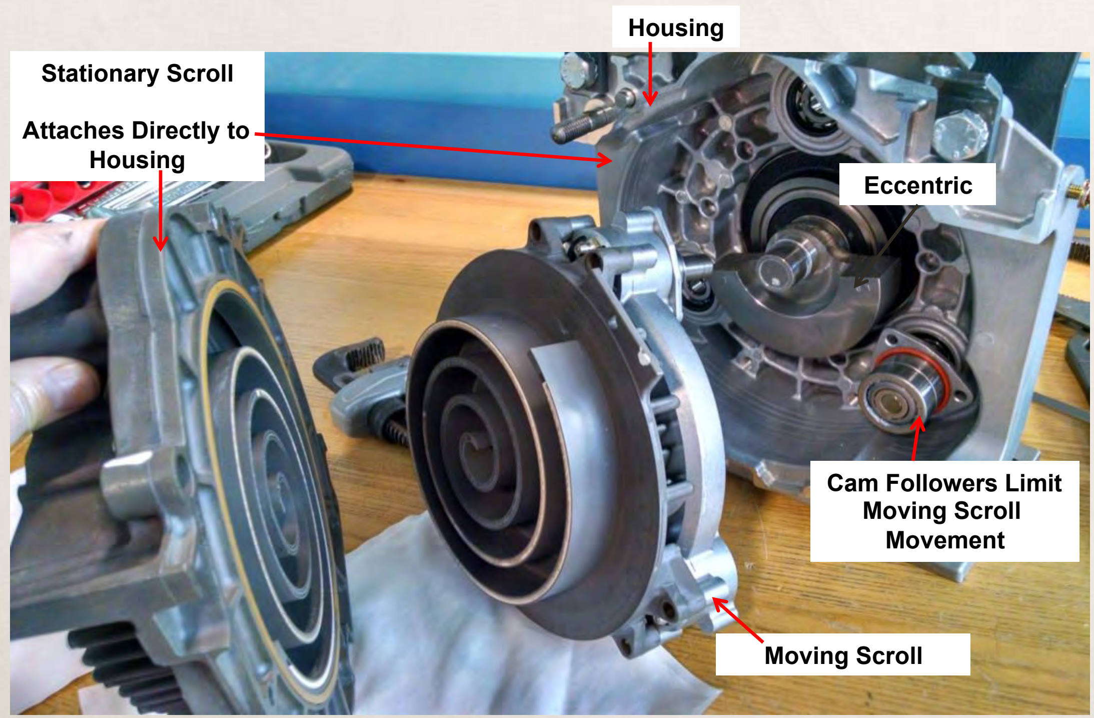
Mars Oxygen ISRU Experiment

- Scroll pump chosen for real time compression to ~1 bar without intermediate storage.
- Energy efficient, can be scaled at least 10-fold. Lifetime TBD.
- *Performance:* 83g/hr for inlet gas P=7 Torr, T= 20°C.

air squared





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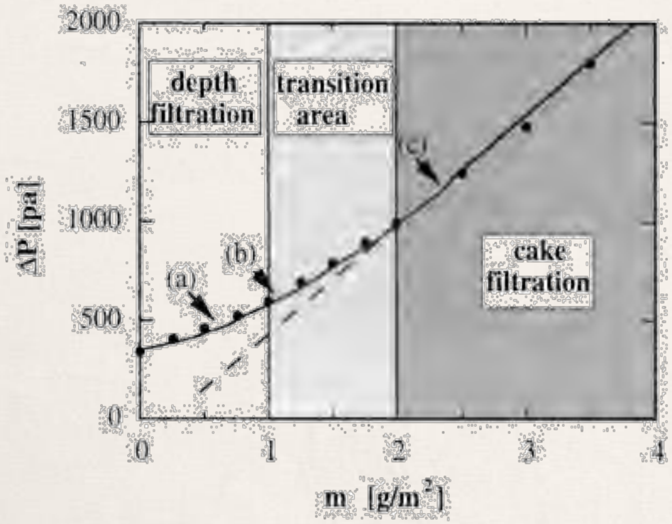
Dust concern retired

Mars Oxygen ISRU Experiment

- During operation (~100 hrs):
  - Airflow a few cm/s
  - Expect ~50 mg dust , <0.1 g/m^2
- Passive exposure (>10,000 hrs)
  - Expect 10^{-6} g/m^2-s → ~2 g/m^2
- Larger particles
  - Saltation, pebbles will be stopped by baffles

Dust exposure at Aarhus wind tunnel



- Significant pressure drops begin at 1 g/m^2 for d_p=0.15 μm. (*Thomas et al. 1999*)
- Cross section correction → expect no problems below ~10 g/m^2
- Tests confirm no effect for comparable loading with Mars simulant (2-10 μm)
- Slip factor provides up to x10 additional margin

MARS

State of the Project

- All except electronics & some mechanical through CDR
  - Extended SOXE life test now at ~50 cycles
  - Integrated tests exploring safe operating conditions
- Outstanding issues
  - Electronics/software behind schedule
  - Some unusual (COTS) sensor behavior
- On track for flight delivery in November, 2018
- Flight-like engineering model to be delivered to MIT for mission support and ongoing testing ~4/19

MOXIE
Mars Oxygen ISRU Experiment

M2020
MOXIE

Full Scale
MOXIE

Extensibility

Power scaling
Mass & Volume scaling

MARS

Where does the power go?

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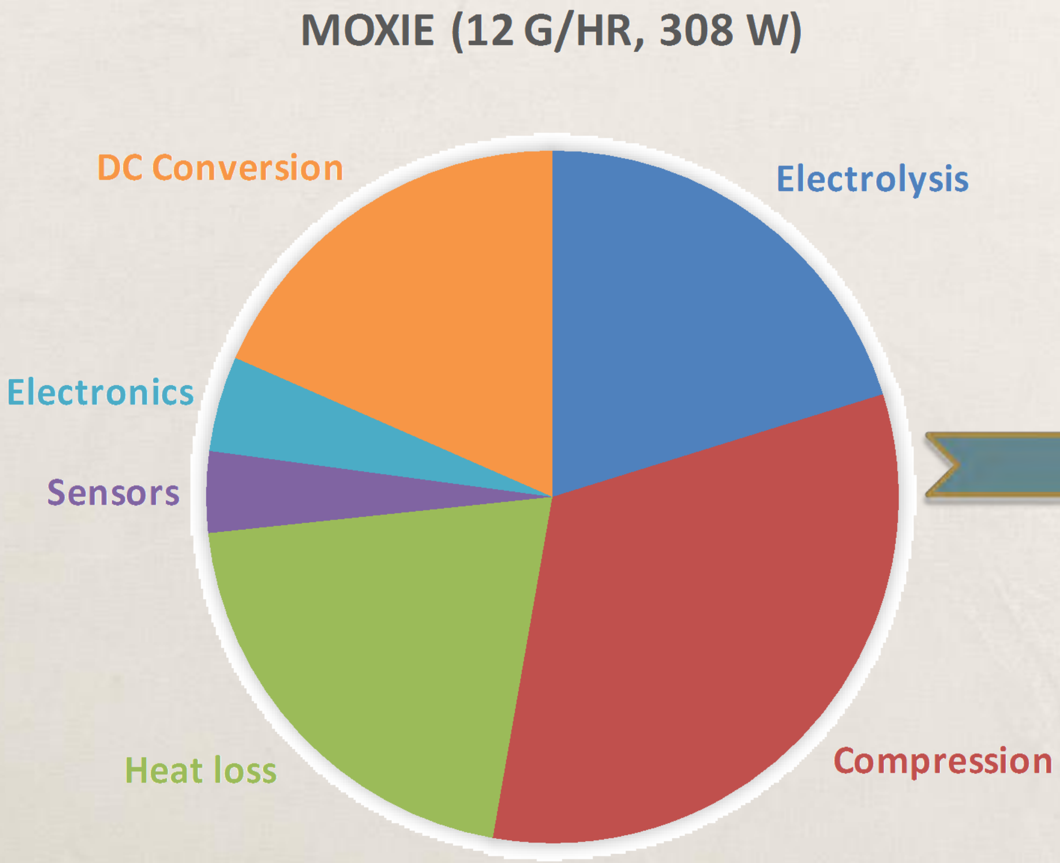
Mars Oxygen ISRU Experiment



Would scale to 51 kW at 2 kg/hr! But…

MARS

Power scaling assumptions

MOXIE
Mars Oxygen ISRU Experiment

- Scales with production rate R (2000/12 (g/hr) = x167):
  - **Electrolysis (including enthalpy) – rigorously!**
  - Compression
- Scales with # of modules (x6, 334 g/hr each, ~sixty 10x10 cm cells)
  - Sensors
  - Electronics
- Scales with surface area $R^{2/3}$ (x30)
  - SOXE heat loss
- **Expected improvements:**
  - Compression power assumed to be 70% of scaled value
    - Lower elevation (like MSL or VL2) gets you to 75%
    - Reduce output pressure
    - Increase utilization (more SOXE cells or CO_2 recovery)
  - Custom DC converters improve from 83% to 90% efficient
  - Gas pre-heat replaced by heat exchange with exhaust
  - Sensor panel captures heat from, e.g., pump body

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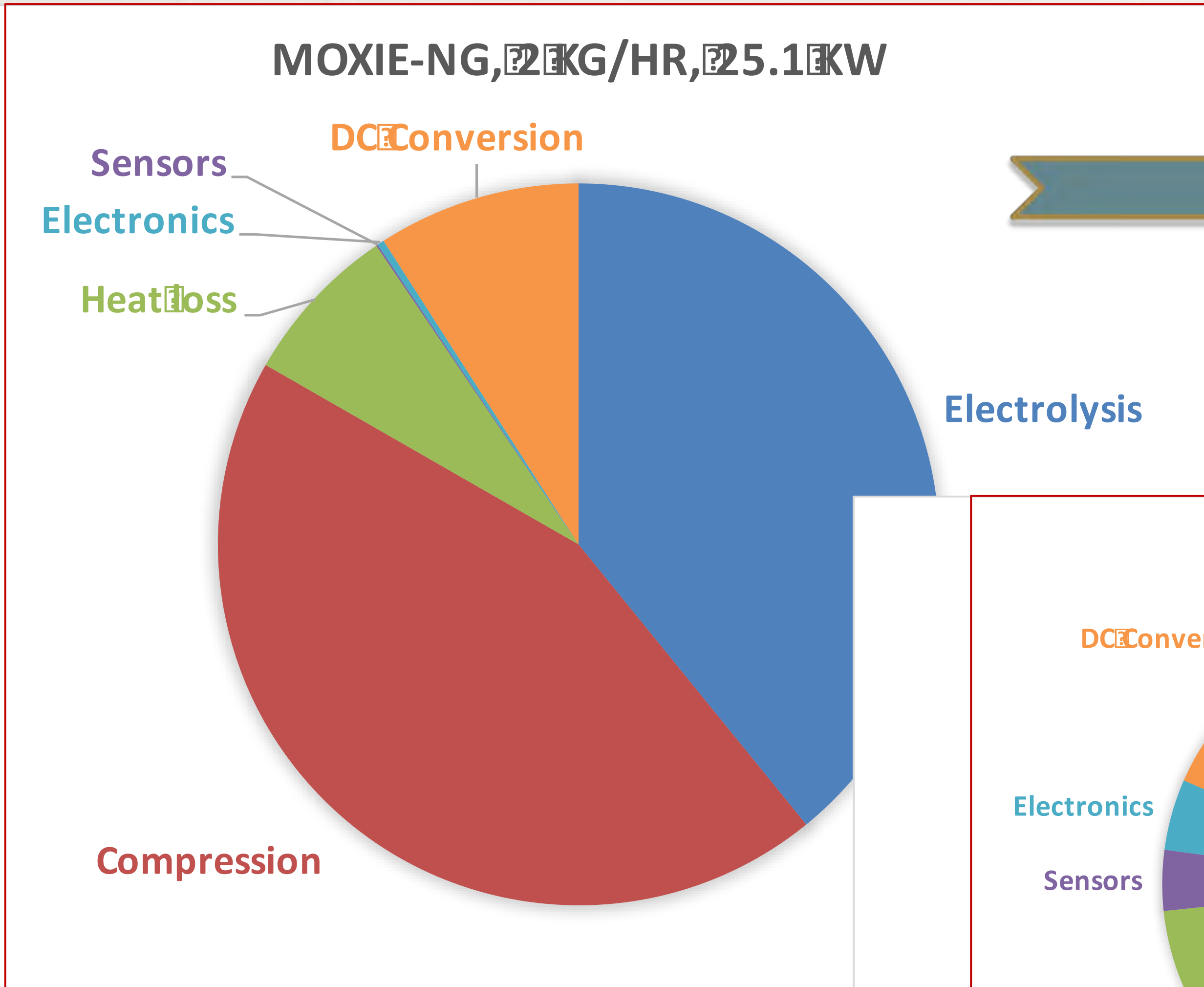
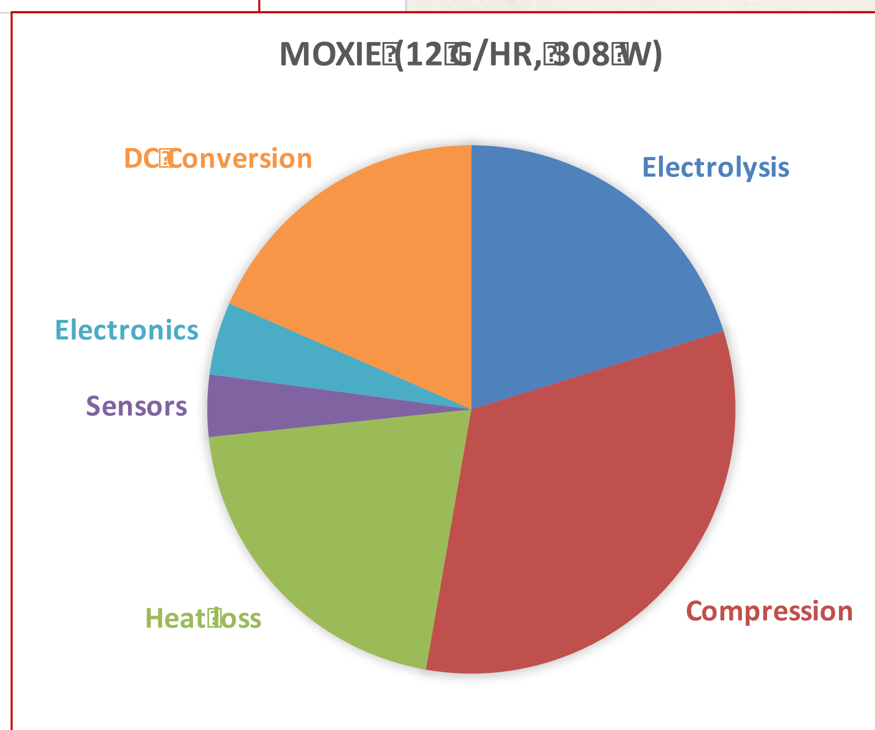
Projected power usage

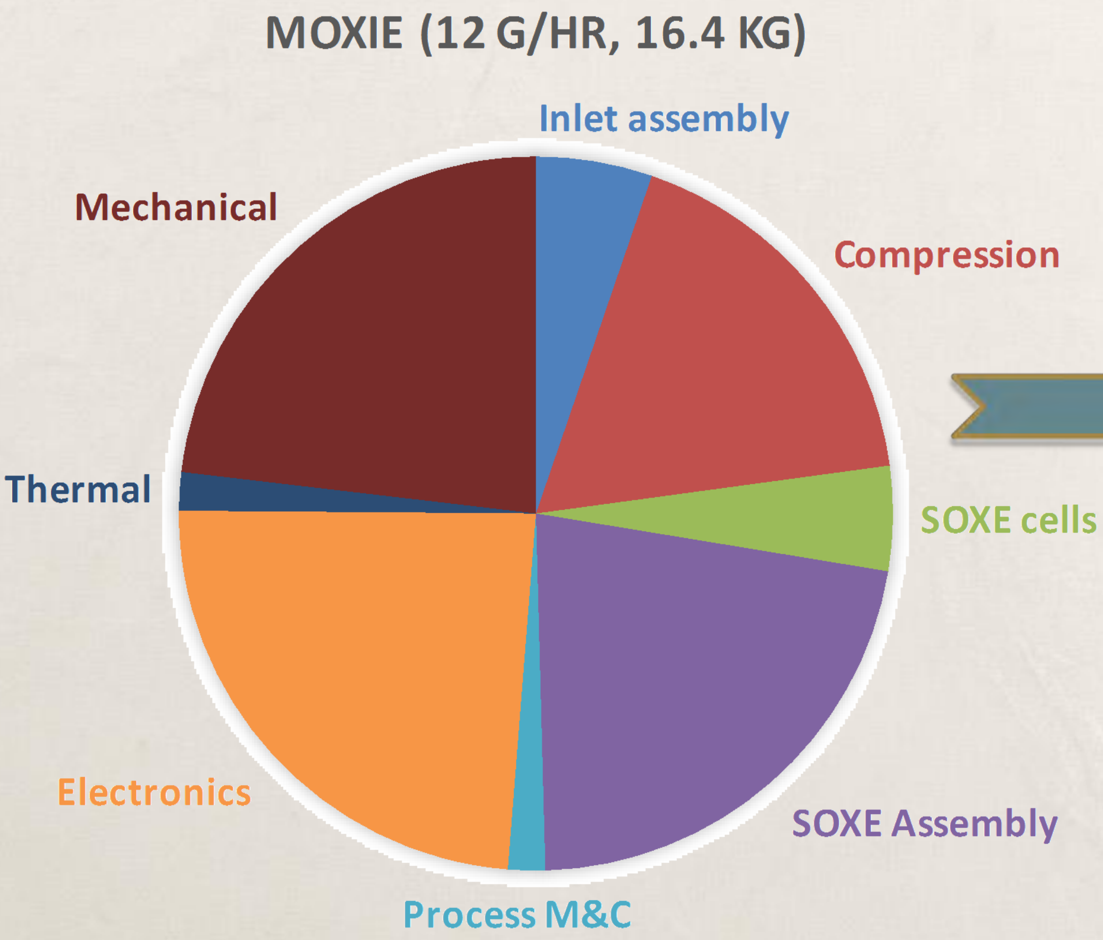
Mars Oxygen ISRU Experiment



Consistent with DRA 5.0



Where does the mass go?



Would scale to 2730 kg at 2 kg/hr!
But…

Mass scaling assumptions

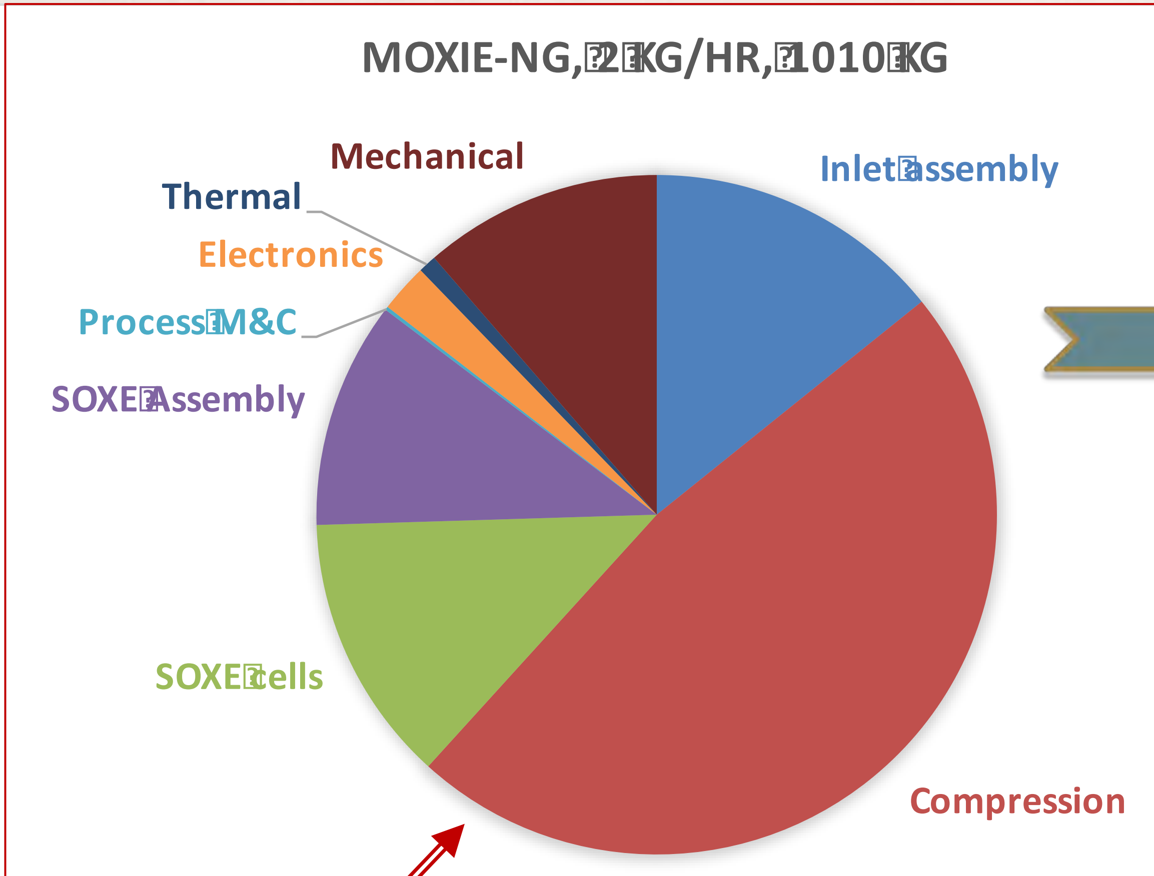
MOXIE
Mars Oxygen ISRU Experiment

- Scales with production rate R (x167):
  - SOXE cell mass
  - Compressor mass
  - Filter assembly
- Scales with # of modules (x6)
  - Sensors
  - Electronics
- Scales with surface area $R^{2/3}$ (x30)
  - Thermal (insulation, etc.)
  - Structure

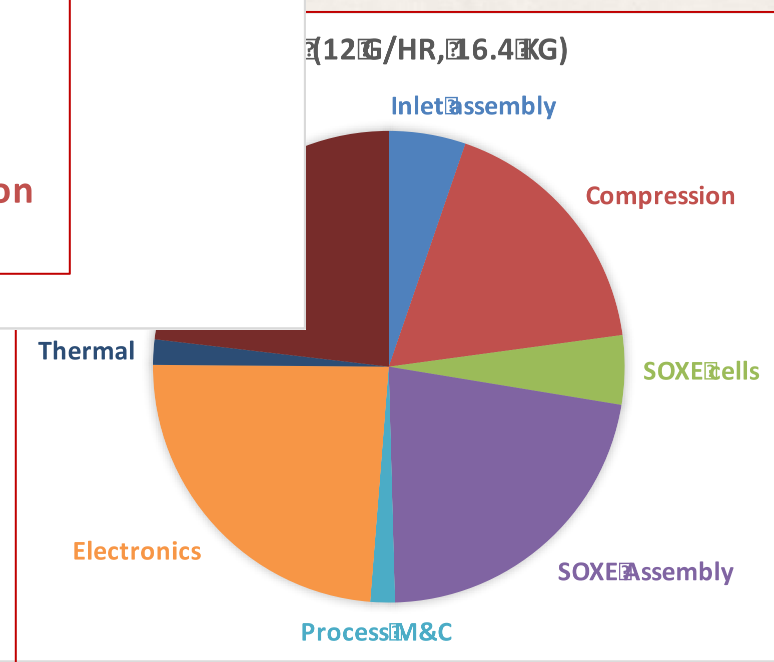
MARS

Projected mass usage

Mars Oxygen ISRU Experiment



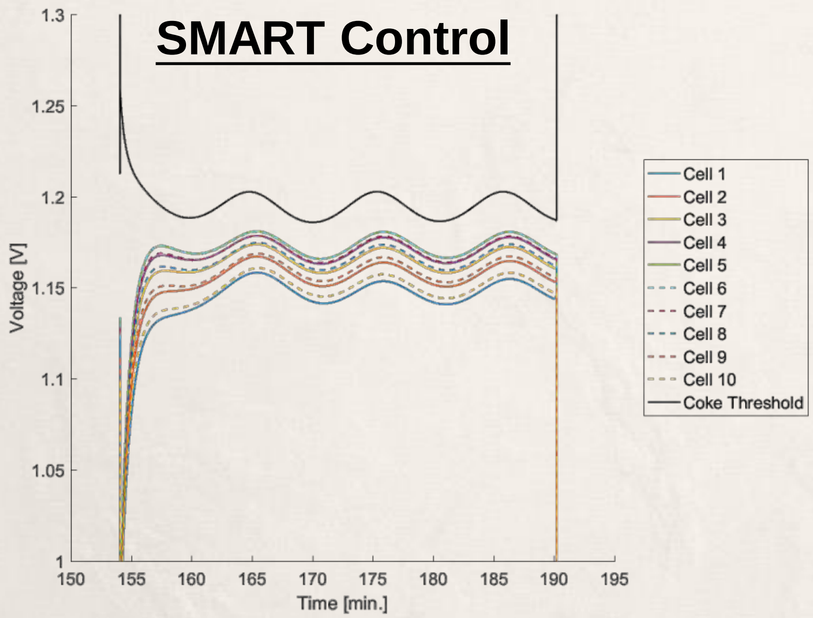
Consistent with M-WIP study



Potential improvement: Small filter assembly following dust-tolerant first stage pump

Other potential improvements

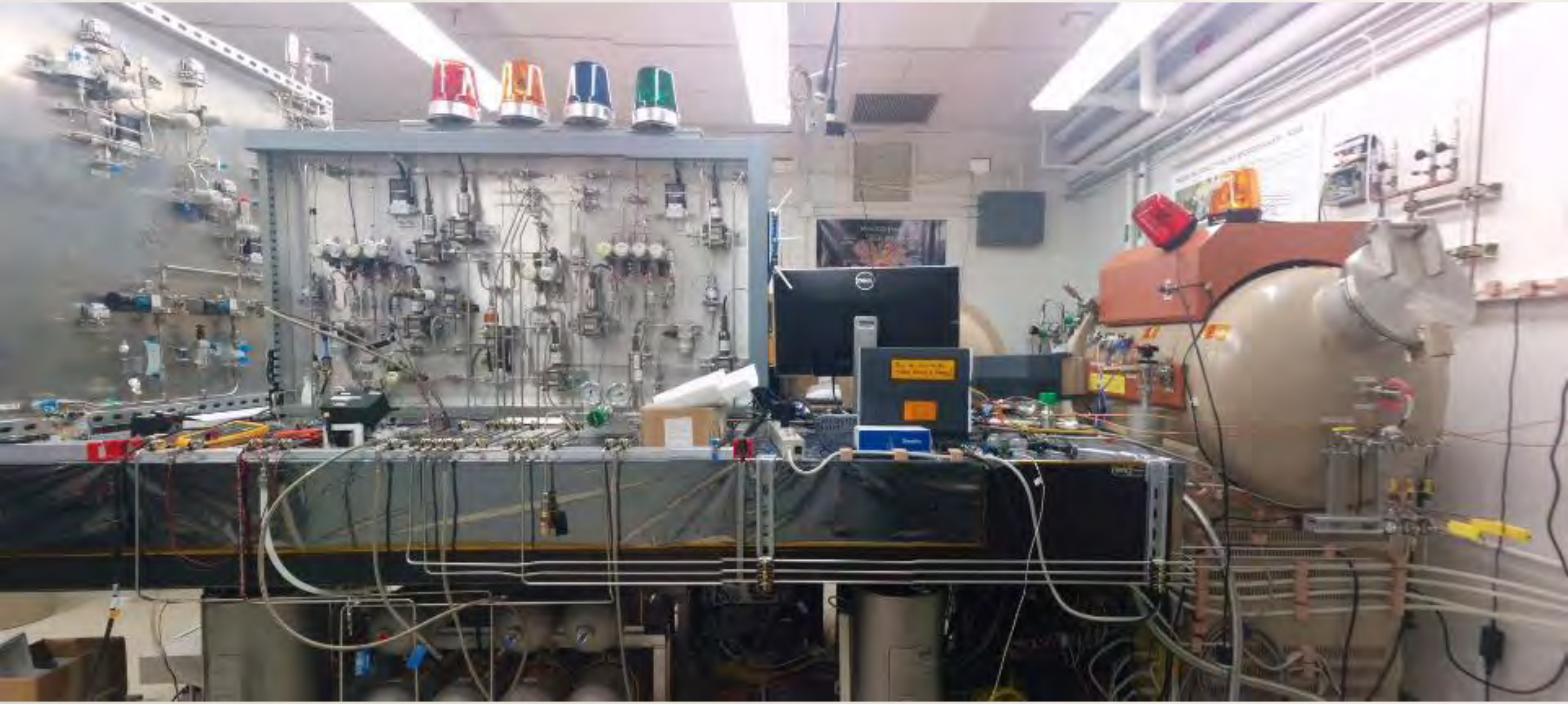
* Higher temperature operation
* Lower pressure operation
* Higher utilization factor (low flow or CO_2 re-use)
* Advanced controls and improved autonomy



F. Meyen thesis

MOXIE
Mars Oxygen ISRU Experiment

Special thanks to the amazing JPL Project Team!



MOXIE Testbed

MARS

Sponsors and Partners

MOXIE
Mars Oxygen ISRU Experiment

- Supported by HEO/AES, STMD/Tech Demos
- Mars 2020 Project managed by SMD

Thank you,

ISRU Technology,
NASA GRC
Aarhus wind tunnel

MOXIE is brought to you by…

Massachusetts Institute of Technology

NASA Jet Propulsion Laboratory
California Institute of Technology

CERAMATEC

air squared

UNIVERSITY OF COPENHAGEN

ASU Arizona State University

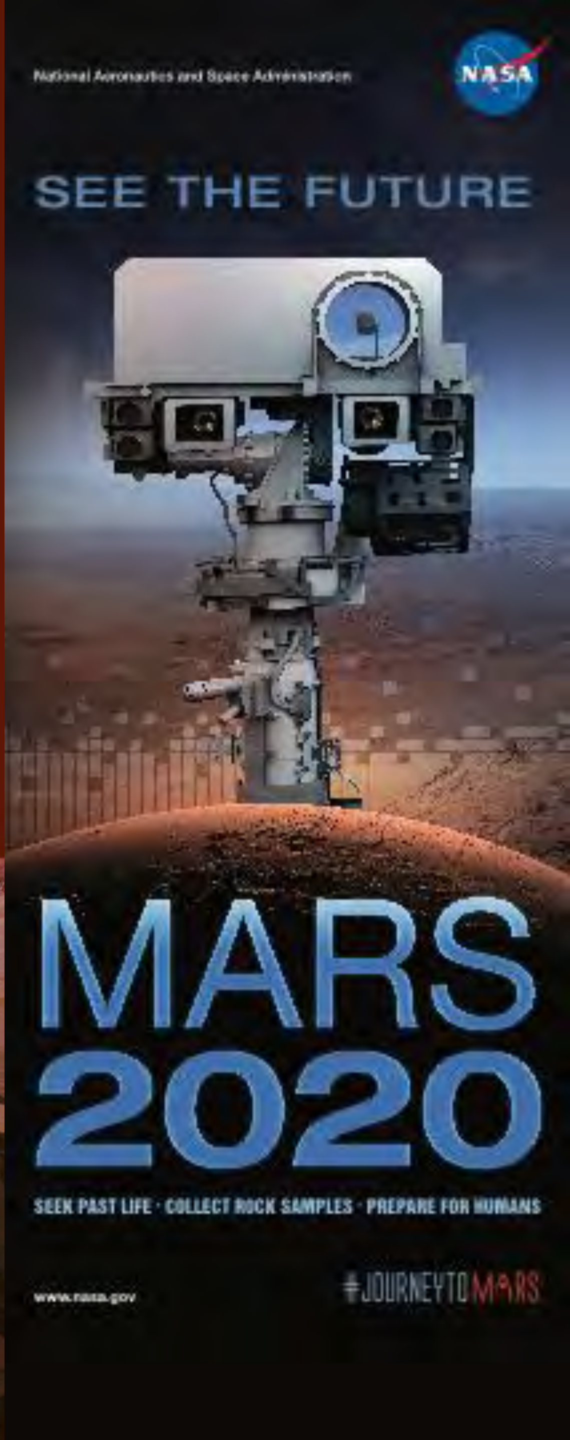
Imperial College London

NASA Johnson Space Center

MARS

Congrats & Thanks, Forrest!


MOXIE
Mars Oxygen
ISRU Experiment
GOT OXYGEN?
United States
NASA
BOSSINAS '89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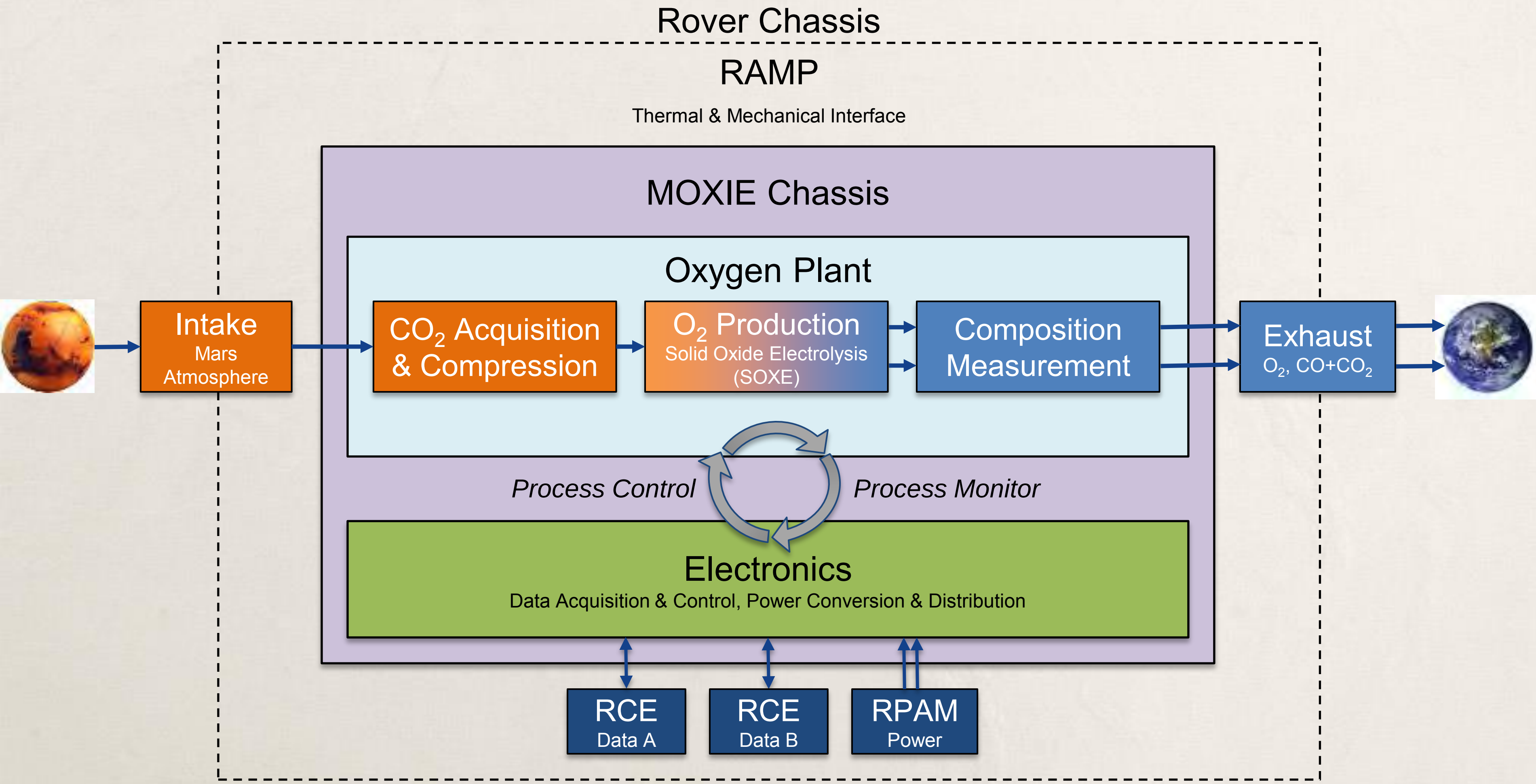
Backup: More MOXIE

Abstract

Mars Oxygen ISRU Experiment

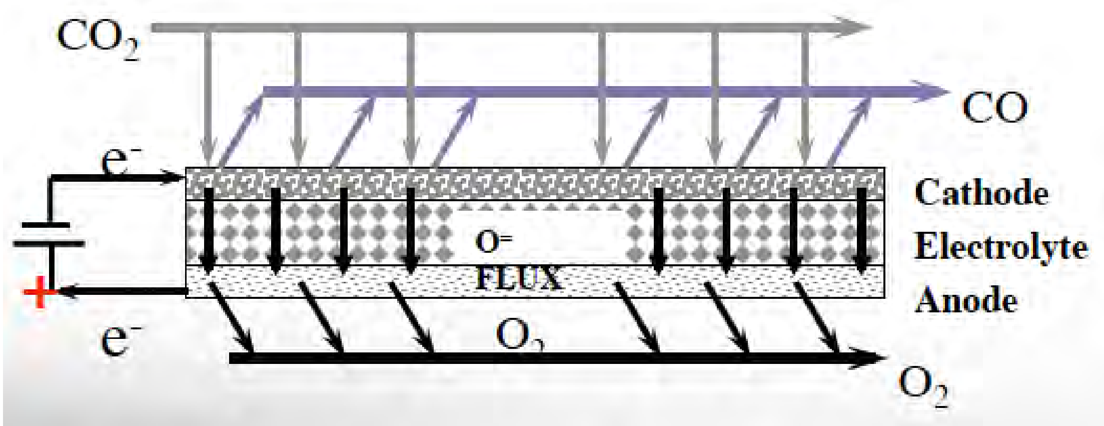
Essential subsystems of the Mars Oxygen ISRU Experiment (MOXIE) on NASA's Mars 2020 mission have passed their Critical Design Review, and the project is beginning a flight build stage that will culminate in delivery of flight hardware in late 2018. Also being delivered to the MOXIE Science Team is an Engineering Model, equivalent in form, fit, and function to the flight hardware, that will support Mars 2020 mission operations and subsequent extensions of the MOXIE flight demonstration (for example, tests of long duration operation). As a scale model of a future oxygen production facility on Mars, MOXIE will generate a minimum of 6 g/hr high purity oxygen from the Martian atmosphere in at least 15 separate runs, sampling different environmental conditions on Mars, in the 2.5 years following landing of the Mars 2020 rover in February, 2021. The presentation will review the MOXIE scroll pump for CO2 collection and compression, the solid oxide electrolysis system and its packaging for CO2 conversion to O2, the monitoring and control subsystem, and the expectations for operation on Mars.

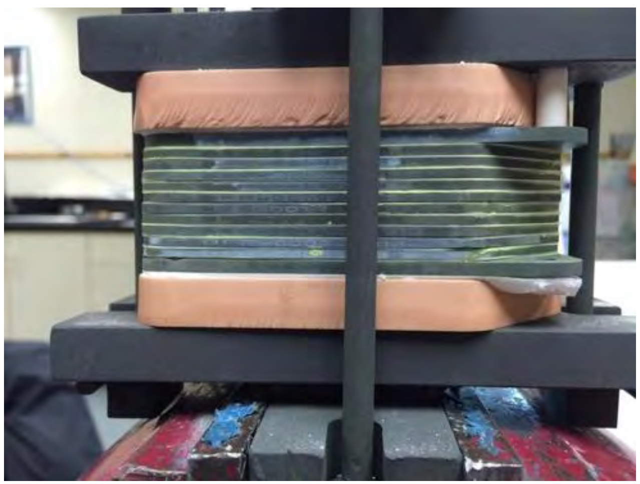
What does MOXIE do?



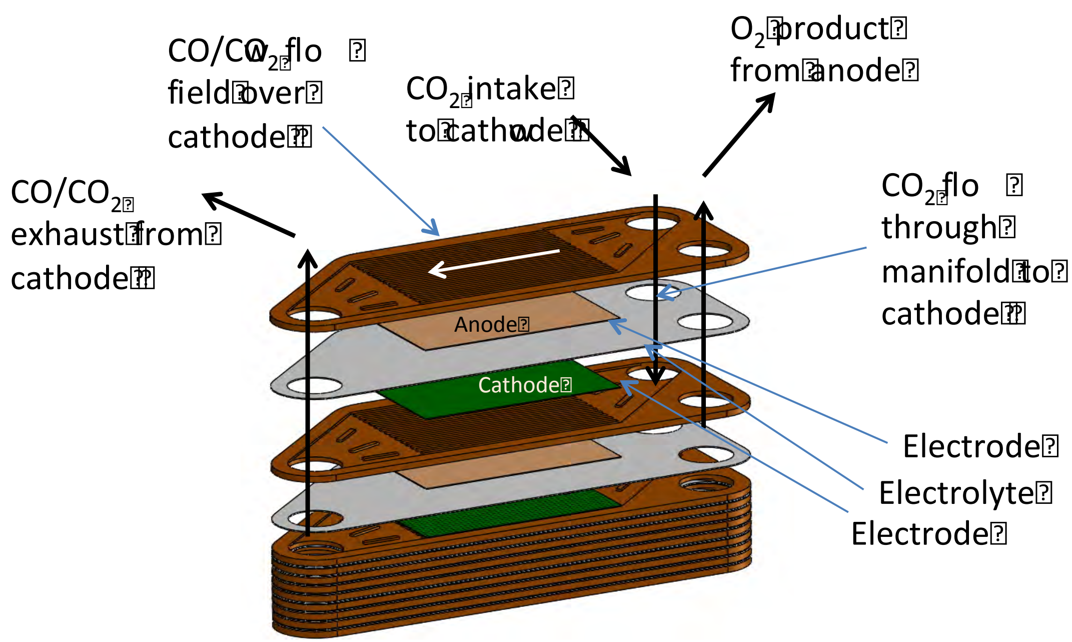
1:200 scale production
1:100 scale operating life

SOXE

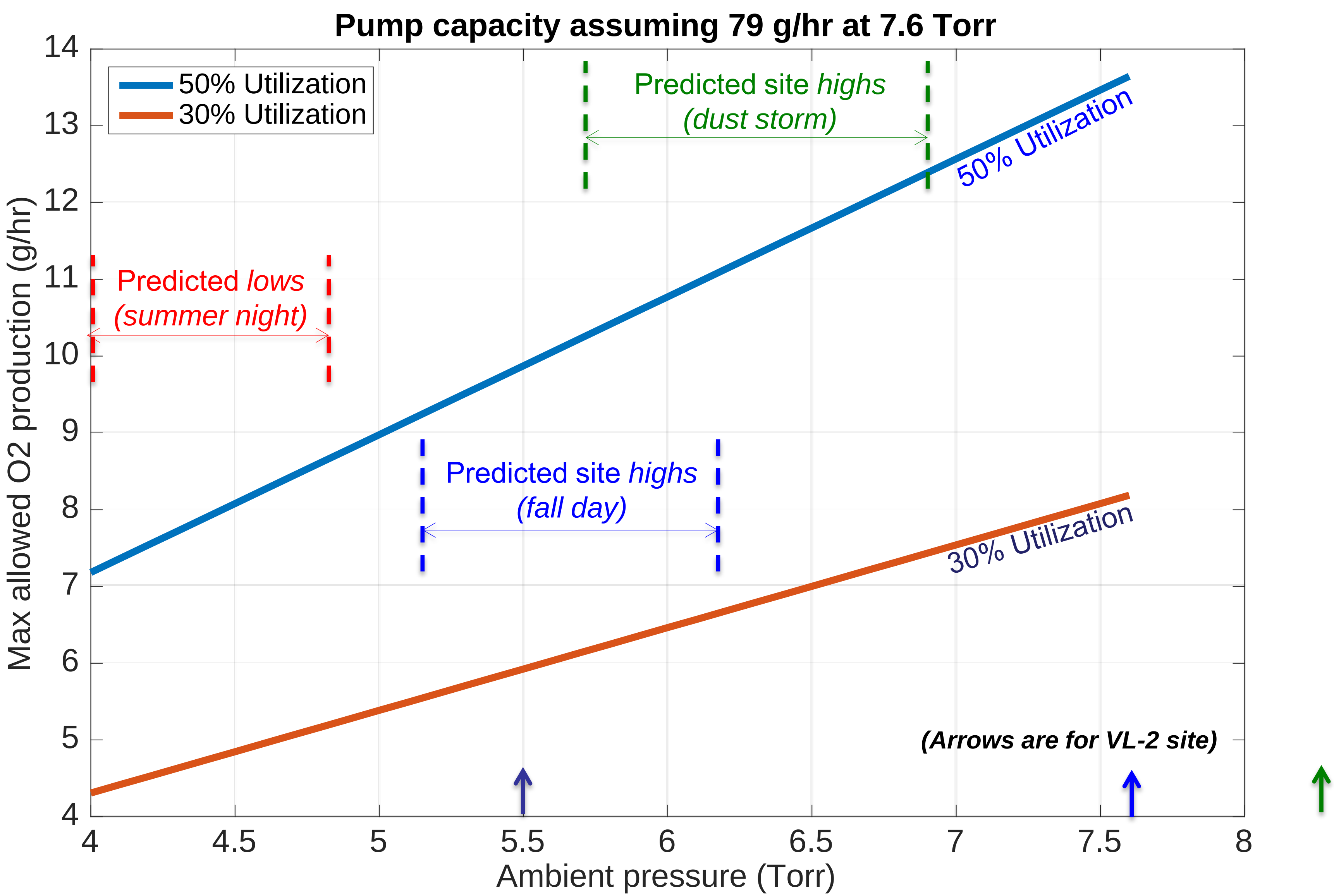




SOXE 11 cell stack fabricated by Ceramatec

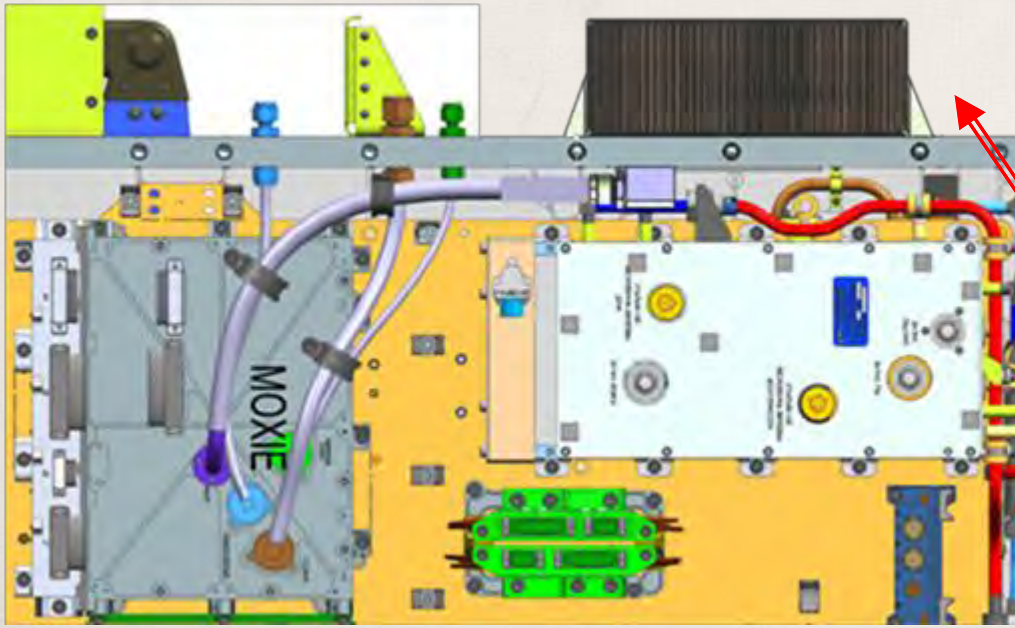


Pump capacity (at 20° C inlet)



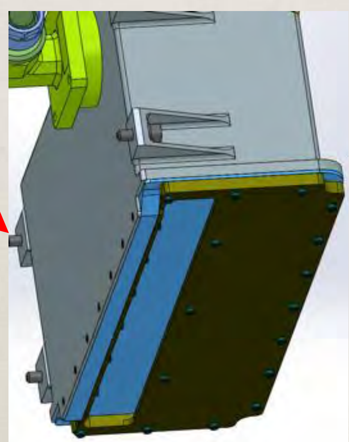
Inlet filter assembly& baffle

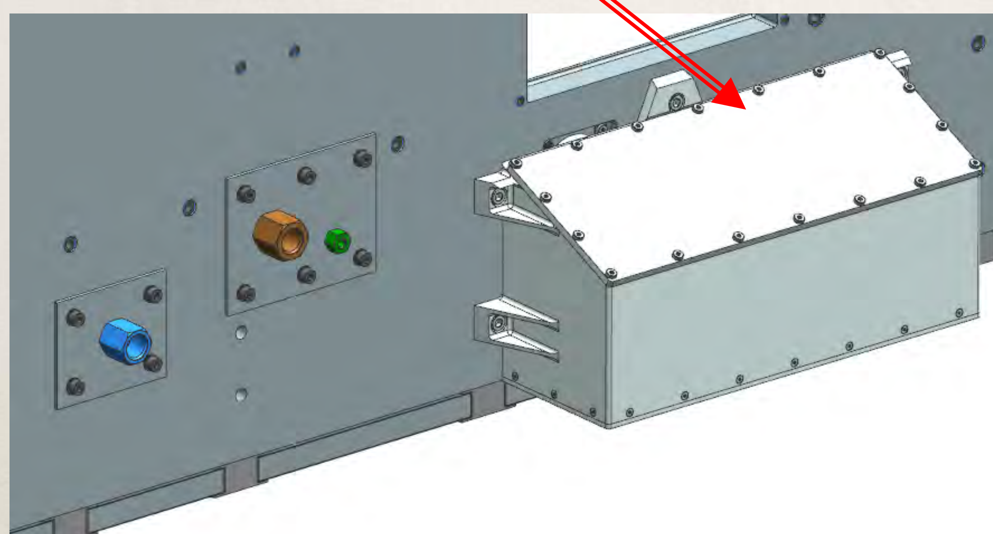
Mars Oxygen ISRU Experiment



Inlet Filter Assembly

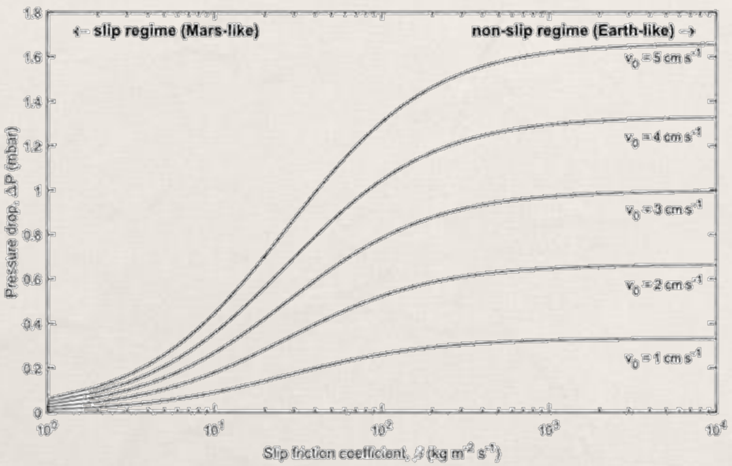
Baffle



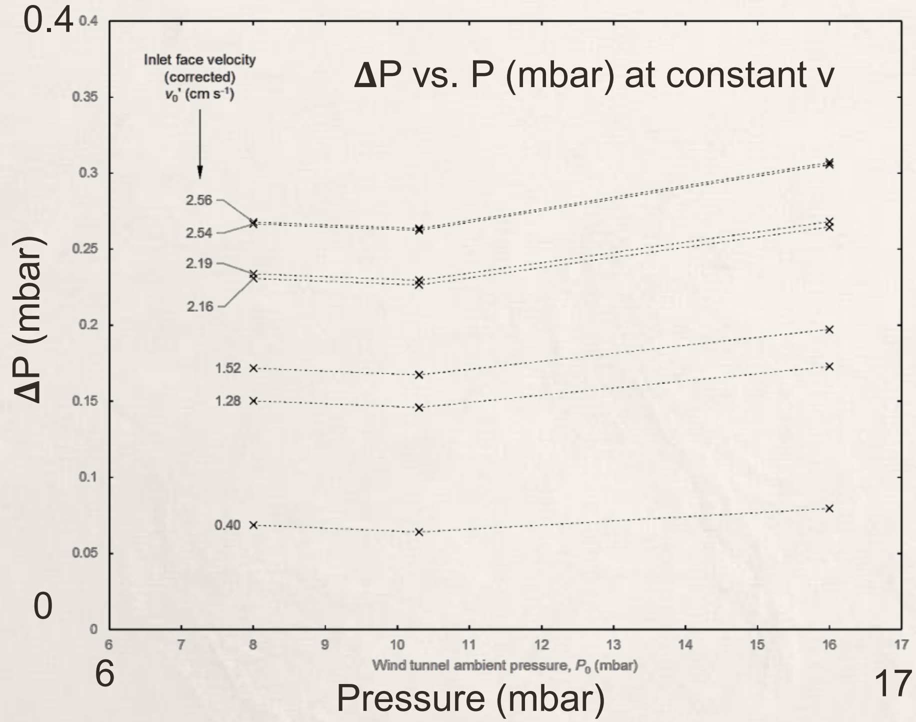


More on the Dust Story

Mars Oxygen ISRU Experiment



Pressure drop of fluid with a viscosity 1.1×10^{-5} Pa-s, through a 0.4 mm long, 1 μm radius tube, using slip friction coefficients from 1 to 10^4 and inlet velocities of 0-5 cm/s

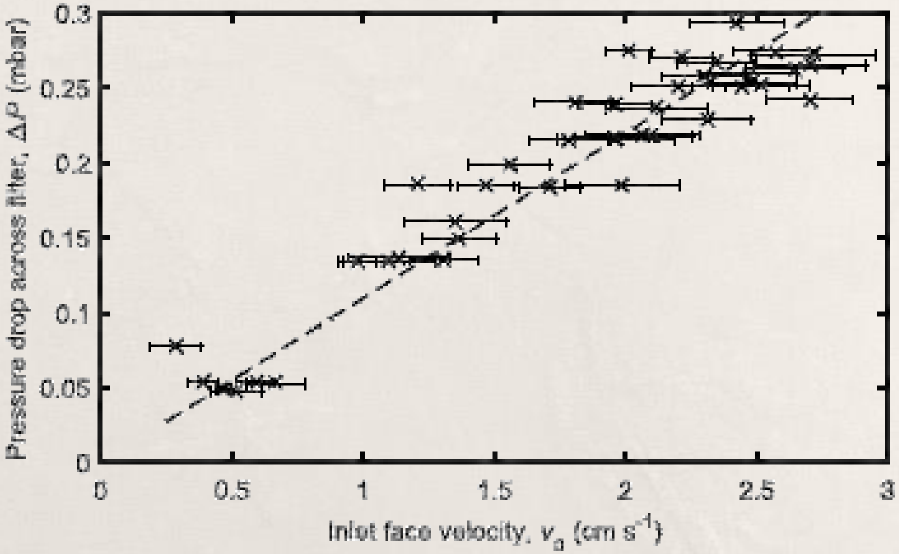


Measured result at Aarhus using laser Doppler anemometer to measure inlet velocity v.

MARS

Yet more on dust…

MOXIE
Mars Oxygen ISRU Experiment



Pressure drop, ΔP, shown to scale with face velocity in Aarhus test

MARS