A Prospect Evaluation for Lunar PGEs

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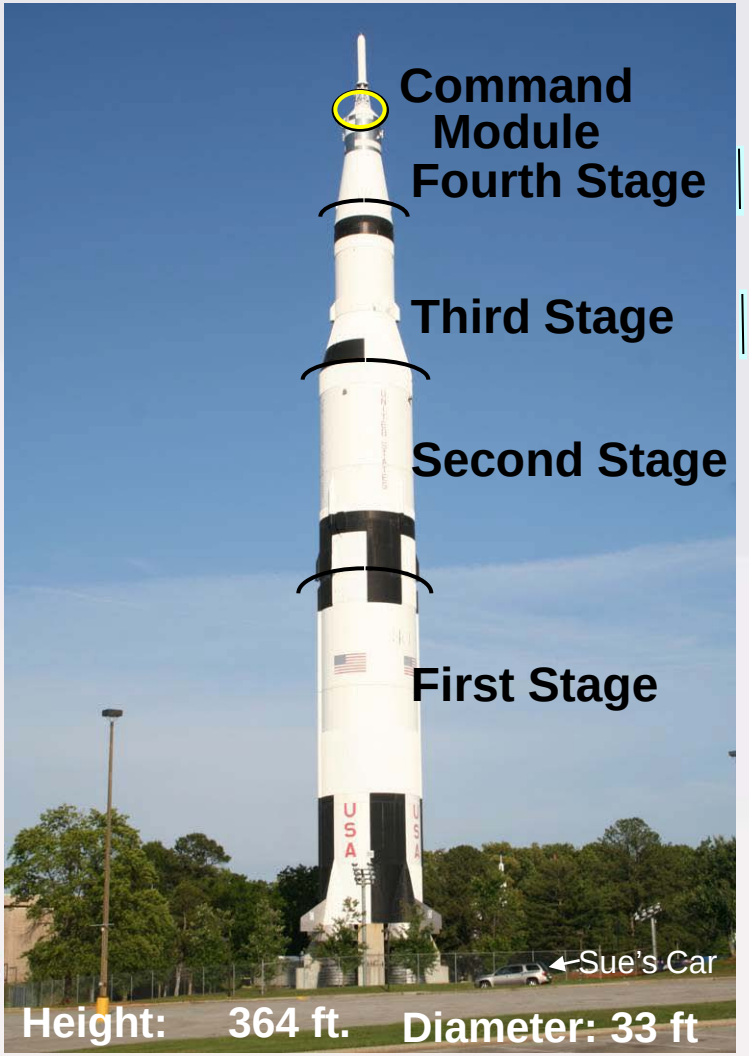
SATURN V



	Weight (lbs.)	Altitude (miles)	Velocity (mph)
Command Module	12,807		
Service Module	54,064		
Lunar Module	32,299		
Trans Lunar Burn	265,000	239,000	24,500
Orbital Burn		115	17,500
Third Stage	1,037,000	114	15,300
Second Stage	4,881,000	38	6,000
First Stage	6,600,000		

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Informal Definitions

- Resource – When something occurs at a concentration above “background” or “normal.”
- Ore – A resource that is economically productive to recover and market.
- Evaluation – The process of determining the value of a resource. Note this is a continuous and non-linear process.
- Reserve – An ore whose characteristics are sufficiently well known to do detailed planning for recovery with specific, detailed financial estimates.

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Steps in an Evaluation

CAVEAT: While terrestrial analogs must be used with caution they can also give a framework for thought and guidance. The general process for evaluating the possibility of resource being an ore is well developed and is applicable to the problem at hand. Geology, engineering, legal and financial considerations are integral part of an Evaluation, the purpose of which is to permit a fiscal decision.

To begin ➔

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Steps in an Evaluation: I

The Obvious Stuff

1. What metals (almost always plural)
2. Where is it
3. Transportation costs
   A. To and from the site for men, materials, energy, and everything else
   B. Within the mining operation
4. What is the geology, shape, size, grade, etc. of the deposit

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Steps in an Evaluation: II

The Other Stuff

5. Legal constraints and considerations
6. Engineering the Processing
   - A. Mining
   - B. Milling – each of the following is commonly a multi-step process
     - i. Size reduction
     - ii. Size separation
     - iii. Beneficiation
   - C. Recovery (thermal (smelting for example), electro-winning, refining, etc.)
7. Market Analysis
8. Valuation (what is it worth - $)
9. Cost of funds
10. Risk Analysis

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Starting Questions: I

1. How do the PGEs occur in the regolith? Terrestrial examples suggest possibly
   A. Free, native PGE or as free PGE minerals
   B. In other metals
   C. In sulfide minerals
   D. In chromite
2. Locked phases?

NOTE: The above two items are frequently hideously complex and utterly essential parameters in the financial viability of a project.

3. Is there more than one source? If so what are their relative magnitudes?
4. Elements of Evaluation which the above three affect
   1. Ore body definition – the techniques used are totally dependent on this one fact.
   2. Extraction techniques
      1. Beneficiation
      2. Recovery

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Starting Questions: II

5. Why are the PGEs there? What is the genesis of this resource? This is critical as it guides exploration within a deposit and for new deposits. It can inform many of the other steps in the evaluation.

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Thoughts from ISRU at NASA: I

1. What is the down mass and the up mass at each point?
2. Where does the energy come from for each surface process?
    1. Chemical
    2. Thermal (solar or nuclear)
    3. Photoelectric
    4. Thermal electric (wells)
3. How much autonomy for each component and system? Does "human-in-the-loop" help or cause problems, especially with Earth-bound personnel and the time lag?
4. How much mass has to be moved at each processing step: mining, milling, beneficiation, recovery?
5. How integral do you want each of the systems that do the proceeding processes?

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Thoughts from ISRU at NASA: II

6. Sensitivity to feedstock that is outside of design criteria. For example what happens if a competent rock gets into a hopper or the concentration of sulfur, phosphorous, or a halide is higher than expected? Or lower than expected?
7. Consumables?
8. “Non-terrestrial” physics i.e. things that happen, like static charging due to abrasion, that may not be a problem on Earth but could be a major factor on the Moon.
9. Size reduction and size sorting are high mass operations. They are also likely to have lots of abrasion. Beneficiation may also follow this pattern. Remember tails must be removed from the milling site or you bury yourself in your own wastes.
10. Recovery processes typically are either very high temperatures (>1000˚ C) or involve aqueous processes. Both are obvious challenges in a lunar environment.

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