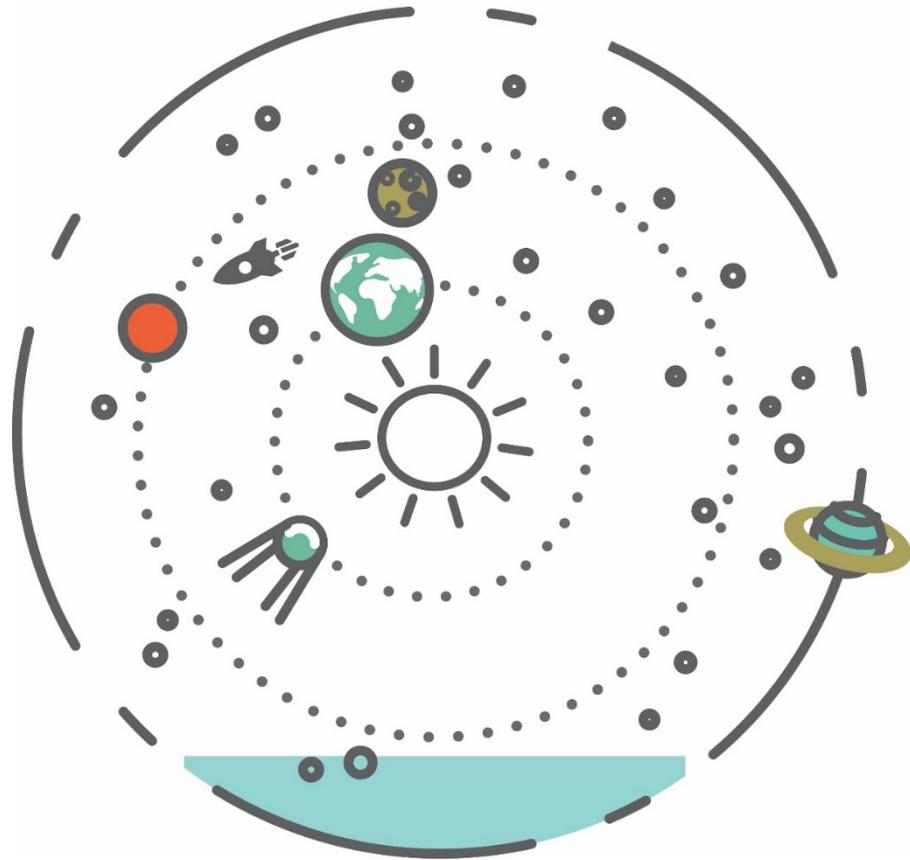


SDA Bocconi
School of Management

SEE Lab
Space Economy
Evolution



SEE LAB

SDA BOCCONI
SPACE ECONOMY EVOLUTION LAB

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RESEARCH PROJECT



OBJECTIVE

We try to answer

- Whether space resource utilization by solely private market is sustainable
- And what type of public-private partnerships are appropriate to enable the development of a space private-sector market.



METHODOLOGY

Based on the data derived from Prof. Sowers' "Commercial Lunar Propellant Architecture" model, we applied

- The Net Present Value to assess the economic sustainability of the project
- And the Monte Carlo simulation to tackle the uncertainties linked to this business.

RESEARCH OUTLINE

Moon mining is a complicated endeavor that involves technical, economic and political uncertainties. We focus on defining a model that encompasses **three blocks**:



ECONOMIC MODEL

It involves **four** steps:

- Identification of commercial uses of Lunar ice;
- Prospecting and exploration of Lunar ice;
- Development of Lunar mining infrastructures;
- Production of commercial goods (propellant).



BUSINESS MODEL

It concerns the identification of two business strategies that can be implemented by private ventures:

- Vertical integration strategy
- Quasi-integration strategy

And the evaluation of their financial feasibility.



RISK MODEL

It models the **probability** of different outcomes of the two business strategies that cannot easily be predicted due to the intervention of random variables.

It is used to understand the **impact of risk and uncertainty** not fully captured by the financial evaluation.

BUSINESS MODEL

STRUCTURE OF THE MARKET



1 EXPLORER

- Reserve definition: location, amount and quality of the ice;
- Mining and recovering technologies rendering



1 MINER

- Mining technologies development
- Production stages:
 - Build phase;
 - Plateau phase;
 - Decline phase.

STRUCTURE OF THE COMPANY



VERTICAL INTEGRATION

It is a means of coordinating the different stages of an industry chain when bilateral trading is not beneficial. A company brings outsourced operations **in-house**.



QUASI-INTEGRATION

Long-term preferred supplier relationship. Such mechanisms also allow the companies involved to retain their corporate identities operating as **stand-alone firms**.

STRATEGY EVALUATION



METHOD

We assume that the business strategy

- Vertical integration
- Quasi-integration

That **maximizes the value** of the company, is considered as the best option to pursue.

BUSINESS MODEL

The evaluation of vertical integration and quasi-integration strategies requires the use of two **methodologies**:

1

NET PRESENT VALUE

- The Net present Value (NPV) is a financial methodology for measuring **value creation**;
- The NPV is defined as
 - the **present values of all cash flows** on the project, including the initial investment
 - with the cash flows being discounted at the appropriate **hurdle rate** which represents the required return of investors (time value of money).
- From a financial standpoint, and if forecasts are correct, an **investment with positive NPV is worth making** since it will create value.
- The NPV is

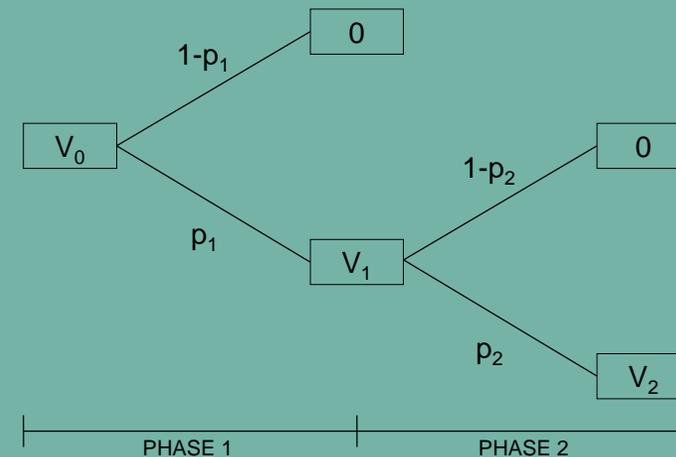
$$\sum_{n=1}^N \frac{F_n}{(1+r)^n} - C_0$$

where F_n are the cash flows generated by the project, r is the applied discounting rate and n is the number of years for which the security is discounted. C_0 are the initial investments.

2

DECISION TREE ANALYSIS (DTA)

- Analyzing **uncertainties** in the exploration (assessment of ice deposits, phase 1, and assessment of recovering technologies, phase 2) of ice deposits;
- Estimating **probabilities** of success (p) and failure ($1-p$) with the exploration (phase 1) and assessment (phase 2) of ice deposits;
- **Discounting** the contingent payoffs or discounted cash flows (v) by probabilities, net of the investment requirements.



BUSINESS MODEL

BUSINESS MODEL				
VERTICAL INTEGRATION		QUASI-INTEGRATION		
Exploring and mining company		Exploring company	Mining company	
KEY ASSUMPTIONS FREE CASH FLOW Derived, computed and projected from <ul style="list-style-type: none"> • Revenues • Costs • Investments 	<ul style="list-style-type: none"> • Revenues based on studies by the Colorado School of Mines (CSM); • Operating costs based on the CSM work; • Investments based on the CSM work. 	<ul style="list-style-type: none"> • Revenues based on the <i>price of information sold</i>; • Operating costs based on the CSM work; • Investments based on the CSM work. 	<ul style="list-style-type: none"> • Revenues based on the CSM work; • Operating costs based on the CSM work; • Investments based on the CSM work and the <i>price of information bought</i>; 	
	PRICE OF INFORMATION Is the technical analysis value of the ice reservoirs of the exploration activity.	<ul style="list-style-type: none"> • Not considered in the model. 	<ul style="list-style-type: none"> • The maximum price that the Explorer is seeking is equal to the one that makes the NPV of the Miner equal to zero. 	<ul style="list-style-type: none"> • The minimum price that the Miner is seeking is equal to the one that makes the NPV of the Explorer equal to zero.
	DTA PROBABILITY Success and failure probabilities of the exploration activity associated with the two phases.	<ul style="list-style-type: none"> • Phase 1: we assume that the success of the acquisition, development and testing of the exploration technology, and in the identification of the location of one (or more) ice reservoir(s) on the Moon is equal to 60%; • Phase 2: we assume that the success of testing the quality and quantity of the ice, and performing a demo extraction procedure is equal to 50%. 		<ul style="list-style-type: none"> • Not applicable
	COST OF CAPITAL Rate of return required by the project's investors.	<ul style="list-style-type: none"> • 19% • The riskiness of the exploring and the mining company is the simple average between the two identified discount factors of stand-alone companies. 	<ul style="list-style-type: none"> • 25% • Based on alternative venture capital investments in "high technology" industries (20%); • Plus an additional premium to estimate the risk/return for the exploration activity on the Moon. 	<ul style="list-style-type: none"> • 13.6% • Estimated with the Capital Asset Pricing Model (CAPM); • Plus an additional premium to estimate the risk/return for the mining activity on the Moon.

BUSINESS MODEL

PRICE OF INFORMATION

- There are only two players: one Explorer and one Miner company.
- This implies a relationship of mutual dependence and exclusivity, essential to balance the **bargaining power** (average price of information).

MAXIMUM PRICE OF INFORMATION

\$ 7.44 b

MINIMUM PRICE OF INFORMATION

\$ 3.70 b

AVERAGE PRICE OF INFORMATION

\$ 5.57 b

EXPECTED NET PRESENT VALUE

- The NPV of the **stand-alone companies** is calculated after the inclusion of the price of information;
- The explorer company sells at \$ 5.57b (revenues);
- The miner company buys at \$ 5.57b (costs).

NPV EXPLORING COMPANY

\$ 0.65 b

NPV MINING COMPANY

\$ 1.93 b

NPV EXPLORING AND MINING COMPANY

\$ 0.11 b

INTERNAL RATE OF RETURN

- The internal rate of return (IRR) estimates the profitability of investments;
- The IRR makes the NPV equal to zero;
- If the **IRR is greater than the cost of capital**, the project is accepted.

IRR EXPLORING COMPANY

33%

IRR MINING COMPANY

20%

IRR EXPLORING AND MINING COMPANY

21%

RISK MODEL

It evaluates the exposure of the ventures to the factors that could lower their profits and lead them to fail. Anything that threatens a company's ability to meet its target or achieve its financial goals is called **business risk**.

BUSINESS RISK

Business risk is associated with the overall operation of a business entity.

These are things that impair its ability to provide investors and stakeholders with adequate returns.

TYPES OF BUSINESS RISKS

- 1 Strategic risk
- 2 Compliance risk
- 3 Financial risk
- 4 Operational risk

IMPACTS

- 1 Revenues
- 2 Operating costs
- 3 Investments

that reflect on the variability of expected cash flows of the company and, subsequently, on the NPV.

METHODOLOGY

The NPV approach assumes that there is only a possible outcome given its **deterministic** input values.

The **Monte Carlo** simulation considers the **factors** of the business risk that can lead to future and unprecedented events (i.e. lower revenues or higher costs).

RISK MODEL

The simulation that we performed

1

- Assumes that both **cost** and **revenue variables** are distributed as **lognormal random variables**, with median values equal to the yearly revenues and costs in the deterministic model.

2

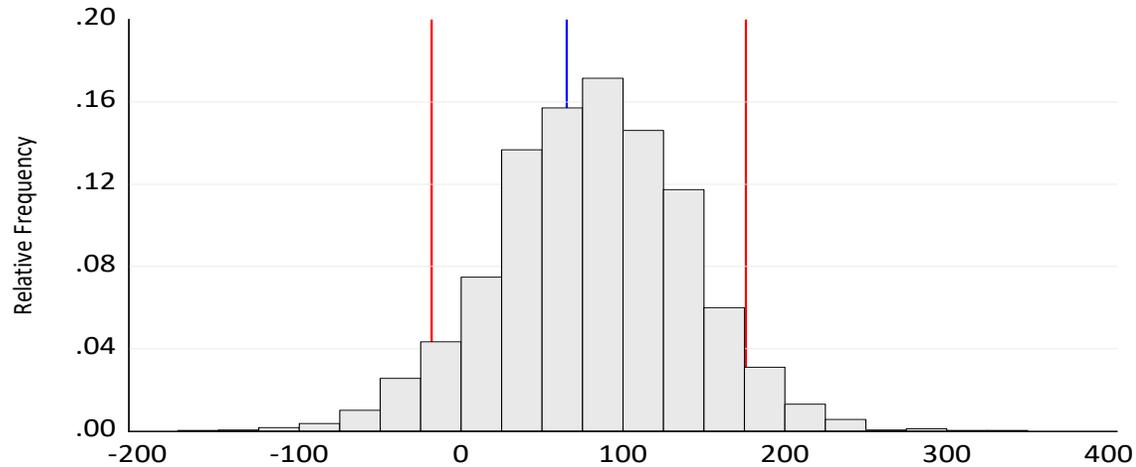
- Replicates **5,000 times** the following steps. At each iteration we calculated a new free cash flow:
 - Revenues and costs are extracted, year by year, from the appropriate distributions;
 - The free cash flow is calculated for the Explorer and Miner;
 - The free cash flow to firm for the Explorer and Miner is discounted by using discount rates from 10% to 50% with 1% increment;
 - Miner's NPV, expected and ex-post Explorer's NPV are computed.

RISK MODEL

Results

QUASI-INTEGRATION

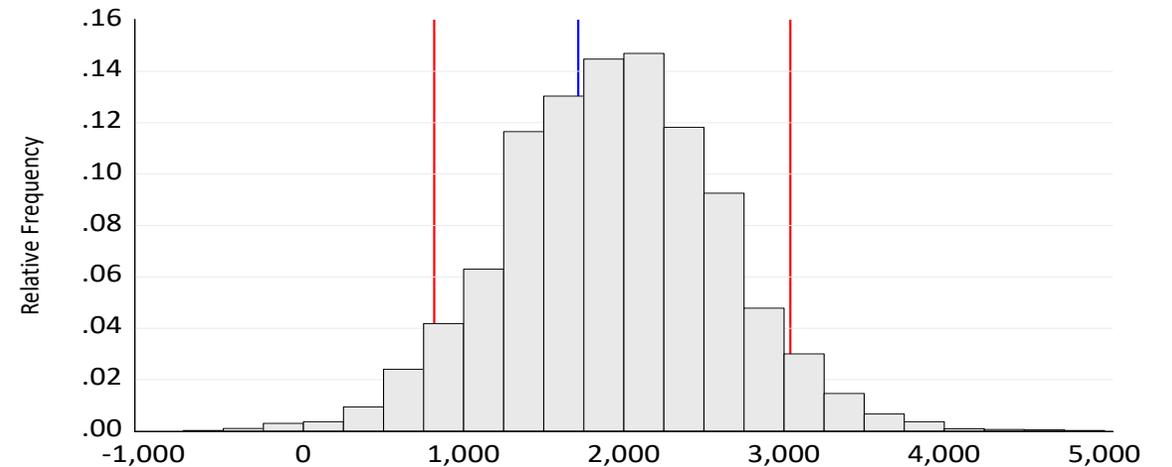
Exploring company



5% and 95% quantiles in red, deterministic value in blue

EXPLORER'S NPV AT 25% DISCOUNT RATE (MLN \$)	
Mean	80
Median	81
Maximum	342
Minimum	-159
Std. Dev.	58
Jarque-Bera	21.84
Probability	0.00

Mining company



5% and 95% quantiles in red, deterministic value in blue

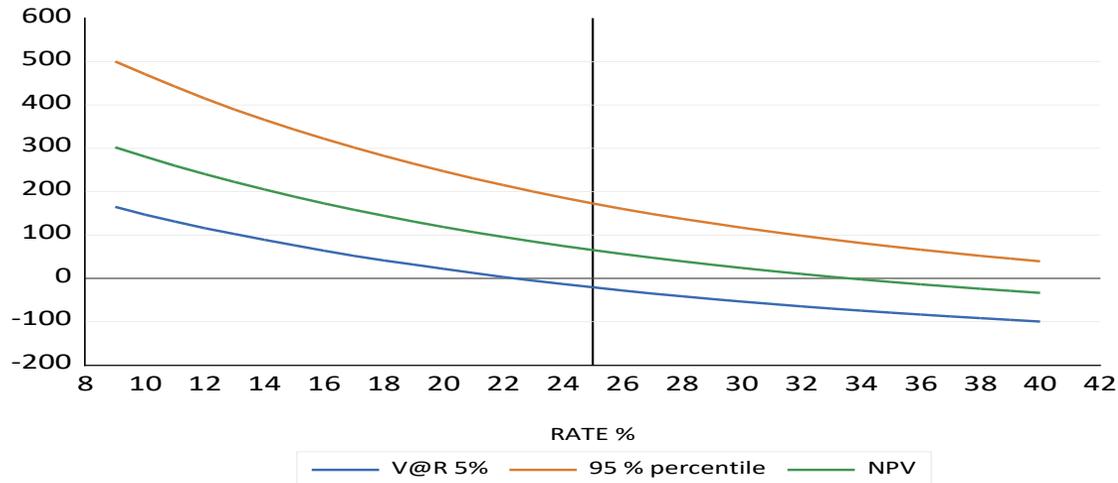
MINER'S NPV AT 13,62% DISCOUNT RATE (MLN \$)	
Mean	1,932
Median	1,036
Maximum	4,981
Minimum	-569
Std. Dev.	676
Jarque-Bera	20.56
Probability	0.00

RISK MODEL

Results

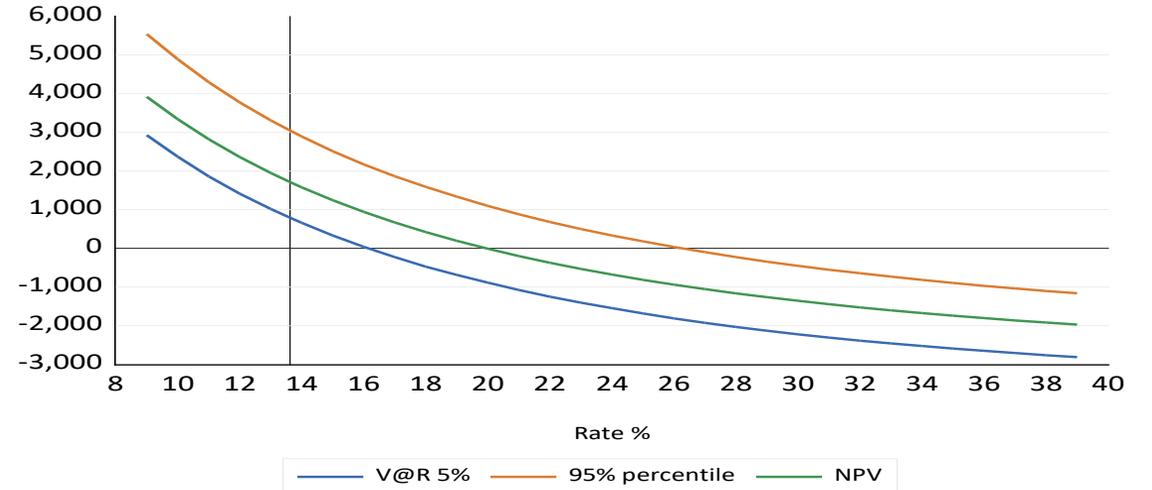
QUASI-INTEGRATION

Exploring company



NPV at discount rate of 25% (MLN \$)		Internal Rate of Return (IRR)	
5% percentile	-20	22%	Lower Bound (5%)
Deterministic	≈ 65	33%	IRR
95% percentile	172	47%	Upper Bound (95%)

Mining company



NPV at discount rate of 13.62% (MLN \$)		Internal Rate of Return (IRR)	
5% percentile	795	16%	Lower Bound (5%)
Deterministic	≈ 1,715	20%	IRR
95% percentile	3,046	26%	Upper Bound (95%)

CONCLUSIONS

- 1 The **value created** by a stand-alone strategy, adopting a quasi-integration business organization, is higher than a vertical integration business strategy.
- 2 A higher IRR of the vertical integration strategy does not validate its implementation because the company is exposed to the risks associated with both the exploration and business uncertainties.
- 3 The probability of negative NPVs is negligible for the Miner but not completely insignificant for the Explorer.
- 4 The expected profitability and high IRRs of both the Exploration and Mining operations imply that they may attract private investors, in addition to Public Grants.
- 5 These findings depend on the data utilized in NPV calculations. Moreover, this is a work in progress as we have not included transportation agents and the ones dealing with storage of propellant in various Moon-Earth orbits in the business model.

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THANK YOU FOR LISTENING

EXPLORATION FINANCING

STRUCTURE OF THE COMPANY



EXPLORATION FINANCING

Technology Development

Hardware Development

Launch Services

Mission Operations

WHAT FINANCE

Parent Company

Governmental Institutions

External Investors

WHO FINANCE

Tracking Shares

Guaranteed Loan

Equity Investment

HOW FINANCE

PHASE 1

PHASE 2

WHEN FINANCE

EXPLORATION FINANCING

	EXPLORATION DIVISION	EXTERNAL INVESTORS
T₀		
Company Value	\$ 0.16 b	
Investment – Tracking Shares Book Value	\$ 0.10 b	
Share Percentage in (%)	100	
T₁		
Company Value	\$ 0.48 b	
Investment by External Investors		\$ 0.2 b
Share Percentage in (%)	59	41
T₂		
Company Value	\$ 1.01 b	\$ 1.01 b
Share Percentage in (%)	59	41
Capital Gain in (%)	532	123