FIREHAWK

Firehawk Aerospace, Inc.

www.firehawkaerospace.com

Lunar Transport System

Lunar Resource Demand Forecast

(2027-2036)

Ronald Jones – Chairman & Chief Scientist

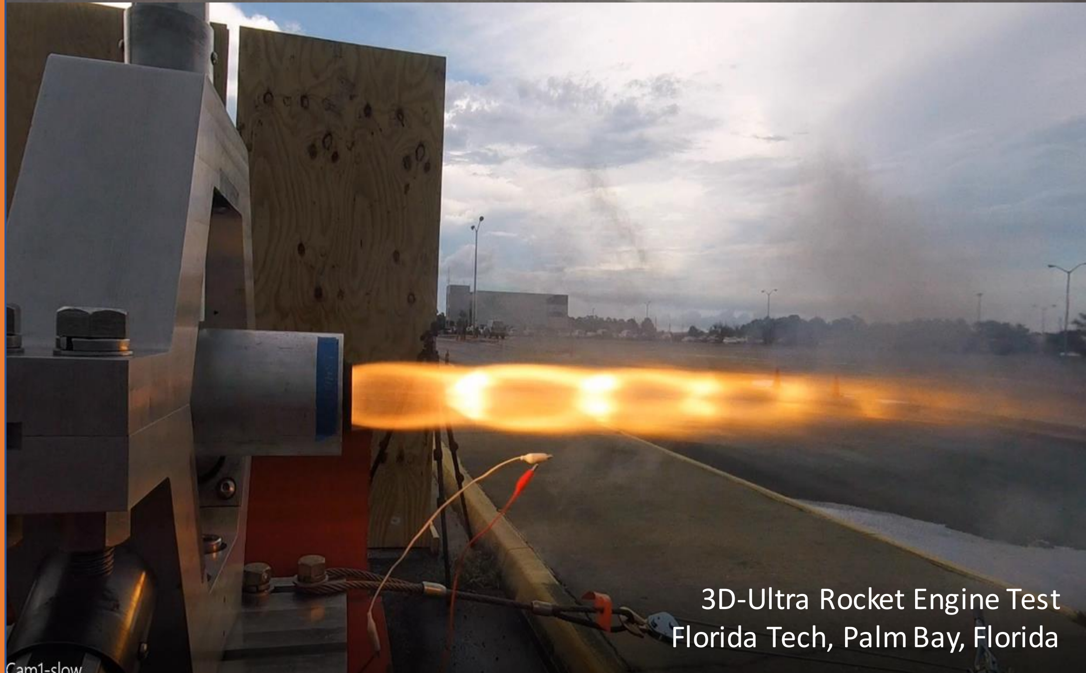
zarha | NEFF | University of CINCINNATI | olis robotics | FLORIDA TECH

www.zarhadesign.com/space | www.ricknefflic.com | www.uc.edu | www.olisrobotics.com | www.fit.edu

Firehawk Aerospace

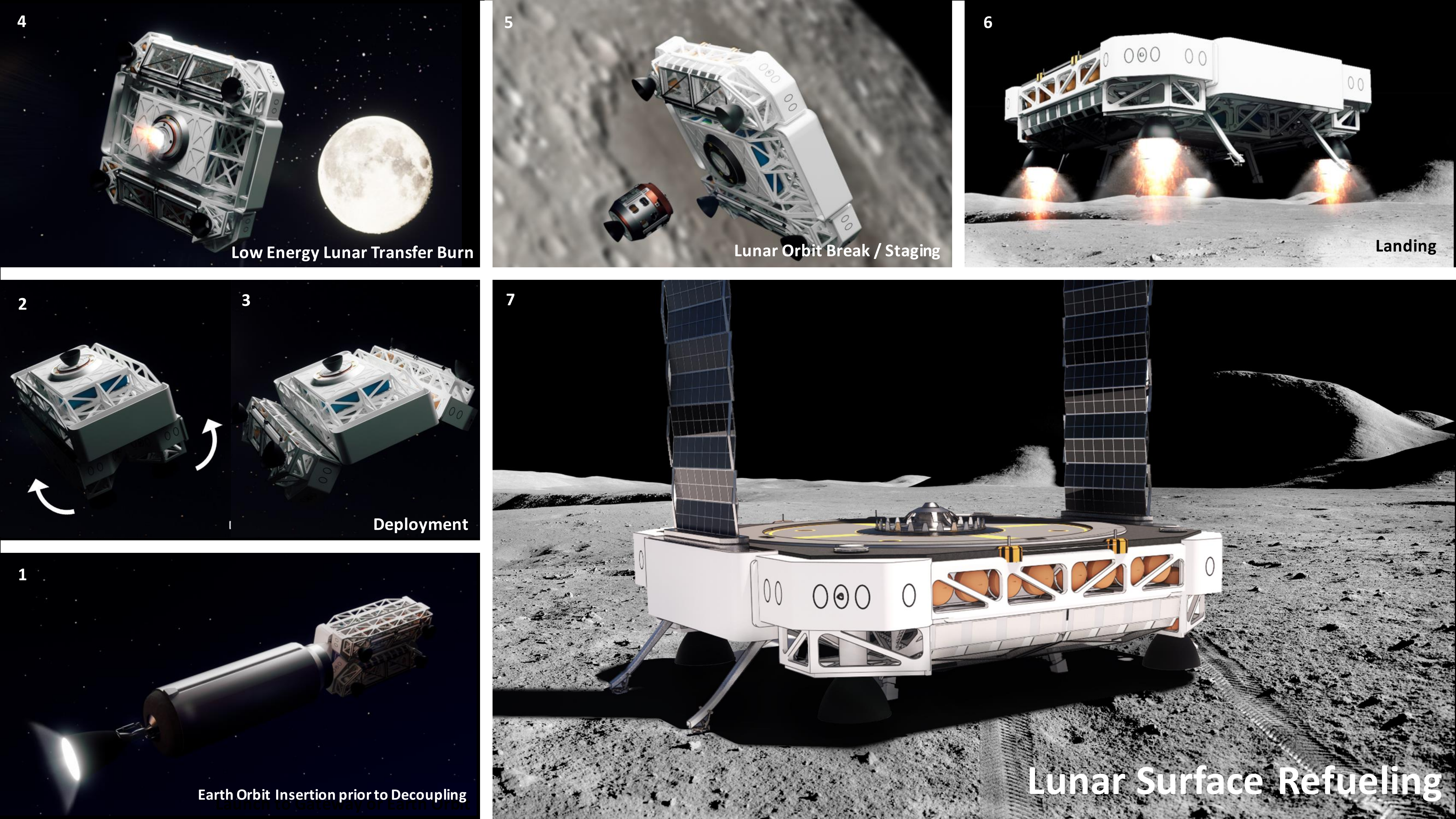
- Firehawk Aerospace, based in Melbourne, FL is a rocket engine design and manufacturing company. Our firm has developed a new advanced hybrid rocket technology called **3D-Ultra™**, a high-performance rocket engine design and production system that can produce rocket engines at only 20% of the cost of comparable liquid bi-propellant rocket engines. 3D-Ultra is backed by five U.S. utility patents.
- We design custom engines for clients in 6 months and complete testing and begin manufacturing in less than a year. Our engines are immune to accidental detonation and are not prone to failure due to their mechanical simplicity. Our propellants are long-term storable on vehicle for immediate use.
- With encouragement from NASA senior leadership, Firehawk Aerospace has been developing a variant of our rocket engine codenamed **ICEALOX** that can make use of **lunar natural resources** for refueling on the lunar surface, in cis-lunar space, or in Earth orbit.
- ICEALOX engine tests are planned to start at the NASA Stennis Space Center during Q1 2021.
- A technology demonstration mission featuring lunar surface refueling is being planned by our firm and our partners for late 2025.
- Lunar produced propellants for customer spacecraft refueling is expected to ramp up upon successful completion of the demonstration mission.

Firehawk Research & Development Center Melbourne, Florida



3D-Ultra Rocket Engine Test Florida Tech, Palm Bay, Florida

ICEALOX Refueling Demonstration


1
Earth Orbit Insertion prior to Decoupling
2
3
Deployment
4
Low Energy Lunar Transfer Burn
5
Lunar Orbit Break / Staging
6
Landing
7
Lunar Surface Refueling

10-Year Refueling Forecast by Type of Spacecraft

Powered by Firehawk Propulsion Systems

10-year mission forecast (not shown)

- **Small Lunar Landers (~20,000 lbf thrust) – Autonomous**
  - Capability: Earth orbit to Moon, Moon to L1, L2, Gateway, Earth GEO Orbit
- **Cislunar Transport Vehicles (~40,000 lbf thrust) – Autonomous**
  - Capability: Moon to Earth GEO Orbit, Moon to Gateway/L1/L2, Gateway/L1/L2 to Moon
- **Cislunar Transport Vehicles (~120,000 lbf thrust) - Manned**
  - Capability: Earth orbit to Gateway, Gateway to L1/L2, Gateway to Moon, L1/L2 to Gateway, Gateway to Earth Geo Orbit, Earth GEO Orbit to Gateway
- **Space Exploration Vehicles (~250,000 lbf thrust) – Manned or Unmanned**
  - Capability: Refueled at Gateway Station after arriving from Earth orbit - Gateway to Mars, Asteroid Belt, Mars/Asteroid Belt to Gateway Station
- **Lunar Colonization Vehicles (250,000 lbf thrust) – Autonomous**
  - Capability: Earth orbit to Moon, Moon to Earth GEO Orbit
- **Lunar Hoppers (40,000 lbf thrust) – Autonomous**
  - Capability: Moon Refueling Station (S. Pole) to Moon locations and Moon locations to Moon Refueling Station
- **Lunar Hoppers (80,000 lbf thrust) – Manned**
  - Capability: Moon Refueling Station (S. Pole to Moon locations and Moon locations to Moon Refueling Station)

Required Resource Acquisition

Water

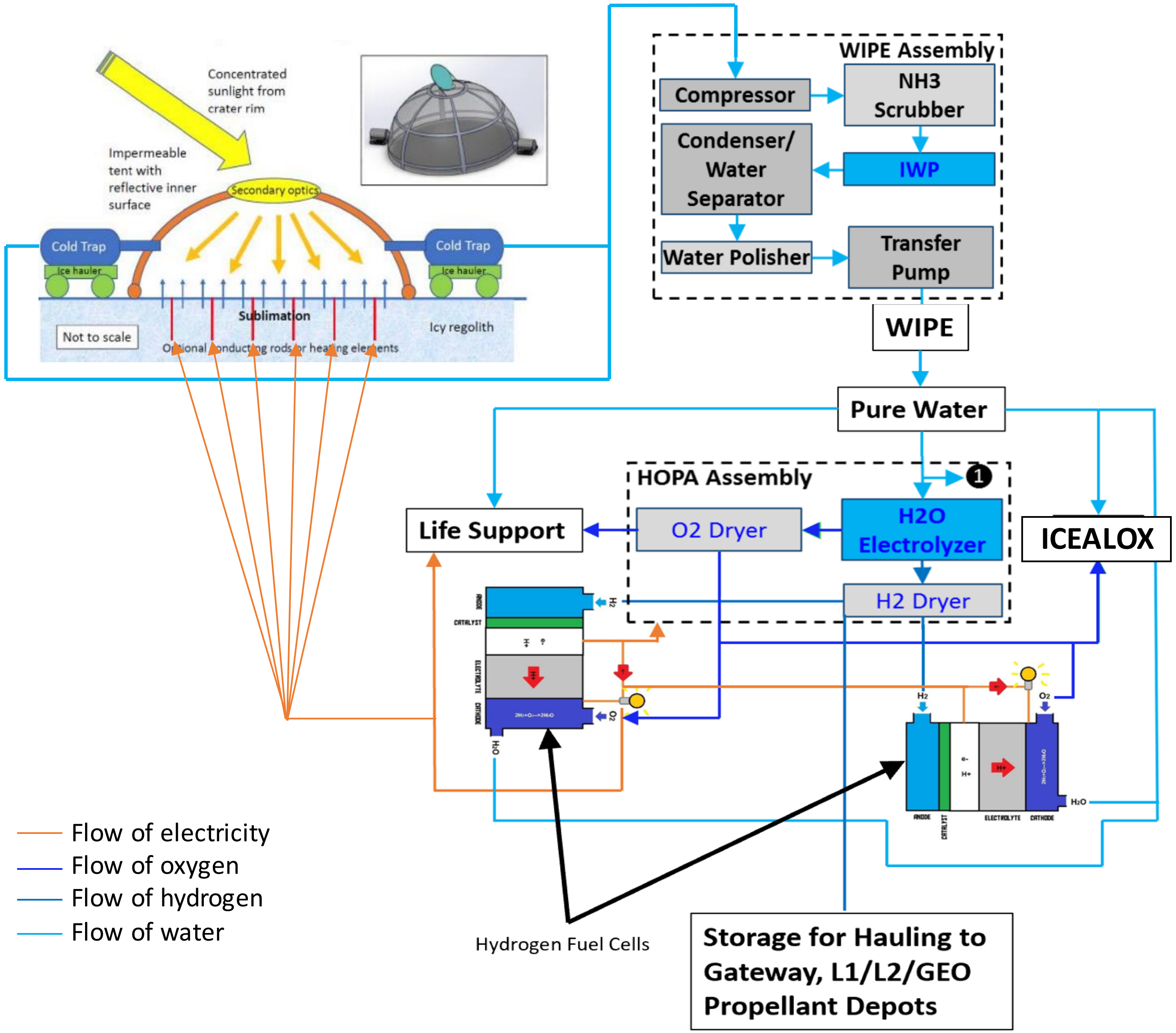
Sublimate icy regolith inside a "tent" via concentrated sunlight that has been directed via heliostats on the crater rim and/or conducting rods inside surfaces. Capture water vapor and other gaseous impurities from regolith into tent and vent into cold traps, where refreezing occurs. Utilize WIPE subassembly to remove excess impurities from water for use as propellant.

Oxygen

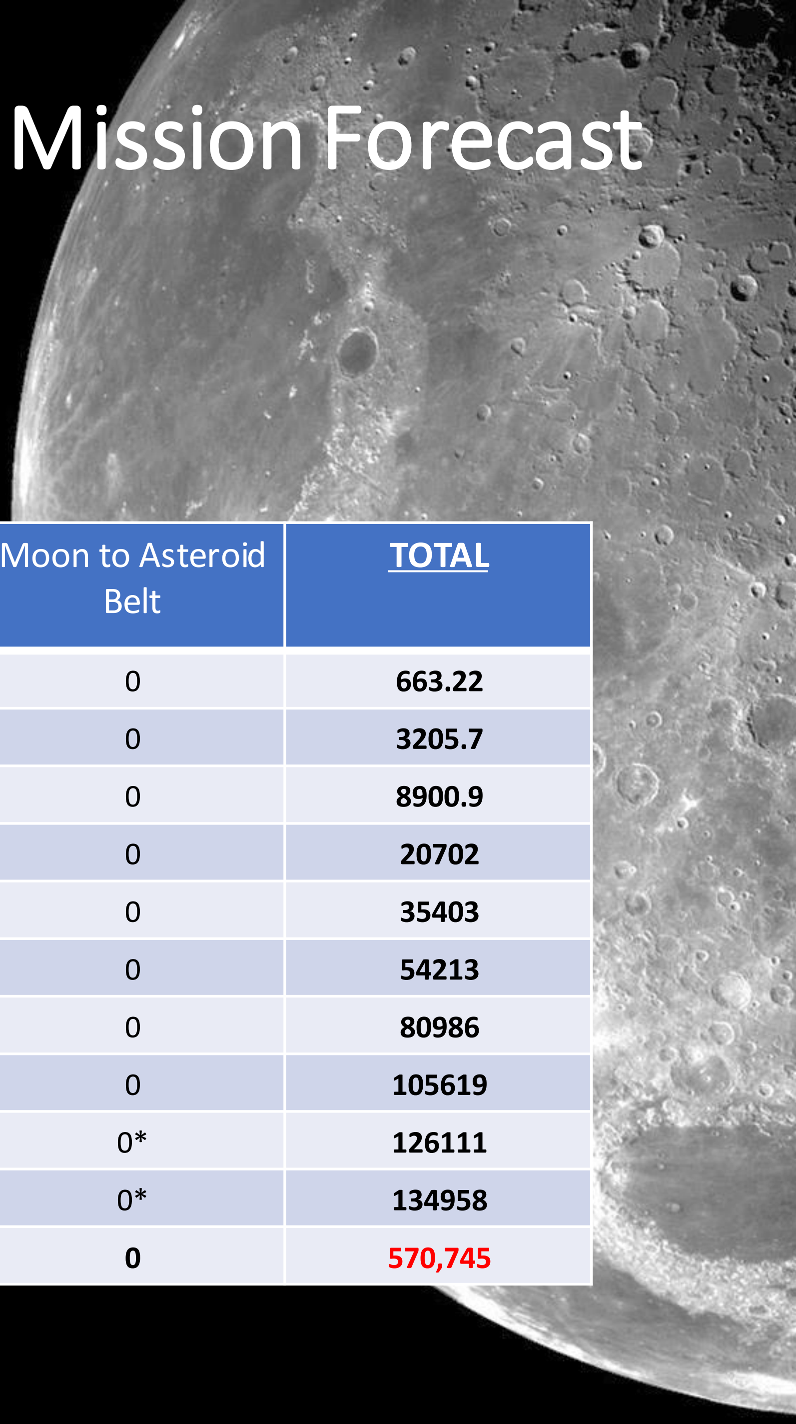
Deliver water to life support systems, LRRE and HOPA. HOPA electrolyzes water to produce hydrogen and oxygen, and then dries it. Additional oxygen can be created as a byproduct of carbochlorination. Oxygen is delivered to life support systems, hydrogen fuel cells, and ICEALOX. Hydrogen is delivered to hydrogen fuel cells.

Aluminum

Separate anorthite from lunar regolith via multi-stage fractional crystallization and distillation as well as a final hydraulic washing (gravity separation) process. Use carbochlorination plant to separate Aluminum from anorthite.



Lunar Resource Demand based on 10-Year Mission Forecast



Water (lbs)

Delivery Year	Moon to Gateway	Moon to EML1/2	Moon to Earth GEO	Moon to Mars Surface	Moon to Asteroid Belt	TOTAL
2027	503.61	70.070	89.536	0	0	**663.22**
2028	2055.90	426.17	723.63	0	0	**3205.7**
2029	4650	1004.0	3246.9	0	0	**8900.9**
2030	10445	2760.4	7496.4	0	0	**20702**
2031	16778	5409.4	13216	0	0	**35403**
2032	26339	8367.3	19507	0	0	**54213**
2033	35901	12812	32273	0*	0	**80986**
2034	45461	14761	45397	0*	0	**105619**
2035	50719	16870	58522	0*	0*	**126111**
2036	53488	18506	62964	0*	0*	**134958**
TOTAL	**246341**	**80967**	**243437**	**0**	**0**	**570,745**

* Spacecraft using propellant sourced from lunar surface that are stored at Gateway

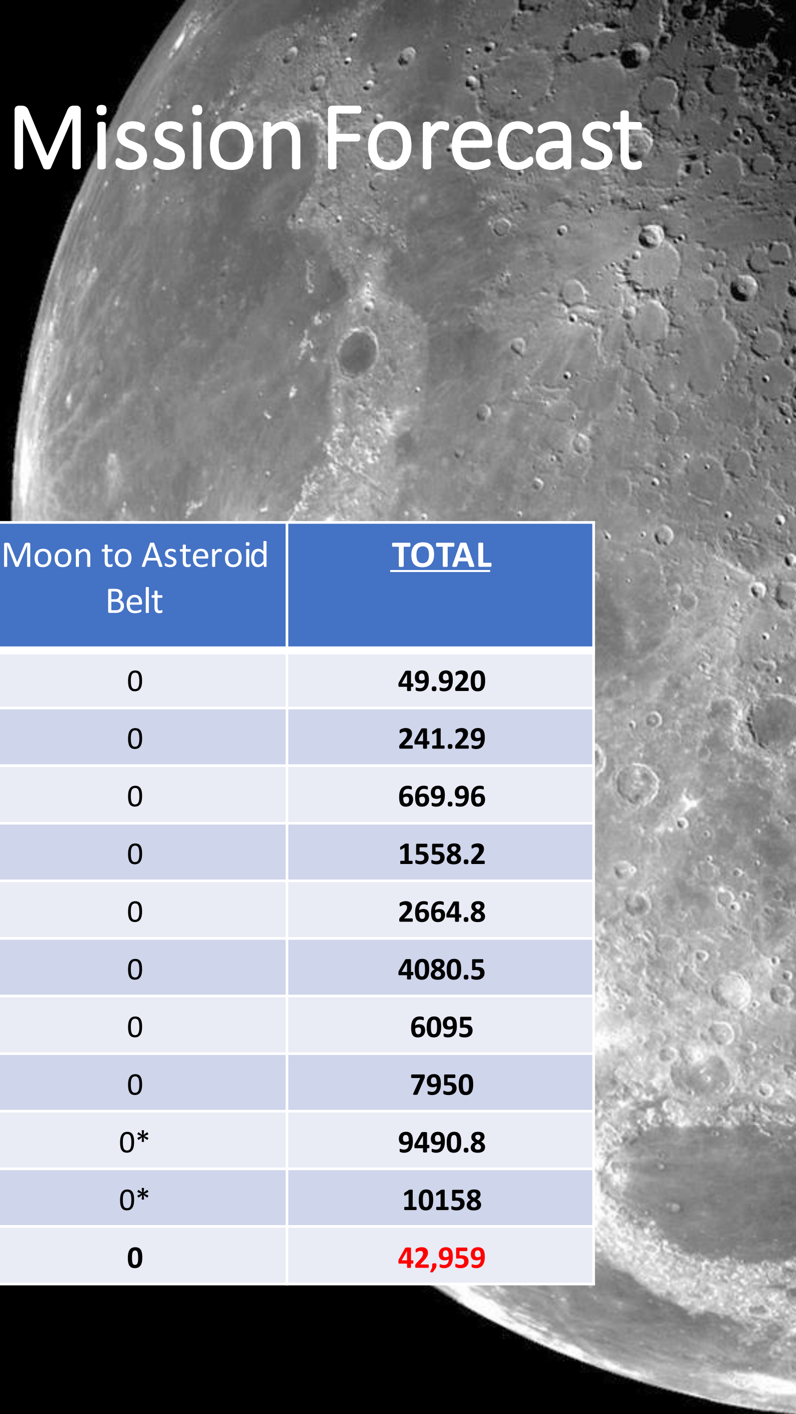
Lunar Resource Demand based on 10-Year Mission Forecast

Oxygen (lbs)

Delivery Year	Moon to Gateway	Moon to EML1/2	Moon to Earth GEO	Moon to Mars Surface	Moon to Asteroid Belt	TOTAL
2027	1353.8	188.36	240.69	0	0	**1782.9**
2028	5526.6	1145.6	1945.2	0	0	**8617.4**
2029	12500	2698.8	8728.3	0	0	**23927**
2030	28077	7420.4	20152	0	0	**55649**
2031	45101	14541	35529	0	0	**95171**
2032	70804	22493	52437	0	0	**145734**
2033	96507	34443	86755	0*	0	**217705**
2034	122210	39681	122040	0*	0	**283931**
2035	136342	45295	157320	0*	0*	**338957**
2036	143785	49748	169260	0*	0*	**362793**
TOTAL	**662207**	**217654**	**653960**	**0**	**0**	**1,533,821**

* Spacecraft using propellant sourced from lunar surface that are stored at Gateway

Lunar Resource Demand based on 10-Year Mission Forecast



Aluminum (lbs)

Delivery / Year	Moon to Gateway	Moon to EML1/2	Moon to Earth GEO	Moon to Mars Surface	Moon to Asteroid Belt	TOTAL
2027	37.907	5.2740	6.7392	0	0	**49.920**
2028	154.75	32.077	54.467	0	0	**241.29**
2029	350.00	75.568	244.39	0	0	**669.96**
2030	786.16	207.77	564.25	0	0	**1558.2**
2031	1262.8	407.15	994.81	0	0	**2664.8**
2032	1982.5	629.80	1468.2	0	0	**4080.5**
2033	2702.2	964.42	2429.2	0*	0	**6095**
2034	3421.9	1111.1	3417.0	0*	0	**7950**
2035	3817.6	1268.3	4404.9	0*	0*	**9490.8**
2036	4026.0	1392.9	4739.2	0*	0*	**10158**
TOTAL	**18542**	**6094.4**	**18323**	**0**	**0**	**42,959**

* Spacecraft using propellant sourced from lunar surface that are stored at Gateway

Mission and Spacecraft Development Challenges

- Lunar Regolith Excavation, Separation and Refinement
- Electric Power Generation
- Temperature Regulation
- Materials Selection – Lunar Temperature Extremes, Vacuum, and Dust Issues
- Orbital Mechanics / Trajectory Simulations
- Spacecraft Robotics – Refueling, Off-Loading / On-Loading, Autonomous and Human-In-The-Loop
- GNC / Hazard Detection – Autonomous Landing / Launch Systems
- Lunar Topography – Exploration and Navigation

We are looking for additional qualified partners and suppliers.
Please contact Ronald Jones, Firehawk Aerospace for more information: ron@firehawkaerospace.com