LOHUM

## Accelerating Sustainable Electrification

# Assignment

You have been provided with a hypothetical scenario and there are follow-up questions based on it.

**Instructions:**

- Use any digital format for the submissions.
- Feel free to respond in any form - long form text, charts, tables
- Provide citations for any data points you use
- Highlight in case of any assumptions or guesstimates
- Feel free to use Google, ChatGPT, or any other tool but please ensure proper citations and justifications for your assumptions.

An emphasis on the quantitative aspect is expected but remember there are no right or wrong answers. So feel free to be creative.

You may refer to the appendix but shouldn't limit yourself to it.

# Low Earth Orbit in 2104

# Background

This is Earth in 2104. You are a successful inter-planetary commodity trader.

There’s recently been concerns raised around satellite debris in low earth orbits and the UN is deliberating on this.

While the bigwigs debate it out, you are looking at this as a business opportunity.

Work through some of the next questions to see whether you can make a buck here.

# Question 1

Do you think space debris are a real problem or is it just environmental alarmism?

At what scale do debris truly start to become a concern in your opinion.

Why/why not.

You might use chatGPT etc to answer this but you'll be asked follow up questions to justify your arguments.

# Question 2

Hypothetically, there are mainly **two** types of satellites in operation —
(i) Communication and (ii) Earth observation.

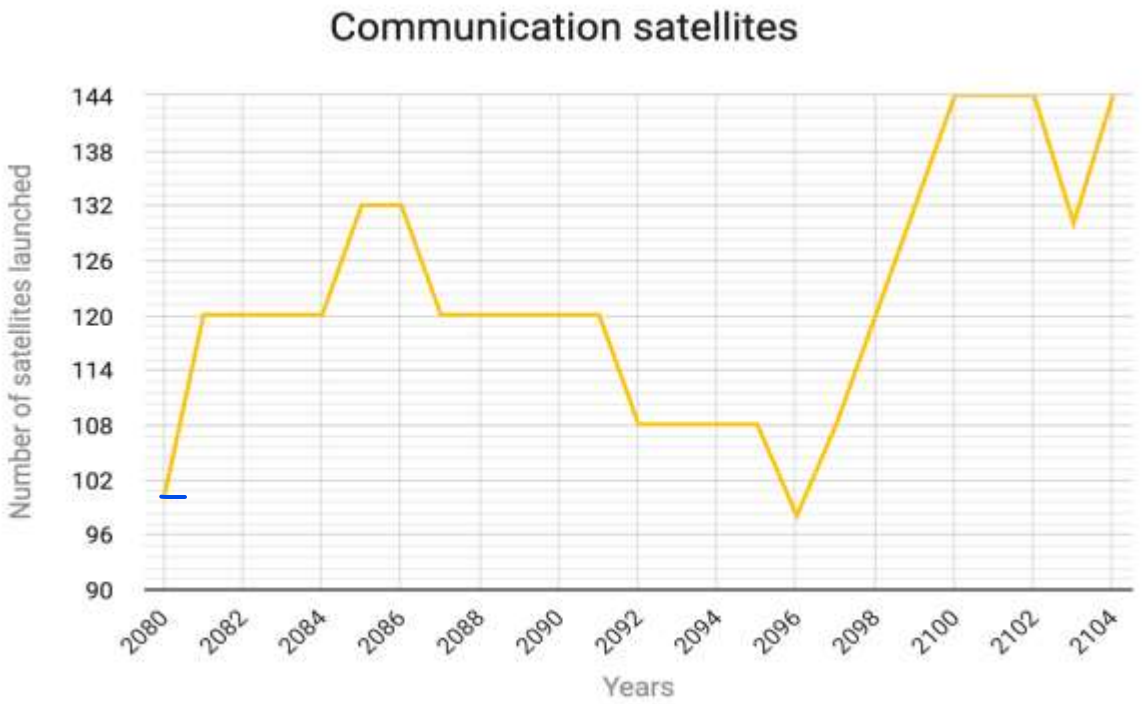
Communication satellites on average weigh **1.5 Tons** while Earth Observation satellites weigh around **750kgs**.

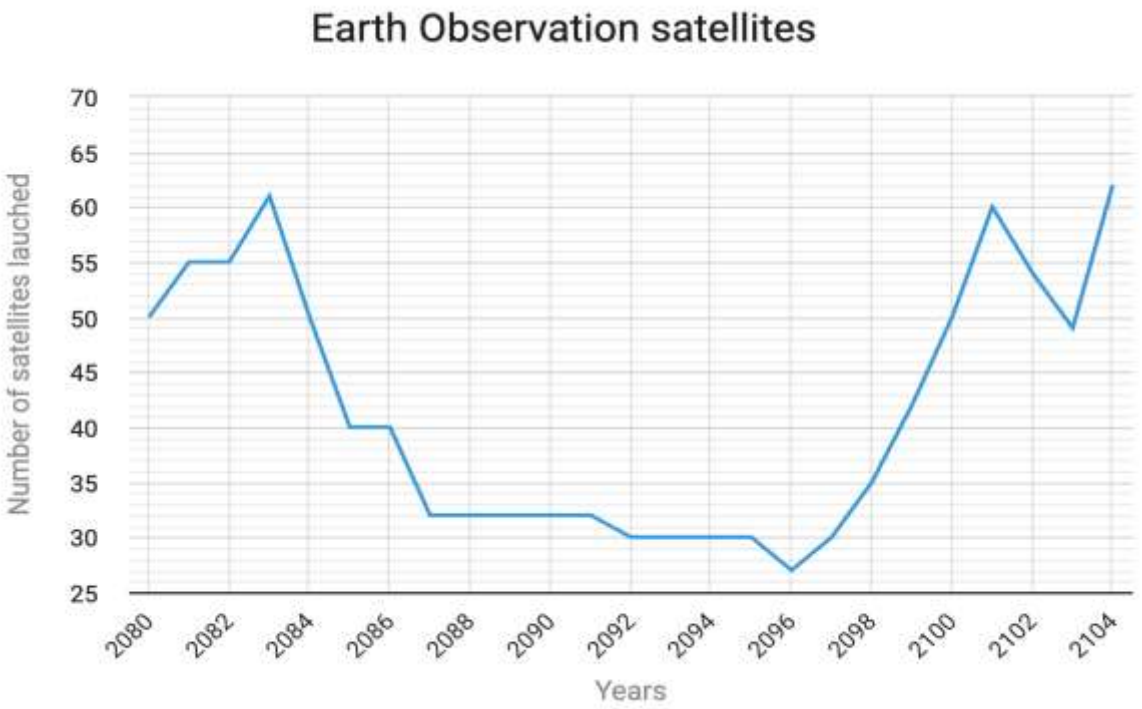
The last major clean up of space debris took place in **2080**, after which we were left with around **1200** and **500** of these satellites in orbit.

Assuming that on average, **5%** of the weight of a satellite is batteries, give your best estimate for the Lithium present in space in the year 2104.

Satellite launch data is given in the next slide. Further supporting data in Annex.

# Question 2



# Question 3

The UN is taking out a tender for the clean up of out-of-service satellites.

What would be your estimate for the value that you can derive from these satellites if you could sell all the metals in them?

Life cycle estimates for each satellite type is given in the next slide. Assume Gaussian distribution for satellite life and **95%** Confidence interval.

The annex contains data on the typical metal composition of a satellite and price of metals.

# Question 3

| Satellite Type | Mean (in years) | Standard Deviation (in years) |
|---|---|---|
| **Communication** | 15 | 5 |
| **Earth Observation** | 7 | 3 |

# Question 4

Your business model typically involves renting reusable debris capturing rockets at **USD 10,000/launch**. These rockets can each capture about **250** satellites per launch and weigh approximately **1000 Tons**.

Your other big cost is fuel. Traditionally, hydrazine was used as a fuel. How much would you have to spend on fuel for the entire debris clean up project?

Assume that the almost all the fuel is used for reaching low earth orbit and subsequent fuel usage is minimal.

Use the rocket equation and the back up data provided in the annex.

# Question 5

Rocket rent and fuel account for **60%** of all your costs if you use hydrazine.

Given this information and the total estimate of the value that you can derive out of the metals in the debris that you calculated earlier, do you think you will make a profit?

How much subsidy should you ask for from the government so that you make at least a **10%** operational profit?

# Question 6

What could be some other business opportunities that you can expand into based on the operational and technological capabilities you build in capturing orbital debris?

Feel free to get creative but provide some justification for your ideas.

# Annexure

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# Simplified Rocket Equation and Other Data

$$\frac{m_{fuel}}{m_{rocket}} = e^{\left(\frac{\Delta v}{c_e}\right)} - 1$$

$m_{fuel}$ = fuel mass
$m_{rocket}$ = payload + structure mass
$c_e$ = exhaust speed
$\Delta v$ = change in spacecraft's speed

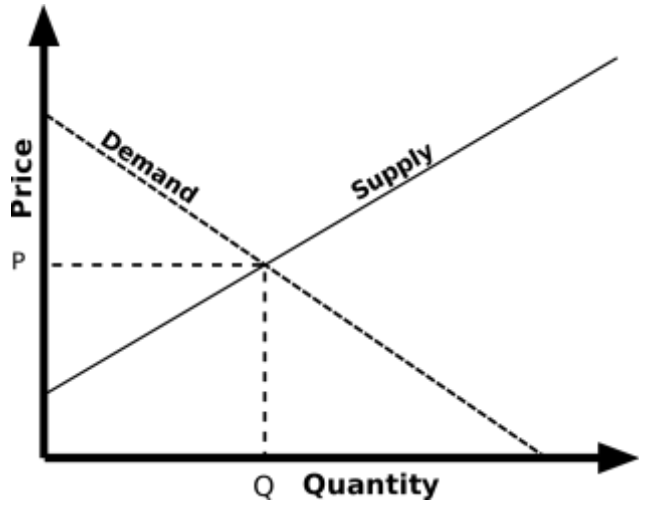
| Constant | Velocity (in km/s) |
|---|---|
| Exhaust velocity of water | 1.40 |
| Exhaust velocity of Hydrazine | 2.30 |
| Exhaust velocity of Hydrogen Peroxide | 2.15 |
| Escape velocity of Earth | 11.20 |
| Escape velocity of Moon | 2.40 |
| Escape velocity of Mars | 5.00 |

| | |
|---|---|
| Cost of Hydrazine (USD/kg) | 52 |
| Cost of Hydrogen Peroxide (USD/kg) | 12 |

# Demand and Supply

- Law of Demand and Supply: As the price of a good or service decreases, the quantity demanded by consumers increases, and vice versa. This inverse relationship reflects consumer behavior—lower prices typically encourage more purchases.

- Market Equilibrium: The interaction of demand and supply determines the market equilibrium price and quantity. At this point, the quantity demanded equals the quantity supplied, and there is no surplus or shortage in the market. Changes in either demand or supply can shift this equilibrium, affecting prices and quantities.



# ICP (Inductively Coupled Plasma)

- Analytical Technique: ICP is a highly sensitive analytical technique used to detect and quantify trace elements in various samples, such as metals, soils, and biological materials. It utilizes a high-temperature plasma to ionize the sample, allowing for accurate measurements.

- Applications: ICP is widely used in environmental monitoring, pharmaceuticals, metallurgy, and geochemistry. It is particularly useful for analyzing metals and metalloids at very low concentrations, making it essential for quality control and regulatory compliance in various industries.

# A typical spacecraft composition

| Metal/Alloy | Percentage |
|---|---|
| Aluminum-Titanium | 65.00% |
| GaAs | 5.00% |
| Copper | 12.00% |
| Steel | 5.00% |

**Metals in a cell**

| | |
|---|---|
| Nickel | 10.00% |
| Cobalt | 10.00% |
| Lithium | 2.00% |

# Reference prices

| Metal/Alloy | Price ($/ton) |
|---|---|
| Aluminum-Titanium | $10,000.00 |
| GaAs | $639,000,000.00 |
| Copper | $10,000.00 |
| Steel | $2,000.00 |
| Nickel | $17,000.00 |
| Cobalt | $25,000.00 |
| Lithium | $100,000.00 |

# Regression

- Regression is a statistical technique used to model the relationship between a dependent variable and one or more independent variables, allowing for predictions and insights into how changes in the independent variables affect the dependent variable.
- Widely used in various fields, including economics, finance, social sciences, and natural sciences, to identify trends, make forecasts, and inform decision-making based on data-driven insights.