ASME® 2019 IMECE
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Salt Lake City, Utah

A PROCESS PLANT FOR PRODUCING ROCKET FUEL FROM LUNAR ICE

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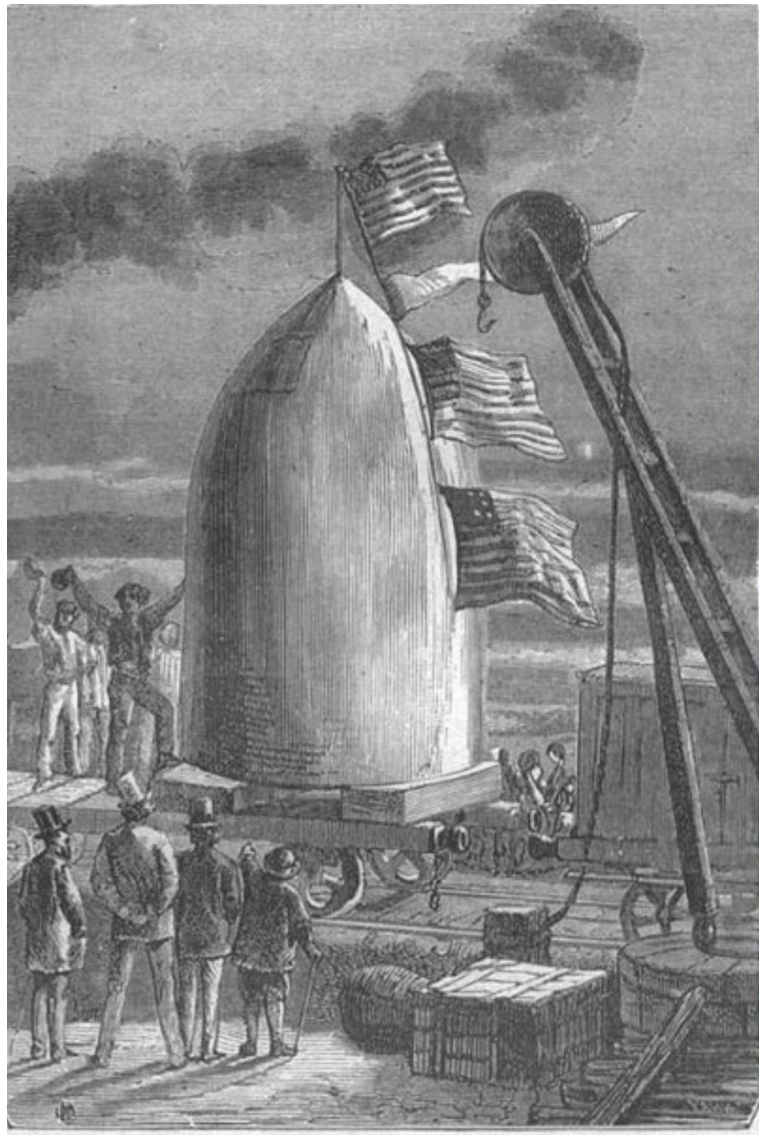
R. Mueller NASA
J. Demitz engNoveX

IMECE Paper 10270

BECHTEL

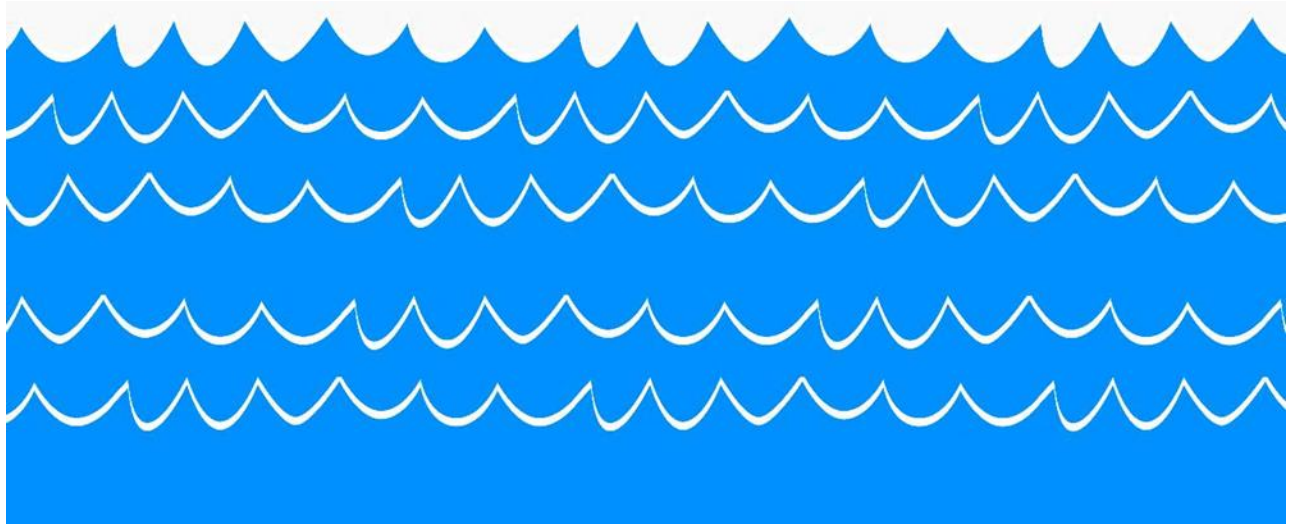
- From the Earth to the Moon
- Jules Verne 1865
- A US space mission
- Launch from Florida
- Land at the lunar pole



L'arrivée du projectile à Stone's-Hill (p. 139).

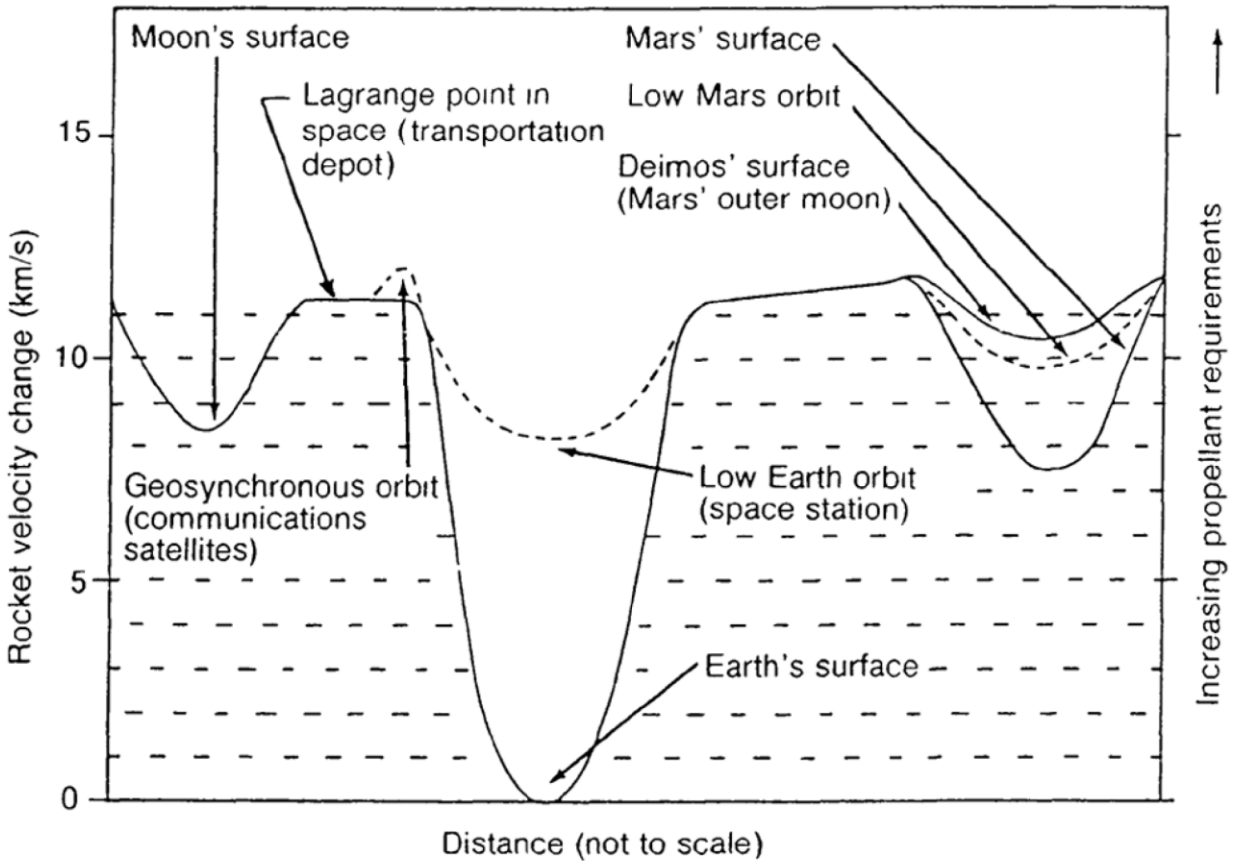
What is the most valuable resource on the Moon?

WATER



The water economy

- Transportation costs dominate Return on Investment (ROI) determination.
- Produce on the moon for a lunar consumer!



NASA SP509

The water economy

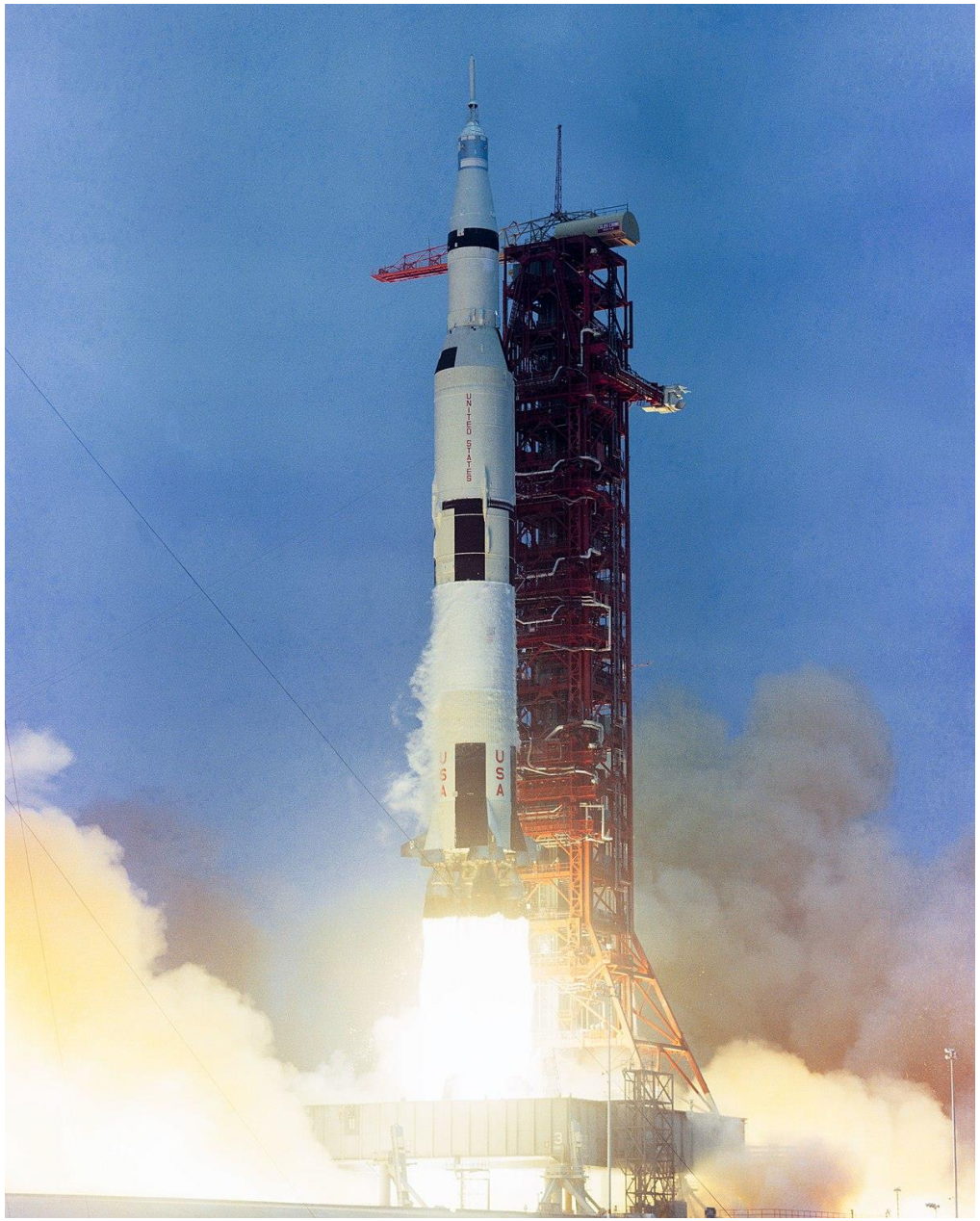
- Water for human consumption
- Water for agriculture
- Water for washing
- Water for material production
- Water to produce elemental Hydrogen and Oxygen

Rocket fuel

Liquid H_2 Liquid O_2

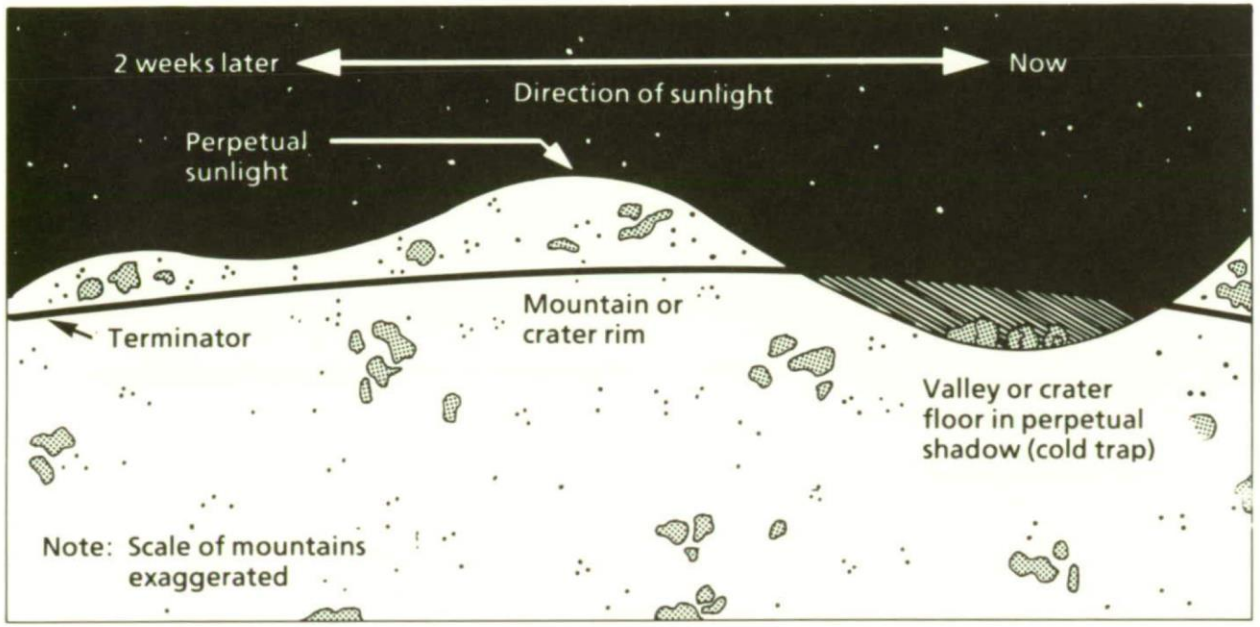
LH2 + LOX = Blast Off!

Saturn V Booster



Where is the water?

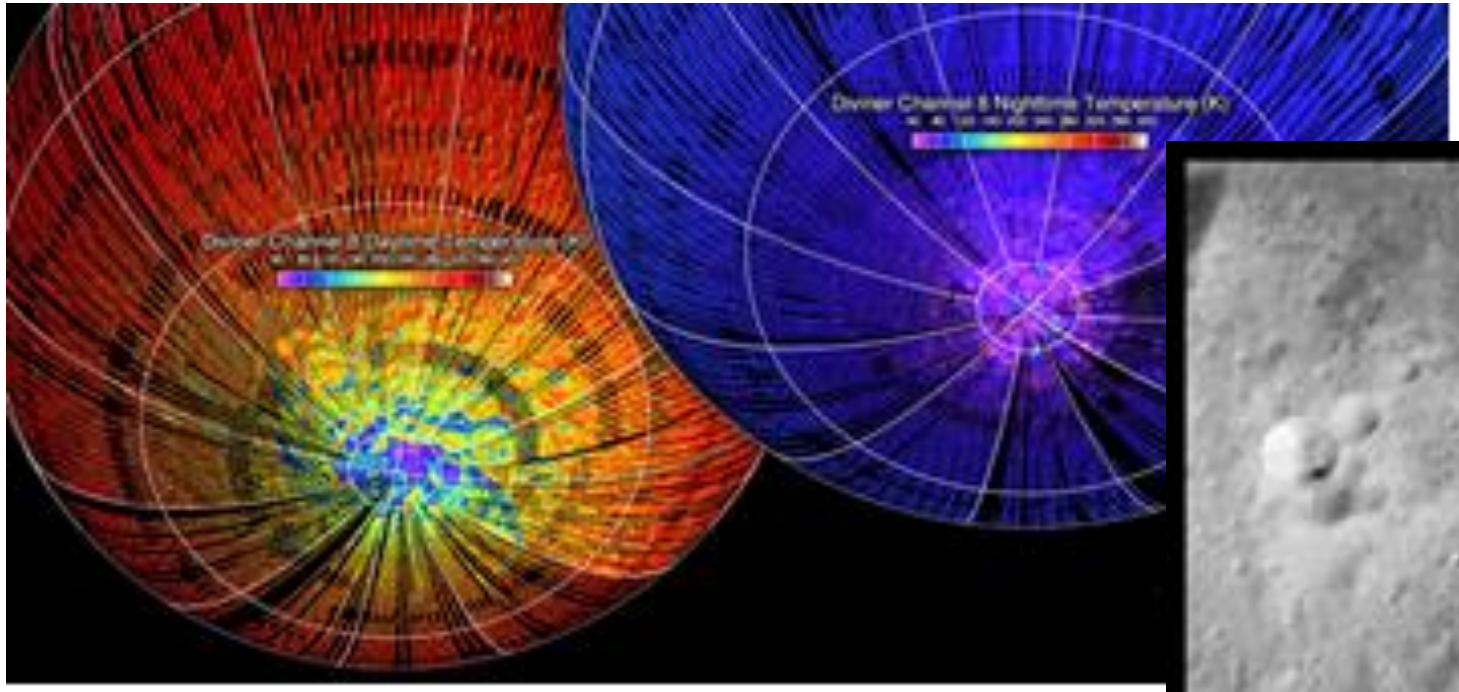
- Permanently Shadowed Regions (PSR)
- At the lunar poles
- 40 K (-233 ºC)



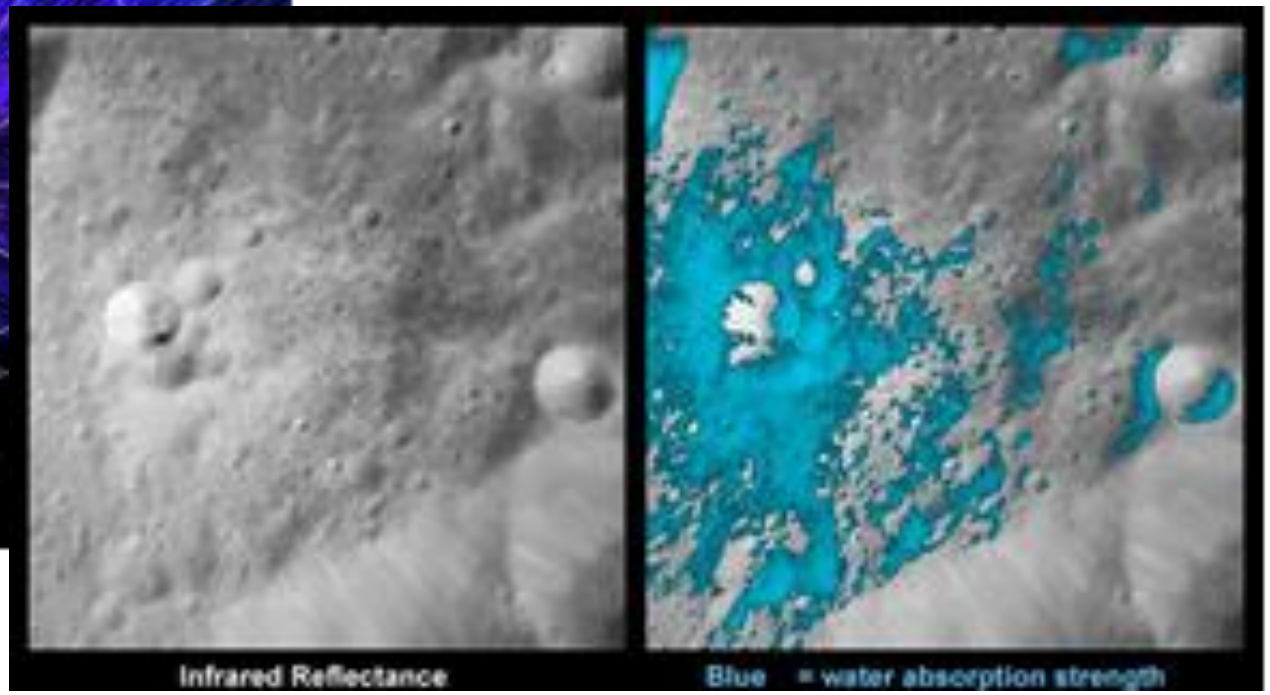
NASA SP509 (1984)

Shackleton Crater Lunar South Pole

Water ice observed on the moon



Surface Temperature Variation LRO's Diviner



Chandrayaan-1 Moon Mineralogy Mapper

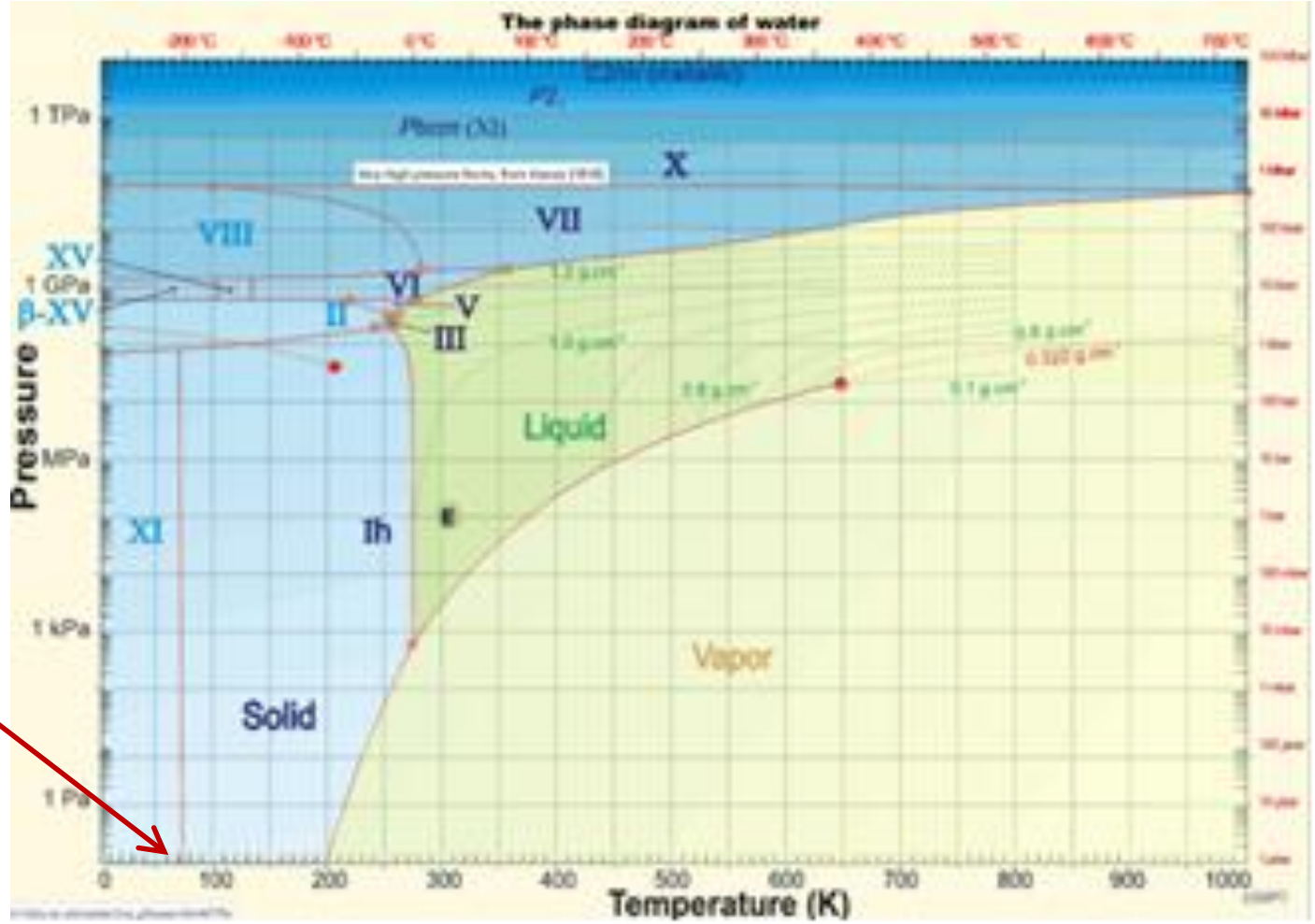
How much water?

The total quantity of water … has been estimated to be between 10 and 300 million tonnes.

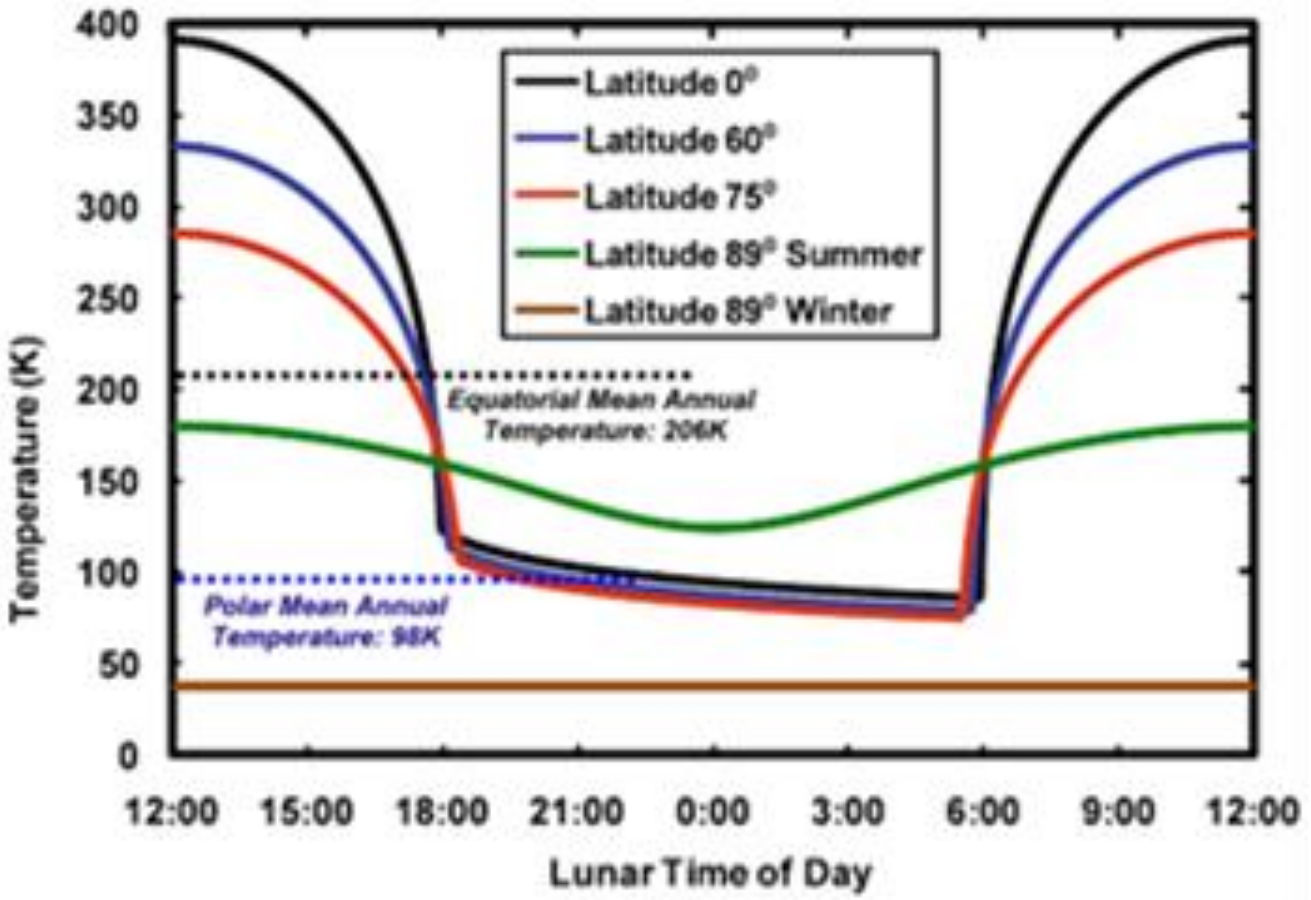
https://www.thefreelibrary.com/Ice+on+the+moon.-a020643670

Temperature and pressure challenge

The surfaced of the Moon is a cold vacuum



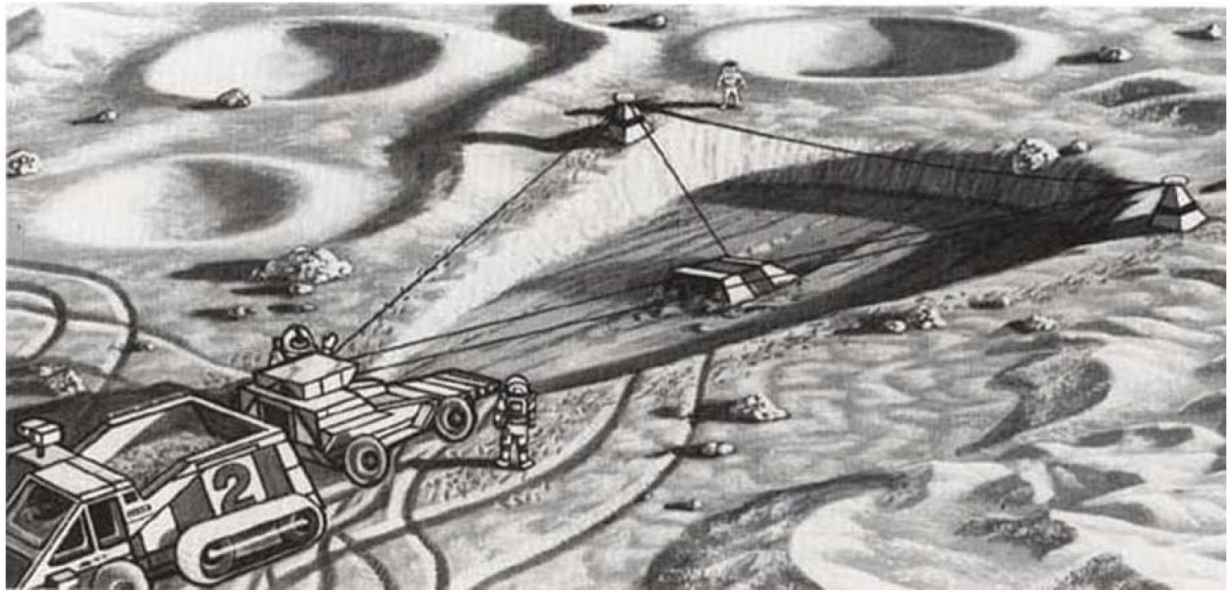
Surface temperature variation



Ice extraction concepts

Solar Heating

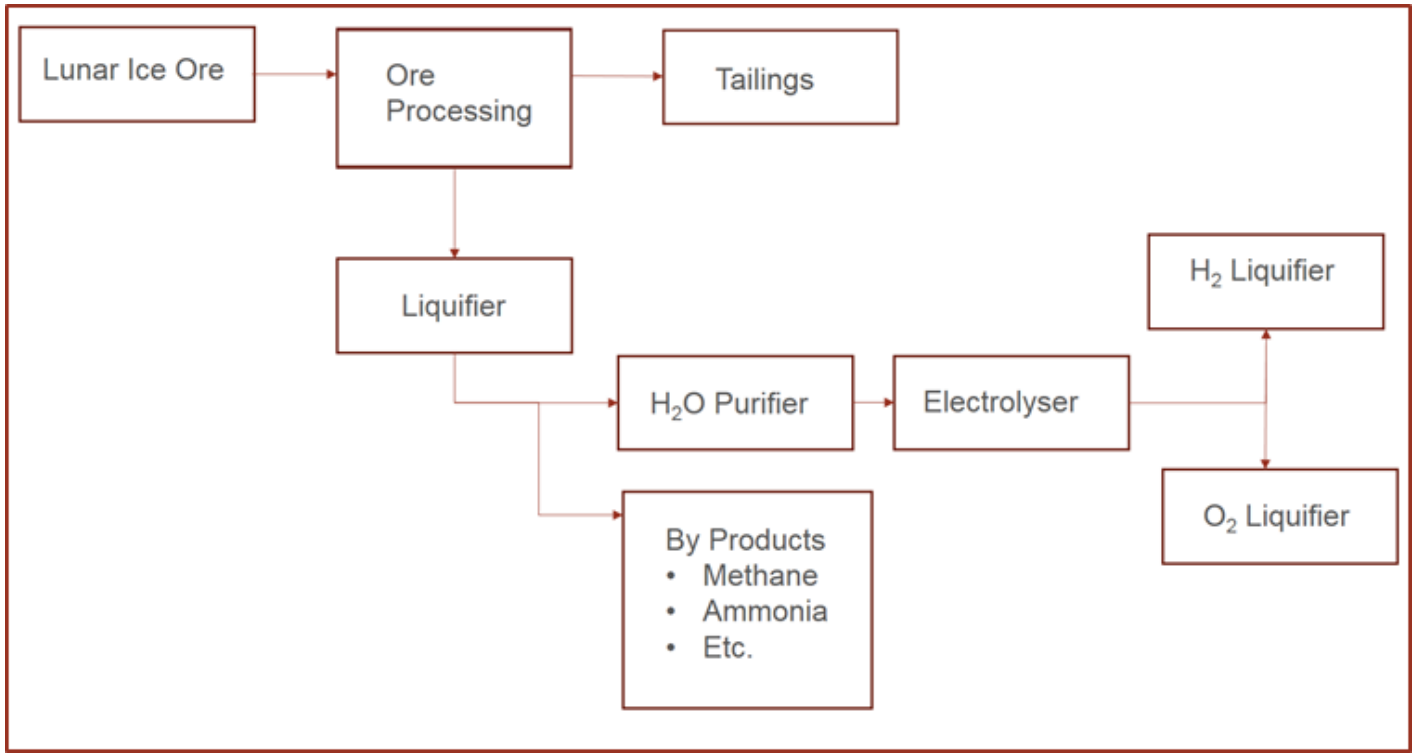
https://www.nasa.gov/sites/default/files/thumbnails/image/niac_2019_sowers.png



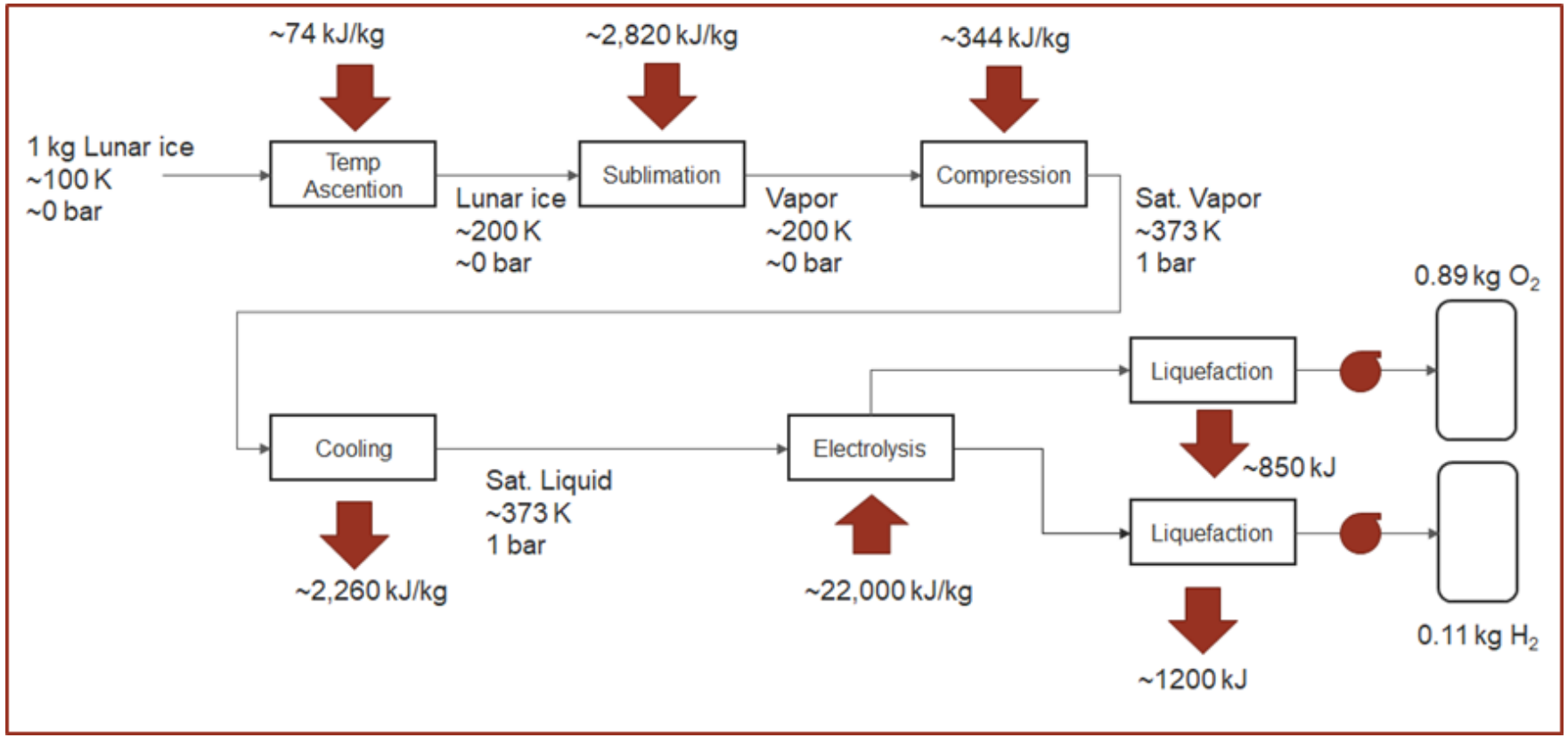
Mobile Slusher

NASA SP509

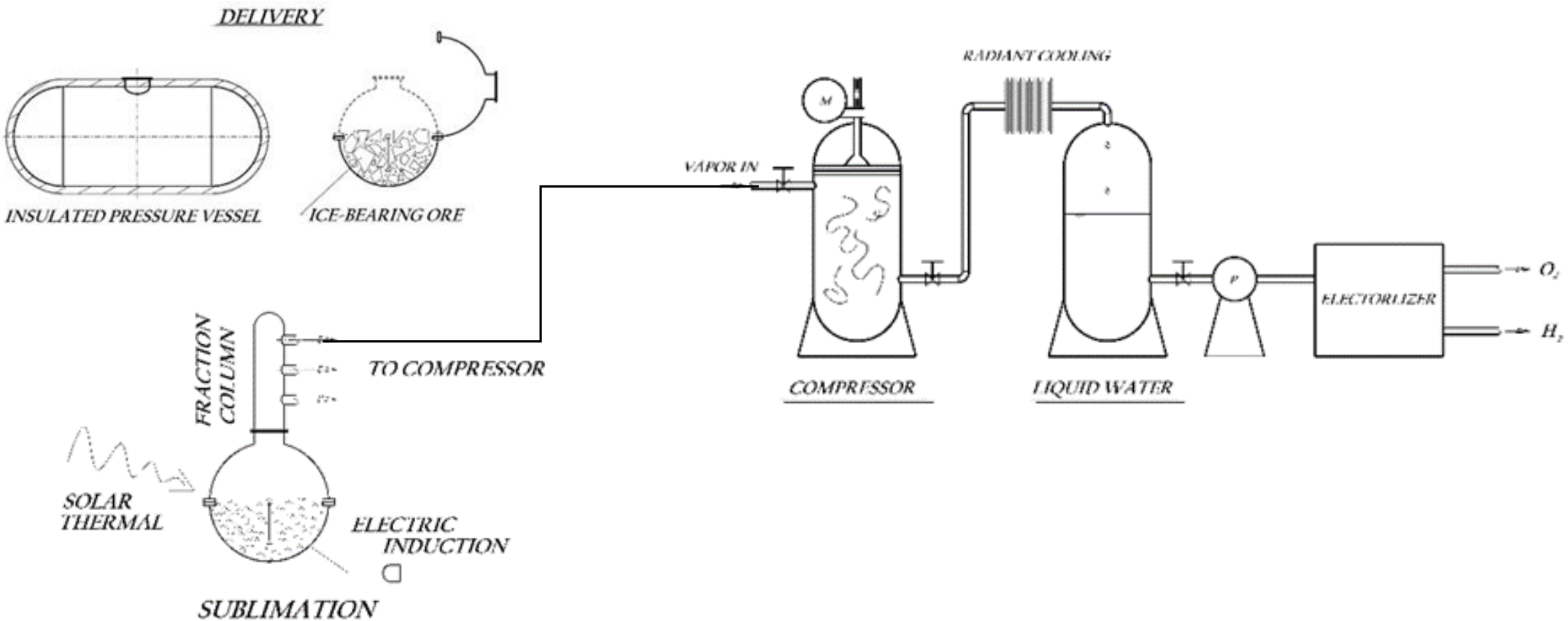
Block diagram



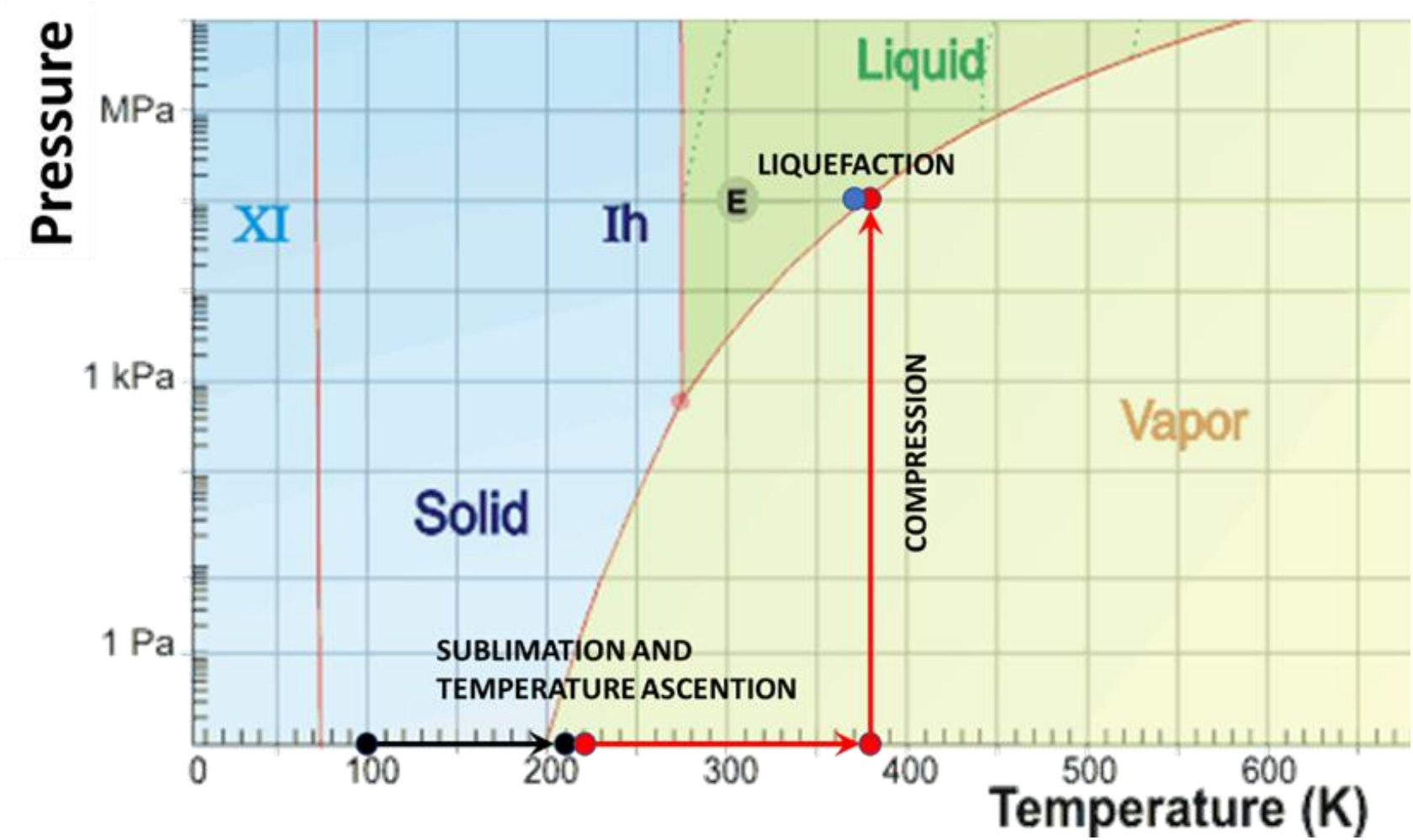
Process flow



Unit operations



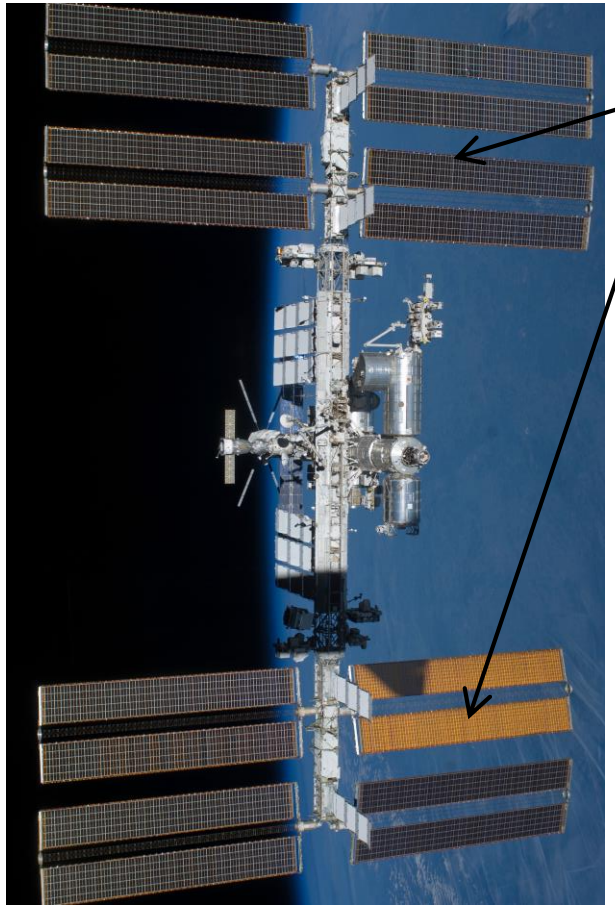
Phase diagram



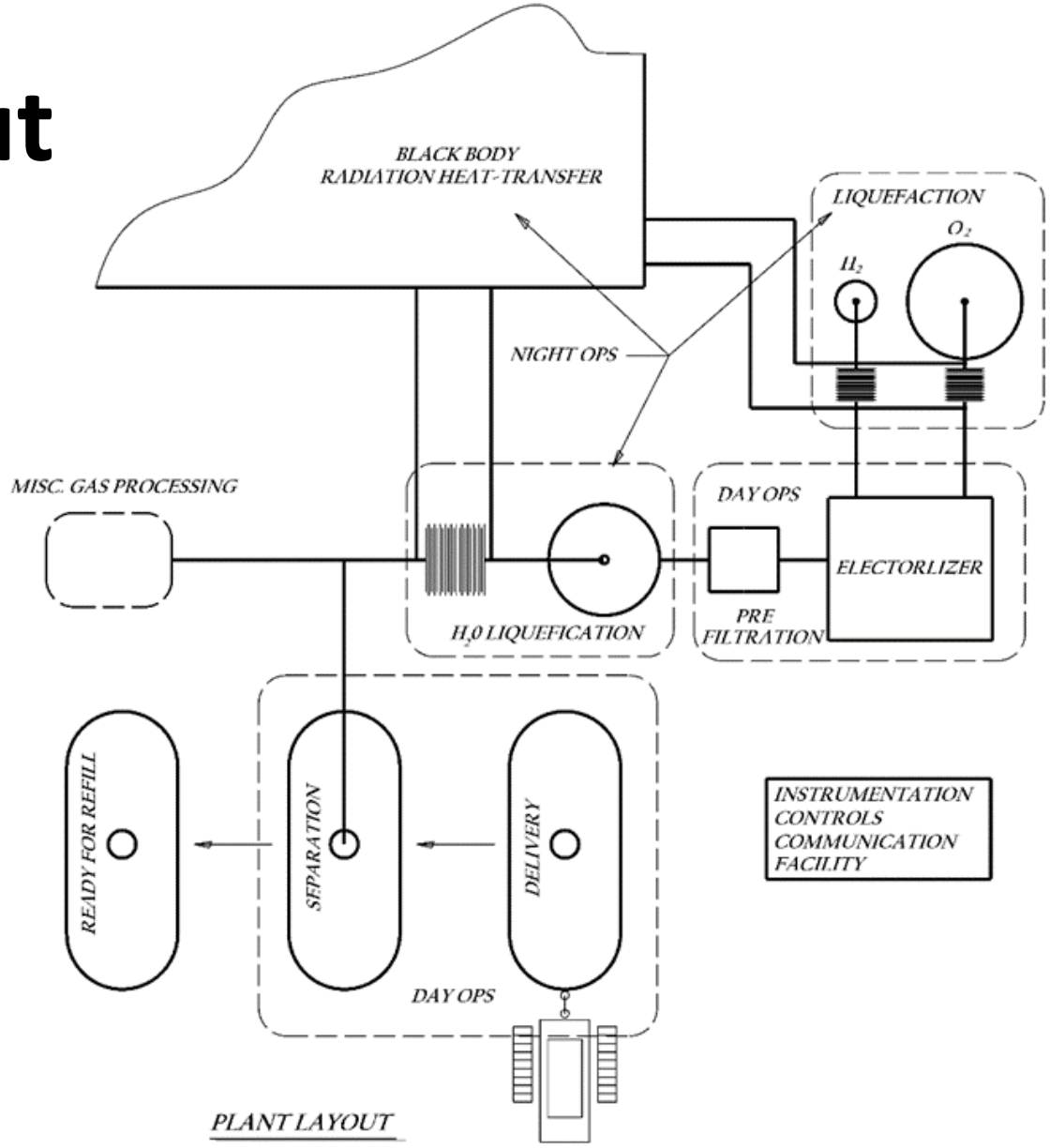
Plant design considerations

- Service life
- Production capacity
- Supplemental electric power supply
- Radiation exposure
- Ambient temperature range
- Remote operation protocol
- Remote maintenance requirements
- Minimum need for onsite human interaction
- Modular construction and transportability
- Reliability of system components
- Maintainability – Ease of changing out major components

Plant layout



Radiators



Challenges

- Logistics
- Temperature and pressure management
- H2 liquefaction
- Heat rejection without convection
- Commercial considerations

Conclusion

- *Space* is not a niche market. It is rapidly becoming mainstream commercial engineering.
- There will be a need for industrial scale surface based facilities on the Moon.
- Large multi-national energy companies can make money producing rocket fuel on the Moon.

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Thank you! Questions?

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