Life After Grad School

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Technologist II
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Jet Propulsion Laboratory
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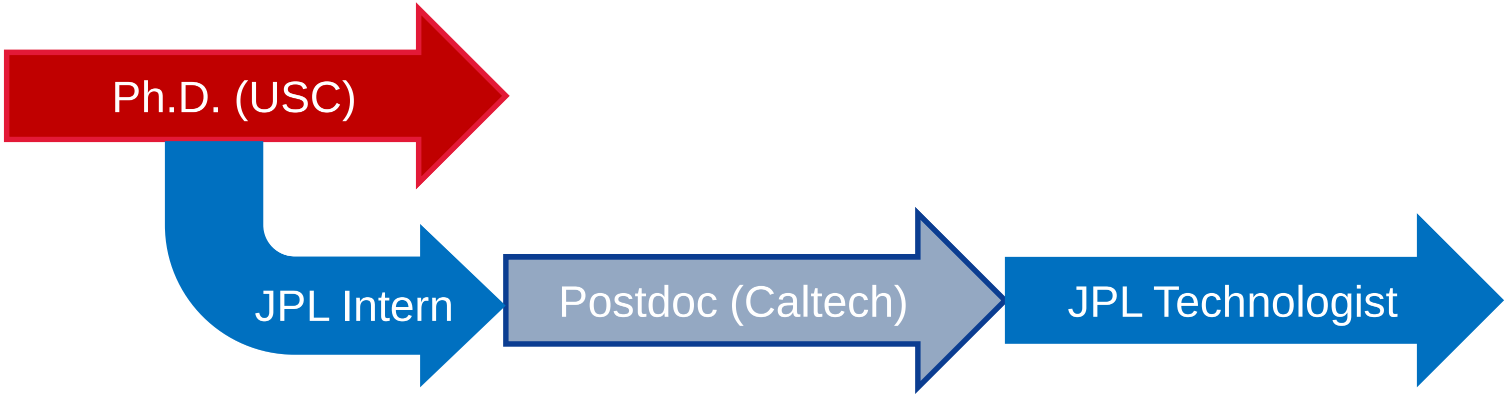
Career path



technologist - a person who uses scientific knowledge to solve practical problems

Electrochemical Technologies Group Overview

Energy and power reqs:
- Science
- Communications
- Mobility

Mission duration:
- Single-use
- Rechargeable

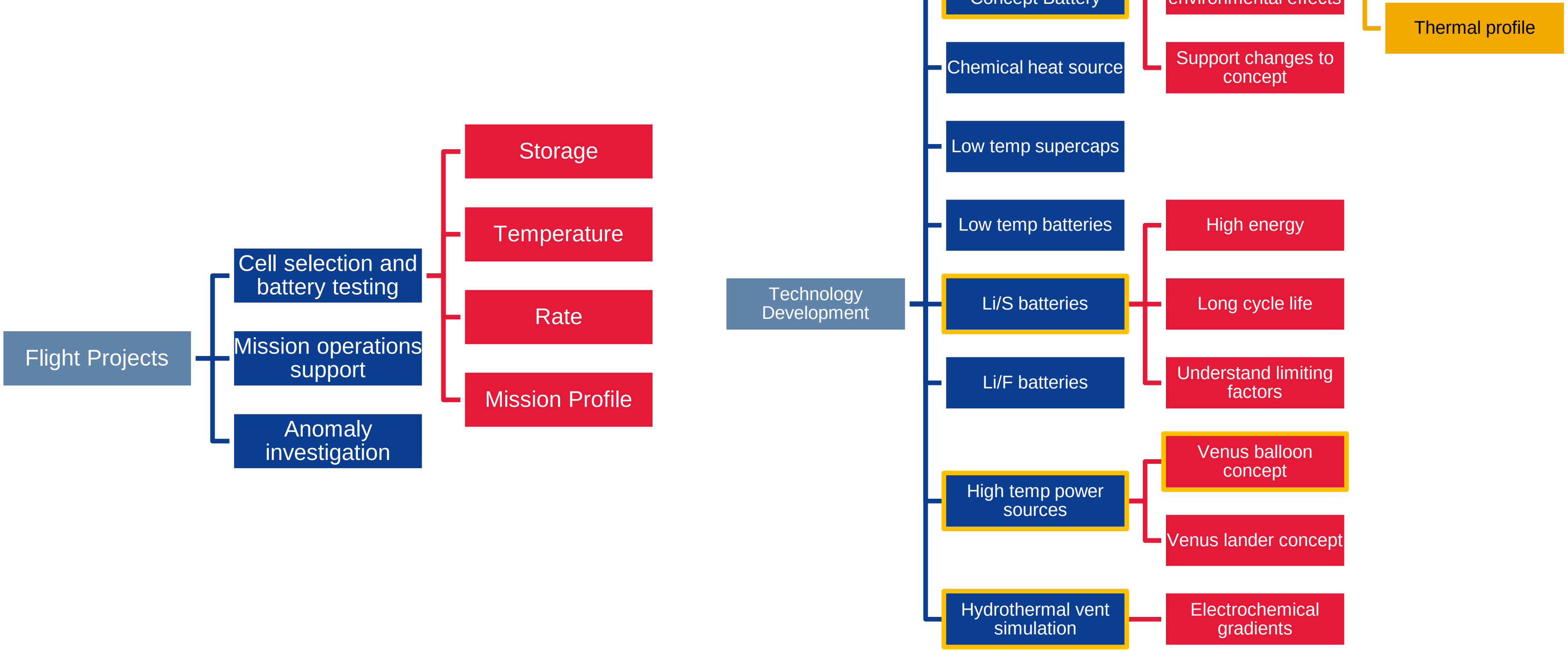
Available energy
- Photovoltaics
- Thermoelectrics

Operating conditions:
- Temperature
- Radiation

Other considerations
- Human-rated?

After launch: health evaluation, lifetime predictions, operational recommendations

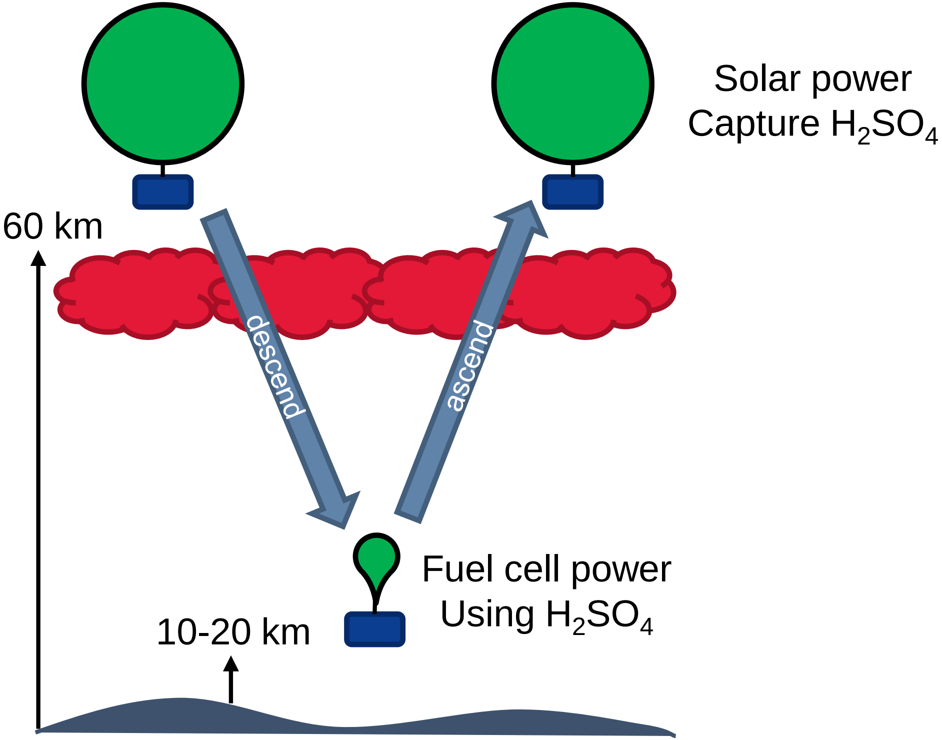
Electrochemical Technologies Group Projects



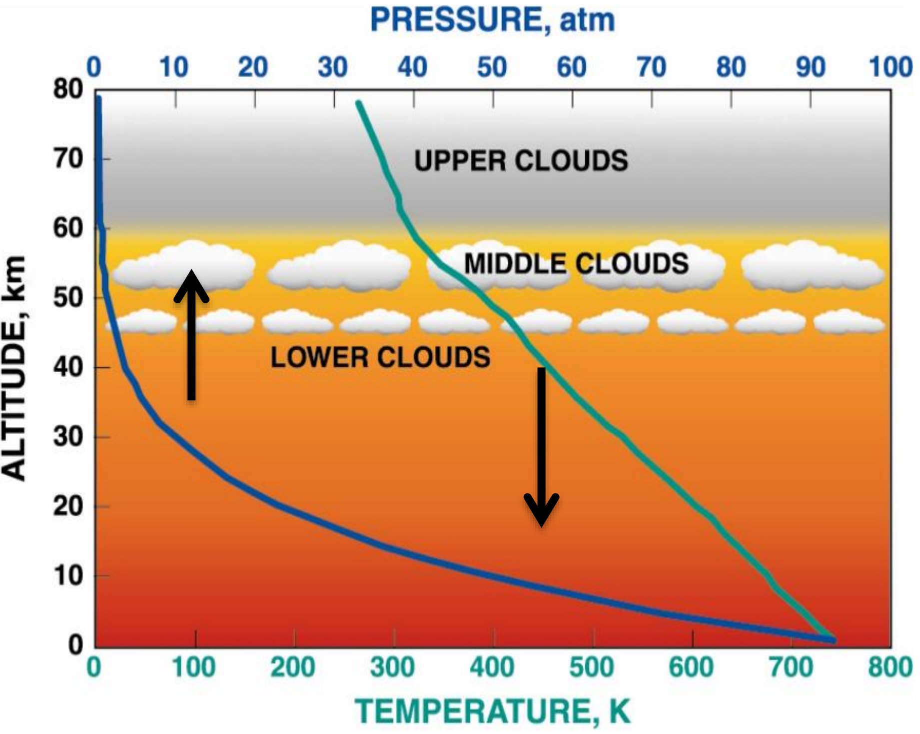
Venus Concept

- What if the sulfuric acid clouds on Venus could be used to power a spacecraft?

Image from Pioneer

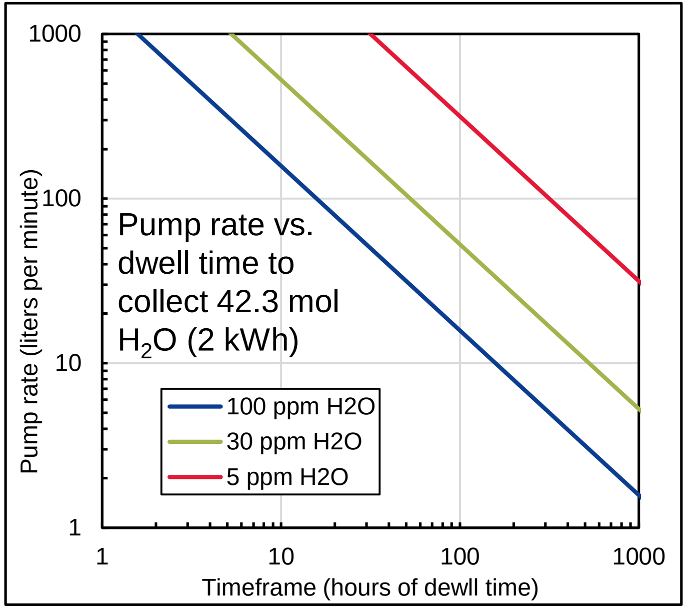


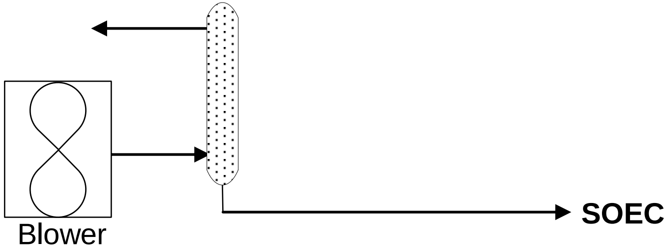
Some Venus Facts



- One day on Venus is longer than a year on Venus
  - 243 Earth days = 1 Venus day
  - 225 Earth days = 1 Venus year
- Most (?) similar planet to Earth
- Hottest planet in solar system
  - Surface ~460 °C
- Densest atmosphere in solar system
  - **93** bar compared to **1** bar on Earth and **0.006** bar on Mars
- Atmospheric super-rotation
  - Clouds travel much faster than surface
  - Balloon in clouds would circle planet every ~4 Earth days

In-situ Resource Capture





- Initial proposal included concept to collect H_2SO_4 from clouds, convert into H_2 and run fuel cell
- Concentration of H_2SO_4 is very low
  - Chemical conversion is not straightforward
- Water is more abundant
  - Could be electrolyzed to H_2 and O_2
- Use chemical water adsorption to capture small amounts of moisture in upper atmosphere

- **How much time would it take to capture a useful amount of water?**
- How does water capture compare to sulfuric acid capture?
- What method can be used to capture water under relevant conditions?

Venus Interior Probe Using In-situ Power and Propulsion (VIP-INSPR)

High Altitude Balloon

- Abundant solar power
- Bring stored H_2 (metal hydride) and O_2 (compressed gas cylinder)

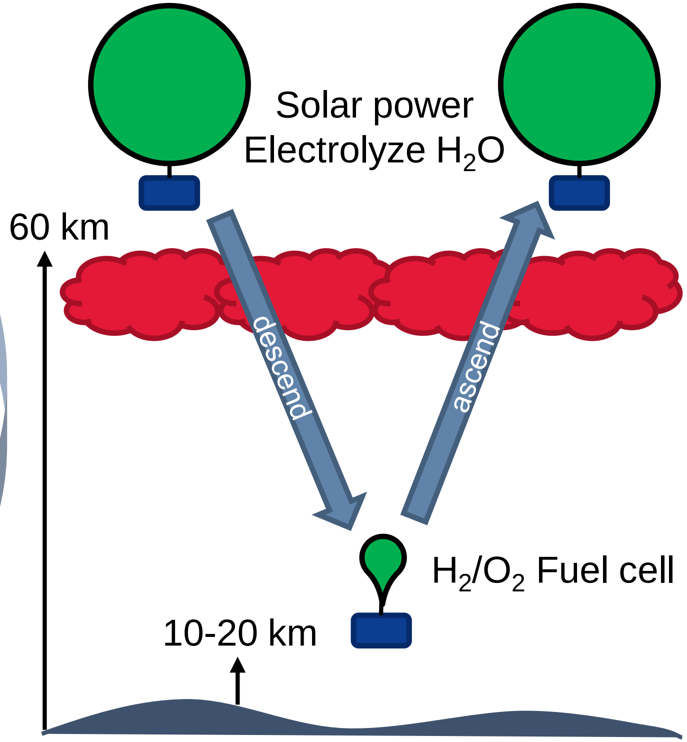
Descend below clouds

- Store ~100 g H_2 from balloon in metal hydride
- Operate on solid oxide fuel cell (SOFC)
- Store H_2O byproduct

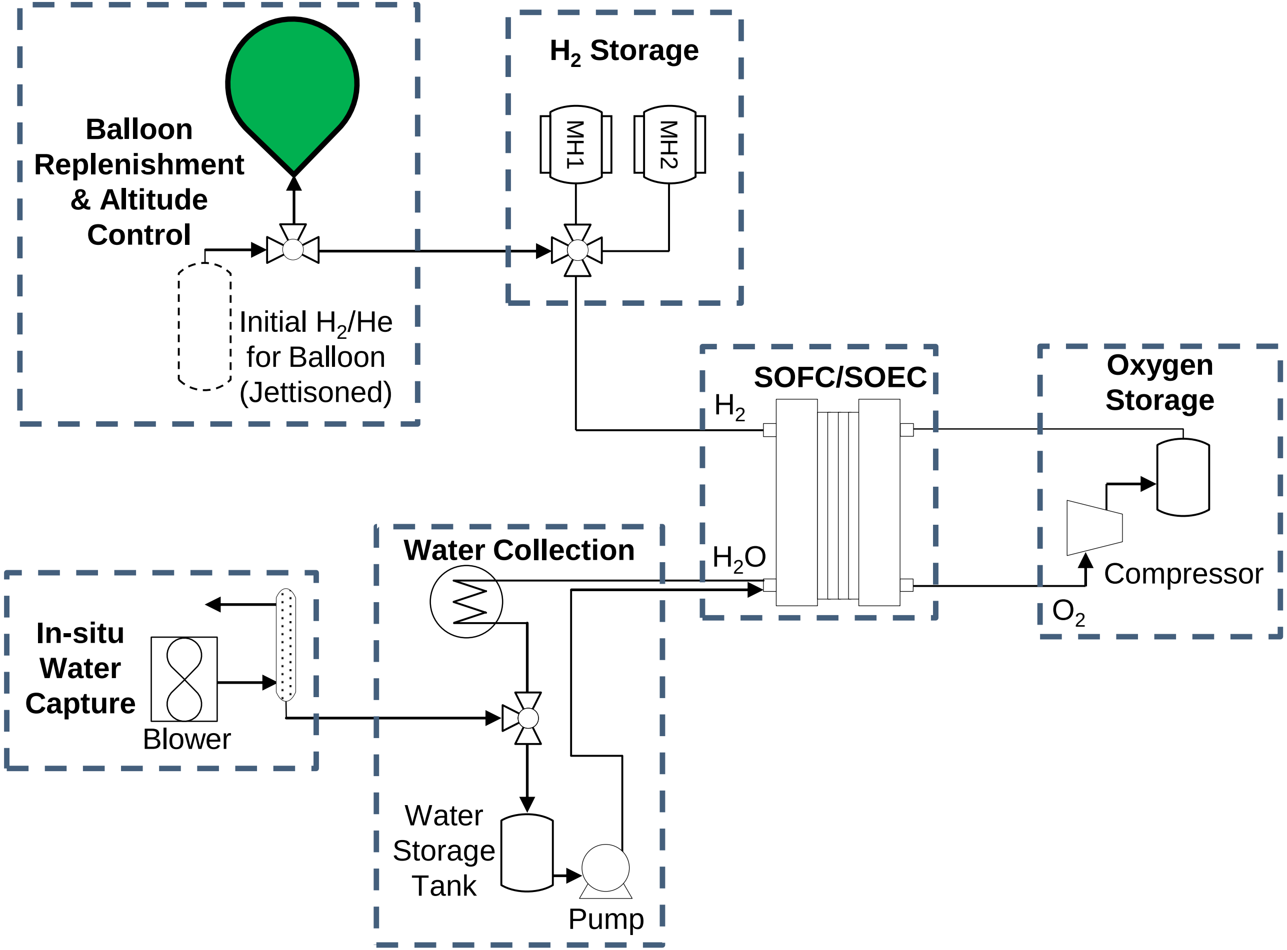
Ascend above clouds

- Release H_2 back into balloon
- Operate on solar power
- Electrolyze H_2O back into H_2 and O_2

Repeat



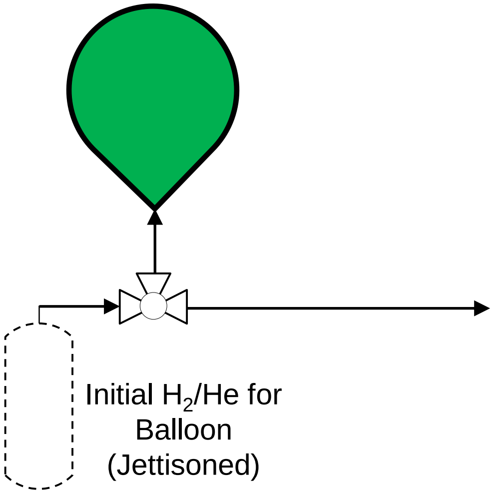
Initial System Design



Balloon Considerations

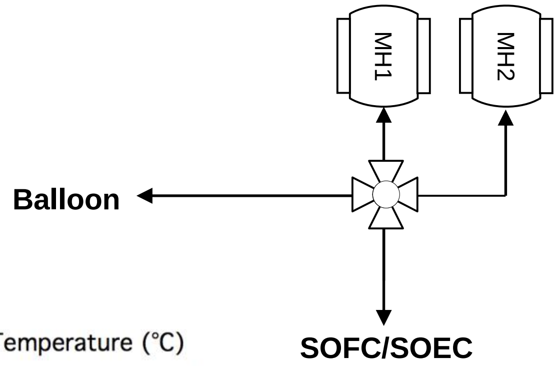
- Baseline balloon design - Global Aerospace Corporation
  - 1 mil thick coated Kapton balloon
  - 8.1 kg H_2
  - Diameter: 11.8 m at 65 km alt.
  - 150 kg payload

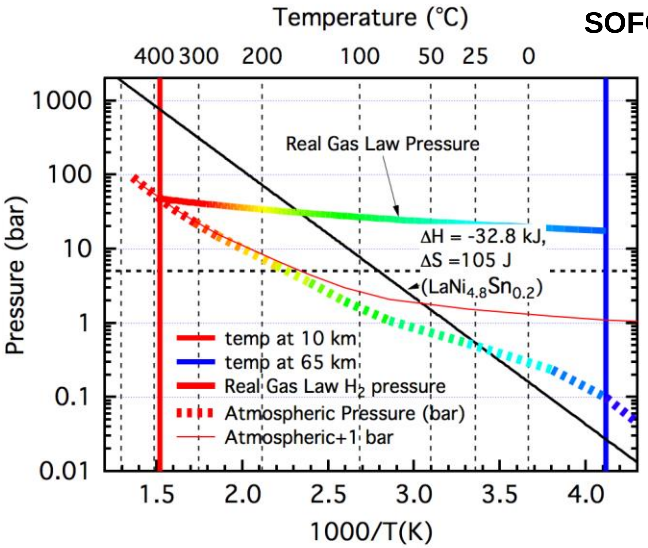
- How fast will lifting gas leak?
  - Leak rate through Kapton
  - Seams may leak more than Kapton



Hydrogen Storage

- Prof. Brent Fultz's group at Caltech has been developing hydrogen storage materials
- Metal hydrides provide a way to easily store H_2 at low temp and release it at high temp
- Carefully selected metal hydride materials can accommodate almost any temperature range on Venus
- Metal hydrides could also be used to store H_2 from balloon (if H_2 is used as lifting gas) for low altitude

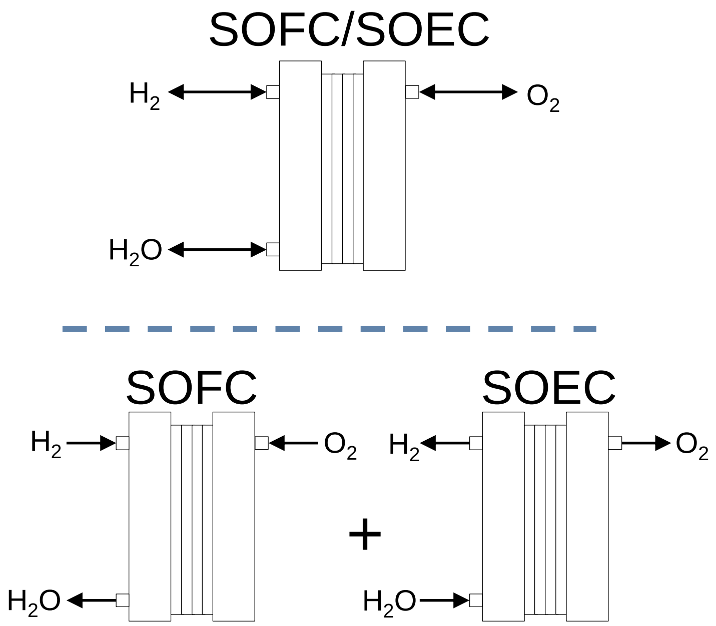




van't Hoff plot generated by Channing Ahn at Caltech

SOFC/SOEC

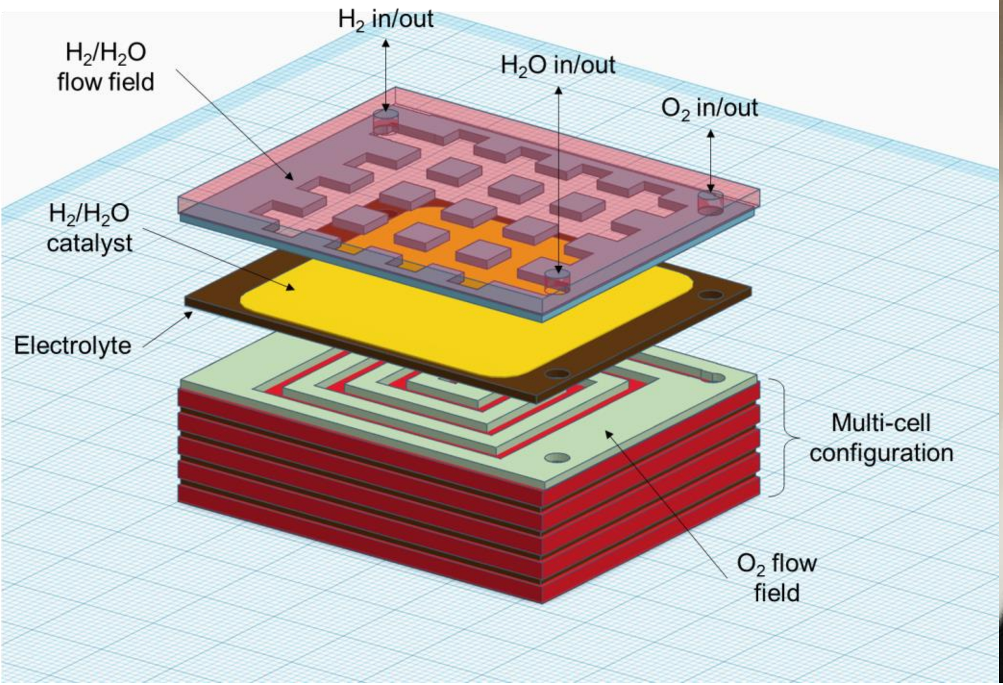
- Can the system be operated as one unit?
  - MOXIE* proposed operating reversibly
  - No changes were made to MEA compared to commercial H_2/O_2 for MOXIE
- What are the flow and pressure requirements?
- Can the O_2 be compressed by the SOEC?
  - Electrochemical compression using PEM cells well-studied
- Is O_2 flow required?
- What are the efficiency losses due to electrochemical compression?



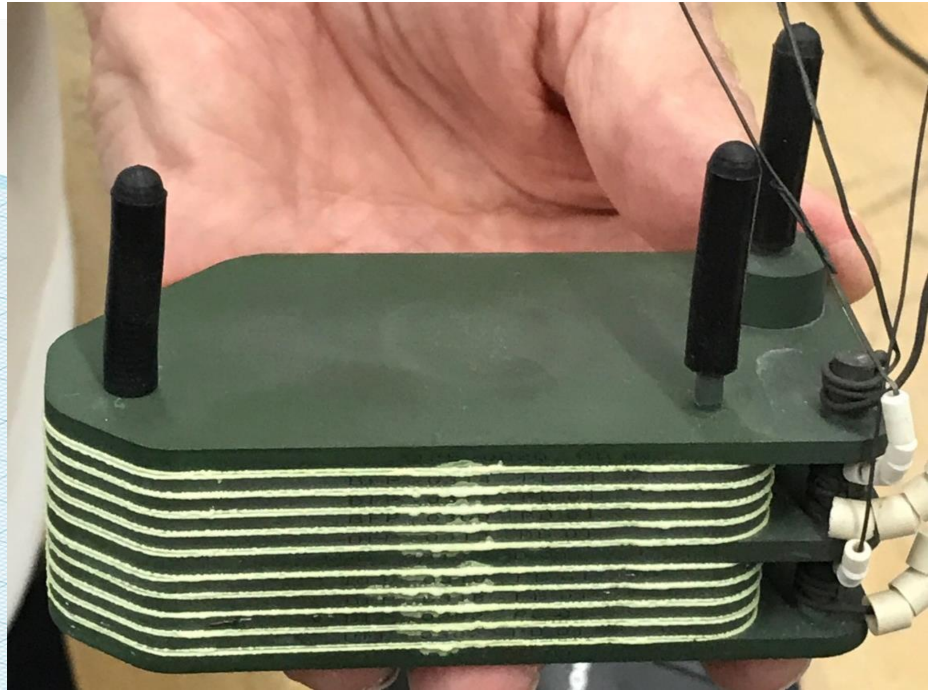
*MOXIE: **M**ars **Ox**ygen **I**n-Situ Resource Utilization **E**xperiment, which is flying on the Mars 2020 rover
https://mars.nasa.gov/mars2020/mission/instruments/moxie/

Beginning the design of the SOXC

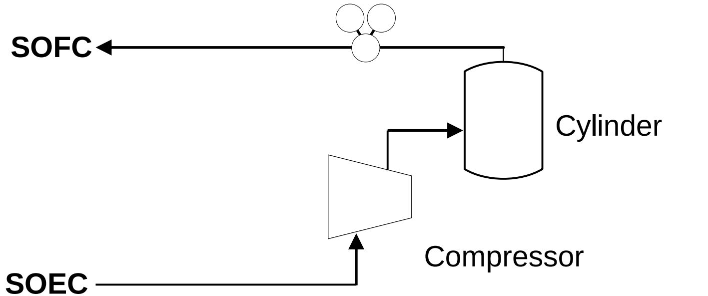
VIP-INSPR

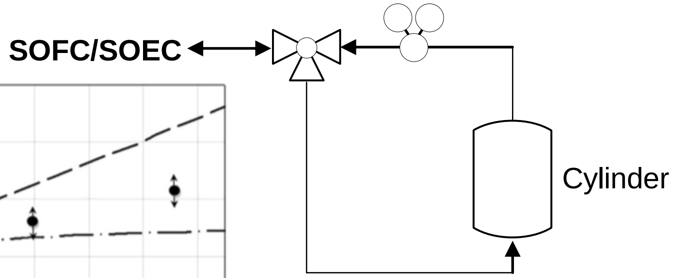


MOXIE



Oxygen Storage





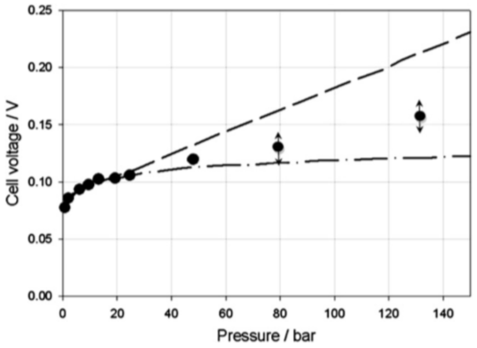


Fig. 6 – (●) Experimental cell voltage *vs.* pressure at i = 0.2 A cm^{-2} and the two limiting cases of extrapolation: linear (–––) and logarithmic (–.–.–).

Simple H_2 pump across a Nafion membrane

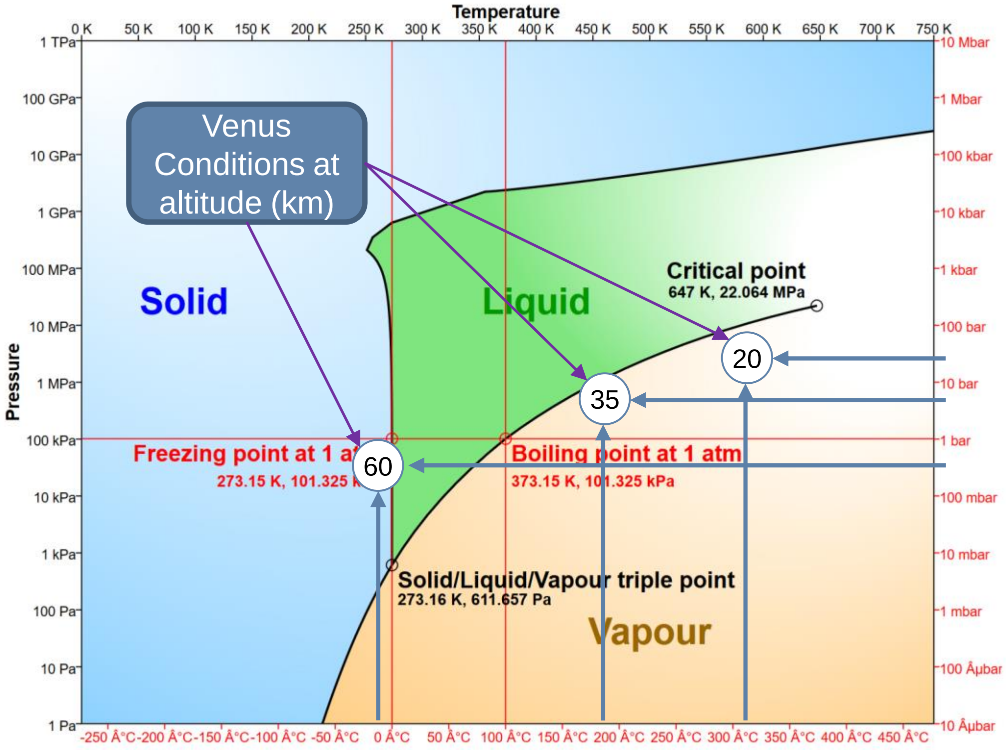
Grigoriev et al., *Int. J. Hydrogen Energy* **2011**
doi: dx.doi.org/10.1016/j.ijhydene.2010.07.012

- No good chemical O_2 storage options exist (so far)
- Baseline is a storage cylinder
- Mechanical compressors not rated for high temperature
  - May be survivable up to 260 °C
- SOEC should be able to compress O_2 with some efficiency loss
  - Well studied in PEM cells with H_2
  - Unproven for solid oxide systems
- Is there any chemical means to store O_2?
- Would a dead end system (no flow) work?

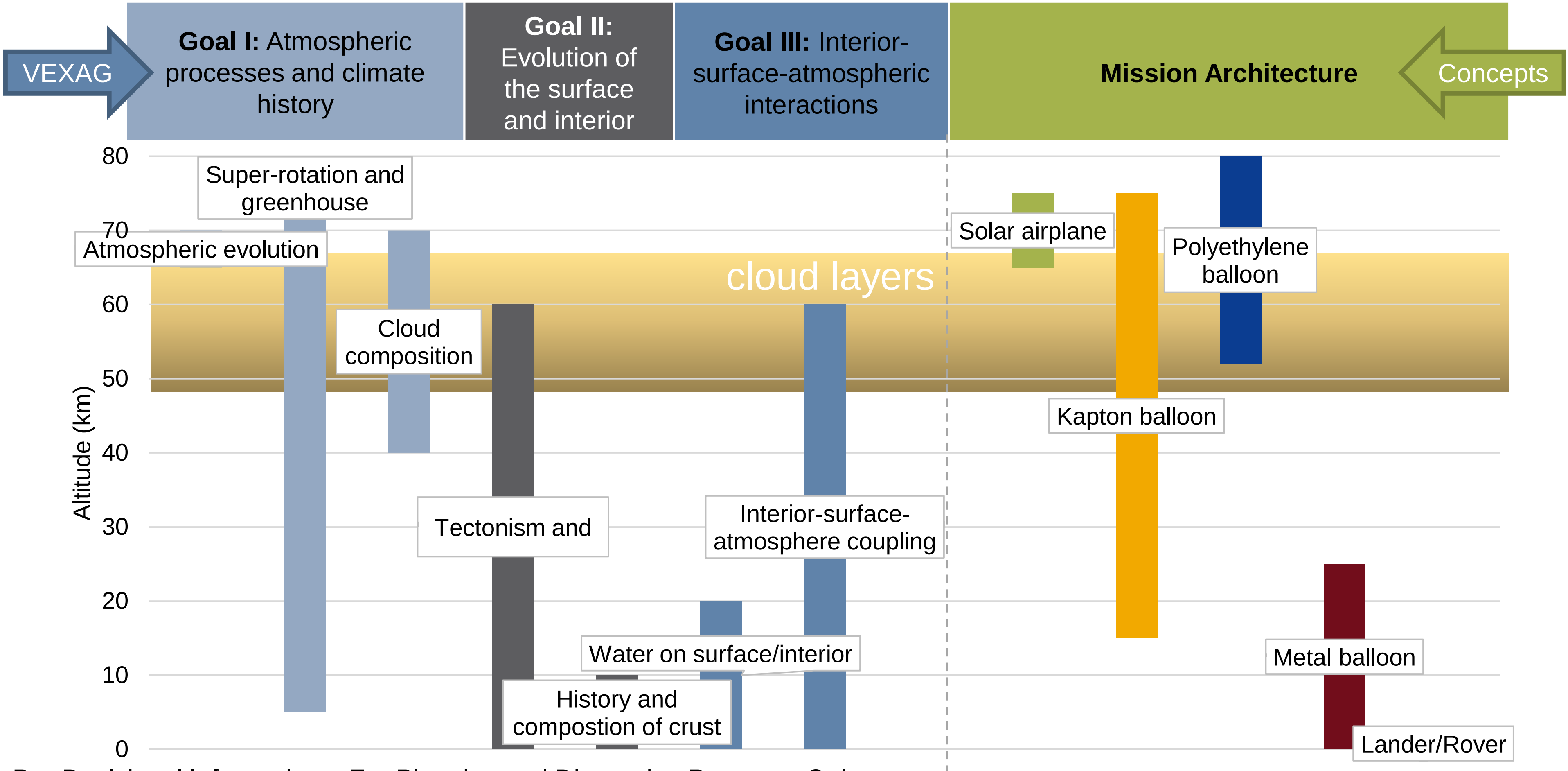
Water collection

- Water will be produced as steam by SOFC at ~800 °C

- Can we condense water under relevant temperature and pressure conditions?
- Is storage in a tank feasible?
- Should water be stored (as liquid + steam) in a pressure vessel?
- Will water need to be vaporized prior to electrolysis?

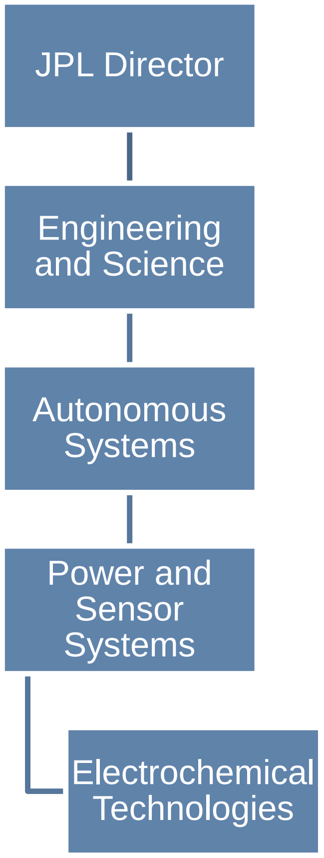


Science and Mission Type Arranged by Approximate Altitude



Advice?

- Be open to a wide variety of projects
- Learn to work on many projects at once
- Try to get involved with writing a grant
- Become a good communicator
- Maintain your connections



Electrochemical Technologies Group Members

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