Comparison of Oil and Gas Industry Business Planning with Space Resource Industry Planning

by

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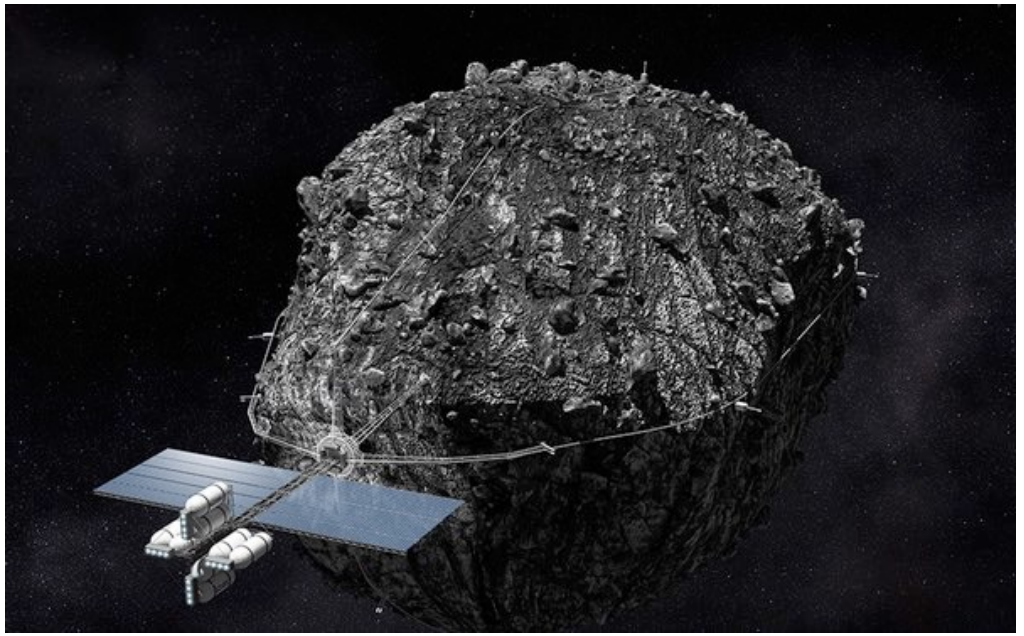
Shell Oil Company

Credit: Saudi Aramco



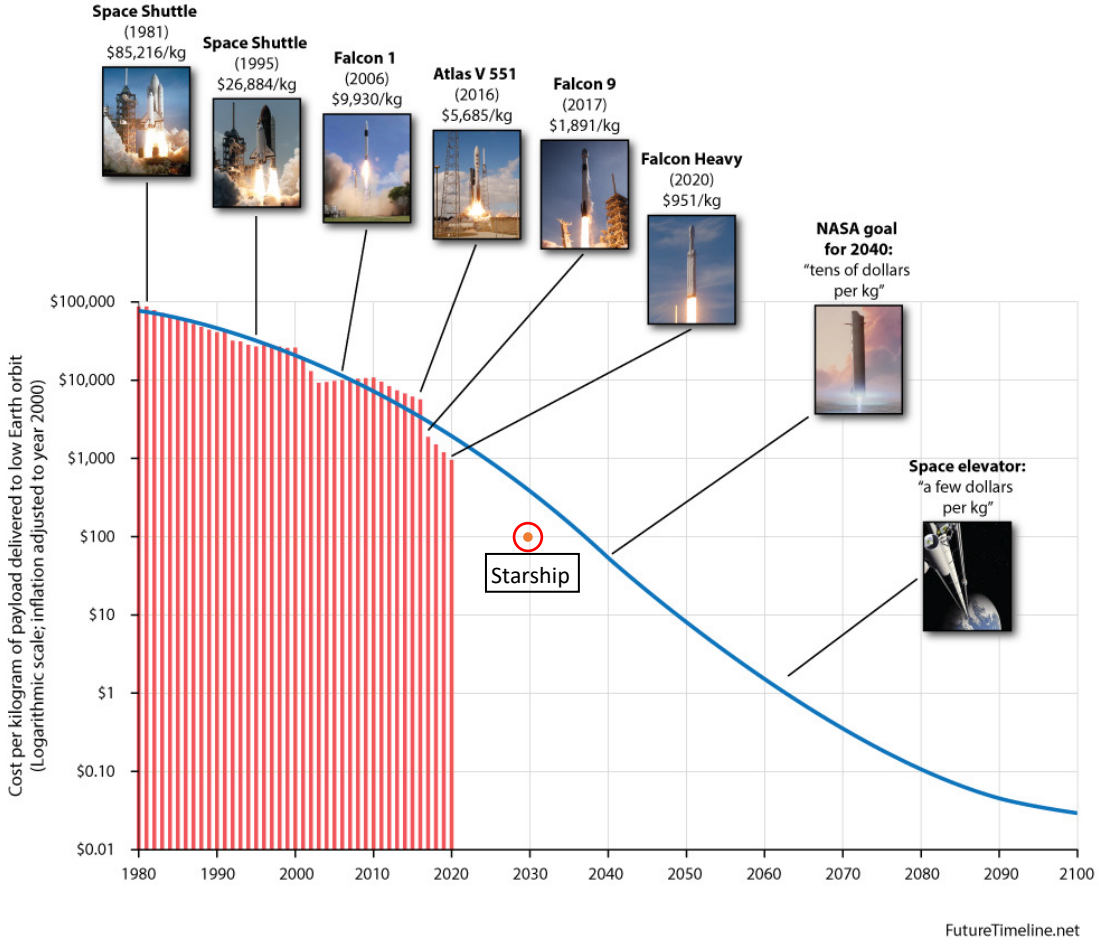
(credit: Brian Versteeg/Deep Space Industries)

The opinions presented herein are solely those of the author

Space Resource Roundtable
Colorado School of Mines
June 7-10, 2022

Why consider extra-terrestrial opportunities now?

- *Cost disruption*
  - *SpaceX and other companies are expected to dramatically reduce launch costs within the decade.*
- *Energy Transition*
  - *Industry must repurpose itself toward carbon free energy.*
  - *Window of opportunity to use current cash flow to start new business opportunities*
- *Maturing of in-situ resource production technology*
  - *'Living off the Land' dramatically reduces cost*
- *First mover advantages*
- *Space resource economy will dominate 'someday'*
  - *Seek low hanging fruit to get in the game*



Example of O&G Project economics

Establishing Minimum Economic Field Size and Analysing its Role in Exploration Project Risks Assessment: Three Examples*

Virendra Singh[1], Elena Izaguirre[1], Ivan Yemez[1], and Horacio Stigliano[1]

Search and Discovery Article #41827 (2016)**
Posted July 11, 2016

*Adapted from extended abstract prepared in conjunction with oral presentation given at AAPG GEO 2016, The 12th Middle East Geosciences Conference and Exhibition March 7-10, 2016, Manama, Bahrain

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Abstract

The Upstream E&P industry is one of the most risky businesses to invest in and is dominated by different types of uncertainties: political, economic, social and technical. There are many areas that can lead to optimistic or pessimistic risk assessment. Overestimation, underestimation, misidentifying critical risks, overselling and underselling projects are some of the common problems that are encountered. For

Technical Risking

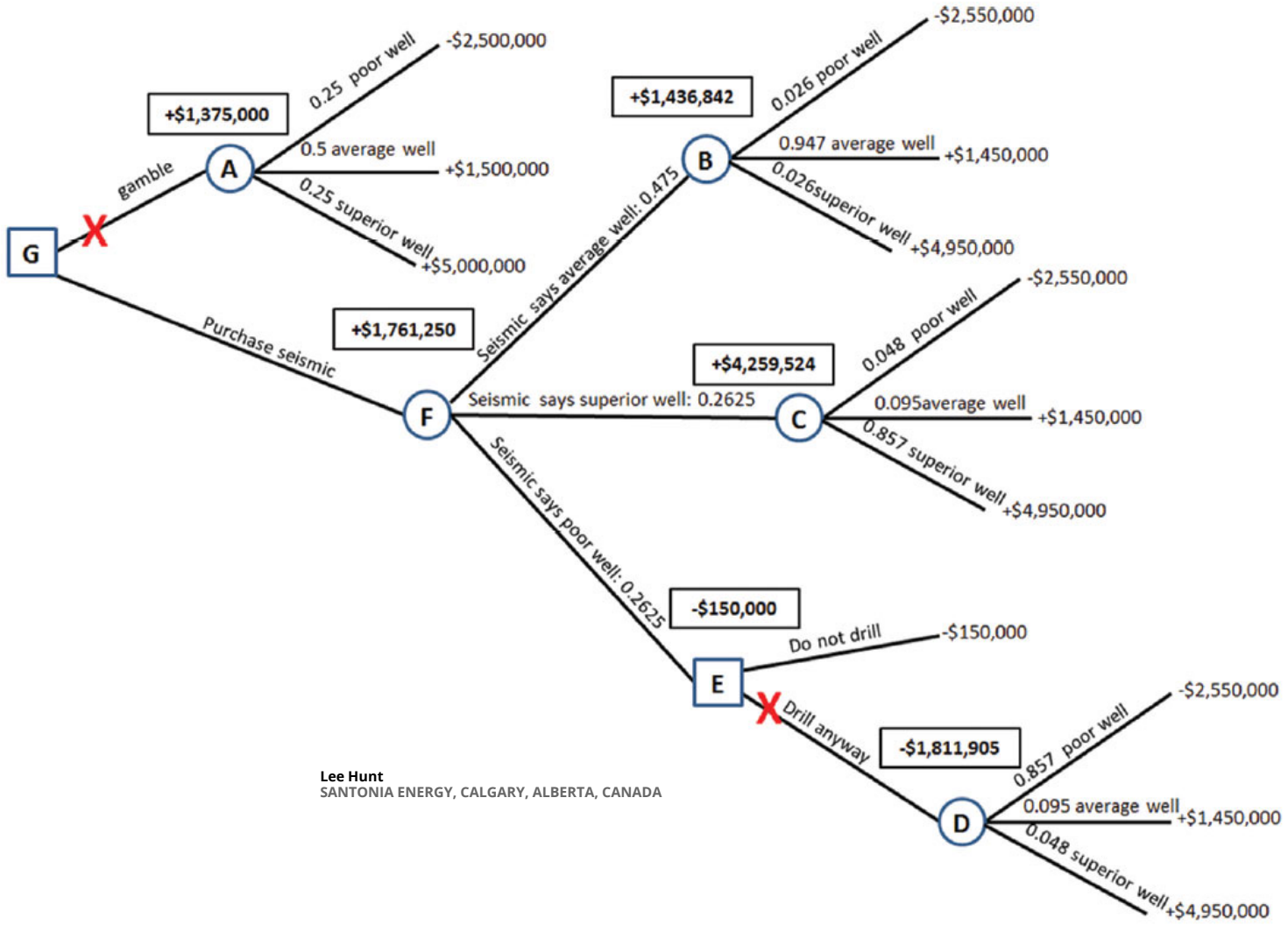
- Hydrocarbon source rock components (P_{source})
- Timing of trap formation, hydrocarbon migration and preservation ($P_{timing/migration}$)
- Reservoir rock components ($P_{reservoir}$)
- Trap geometry (closure) components (P_{trap})
- Seal effectiveness (P_{seal}).

The P_g is obtained by multiplying the probabilities of the occurrence of each of the five factors of the play concept.

$$P_g = P_{source} \times P_{timing/migration} \times P_{reservoir} \times P_{trap} \times P_{seal}$$

Example: 0.8*0.8*0.8*0.8*0.8=0.33

Decision Trees and Value of Information



Lee Hunt
SANTONIA ENERGY, CALGARY, ALBERTA, CANADA

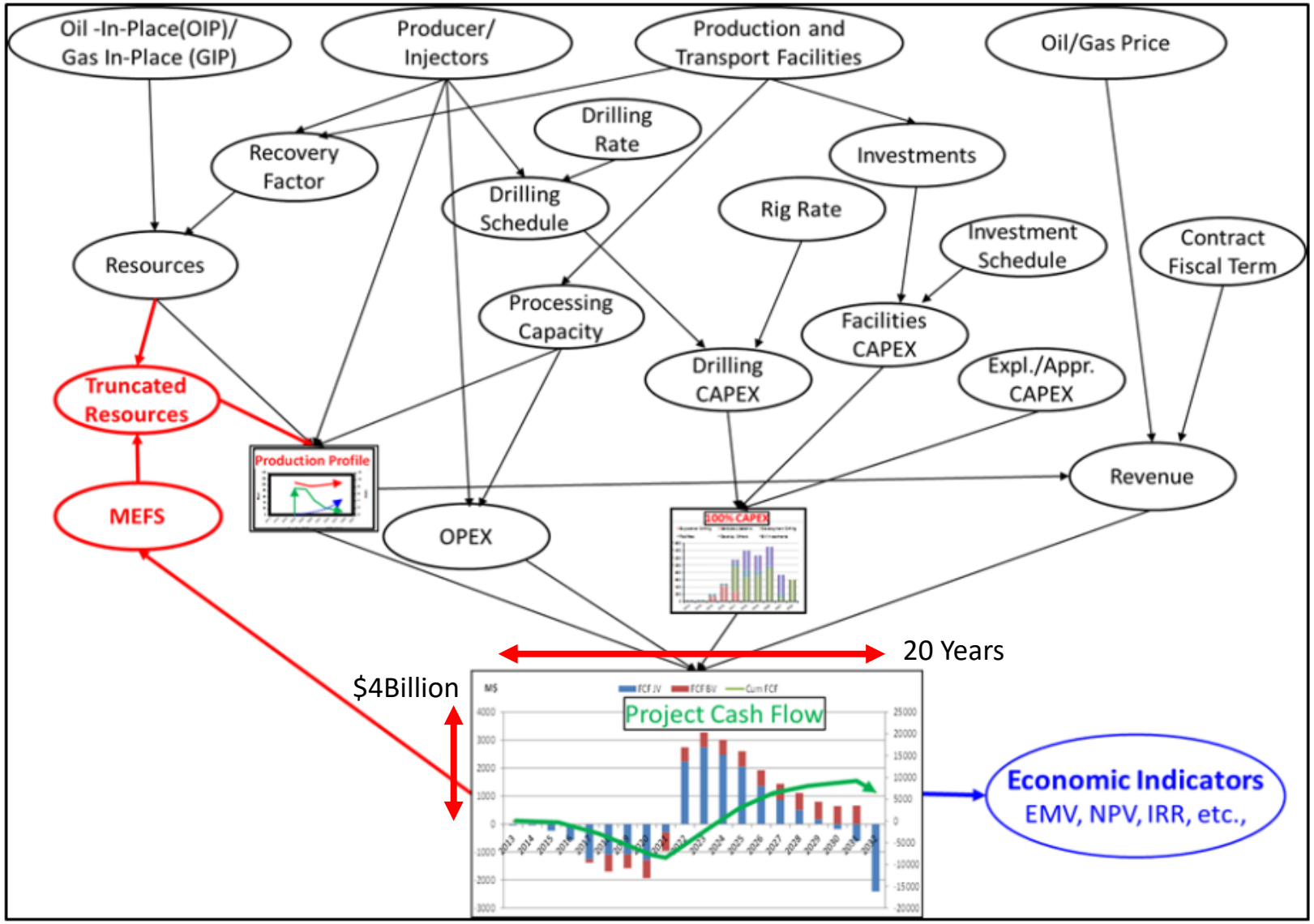


Figure 1. Influence diagram for Integrated Risk/Opportunity Analysis of an E&P Project.

Cases		Case-1: Gas and Water Reinjected		Case-2: Gas and Water Reinjected (Permability Sensitivity)		Case-3: Gas Exported (Water injection sensitibity)	
Description							
Develoment Concept		Sebsea Tie back to Leased FPSO		Sebsea Tie back to Leased FPSO		Sebsea Tie back to Leased FPSO	
Well Type		Vertical/Slanted		Vertical/Slanted		Vertical/Slanted	
Well appraisal		1		1		1	
Total well		14	15	13	15	23	24
Fluid Type		Volatile Oil	Volatile Oil	Volatile Oil	Volatile Oil	Volatile Oil	Volatile Oil
First oil Date from date of discovery		5.5 Years	8.5 years	5.5 Years	8.5 years	5.5 Years	8.5 years
Plateau duration	Year	5	6	3	4	8	9
Field Life	Year	24	24	24	24	24	24
Resources							
Pmean untruncated resources	MBOE	232	232	232	232	232	232
P_g	%	39.7	39.7	39.7	39.7	39.7	39.7
Production							
Cumulative production	MBbl	488	488	443	464	422	450
Oil rate (Peak production)	Bbl/d	90000	90000	110000	110000	110000	110000
Gas rate (Peak production)	M stcf/d	162	162	200	200	200	200
Cost Estimate							
Exploratory phase	MUS$	164	164	164	164	164	164
CAPEX	MUS$	4461	4278	3939	4383	5939	5967
OPEX	MUS$	7007	6993	6609	6751	5593	5208
ABEX	MUS$	547	520	467	528	765	780
Total Cost	MUS$	12179	11955	11179	11825	12461	12118
Resources Truncated Case							
Pmean truncated	MBOE	456	488	443	464	422	450
WACC+2%	%	10.47	10.47	10.47	10.47	10.47	10.47
MEFS	MBOE	**207**	**246**	**186**	**204**	**151**	**167**
P_e	%	**14.90**	**12.40**	**17.00**	**15.00**	**20.00**	**18.00**
EMV	MUS$	-2.3	-21.3	6.0	-12.9	27.9	6.1
TIR Risked	%	12.24	10.16	13.10	11.12	14.51	12.93

Table 4. Summary of different development scenarios and MEFS Estimates for Example 3.

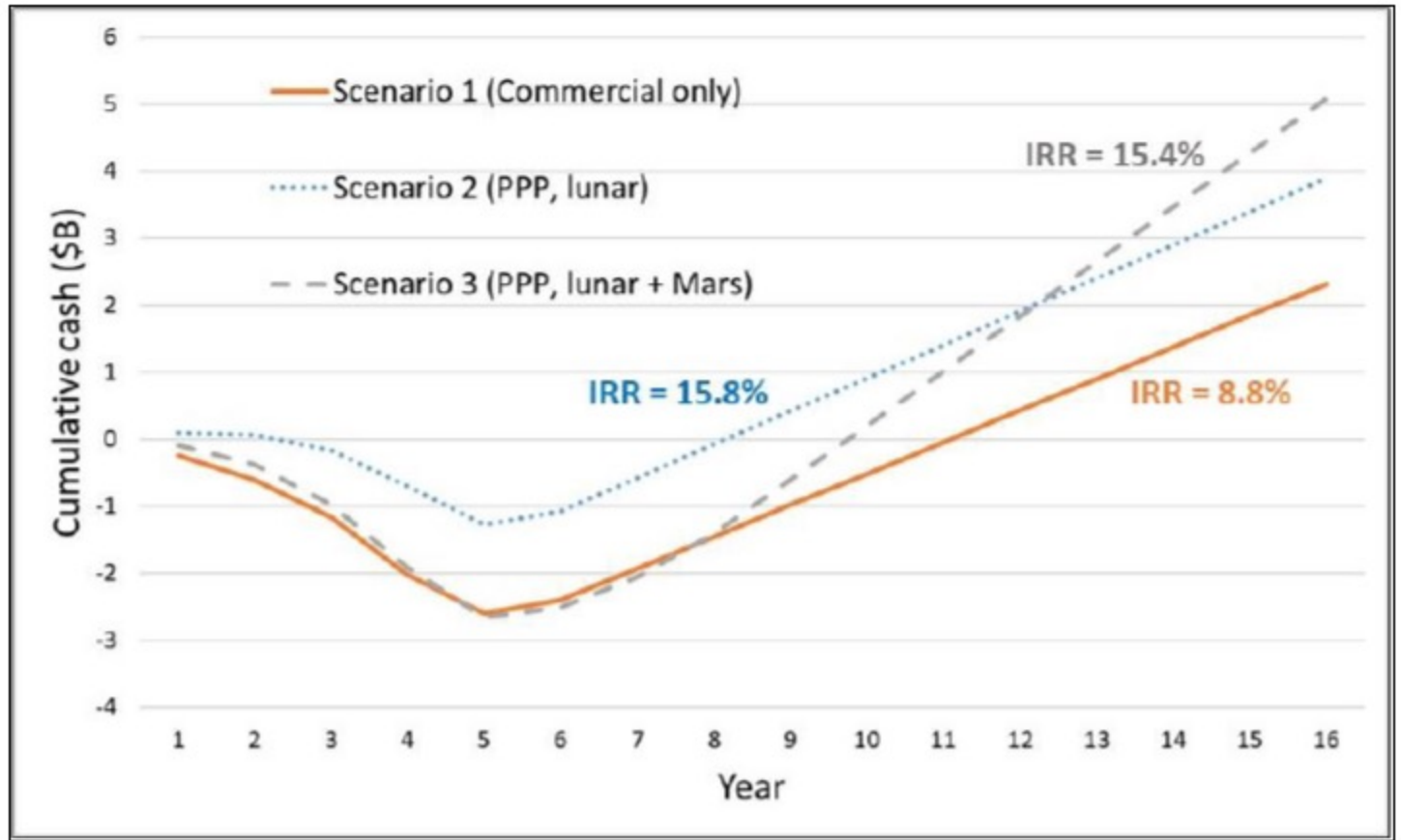


Figure 8. *Cumulative cash for the Propellant Production Company.*

George Sowers, "The Business Case for Lunar Mining" preprint

Sample business cases

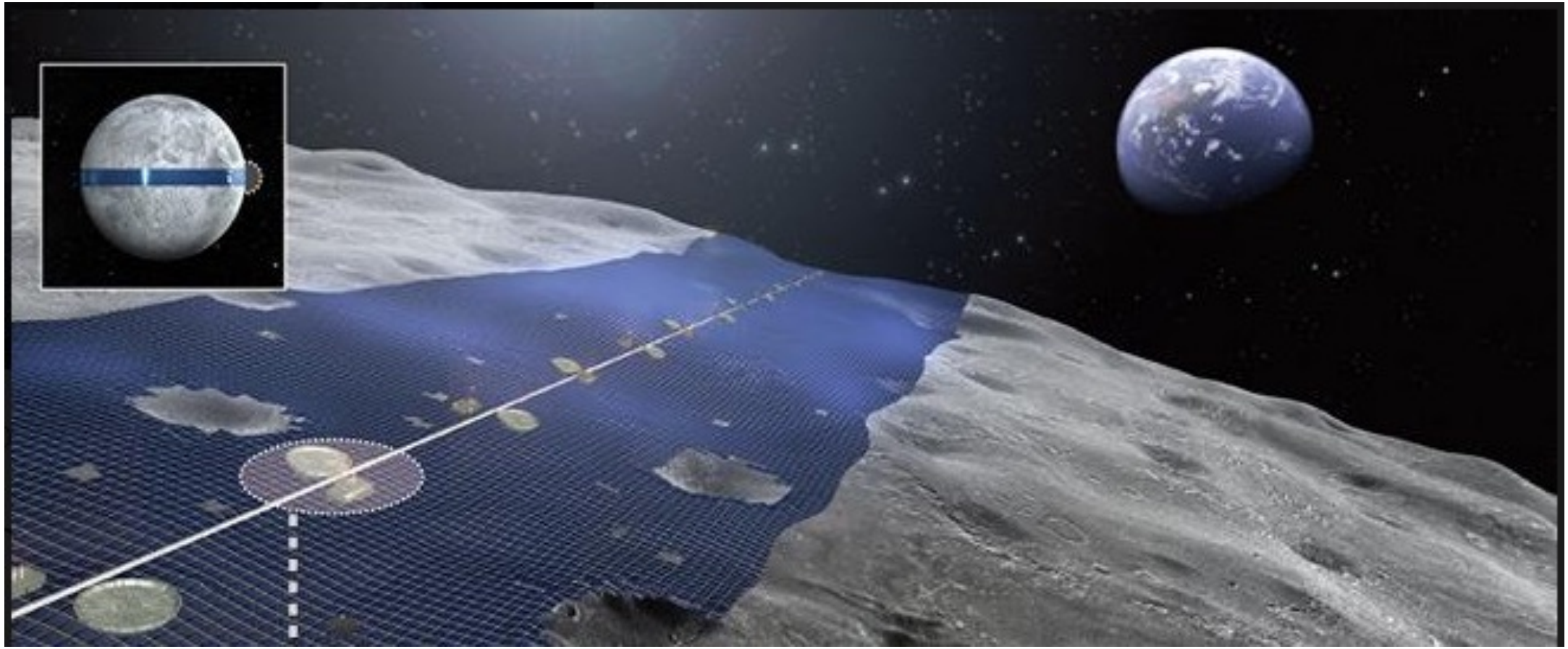
Assumptions:

- *SpaceX Starship reduces cost to orbit 10x, to $200/kg by 2030.*
- *Industry will stick with its core mission as an energy/fuel company. Opportunities that merely seek government contracts are excluded, but these can be part of a larger plan.*
- *Opportunities for mining are excluded, unless related to energy.*
- *First revenue no later than 2030 (e.g. probably no He^3 cases)*

Examples:

- Lunar electric company – own solar cells on Moon, likely produced locally, to provide power for customers there.
- Own the extraterrestrial propellant value chain – produce water from the moon or asteroids and transfer it to high orbits (LEO likely not competitive).
- Mine asteroids for water (fuel), or metals for the electric economy (platinum, lithium, etc)
- Own orbiting solar stations that beam power back to earth (maybe just own the ground receiver stations).
- Provide SpaceX with platform near gas field for launch/landing with methane provision.

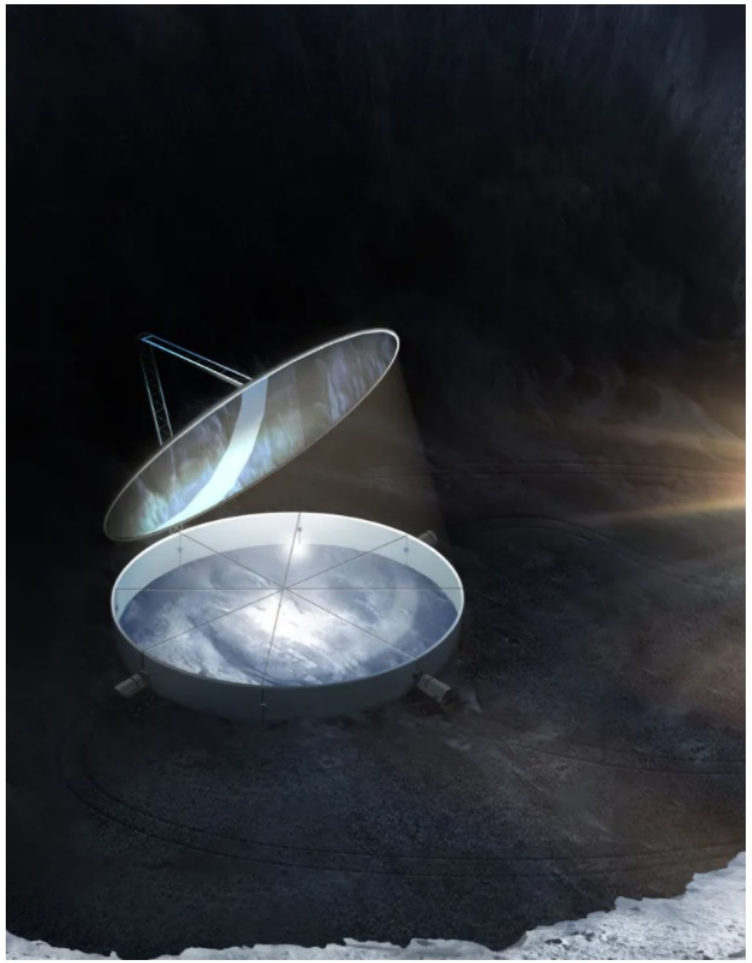
Luna Ring – Shimizu Corporation



Shimizu Corporation

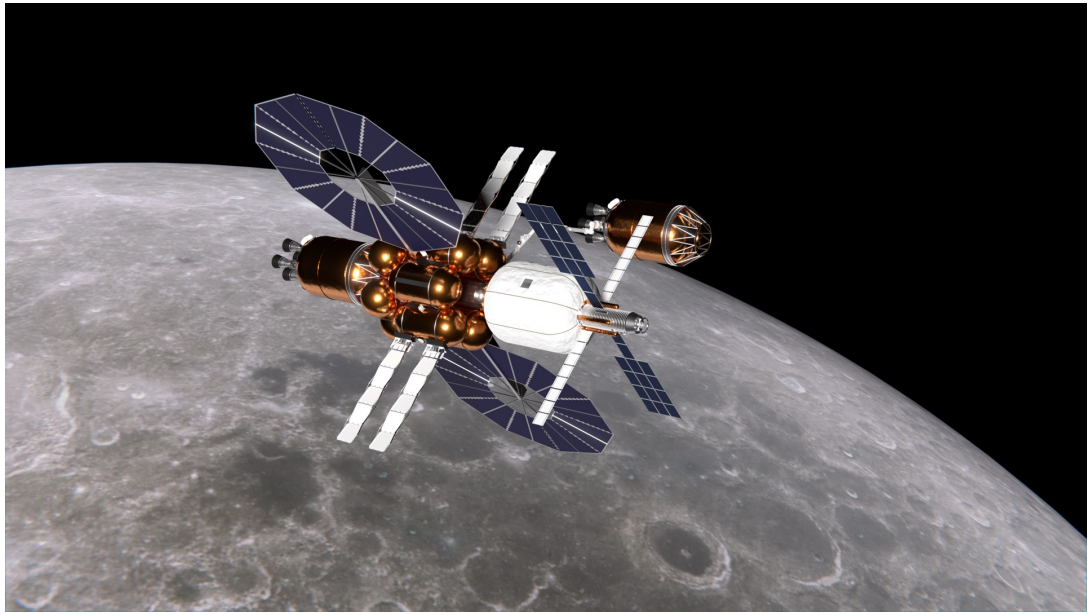
400 km wide
100 TW
World energy consumption 2019: 18.5 TW

In situ resources



In this proposed design, mirrors use sunlight to heat the water ice in the lunar soil. The water vapor is transferred into tanks on the side.

COURTESY GEORGE SOWERS



ULA/Lockheed Martin/Bigelow lunar depot concept

Lunar orbiting propellant depot

EML1 **EML2** **GEO**

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Investigation of Equatorial Medium Earth Orbits for Space Solar Power

Michael A. Marshall, Richard G. Madonna, *Senior Member, IEEE,* and Sergio Pellegrino

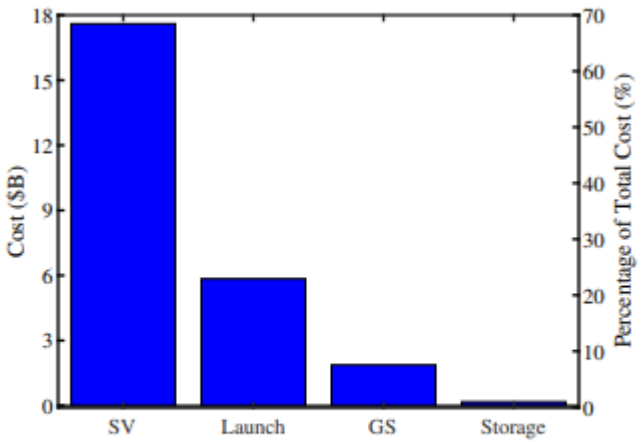


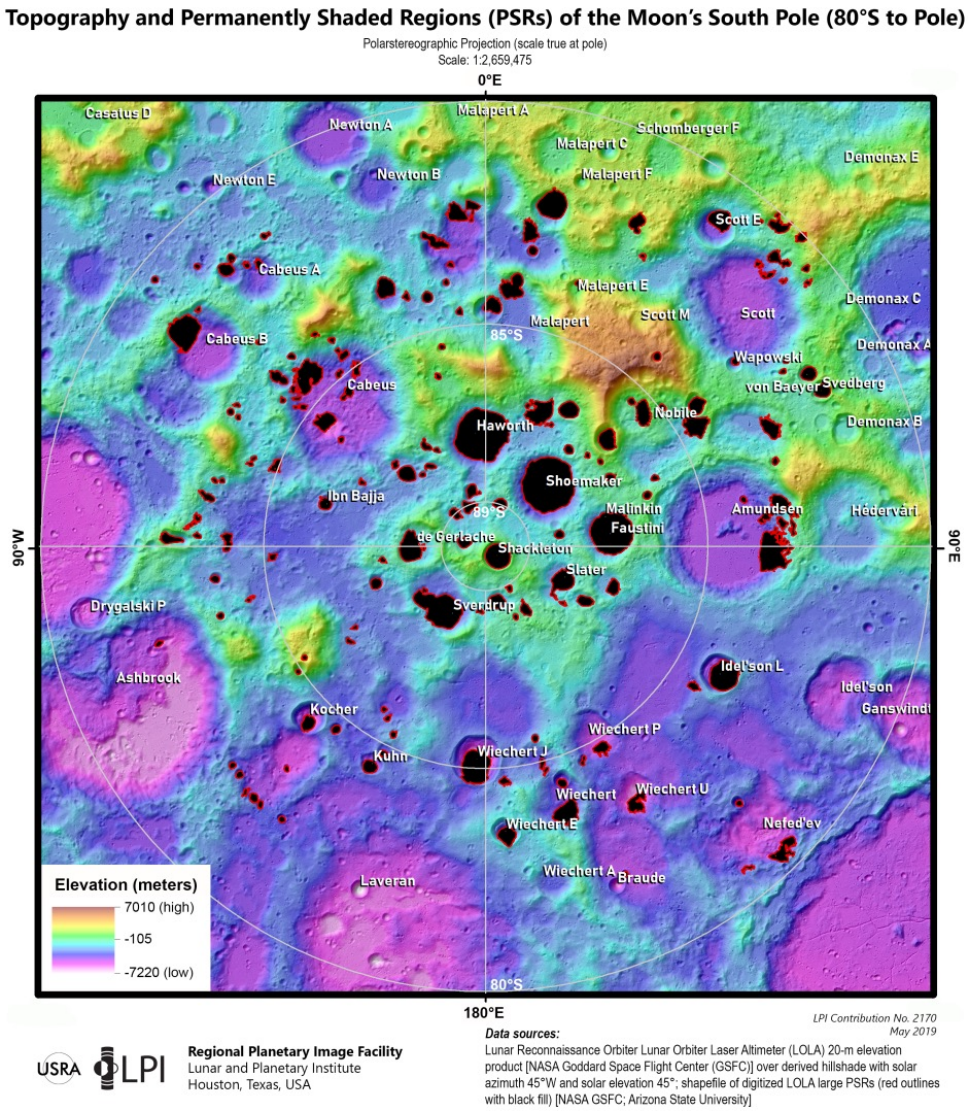
Fig. 9. LCOE breakdown for one GEO power station and ground component. SV and GS denote space vehicles and ground segment, respectively. Most of the cost resides in the space vehicles.

Total cost quoted at $2320/MWh
Ground station alone would be $200/MWh
Total cost needs to be <$50-70/MWh in large markets

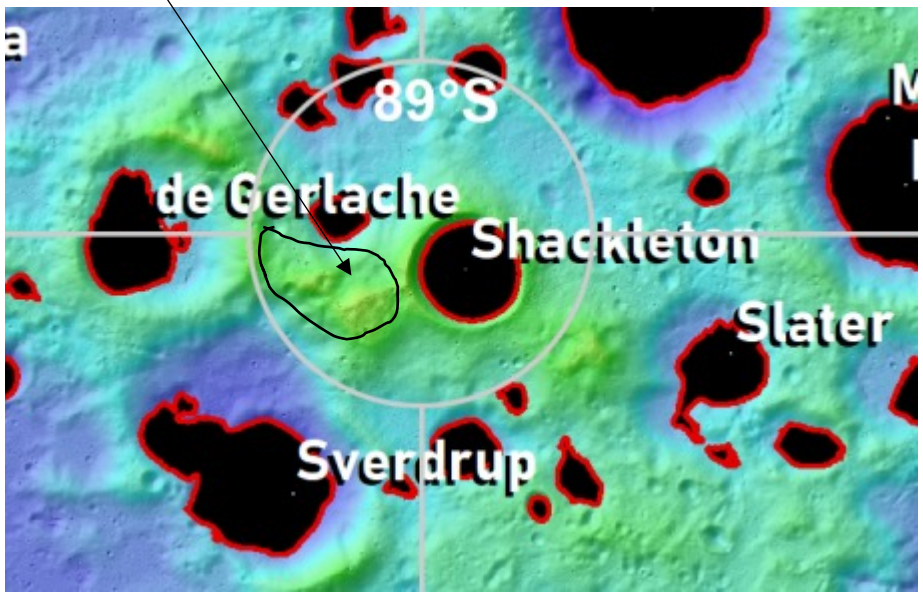
Still quite a ways to go before economic viability

SpaceX “Phobos” platform – “Deimos” also exists

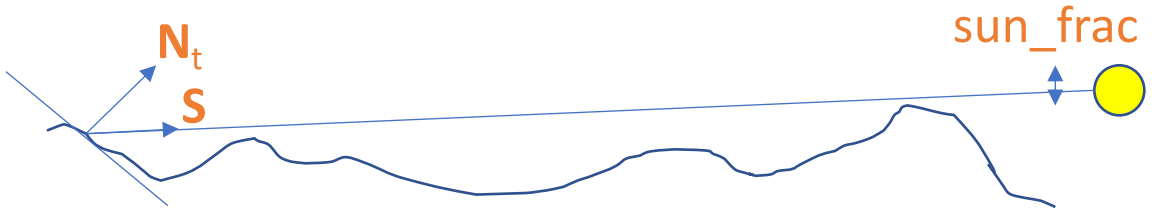
Lunar south Pole



- *Lunar axis at 1.6° compared to Earth's 23.5°*
- *Permanently Shaded Regions*
- *"Peaks of eternal light"*
  - *First mover advantage?*



Insolation modeling

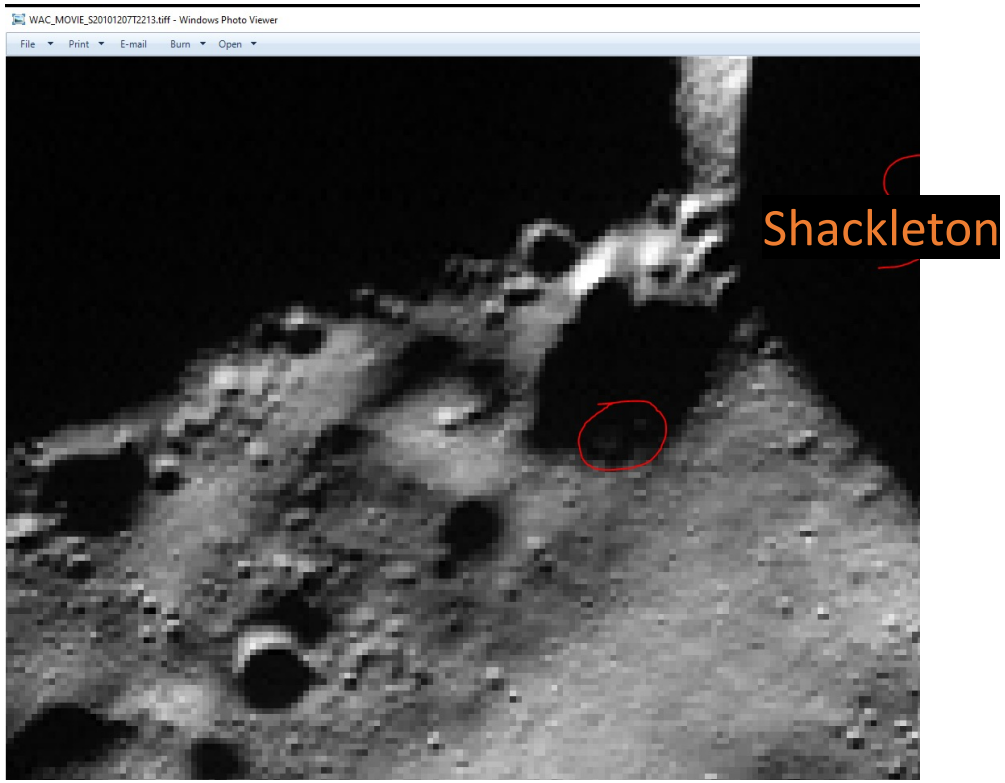


Combine DEM with Sun ephemeris

Compute horizon functions: elevation as function of azimuth

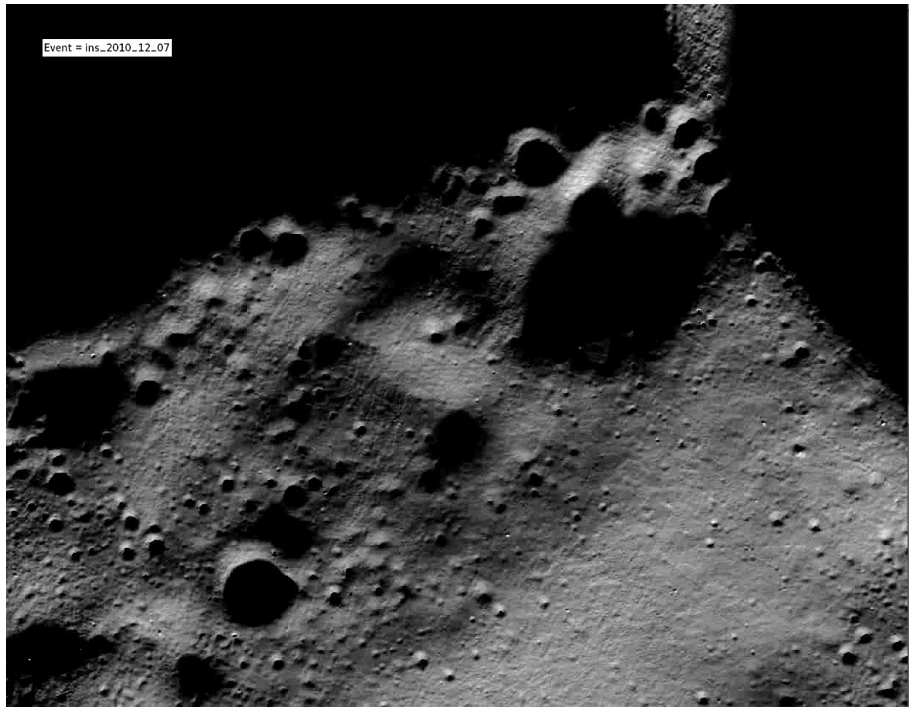
Insolation=($\mathbf{N}_t \bullet \mathbf{S}$) * sun_frac

Accuracy check:



Actual LROC image on Dec. 7, 2010

Camera Resolution: 100m

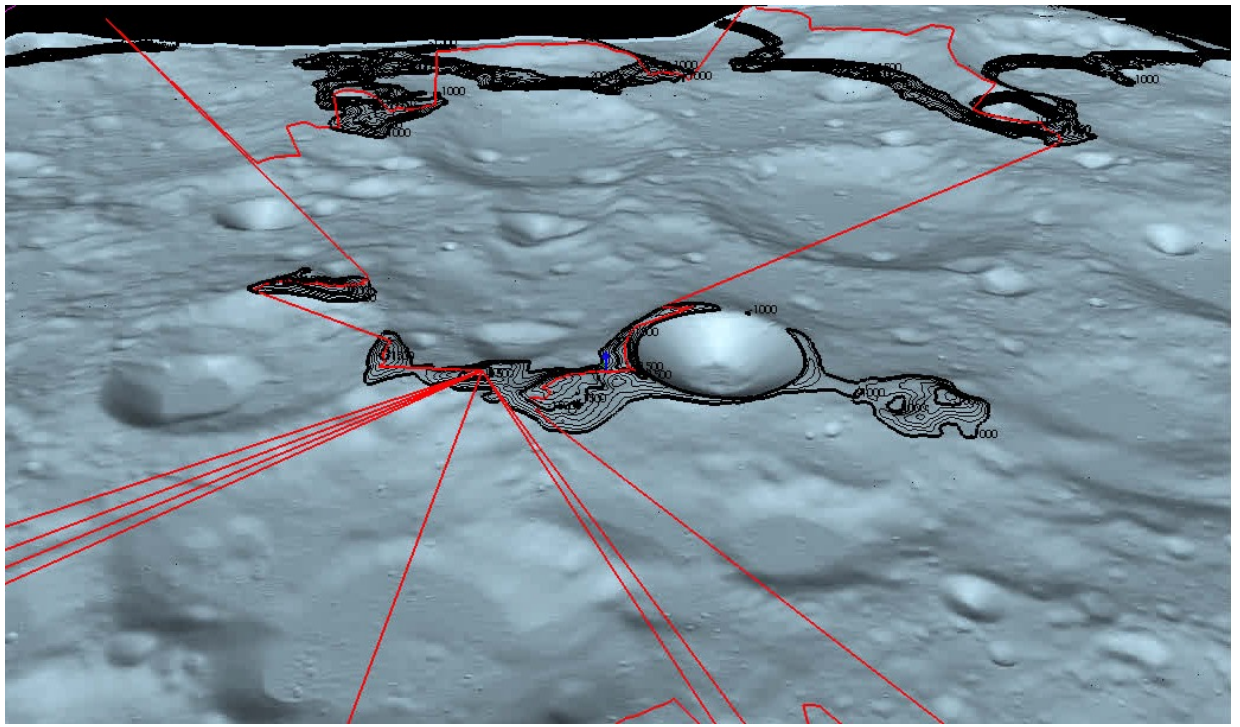


Modelled insolation on Dec. 7, 2010

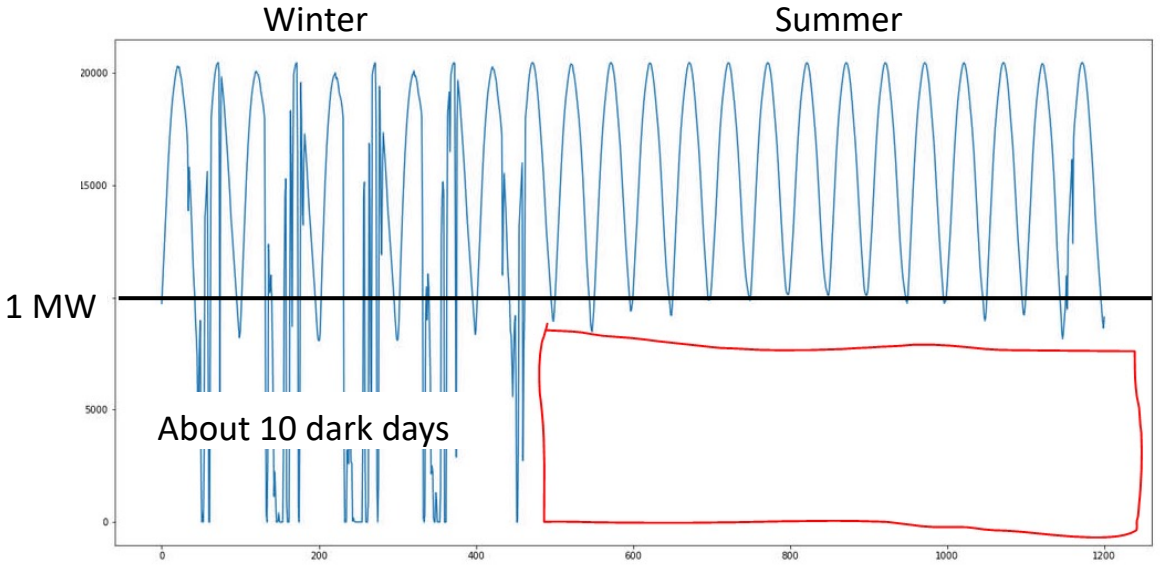
DEM Resolution: 10m

Lunar South Polar power

- Visualization
  - 3D terrain
  - Horizon function
  - Partial Contours



Power profile for array in 2030



Power modelling for Lunar Resources

- In situ solar panel fabrication

Still looking for:

- Confidence in demand estimates
- Competition

Summary - What does O&G Industry bring?

- *Large Project management*
  - Capital intensive
  - Complex
  - Rigorous Risk accounting
  - Cost-effective commodity production and delivery
- *Long View*
  - Revenue likely years away (profit even further)
  - Decades-scale projects, not ‘mission’
- *Legal*
  - Legal framework not fully defined
  - No land ownership, but recognized expectation of non-interference with operations
- *Technical*
  - Subsurface imaging
  - Pipeline
  - Drilling?

Thank you!