New Space Economy: opportunities for private businesses on the Moon
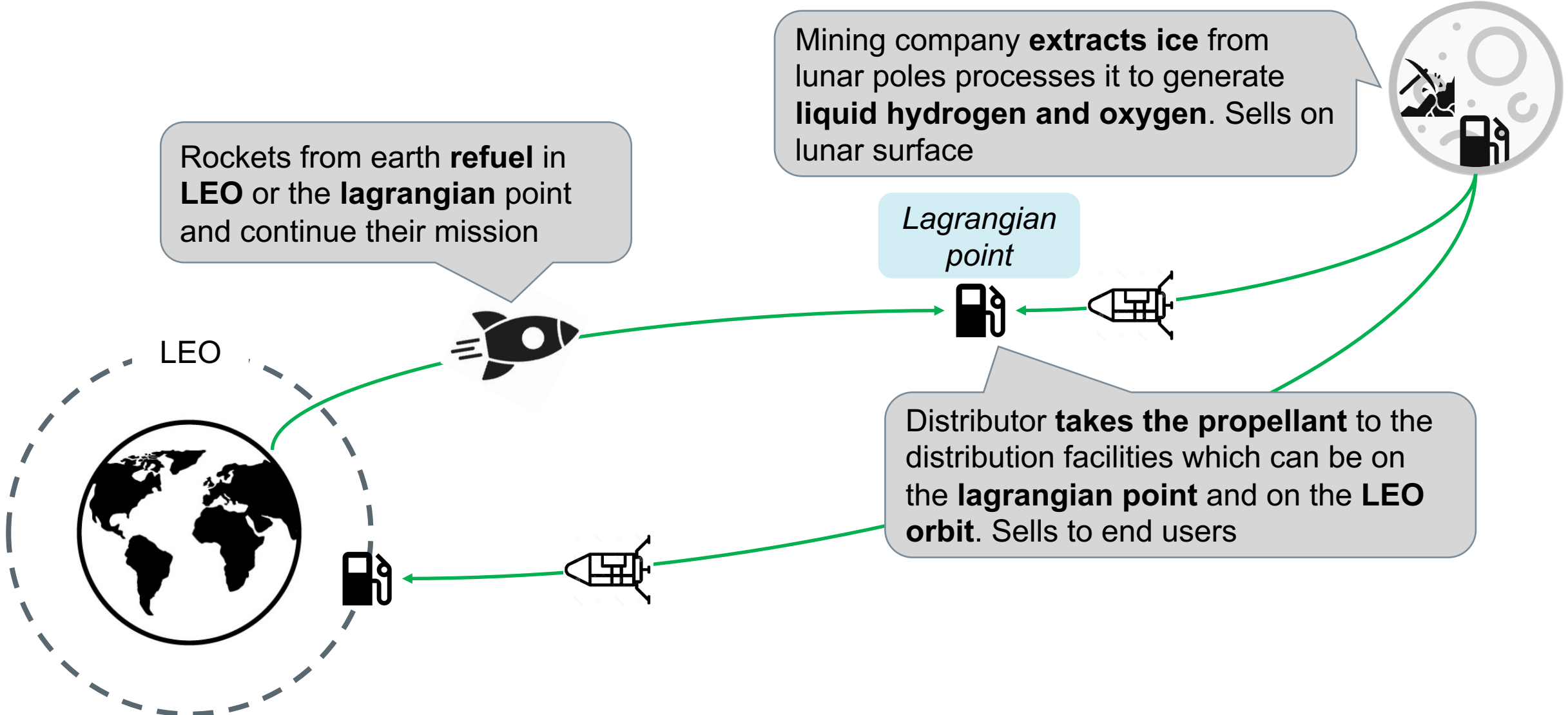
Mining the Moon for propellant and in-orbit refueling
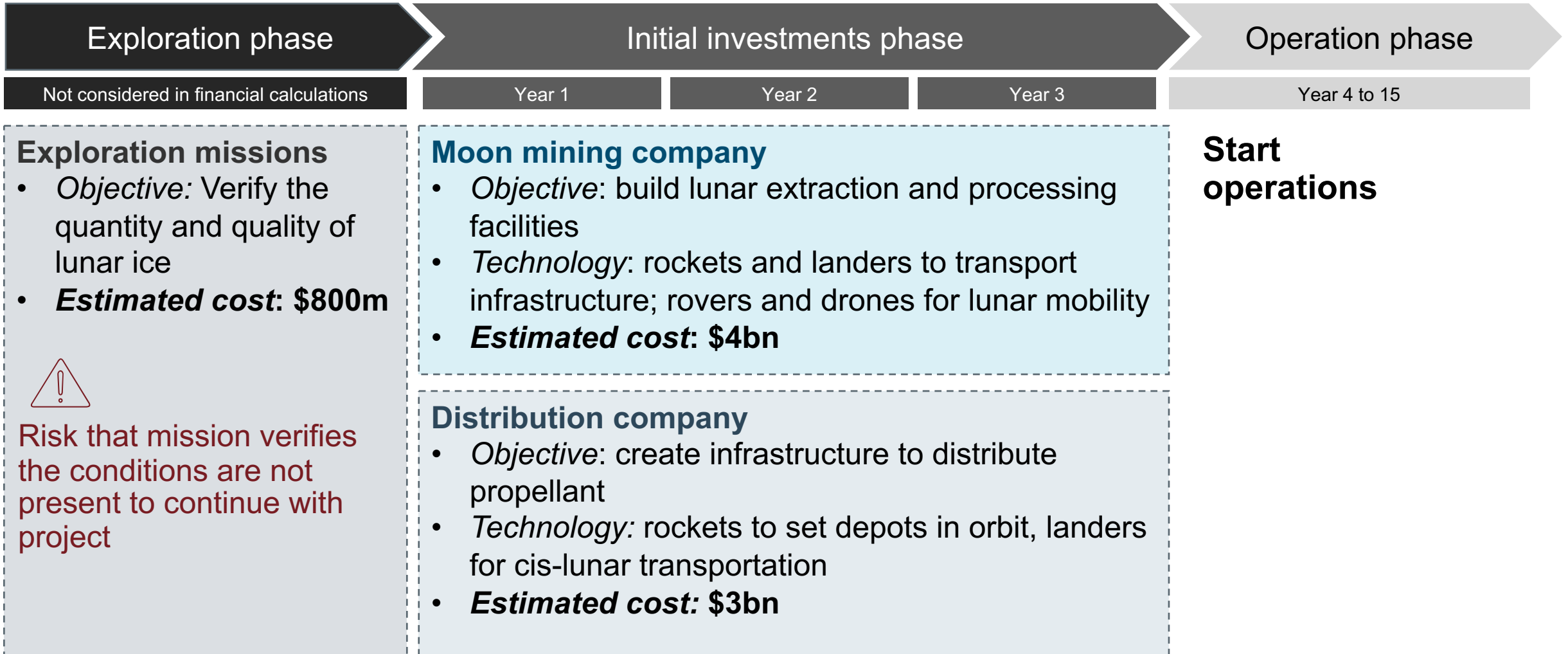
December 6th, 2023

Dr. Edoardo Vittori

Space Economy Evolution Lab, SDA Bocconi

Moon mining and in-orbit refueling configuration consists in a mining company, a distribution company and end-users

Mining company **extracts ice** from lunar poles processes it to generate **liquid hydrogen and oxygen**. Sells on lunar surface

Rockets from earth **refuel** in **LEO** or the **lagrangian** point and continue their mission

Lagrangian point

LEO

Distributor **takes the propellant** to the distribution facilities which can be on the **lagrangian point** and on the **LEO orbit**. Sells to end users

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Timeline and estimated investment costs to build lunar and cislunar infrastructure

Exploration phase	Initial investments phase			Operation phase
Not considered in financial calculations	Year 1	Year 2	Year 3	Year 4 to 15

Exploration missions
- *Objective:* Verify the quantity and quality of lunar ice
- ***Estimated cost*: $800m**

⚠️

Risk that mission verifies the conditions are not present to continue with project

Moon mining company
- *Objective*: build lunar extraction and processing facilities
- *Technology*: rockets and landers to transport infrastructure; rovers and drones for lunar mobility
- ***Estimated cost*: $4bn**

Distribution company
- *Objective*: create infrastructure to distribute propellant
- *Technology:* rockets to set depots in orbit, landers for cis-lunar transportation
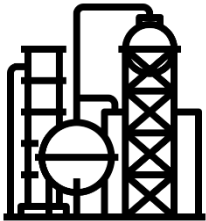- ***Estimated cost:* $3bn**

Start operations

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The initial investment costs are estimated to be around $7bn, between the cost of LHC and Starship development
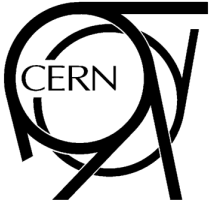
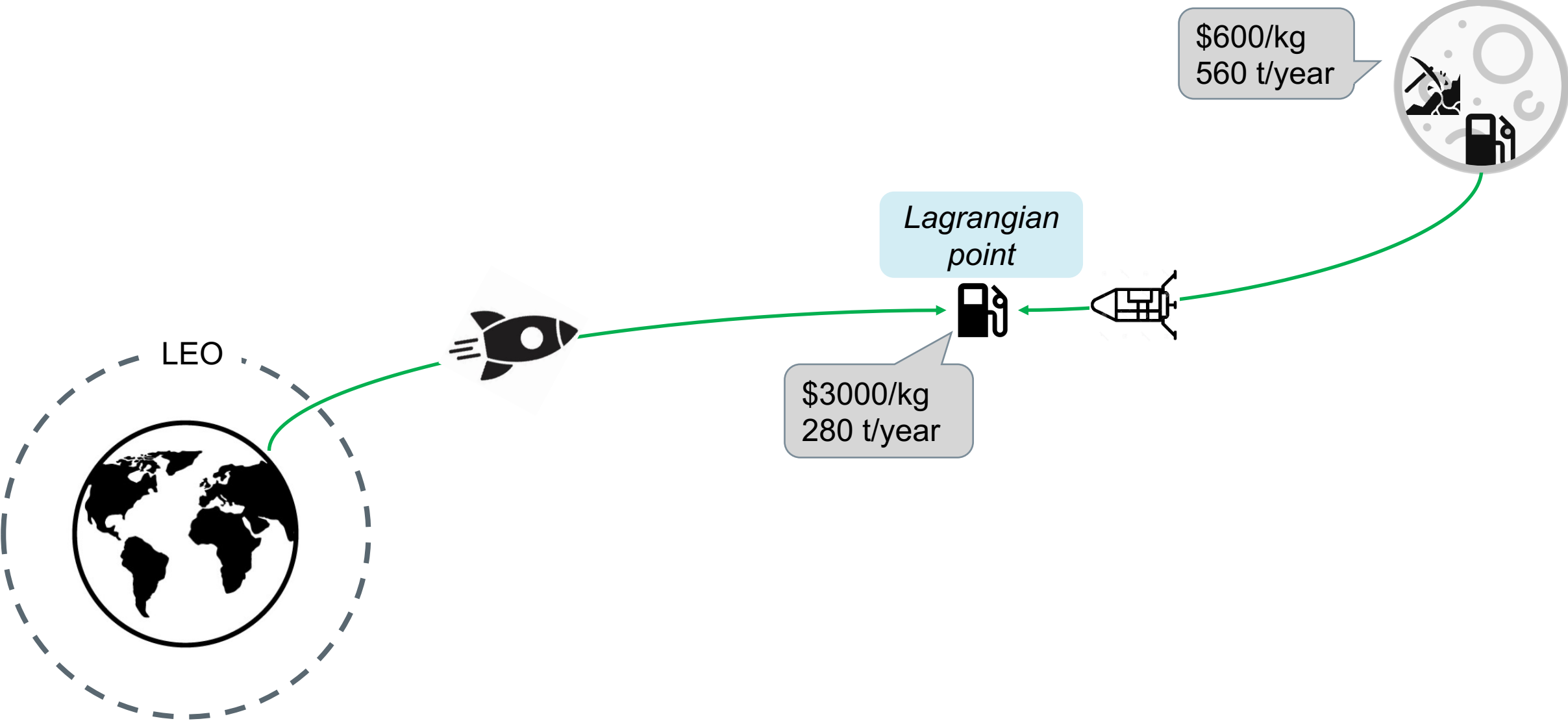Large hadron collider
$5bn
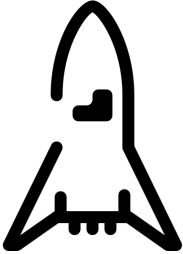
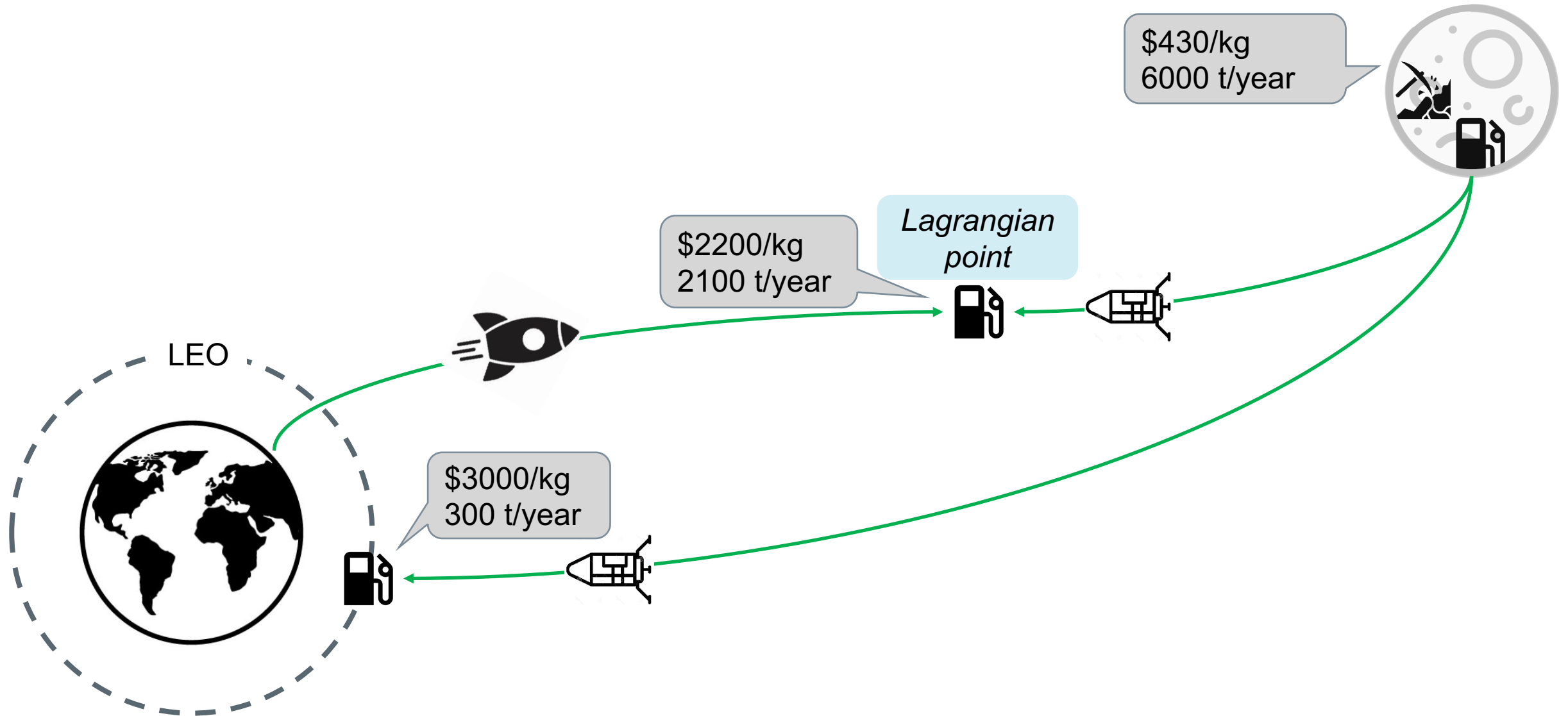Starship development
$10bn

Jazan refinery complex
$21bn

Emirates placed
$52bn aircraft order

In year 1, the estimated fuel price is $600/kg on the Moon (miner) and $3000/kg on the Lagrangian point (distributor)

$600/kg
560 t/year

Lagrangian point

$3000/kg
280 t/year

LEO

Demand will increase and fuel price will decrease with time, below are estimates for year 5

We can calculate the revenues using demand and fuel price, operating costs include maintenance and replacement costs

OPERATING COSTS AND REVENUES

	Year of operation	Revenues	Operating costs
Mining company	1	**$340m**	**$230m**
	5	**$2600m**	**$1780m**
Distribution company	1	**$840m**	**$680m**
	5	**$5500m**	**$4180m**

HIGHLIGHTS

- **Fuel costs** will generally **decrease**, perhaps in the future they will be listed on the financial markets

- We assume **15 years** of operation (including 3 years of initial investment), increasing the length makes it more profitable

- Operating costs for the distributor include **propellant** it buys from the miner

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The Net Present Value (NPV) is used to determine the economic feasibility of the projects

OBJECTIVE

- We need to calculate the **NPV for both the mining company** and the **distribution company**

- A **positive NPV** means the investment **generates value**

- The **NPV** considers the **time value of money**.

$$NPV = -\sum_{t=0}^{N} \frac{CAPEX_t}{(1+r)^t} + \sum_{t=N+1}^{T} \frac{CF_t}{(1+r)^t}$$

Initial investments

Free cash flow

r is the discount rate or cost of capital. It can be estimated by analyzing other projects with a similar level of risk. For these calculations we used 16%.

The positive NPV results prove the economic feasibility of both the mining and distribution projects

	Mining	Distribution
NPV (15 years)	$2.9bn	$4.6bn
Considerations	This project could be undertaken by oil & gas companies given the proximity to their business and given that they have the necessary resources.	Transporation or space transportation companies are probably the most appropriate for this venture.

Conclusion

- The project requires relevant initial investments which will then unlock very high revenues with low operating costs
- As the necessary technologies are developed, NPV estimates will be more precise and uncertainty reduced
- The obtained NPVs represent an estimate and depend on specific assumptions

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