BLUE ALCHEMIST

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Executive Summary

Market Analysis | Company Analysis | Unpursued Ideas | Options | Final Recommendation

In-Space Resource Utilization Market

$63 billion by 2040

Options

- Subscription Models
- Lunar Rovers
- Refueling Station

In-Space Resource Utilization Market Definition

What is ISRU?

- **Extracting and utilizing resources found or manufactured on other celestial bodies (Moon, Mars, etc) to support space exploration and operations,** including:
  - **Collecting and processing materials** like water ice, metals, and regolith (loose, unconsolidated surface material)
  - Using these resources as a s**ource of fuel, building materials, water, and other necessities** for astronauts and robotic missions
  - **Manufacturing new materials and products** in space

Value Proposition

- **Cost reduction:** ISRU can significantly reduce the cost of space exploration by eliminating or **significantly reducing the need to transport resources** from Earth
- **Mission Sustainability:** ISRU can enable sustainable space exploration by providing a local source of resources
- **Eco-Friendly:** Less flights into space, less rocket fuel used
- **Innovation:** ISRU can drive innovation in space technology by developing new and creative solutions for resource utilization

Industry Success Factors

- **Technology:** Companies will need to develop and demonstrate the ability to extract and process resources in space
- **Partnerships:** Companies will need to partner with other companies, governments, and research institutions to develop ISRU projects
- **Resources:** ISRU is a capital-intensive industry, and companies will need to secure significant funding to develop, deploy, and test their technologies
- **Regulatory approval:** Companies will need to obtain the necessary regulatory approvals to operate in space

ISRU Market Outlook

Technology

- **In-situ resource identification:** This includes technologies for **identifying and assessing the location, quantity, and quality of lunar and Martian resources**
- **Resource extraction and processing:** Extracting and processing resources from **lunar and Martian regolith**, such as water, oxygen, and metals
- **In-situ manufacturing: Manufacturing products from lunar and Martian resources**, such as solar cells, construction materials, and fuel.

Application

- **Space exploration:** Supporting **human and robotic missions to the Moon and Mars**, as well as establishing permanent settlements
- **Space infrastructure development: Constructing and maintaining space infrastructure**, such as power grids, transportation systems, and communications networks
- **Commercial space applications:** Developing **commercial products and services from lunar and Martian resources**, such as mining, manufacturing, and energy production.

Geography

- **Lunar ISRU:** This includes technologies specifically designed for the **Moon's environment**
- **Martian ISRU:** This includes technologies specifically designed for **Mars' environment**
- **Deep space ISRU:** This includes technologies for ISRU in other **deep space environments**, such as asteroids and comets

Customer Type

- **Government agencies:** This includes **NASA and other space agencies**.
- **Private companies:** This includes companies such as **SpaceX, Virgin Galactic, etc.**
- **Research institutions:** This includes **universities and research laboratories**.

Market Segmentation

Propellant

Time Frame

- **20-30 years** from now (as space travel becomes more common)

CAGR and Market size

- **16% CAGR** from 2023 to 2040
- **$5BN -> $60BN** market
- Driven by increased need for space travel, increased number of space programs

Applications/technology in the market

- Increase **cargo capacity** for space vessels
- Public/private **space exploration**

Solar Energy

Time frame

- Solar energy arrays projected to be deployed between **2028-2035**

CAGR + Market Size

- **CAGR 7.8%**
- Market Size: **$900 million** by 2030
- Driven by increase in demand for space-based solar power systems

Applications/technology in the market

- Solar cells, power grids, satellites during eclipse, orbital transfer vehicles

Life Support

Time Frame

- First launch of products related to in-situ oxygen production is between **2030-2035**

CAGR & Market Size

- **CAGR:** between **15%-25%** from 2030-2040
- **Market Size:** by 2040, predicted to be **between $500M and $1B**
- Driven by increasing number of space exploration missions & astronaut need for sufficiency

Applications/technology in the market

- Provide breathable air for astronauts, lunar ice electrolysis

Lunar Rovers

Time Frame

- Current industry leaders anticipate having first lunar rover on the Moon between **2025-2029**

CAGR & Market Size

- **CAGR: 9.2%** from 2023-2030
- **Market Size:** by 2030, predicted to reach **$1B**
- Driven by large investments by NASA and favorable space regulations for commercial missions

Applications/technology in the market

- Space landers, lunar rovers, launch vehicles

Market Size of Lunar Resource Utilization

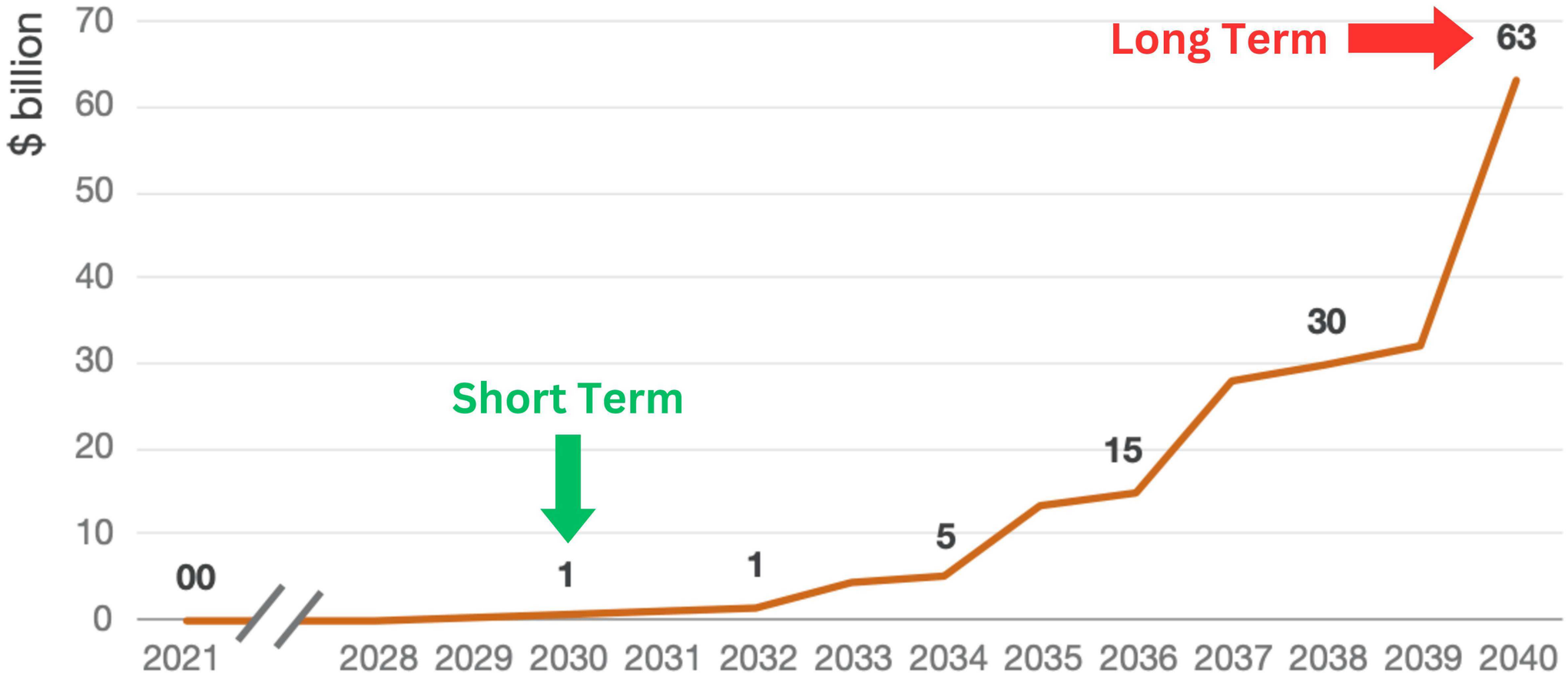
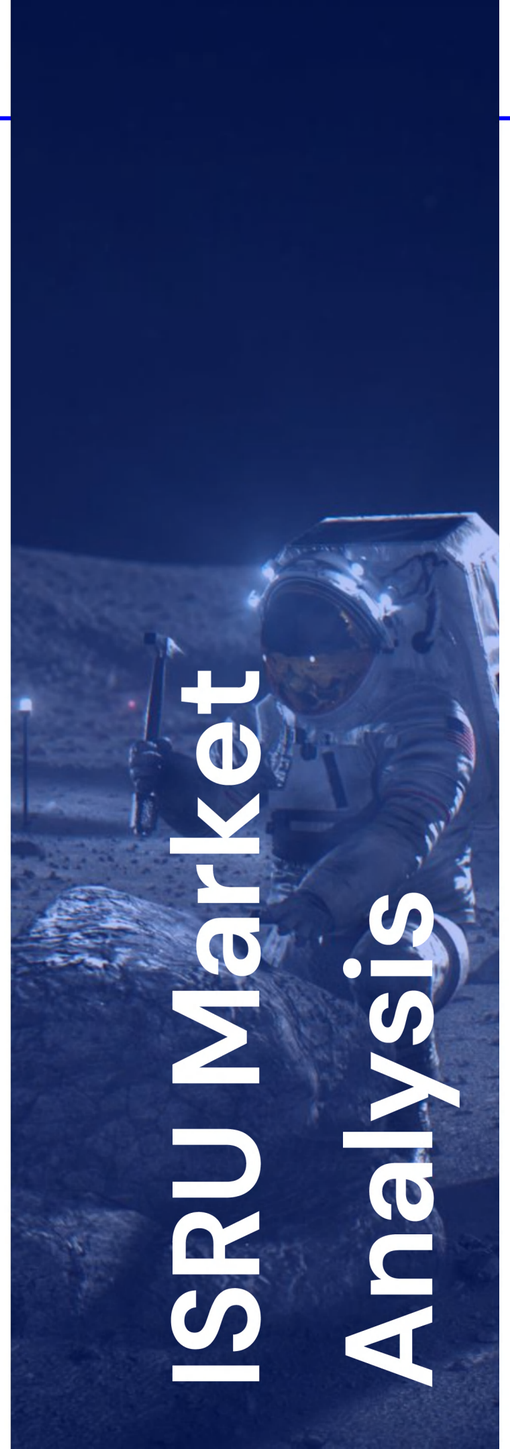


Figure 23 - Evolution of the cumulative SRU market size

**PWC Lunar Market Assessments*



ISRU Market Analysis

Market Trends

- **Increasing interes**t in space exploration: There is growing interest in space exploration from both government agencies and private companies
- **NASA's budget increases** every single year: **~1 billion dollar increase** from 2023 to 2024
- NASA's **Artemis Program** reflects this trend as well
- **Missions to Mars** are expected to grow significantly in the next 20 years
- Need for **propellant + life-support** on the Moon increases
- "**Commercial actors** are also expected to play a role in the future lunar ecosystem as service providers of transportation services (landers, rovers)"
- Advances in technology: **Advances in technology** are making ISRU more **feasible and cost-effective**
- Demand for sustainable solutions: There is a **growing demand for sustainable solutions** in space exploration

Market Challenges

- **Technical challenges:** Developing and testing ISRU technologies is challenging due to the **harsh environment** of space
- **Cost challenges:** ISRU technologies can be expensive to develop, test, and implement.
- **Regulatory challenges:** There will be regulatory challenges that need to be addressed before ISRU can be fully commercialized

Blue Origin SWOT Analysis

Strengths

- **Early mover** in lunar ISRU and solar power R&D
- Existing **rocketry knowledge**
- **Vertical integration** of launch services with lunar ISRU & logistics
- **R&D financial backing** from Jeff Bezos

Weaknesses

- **Lack of in-house rover/mining experience**
- **Mostly an R&D company**
- Most profit coming from space tourism
- Technology unproven at scale

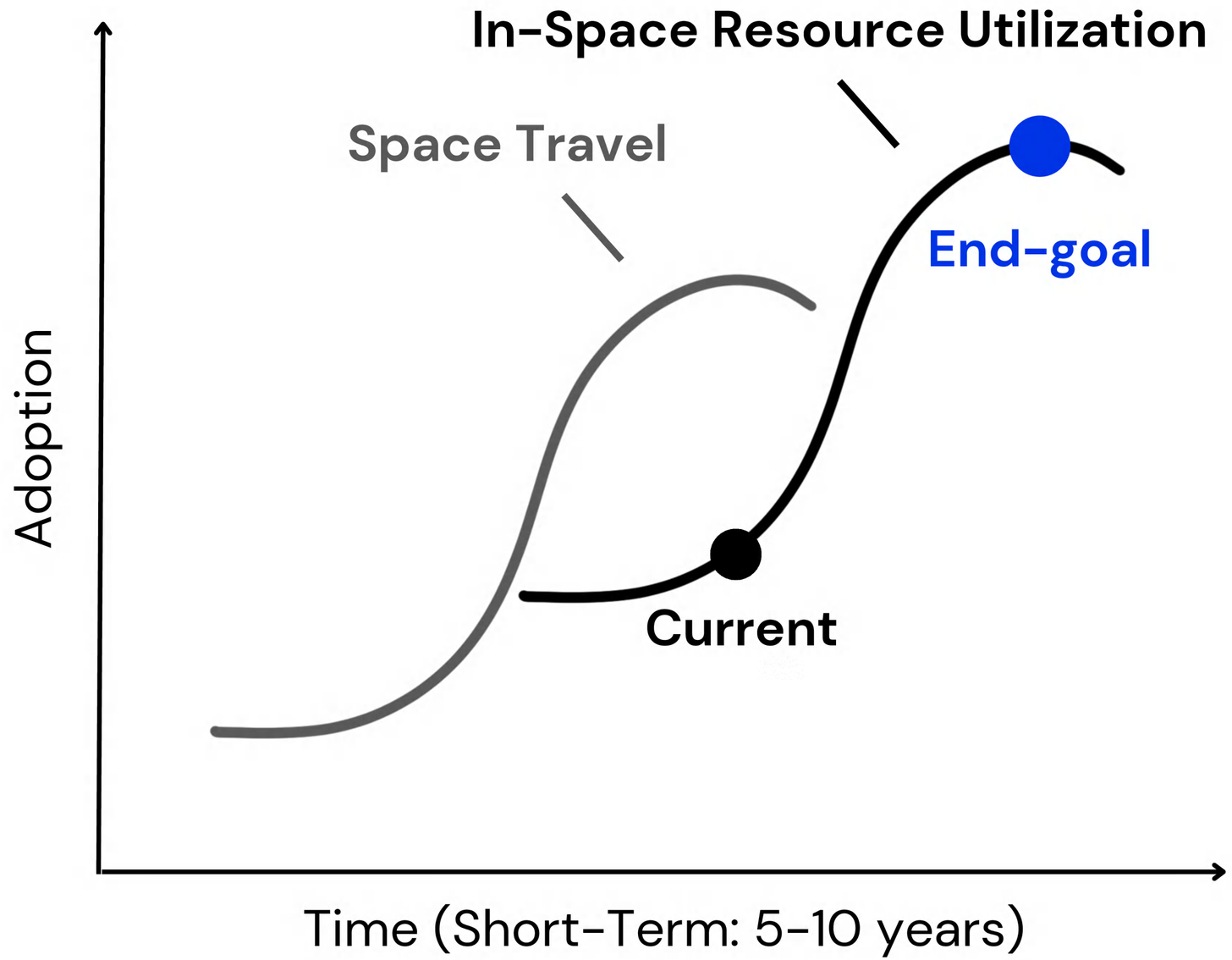
Opportunities

- Growing government and commercial interest in **cislunar operations**
- **Honeybee Robotics**
  - Specialized R&D in-space mining robots, end-to-end sample chain, solar array drive assemblies, maintenance/repair mechanisms

Threats

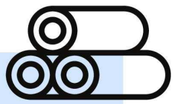
- **Military activity limits in space**
- **Competition** from existing energy/oxygen providers (SpaceX, Orbital Sciences Corporation, etc.)
- Dependency on a **few early customers**

S-Curve Visualization



Unpursued Ideas

Limiting Factors: Alignment with Technology, Potential Profit, Cost of Transportation



Europium

Raw Materials

- **Low Revenue:** potential of **$210 million**
- **Low Market Growth**
- Supply chain can be impacted by **geopolitical factors** (extraction concentrated in a few countries)

Railgun

Cargo Transportation

- **Unaligned with Blue Alchemist vision**
- Potential **legality issues**
  - 1967 Outer Space Treaty
- **High cost** of R&D, high need for electricity
  - Need for batteries

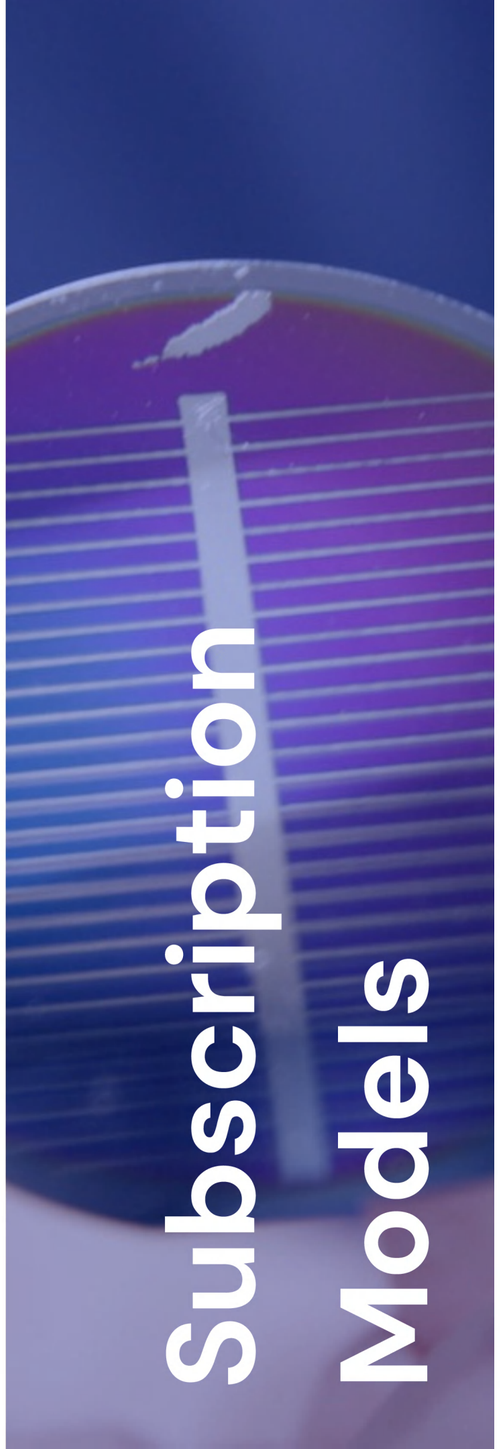
Regolith Construction Bricks

Construction

- **Unaligned with Blue Alchemist vision**
- **Not profitable** in the short term
- **Cost** to transport back to Earth is **not feasible**

Option #1

Subscription Model



Subscription Models

Oxygen Production Subscription

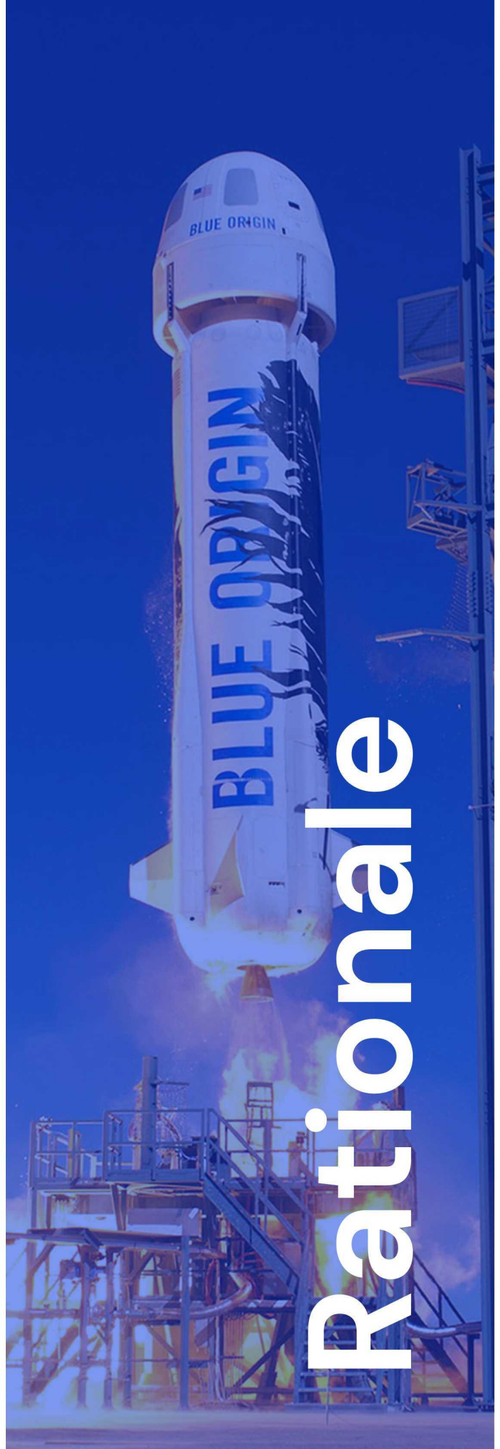
- Oxygen is a byproduct of molten regolith electrolysis, which is used to refine lunar regolith
- BA provides **daily oxygen via rovers mining lunar regolith**
- Subscription tiers based off of volume of oxygen provided
- **Honeybee tech:** Space mining robots & end-to-end sample chain

Solar Array Subscription

- BA **deploys and maintains** solar arrays
- Offers tiers based on kW capacity
- **Honeybee tech:** Manufacturing solar array drive assemblies

Additional Service/Maintenance Fee

- BA **deploys and maintains** solar arrays
- Offers tiers based on kW capacity
- **Honeybee tech:** Infrastructure for remote repairs



Rationale

Market Potential

- Plays into 2 segments of the in-space resources utilization market: **life support & solar energy**

Leveraging Capabilities

- Allows Blue Origin to leverage its capabilities to **provide for lunar infrastructure and sustainable human presence** on the Moon:
  - Proven **spacecraft development and launch capabilities**
  - Advanced space infrastructure development
  - Robotic systems and autonomy (i.e. Honeybee's space-mining robots)
  - **Vertical integration strategy** for both spacecraft development and launch operations
  - **Honeybee technology** for resource utilization and maintenance

Advantages of a Subscription Model

- Recurring revenue
- Customer acquisition and retention
- Predictable resource utilization and cost management

Government Contracts

Goal of Government Agencies

- Examples include: Space Force, Artemis Program
- Space exploration
- Sustainable human presence on the Moon

Blue Alchemist's Role

- We offer the opportunity for sustainable, cost-effective, independent space operations
- We enable lunar habitats/labs
- Reduce reliance on Earth-based resources
- Rapid deployment of solar power infrastructure → Everything is made on the Moon / not dependent on external supply chains
- Eco-Friendly lunar infrastructure → The technology minimizes the environmental impact of space exploration

Space Stations

Operational Space Stations

Name	Deorbiting year
International Space Station	2030
Tiangong Space Station	N/A

Goal of Space Stations

- **Scientific research** in materials science
- Technology development for life support, propulsion, and robotic systems, enabling **long-term human presence in space**

Blue Alchemist's Role

- Extracting lunar resources to **reducing reliance on Earth-based resources**
- In-space manufacturing capability would **reduce costly and time-consuming transportation** of materials from Earth
- Technology to develop **lunar infrastructure**

Planned & Proposed Stations

Name	Launch Year
Lunar Gateway	2024
Axiom Station & Haven-1	2025
LIFE Habitat Pathfinder	2026
Orbital Reef Station, Russian Orbital Service Station, & Starlab Space Station	2027
Lunar Orbital Station	After 2030
Bharatiya Antariksha Station	2035
Northrop Grumman	TBD

Competitive Analysis

Category	Blue Alchemist	LUNAR RESOURCES	AIRBUS* ROXY

Technology	• Molten Regolith Electrolysis
	• Solar cell/solar panel creation
	• Oxygen byproduct
	• **Successful lab tests**
		• Molten Regolith Electrolysis
		• MW Program: Power Grids
		  ◦ In-situ photovoltaic arrays
		  ◦ Transmission lines
		• **No succeeded lab test**
			• ROXY reactor (Regolith to Oxygen)
			• Oxygen and metals
			• **Successful lab tests**

Partnerships	• **Honeybee robotics acquisition**
	  ◦ Robots that maintain solar panels
	• Therefore, capability to offer product maintenance under subscription as well
		• No existing partnerships	• Mexican Space Agency
			  ◦ Government backing
			• Dereum labs
			  ◦ Rovers to carry materials

Finances	• **11,000** employees • **$600 million** in funding • **$43 million** annual revenue	• **10** employees • Main source of income is grant money • **$1.4 million in** funding	• **~110 billion** Market Cap • **11.2 billion** in annual revenue • **10,000+** employees

In a world where everyone's technology works, Blue Alchemist will be **best suited for the subscription model** because of their ability to provide **maintenance** on their services through the acquisition of **Honeybee Robotics.**

* ROXY is a project under Aribus Defense and Space, a division of Airbus SE

Pricing Model: Oxygen Subscription

Assumptions

- The **International Space Station** (ISS) uses about **2.5 kg of oxygen** per day
- 2015 NASA report indicates that it costs from $12,570 to $29,857/kg to produce oxygen on the lunar surface (adjusting for inflation, this is equivalent to **$14,930 to $35,460/kg** in 2023)
- Since oxygen is only a byproduct of molten regolith electrolysis, and factoring in transportation costs, we assume the **total cost of selling oxygen to be around $35,000**.
- The average profit margin of the aerospace and defense industry is 27.5%, so we set our **margin to 30%**

Pricing Model

Category	Starter Tier	Mid Tier	Premium Tier
kg of oxygen/month	Up to 100	101-500	501+
Price per kg	$45,000	$45,000	$45,000
Profit margin per kg	30%	30%	30%
Added maintainence fee	5%	10%	15%

Pricing Model: Solar Energy Subscription

Assumptions

- The **International Space Station** (ISS) uses about **84 kW of solar energy per day**.
- Based on the Moon escape velocity, we calculated that it takes an average of **43,000 kg of rocket fuel for a 70,000 kg rocket** (the size of Blue Origin's New Shepherd) to get into space, and the cost of this can range from **$13,000 - $430,000** depending on the type of fuel.
- The **ISS invests $1M per year** to maintain 6 out of their 8 solar panels, which will last 15-20 years. This is roughly equal to a **cost of $60/kW/day** to maintain solar panels on the Moon.
- The **average profit margin** of the aerospace and defense industry is **27.5%**, so we set our margin to 30%

Pricing Model

Category	Starter Tier	Mid Tier	Premium Tier
kW of solar energy/month	Up to 1500	1530-3000	15,030+
Price per kW	$80	$80	$80
Profit margin per kW	30%	30%	30%
Added maintainence fee	5%	10%	15%

Pricing Model: Enterprise Package

Assumptions

- **All of the assumptions** for both oxygen and solar energy subscriptions **are remaining consistent**
- Kg of oxygen and kW of solar energy sold are based on **annual contracted amounts**
- Each customer will be offered a 5-15% discount on the total price per tier
- An **additional maintenance fee** will be added onto the discounted price

Pricing Model

Category	Starter Tier	Mid Tier	Premium Tier
kg of oxygen/month	Up to 1200	1212-6000	6012+
kW of solar power/year	Up to 18250	18615-36,500	36865+
Price per kg	$45,000	$45,000	$45,000
Price per kW	$80	$80	$80
% discount	5%	10%	15%
Added maintainence fee	10%	15%	20%

Potential Revenue

Mid Tier Enterprise Package

Assuming an organization contracts the **Mid Tier Enterprise Package** for a lab on the Moon for 1 year, they would be paying around:

$283 million

Mid Tier Solar Package

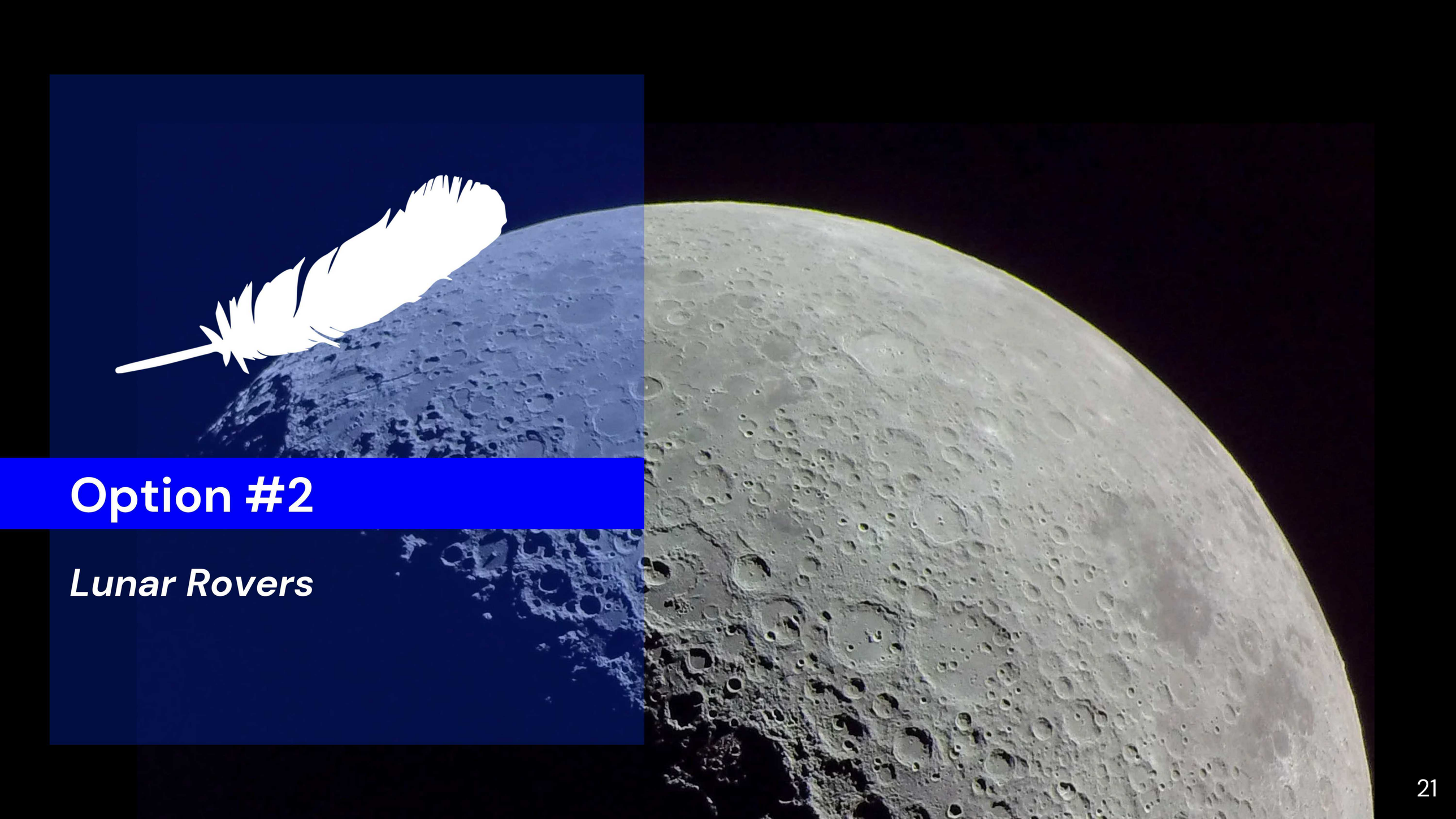
Assuming an organization contracts the **Mid Tier Solar Package** for the space station for 1 year, they would be paying around:

$3 million

Mid Tier Oxygen Package

Assuming an organization contracts the **Mid Tier Oxygen Package** for a lab on the Moon for 1 year, they would be paying around:

$270 million



Option #2

Lunar Rovers

Partnership

BLUE ORIGIN

+

Toyota's Lunar Cruiser

- **Manned Lunar Cruiser** set to **deploy by year 2029**
- **Toyota's Lunar Cruiser** generates power using solar energy and stores it in fuel cells to be used during the night
- In the future, Toyota wants to use water ice from the lunar poles to power rover
- Rovers can be used for **space tourism** as the main source of transportation for wealthy space travelers on the Moon
- Toyota would profit from government/startup contracts initially and then commercial customers later

Blue Alchemist's Role

- Toyota is hopeful that another space company can figure out logistics of mining water ice & transporting critical ingredients for fuel cells on the Moon
- They **want to depend on collaborations** with other companies for such capabilities (Blue Origin)
- **Blue Alchemist technology reduces costs for Toyota** as solar cell capabilities can be made on the Moon itself

Toyota SWOT Analysis

STRENGTHS

- Robust **brand reputation**
- **Global distribution facilities**
- **67 manufacturing companies worldwide**
- Markets products in **170+ countries**
- **Protects environment** by reducing energy use and minimizing waste at every stage of operations
- **Expertise in vehicle design**

WEAKNESSES

- **High production costs**
- **Environmental challenges**
- **Negative publicity** that affects brand image

OPPORTUNITIES

- Artemis V Mission
- **Tech advancements in maintenance and sample collection tools**
- Funding from NASA
- “Space race of the 2020s”
- First mover in lunar rover market

THREATS

- **Supply chain disruptions**
- Regulatory changes
- Economic downturns

Competitive Analysis

Category	TOYOTA 	General Motors x Lockheed Martin 	Astrolab x SpaceX 

Technology	• Blue Origin's Solar Cells **(built on Moon)**:
	  ◦ Molten Regolith Electrolysis
	  ◦ Solar panel creation
	  ◦ Oxygen byproduct
		• General Motors electric battery technologies **(built on Earth)**	• Onboard lithium-ion batteries charged by side-mounted solar panels **(built on Earth)**

Rover Functions	• **Pressurized rover** so astronauts won't have to wear suits inside • Offers both mobility and habitability • **7 square meter cabin** to provide a living space for astronauts • Space exploration	• Robotic arm to **relocate payloads** • Explore permanently shadowed regions for multiple Earth days • **Map** square kilometers of **lunar surface** • Enable landing site investigation, film lander descents	• **Pick up and unload modular payloads** • Site survey/preparation • Space exploration • Construction SpaceX is helping to send Astrolab's rover to the Moon using Starship.
Resources	**Blue Origin** • **11,000** employees • **600 million** in funding • **$43 million** annual revenue **Toyota** • **350,000** employees • **$279 billion** annual revenue • Market Cap: **$314.5 billion**	**General Motors** • **167,000** employees • **$156.7 billion** annual revenue • Market Cap: **$44.32 billion** **Lockheed Martin** • **116,000** employees • Market Cap: **$67.7 billion**	**Astrolab** • **< 50** employees • **$160 million** in funding • **$2 million** annual revenue **SpaceX** • **13,000+** employees • **~$10 billion** in funding • **$4.6 billion** in revenue 2022

Blue Alchemist should partner with Toyota because Toyota has a large amount of funding and would be the first in the world to create a commercial, pressurized lunar rover.

Government Contracts

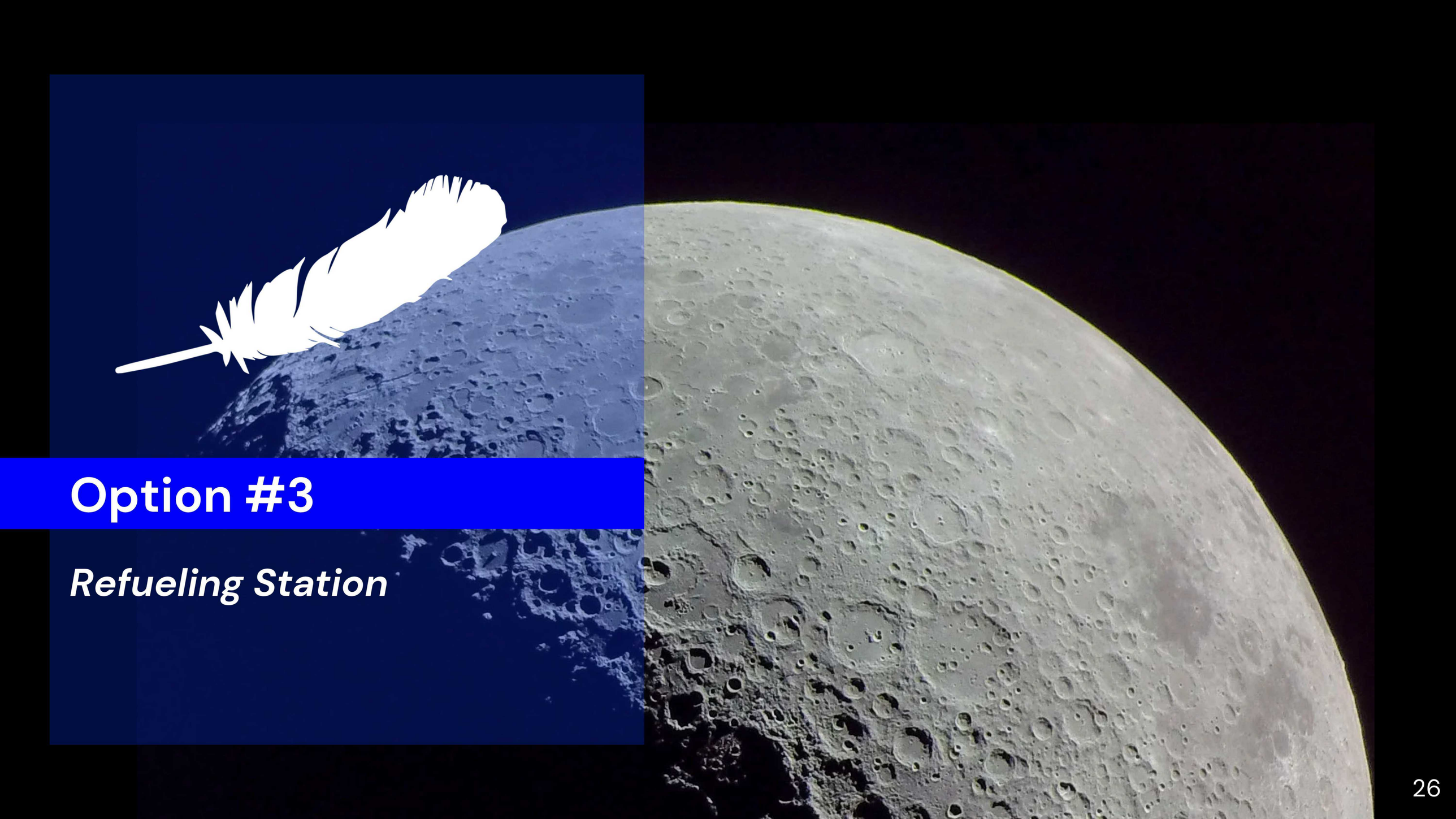
- **$3.235 billion** for Artemis Campaign Development to advance lunar exploration capabilities
- **$3.383 billion** for Planetary Science, which includes funding for the Lunar Discovery and Exploration Program in support of NASA's Artemis Program
- **$472 million** for JAXA to participate in NASA's Artemis Program
- NASA's awarding of a Lunar Terrain Vehicle (LTV) services contract got delayed by 4 months; Blue Origin should try to win this after partnering with Toyota

Startup Contracts

- Astrolab, one of Blue Origin's competitors, has sold 8 contracts to startups for its lunar rover totaling **over $160 million**; Blue Origin can make around this amount or even more

Blue Alchemist's Benefit to Toyota

- Solar Panels Weigh: ~50 pounds each
- # of Panels Needed for Toyota's Rover: ~48 solar panels
- Cost per Pound to Transport Things to the Moon: ~$25,000-50,000
- By partnering with Blue Origin, Toyota would save:
  48 x 50 x Cost per Pound = estimated **$60,000,000 to 120,000,000 per rover**



Option #3

Refueling Station

Logistics

Initial Idea

- The Moon as a “rest stop” for space travelers
- As space markets grow, the number of space travel programs will **increase**
- **3000 metric tons of fuel** needed to get to the Moon alone
- **4000 metric tons of fuel** needed to get to Mars
- Costs can be cut **significantly** if the Moon is used as a rest/reloading point
- By refueling on the Moon, you **only need to carry enough fuel to get you to the Moon**
- Could essentially **double** the cargo capacity of spaceships by refueling on the Moon.
- Less things carried for less time = **higher efficiency**

Feasibility

Fuel Cost Assumptions:

- LH2 and LOX = Liquid Hydrogen, Liquid Oxygen
- **Majority of cost: Cryogenic Cooling LH2 and LOX**
  - Need to cool the substances to -450°F and -300°F
  - Lunar surface, -250°F to -400°F (coldest at the poles)
  - Cooling cost on the Moon is **1/2- 1/4 of original**

Current Availability of Raw Materials:

- Oxygen made as byproduct of Blue Alchemist
- Hydrogen found in many parts of lunar surface
  - Lunar craters contain frozen H_2O
  - Regolith contains deposits of hydrogen from solar winds

Next Steps

- R&D for lunar fuel containers
- R&D for hydrogen procurement using Blue Alchemist mining tech

Competitive Analysis

Category	Blue Alchemist	OxEon energy	SKYRE
Technology	• Molten Regolith Electrolysis • Solar cell/solar panel creation • Oxygen byproduct • **Successful lab tests**	• Formation of fuel from ice in lunar craters (water electrolysis)	• Formation of fuel from ice in lunar craters (water electrolysis) • 31 patents • All stages of electrolyzer development
Partnerships	• Access to New Glenn, New Shepherd, etc. • NASA Tipping Point Partnership ($10M)	• NASA Tipping Point Partnership ($1.8M)	• NASA Tipping Point Partnership ($2.6M)
Resources	• **1000-5000** employees • **$48 million** annual revenue	• **36** employees • **~$3 million** grant funding	• **~25** employees • Over **$25 million** in grant, contract, VC funding • **$6.5 million** revenue

As of now, Skyre is ahead in fuel refining. However, their model is based on mining lunar ice. Blue Alchemist could follow that model and modify existing tech to extract hydrogen from lunar regolith, increasing fuel production.

Pricing: Cost of Using Different Fuels on the Moon

Liquid Hydrogen Cost

LH2 production and delivery stage	Cost per kilogram (From Earth)	Estimated Cost per kilogram (Moon)
Production	$3-5	$1-3
Shipping to Moon	$10,000	$1-3
Dispensing	$1-2	$1-2
Total Cost	$10,004-10,007	$3-8
Selling price (+30%)	$13000	$4-11

Liquid Oxygen Cost

LOX production and delivery stage	Cost per kilogram (From Earth)	Estimated Cost per kilogram (Moon)
Production	$0.20-0.30	$0.10-0.15
Shipping to Moon	$10,000	$0.10-0.20
Dispensing	$0.10-0.20	$0.10-0.20
Total Cost	$10000	$0.30-0.55
Selling price (+30%)	$13000	$0.40-0.75

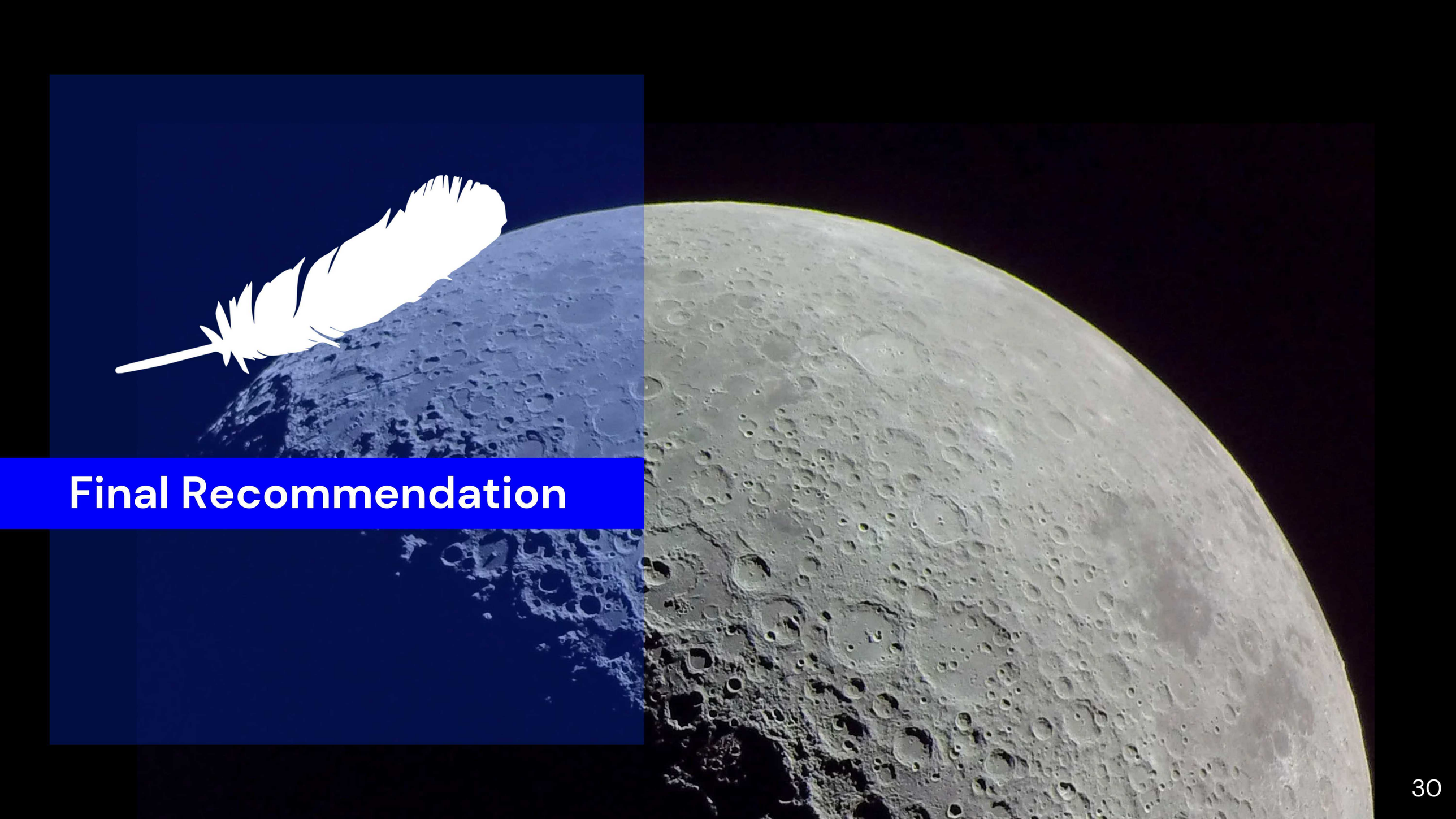
Low end:

- $4 per kg of LH2, $0.40 per kg of LOX
- 6:1 ratio LH2 and LOX in rocket fuel
  - 3000 metric tons of fuel required
- **= $10,500,000 per refuel**

High end:

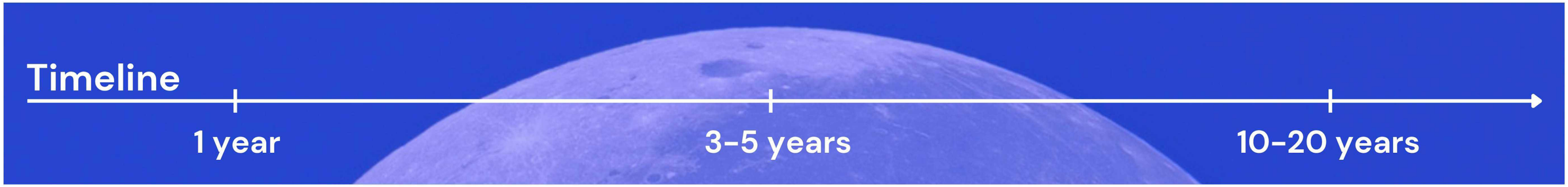
- $11 per kg of LH2, $0.75 per kg of LOX
- 6:1 ratio LH2 and LOX in rocket fuel
- 3000 metric tons of fuel required
- **= $28,700,000 per refuel**

As shown, two of the biggest price differences between fuel made on Earth and fuel made on the Moon is the cost of production (which is cut in half on the Moon), and the cost to bring it to the Moon.



Final Recommendation

Final Plan of Action



Phase 1

- Assuming that the Blue Alchemist technology is currently working, we recommend starting off with the **subscription model**, **selling oxygen and solar energy** to space stations
- Honeybee Robotics used for **maintenance** of solar arrays, and can also be used for rovers
- Continue **R&D** from NASA Tipping Point partnership to develop Lunar **fuel refinement and storage**

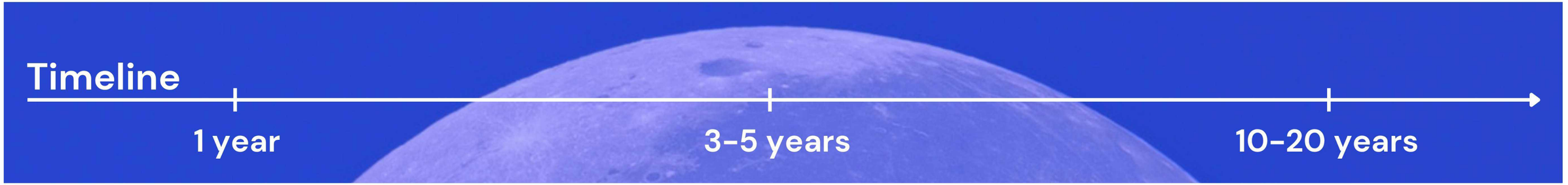
Phase 2

- Partner with **Toyota**
- Offer both Blue Alchemist **solar cells** to power their Lunar Cruiser and **maintenance packages** from the Subscription Model in Phase 1
- Compete for **NASA's** Lunar Terrain Vehicle **(LTV)** services **contract**
- **Develop** Blue Alchemist capability to obtain Hydrogen from regolith as well as from lunar ice

Phase 3

- **Combine the tech** developed during Phase 1 and 2 to become an initial player in the lunar fuel market
- Use Blue Alchemist tech and developed Toyota Lunar Cruiser tech to **harvest Hydrogen and Oxygen**
- Use NASA Tipping Point tech to **refine and store fuel**

Potential Risk



Challenge

14-Day-Long Lunar Night

Blue Alchemist solar panels will experience **14 days of zero power generation** due to the nature of the Moon's night cycle.

Phase 1

- **Lunar Base:** Would require a form of energy storage that could hold 14 days worth of power at any given time
- **Space Stations:** Constant power as the panels will be in space

Phase 2

- Lunar rovers will use **solar panels** for power **during the day** while collecting **lunar ice** and refining fuel, and using the fuel for internal **combustion** to power the rover **during the night**
- The companies developing lunar rovers have **already taken the Lunar Night into consideration**

Phase 3

- Mining lunar ice, using Blue Alchemist mining equipment, or cryogenically cooling fuel does not **necessitate the use of solar panels**.
- Even if they did, these **actions can be done during the day**, or using the aforementioned lunar rovers.
- The collection and refinement of rocket fuel **does not directly involve solar energy**

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