Electrochemistry's Role in Current and Future Environmental Control and Life Support Systems

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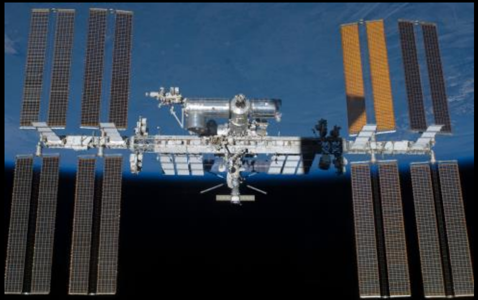
What is ECLSS?



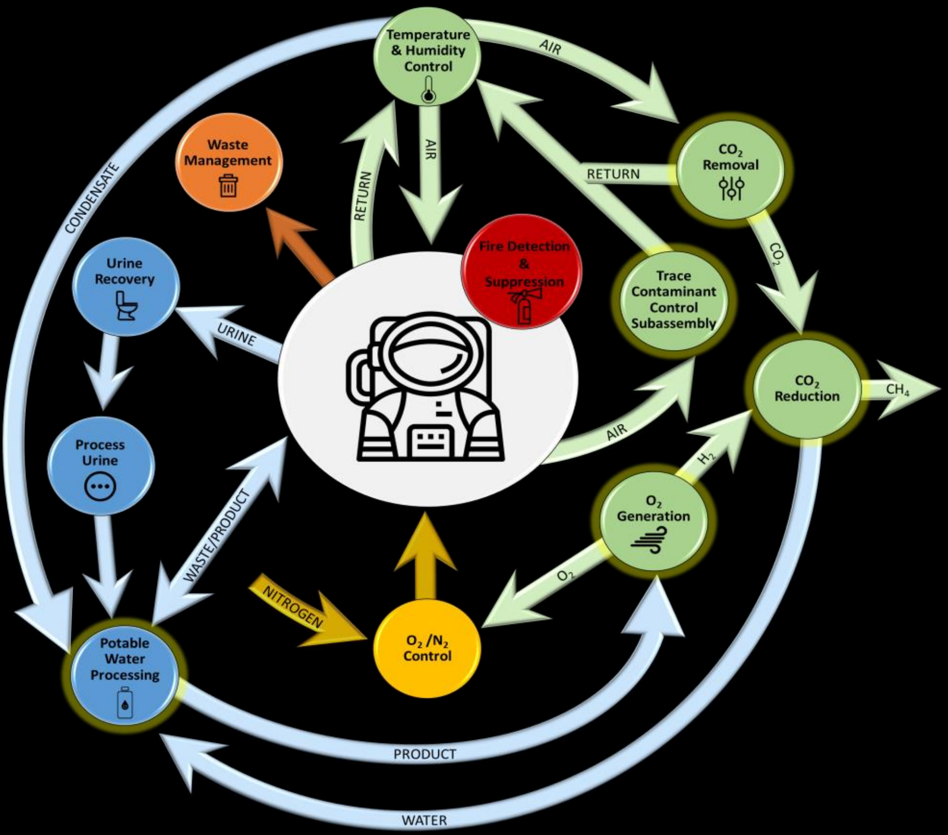
Current Electrolytic ECLSS Applications

&

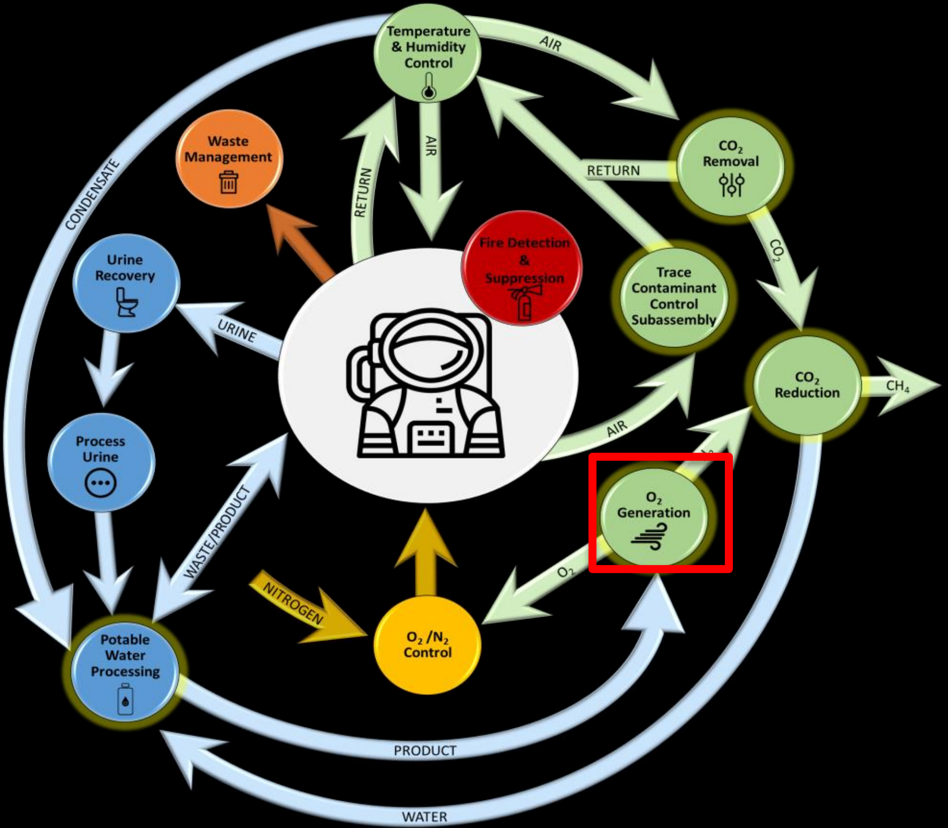
Future Electrolytic ECLSS Applications

Environmental Control and Life Support Systems (ECLSS) keep astronauts alive and happy in space.

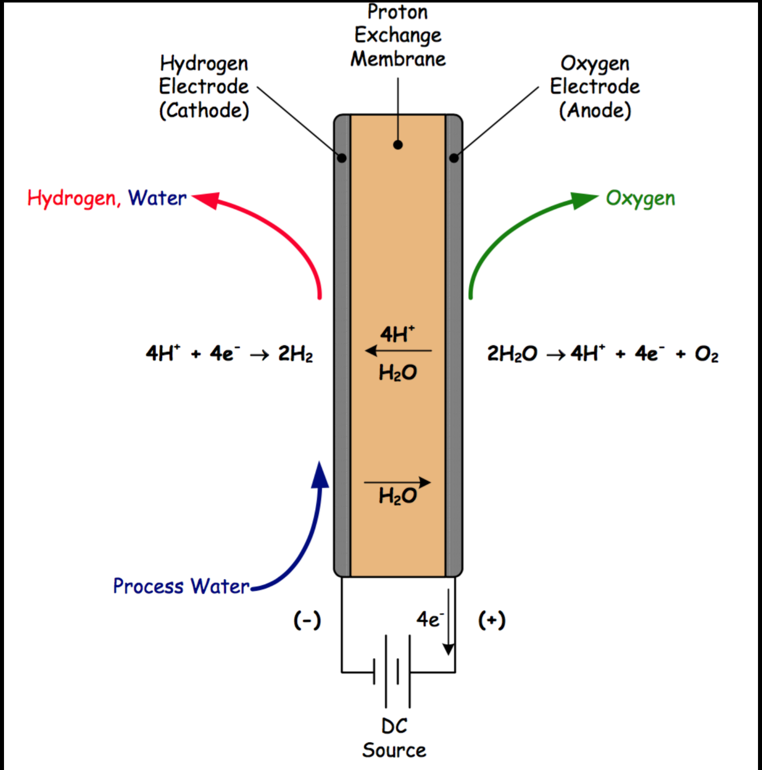
ECLSS is vital to current/future exploration missions by lowering Earth reliance by utilizing byproducts.



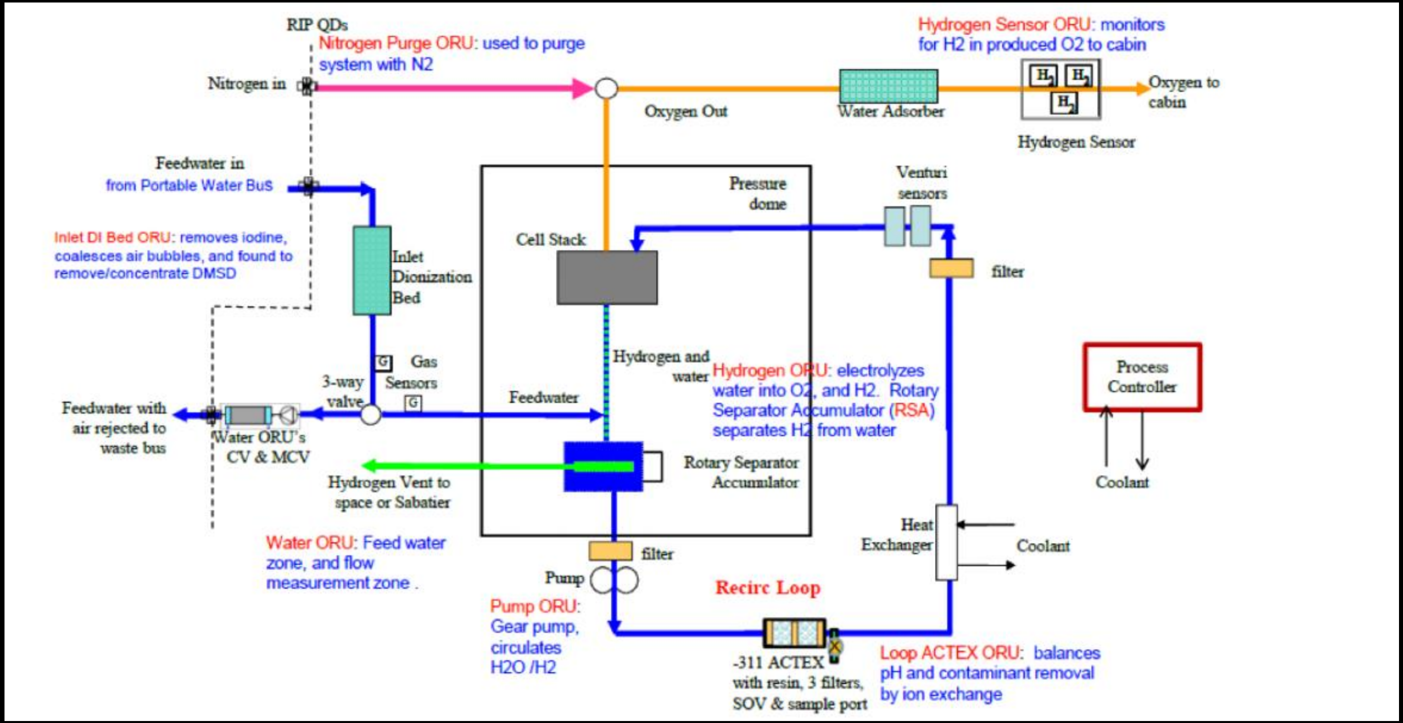
Electrochemistry is currently implemented onboard the ISS in the O_2 Generation Assembly (OGA).



The OGA electrolyzes water to produce oxygen required for crew.



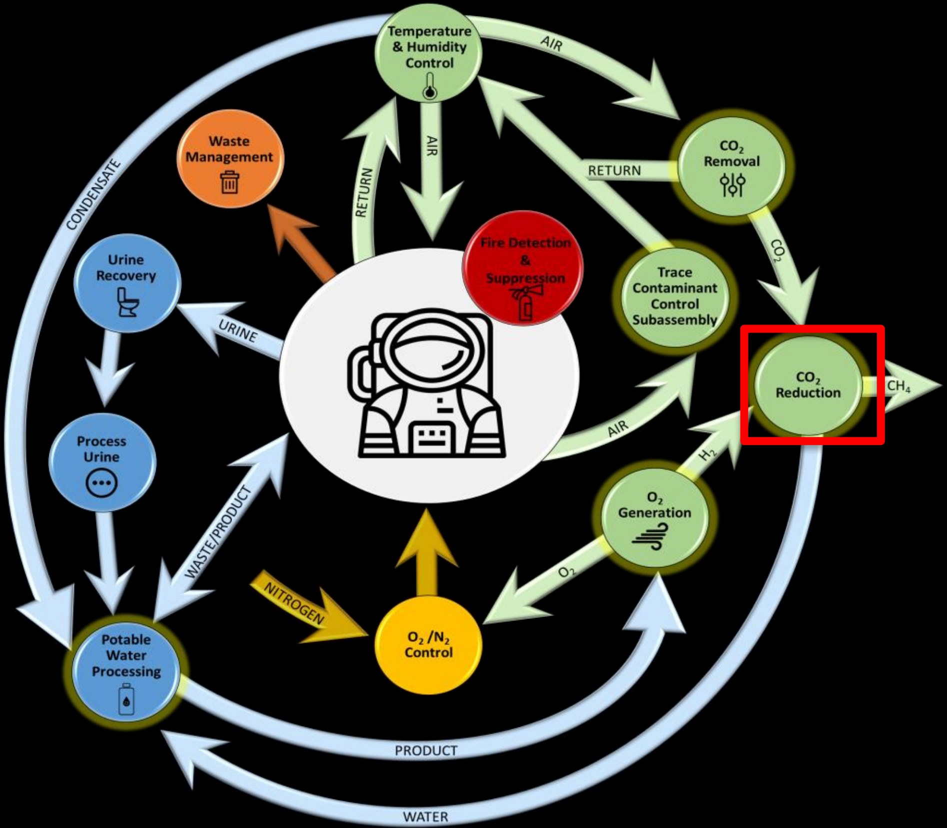
OGA consist of nine Orbital Replacement Units (ORUs).



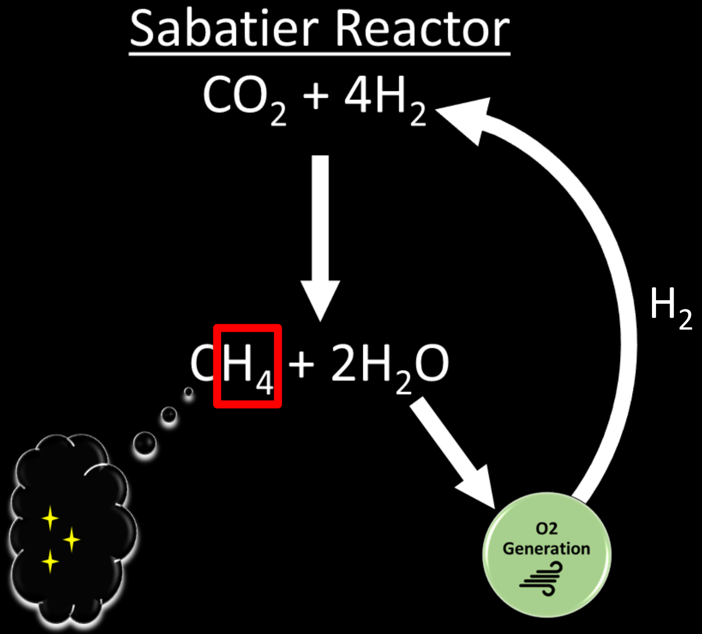
ORU	
1	Water
2	Inlet Deionizing Bed
3	Hydrogen
4	Recirculation Pump
5	Nitrogen Purge
6	Oxygen Outlet
7	Hydrogen Sensor
8	Power Supply Module
9	Process Controller

Over 16,184 lbm of O_2 and 2,023 lbm of H_2 has been produced by OGA as of April 21, 2019.[1]

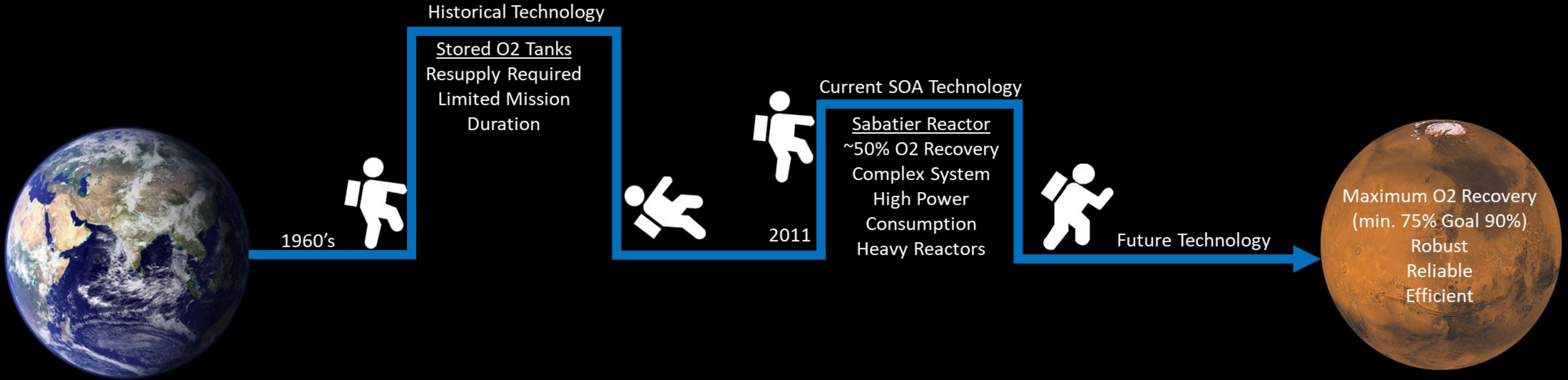
Applications of electrochemistry are currently under investigation for future CO_2 Reduction systems.



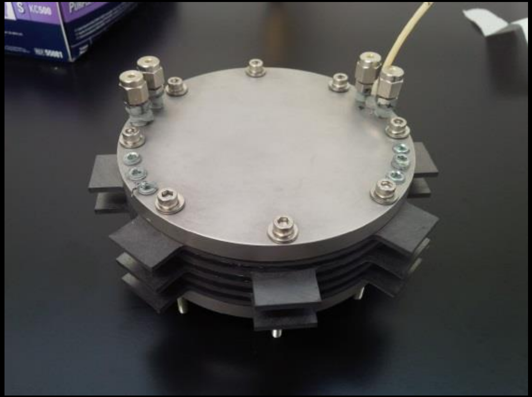
The current SOA CO_2 Reduction Assembly (CRA) only recovers 50% O_2 due to CH_4 vented overboard.



For future long duration missions, O_2 recovery rate must be a minimum of 75% with target goal of 90%.

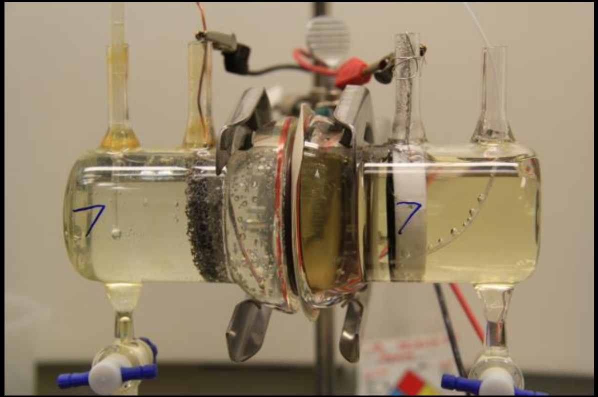


Electrolytic technologies are being investigated to increase the recovery rate for long duration missions.



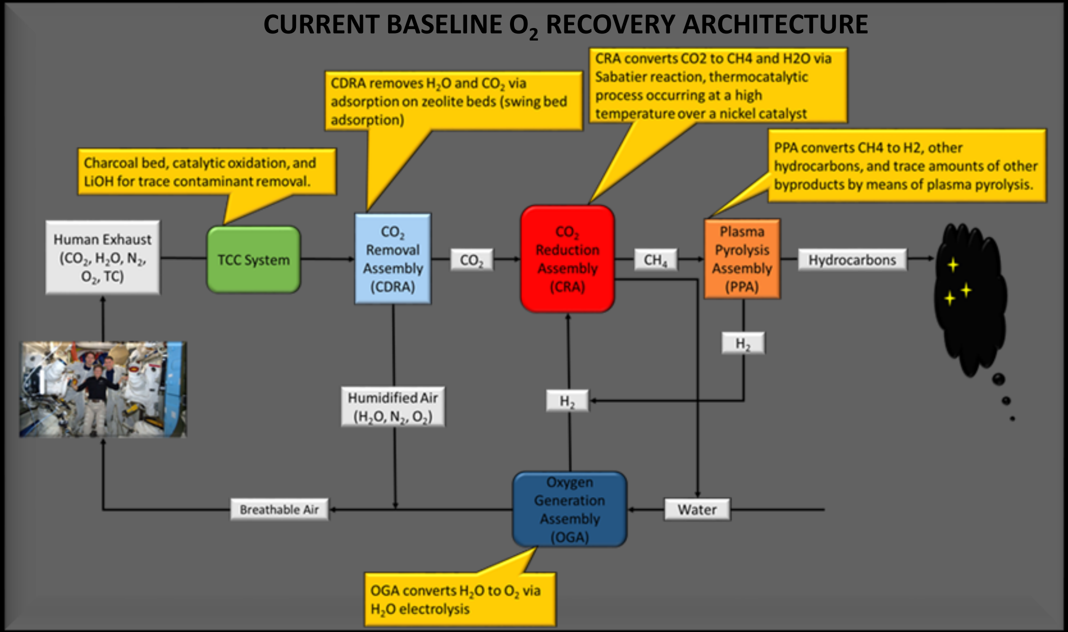
MICROFLUIDIC ELECTROCHEMICAL REACTOR:
CO_2 to O_2 + ETHYLENE

ELECTROCHEMICAL SEPARATION/PURIFICATION OF H_2

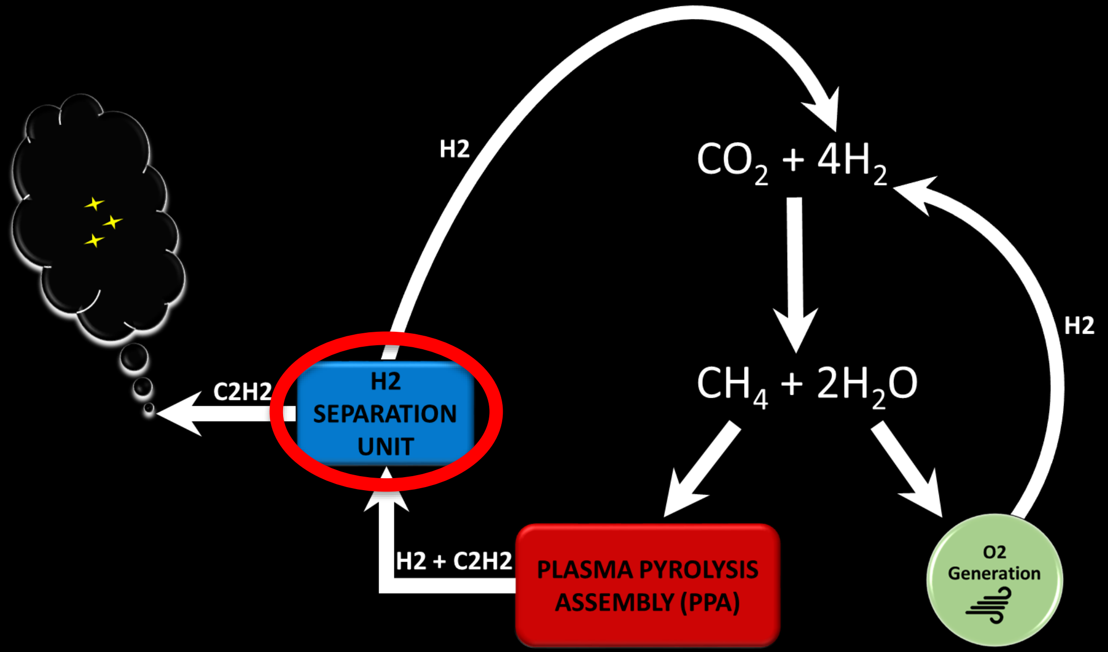


ELECTRODEPOSITION OF CATALYSTS

The current exploration baseline O_2 recovery architecture includes SOA CRA with the addition of PPA.

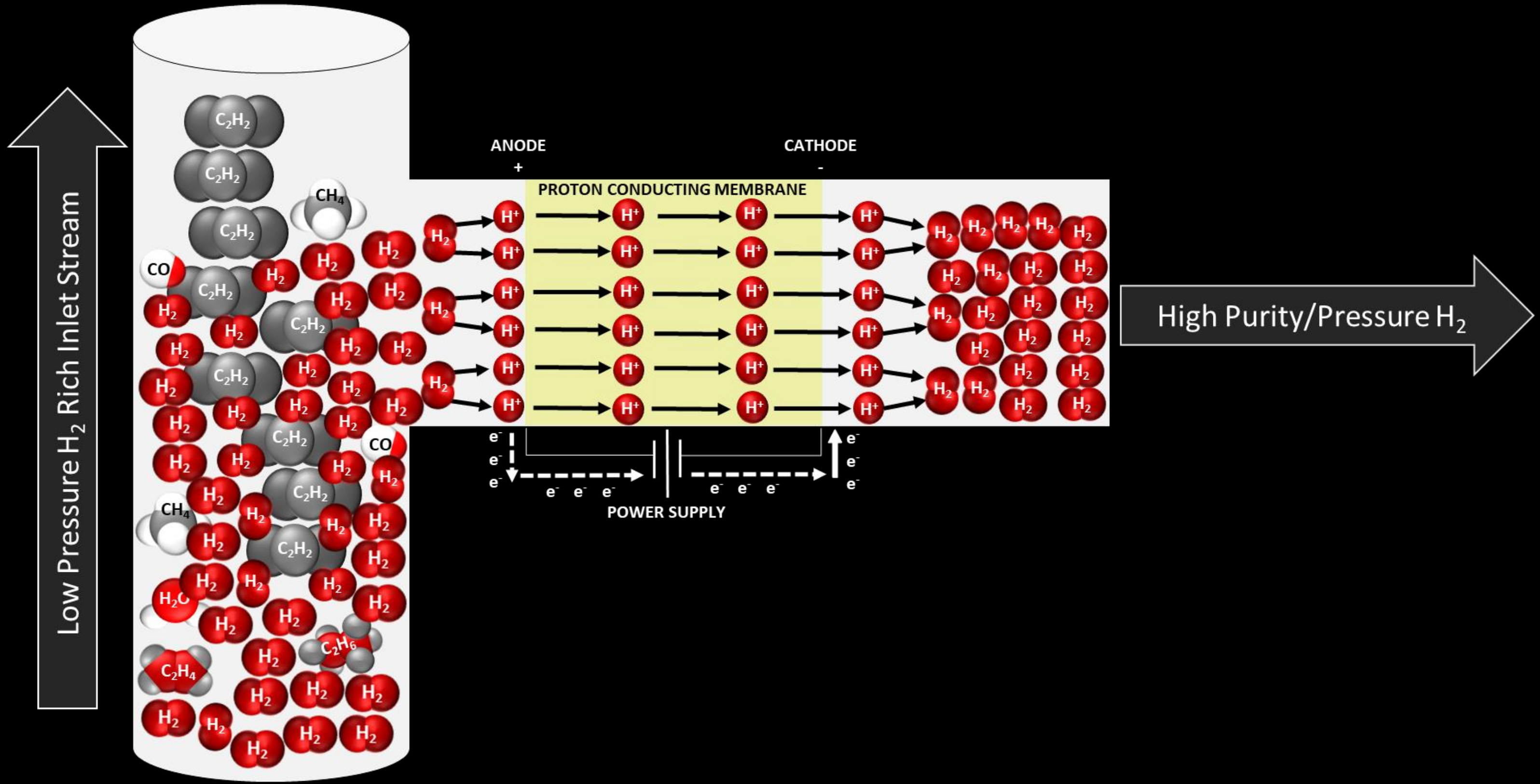


PPA generates a H_2/CH_4 plasma to convert CH_4 to H_2 and C_2H_2, ultimately requiring a H_2 separator for success.



An electrochemical H_2 separator, that separates H_2 and C_2H_2 from the PPA outlet stream, is under investigation.

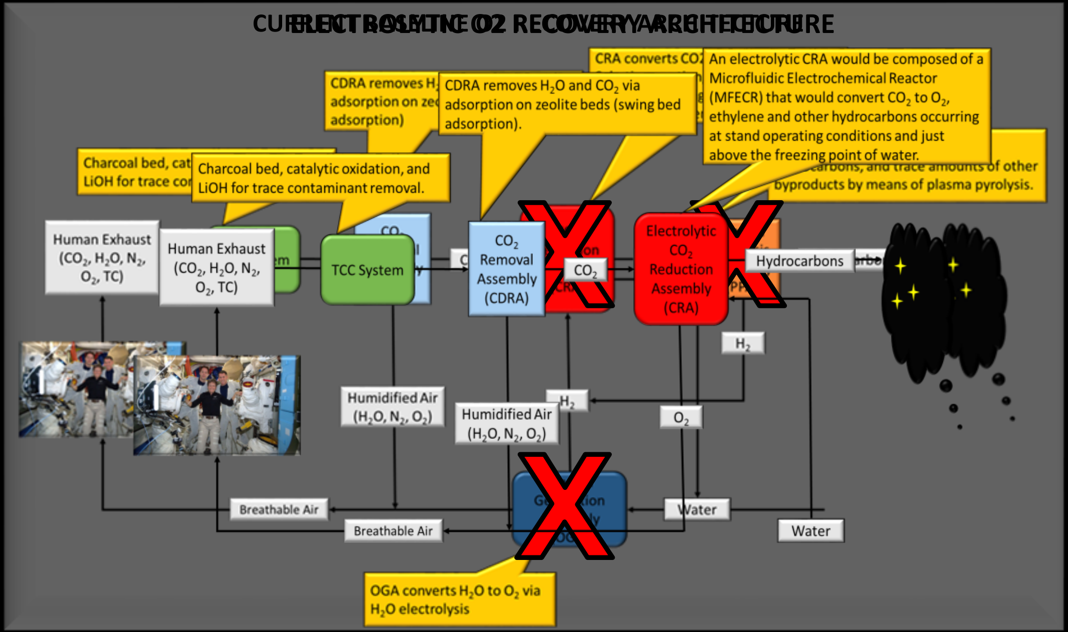
H_2 is electro-oxidized to protons and electrons and the protons are electro-reduced in another chamber.



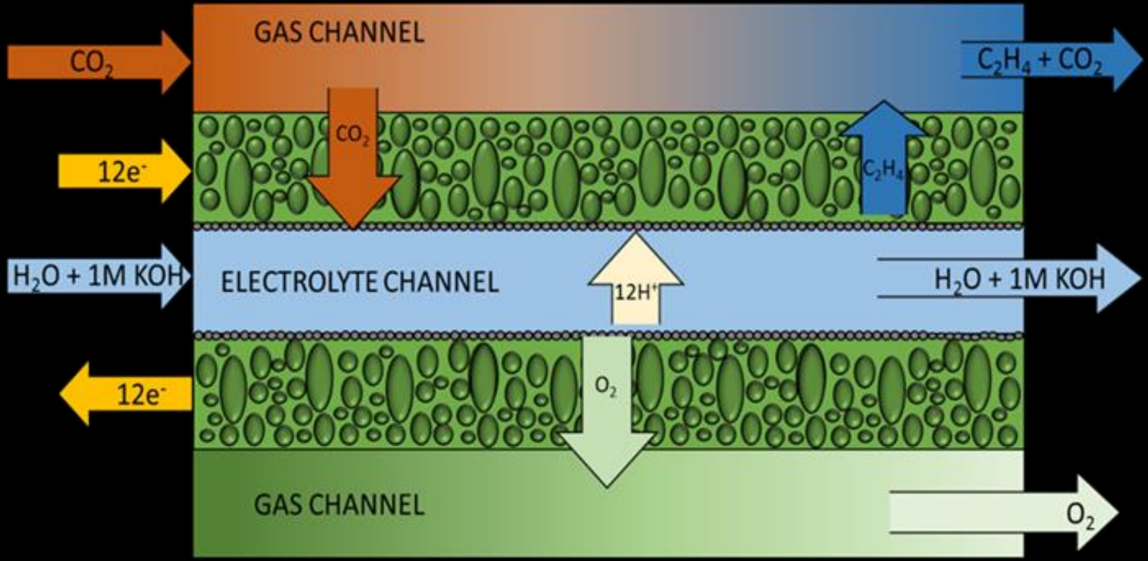
Alternative technologies, other than PPA, are being investigated to increase the recovery rate to >50%.

ELECTROCHEMICAL REACTORS: >70%

An alternative electrolytic CRA, would eliminate 3 pieces of baseline O_2 Recovery Architecture hardware.



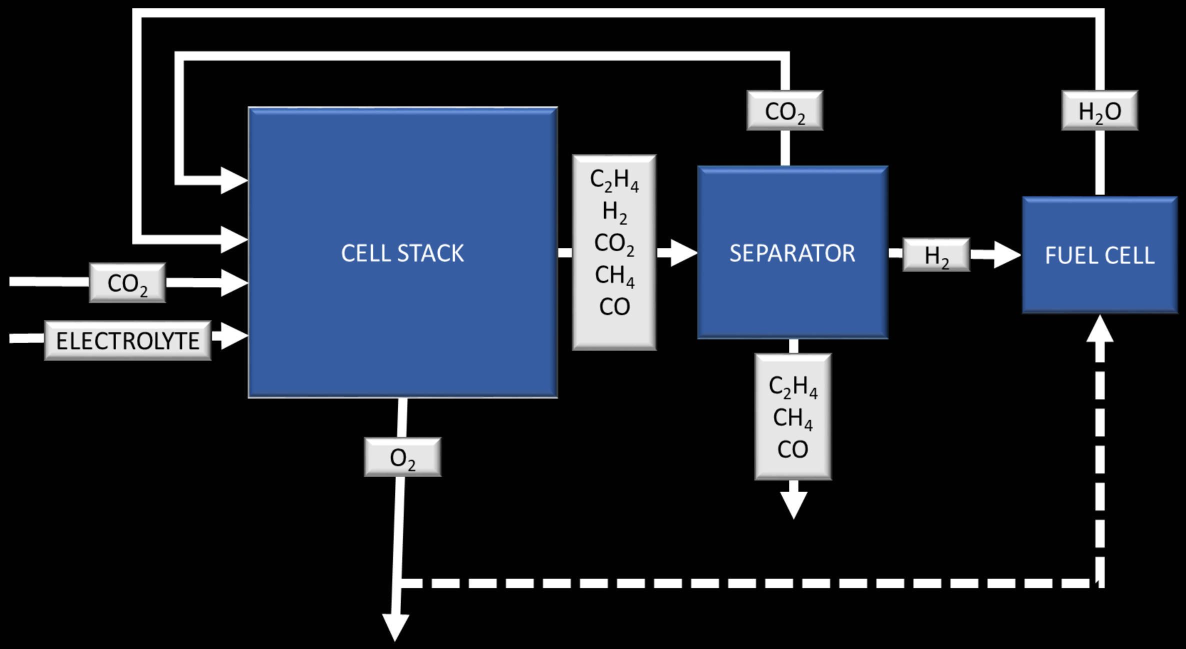
Electrochemical reduction of CO_2 to ethylene (C_2H_4) using water as a proton source.



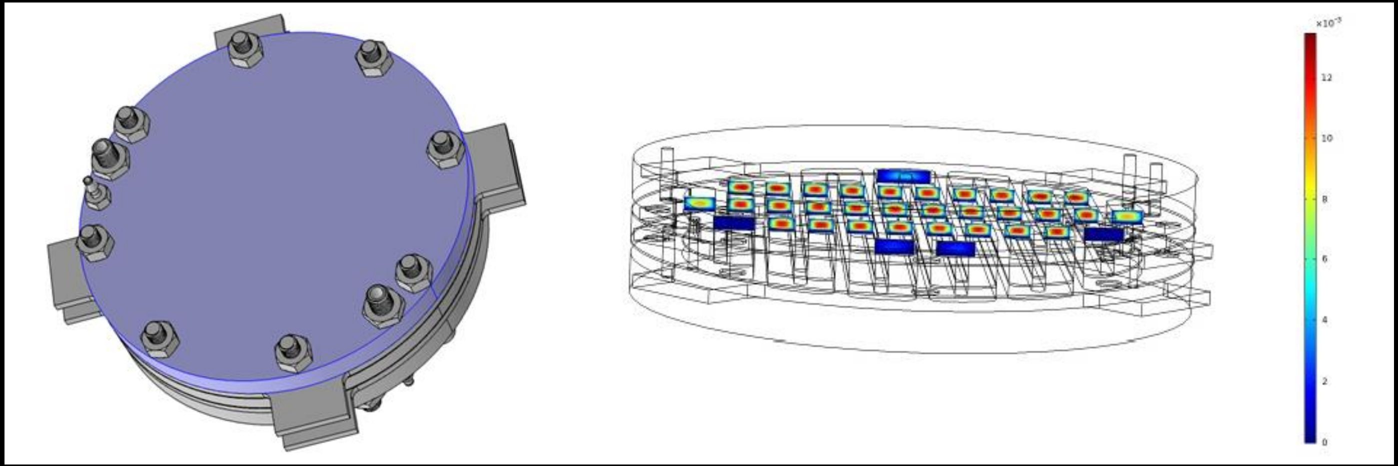
$$CO_2 + H_2O \rightarrow 0.5C_2H_4 + 1.5O_2$$

Theoretical O_2 Recovery Rate: 73%

Currently partnering with UT Arlington to further develop the technology to maximize CO_2 recovery rate.



3D Multi-physics model developed to optimize the EDU design and operation.



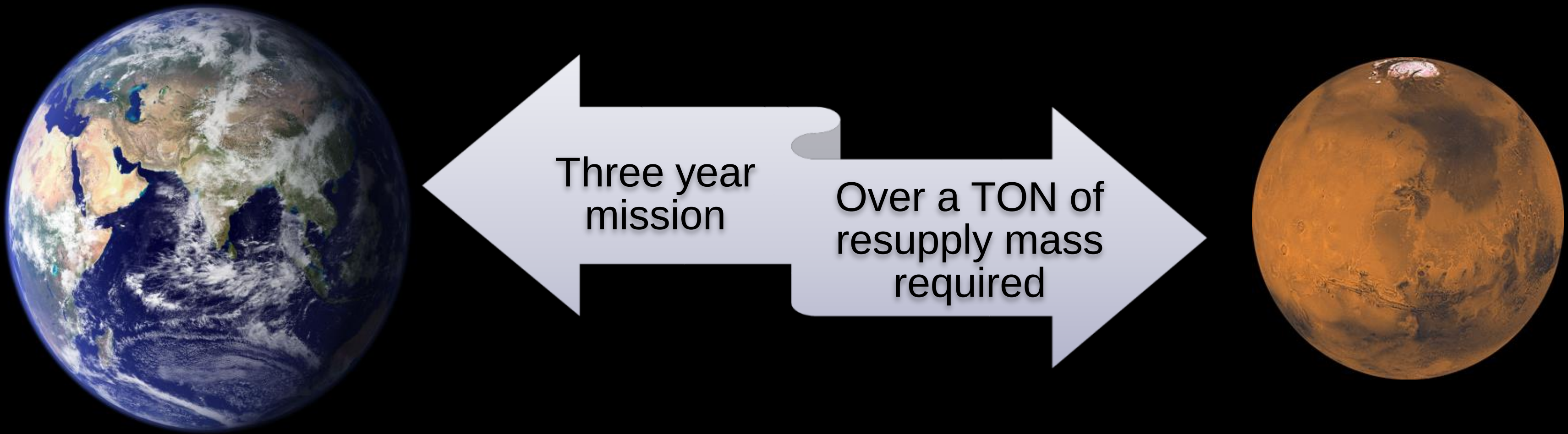
Sabatier/PPA results in ~85% O_2 recovery and a MFECR results in 73%, but 100% recovery may be possible.

BOSCH TECHNOLOGY: 100%

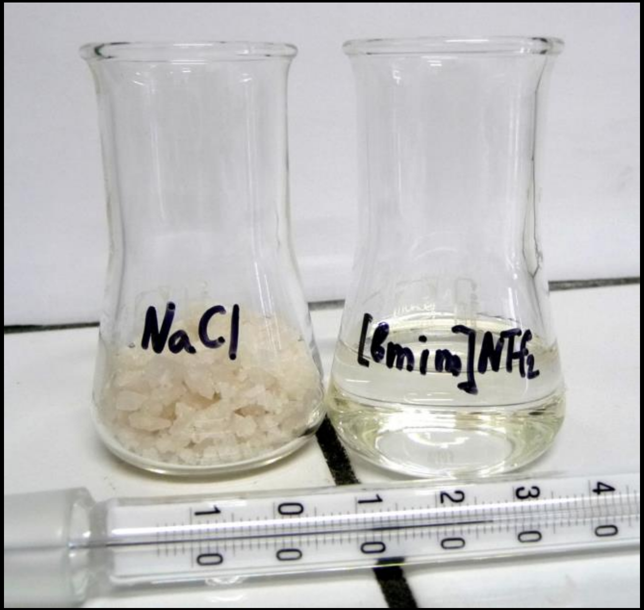
100% O_2 recovery is possible with Bosch technology, but carbon fouling of catalysts is a major disadvantage.

$CO_2 + H_2 \leftrightarrow H_2O + CO$		RWGS
$CO + H_2 \leftrightarrow H_2O + C(s)$		CO Hydrogenation
$2CO \leftrightarrow CO_2 + C(s)$		Boudouard
$CO_2 + 2H_2 \leftrightarrow 2H_2O + C(s)$		Bosch

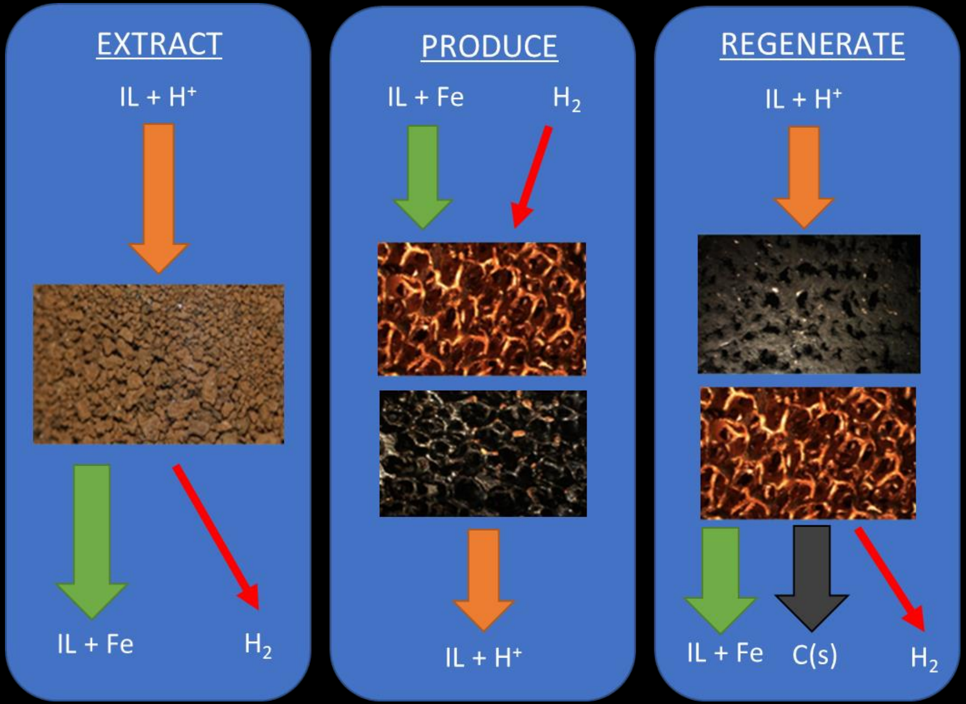
Historical Bosch systems produce 1kg of C(s) per day. C(s) fouling would result in significant catalyst resupply.



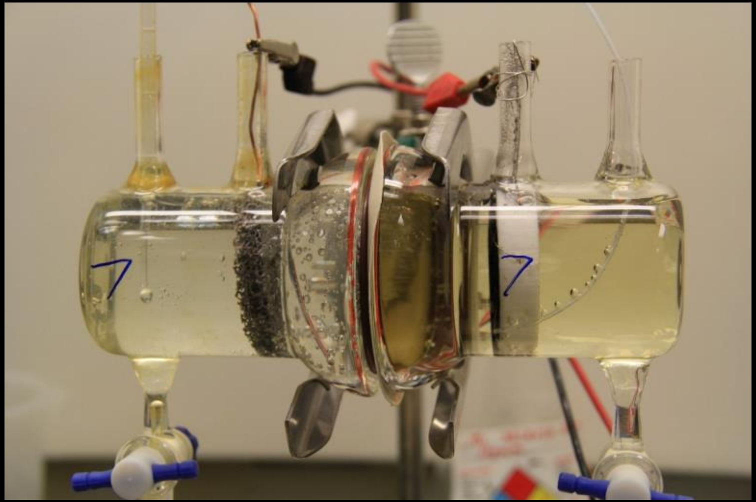
Elimination of catalyst resupply can be achieved by a fully regenerable system that utilizes Ionic Liquids.



Electrodeposition of Fe onto catalyst substrates will eliminate catalyst resupply for Bosch technology.



Feasibility studies prove that catalyst substrates can be generated by electrodeposition utilizing ILs.



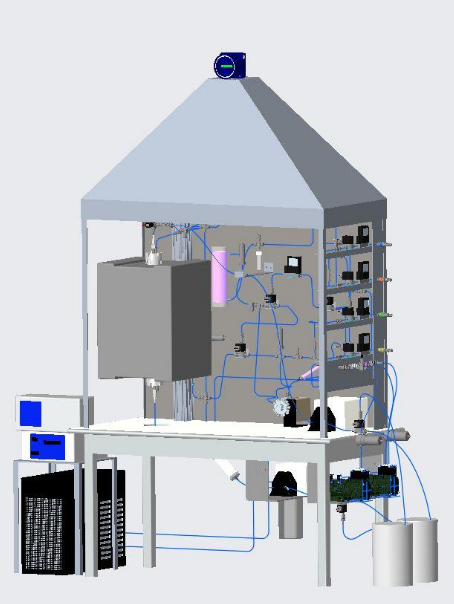
Electroplating Chamber

Substrate Pre-plating

Substrate Post-plating

Feasibility studies prove that IL can be used to extract Fe and regenerate the carbon fouled catalyst.

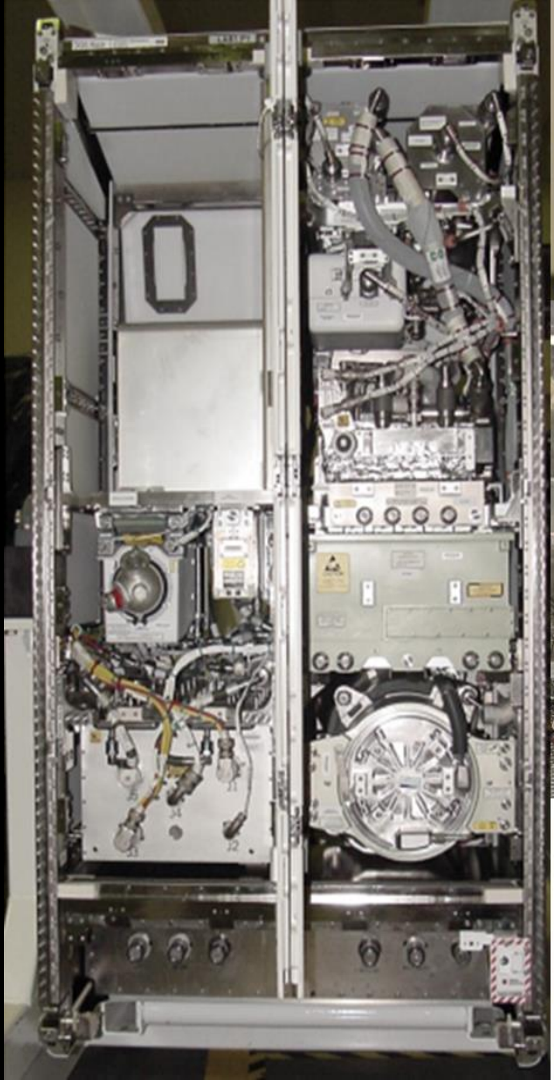
Current efforts are underway to build an IL regenerable carbon formation reactor.

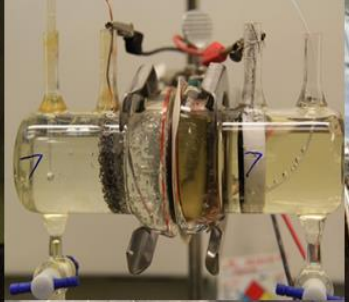


CAD Model of IL Test Stand

Electrochemistry for ECLSS

Paving the way for future human exploration beyond our solar system.





References

[1]Takada, K., Velasquez, L., Keuren, S., Baker, P., McDougle, S., "Advanced Oxygen Generation Assembly for Exploration Missions", ICES-2019-107, *49th International Conference on Environmental Systems*, Boston, Massachusetts, July 2019.

[2]Murdoch, K., Blanchard, R., Mukerjee,S., Stracensky, T., Sharma,M., Pavlicek,R., DeCastro,E., Greenwood,Z., "Closed Loop Hydrogen Recovery Enabled by Electrochemical Hydrogen Separation", ICES-2019-150, *49th International Conference on Environmental Systems*, Boston, Massachusetts, July 2019.

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