Mike Jude, Ph.D.

Risk Assessment of Space Mining Ventures Using Decision Modeling and Monte Carlo Simulation

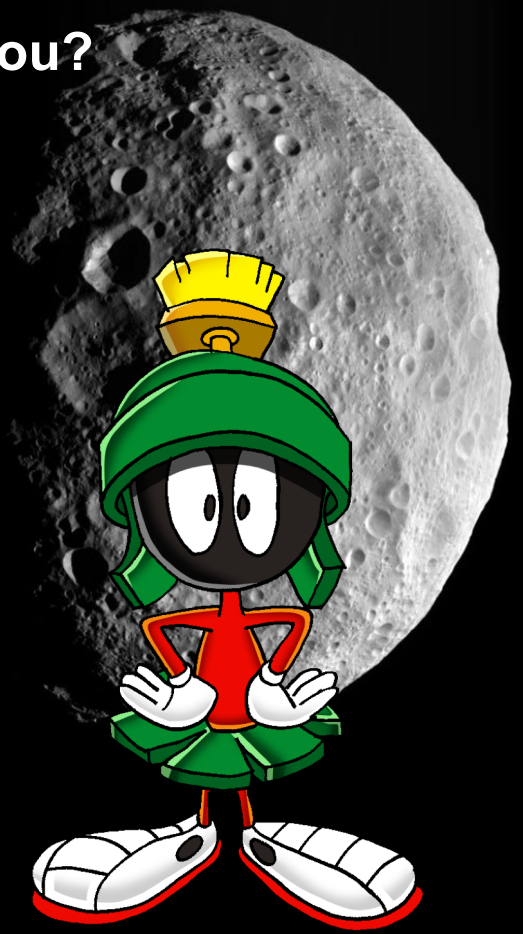
If You Could Invest In Asteroid Mining….Would You?

If not, why not?

Might lose your money?

Might take too long to realize a return?

Might make more money investing in other things?



Problem Statement

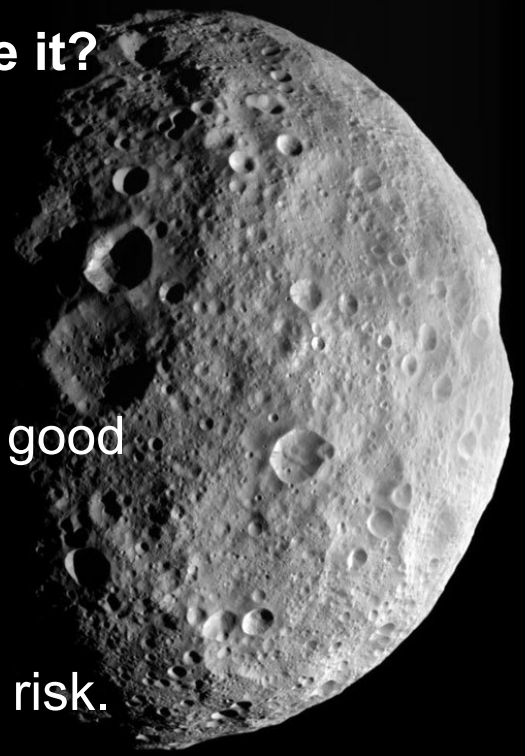
Current estimates of space mining viability do not adequately factor risk into their analysis. By doing an assessment of the variables that impact the financial analysis of space mining ventures, this study seeks to determine the impact of risk to arrive at a more realistic assessment of space mining viability.

Research Questions

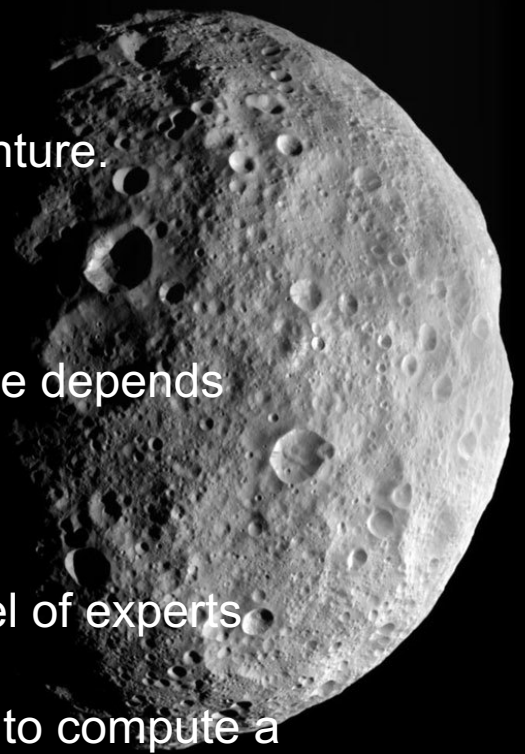
- What is a reasonable payback period and return on investment?
- Which variables are most important to financial viability?
- How important are terrestrial production dynamics to the viability of a space mining enterprise?
- Can current technology support a business model that would deliver financial viability?
- What externalities are important to the financial model?

Literature: What is Risk and How do you Measure it?

- Mostly, you'll know it when you see it….
- But….
- Henderson and Hooper (2006) point out that a good working definition is simply the chance of a bad outcome.
- Statistics, then, give us a method for assessing risk.



Research Design



- Develop a statistical model for a space mining venture.
- Start with an established business case
- Develop a list of variables upon which the outcome depends
- Check variables against the literature
- Validate and scale the variable values with a panel of experts
- Load the model and use Monte Carlo simulations to compute a range of outcomes
- Determine the risk of the business case by comparing the model outcomes to the desired outcomes

Business Case

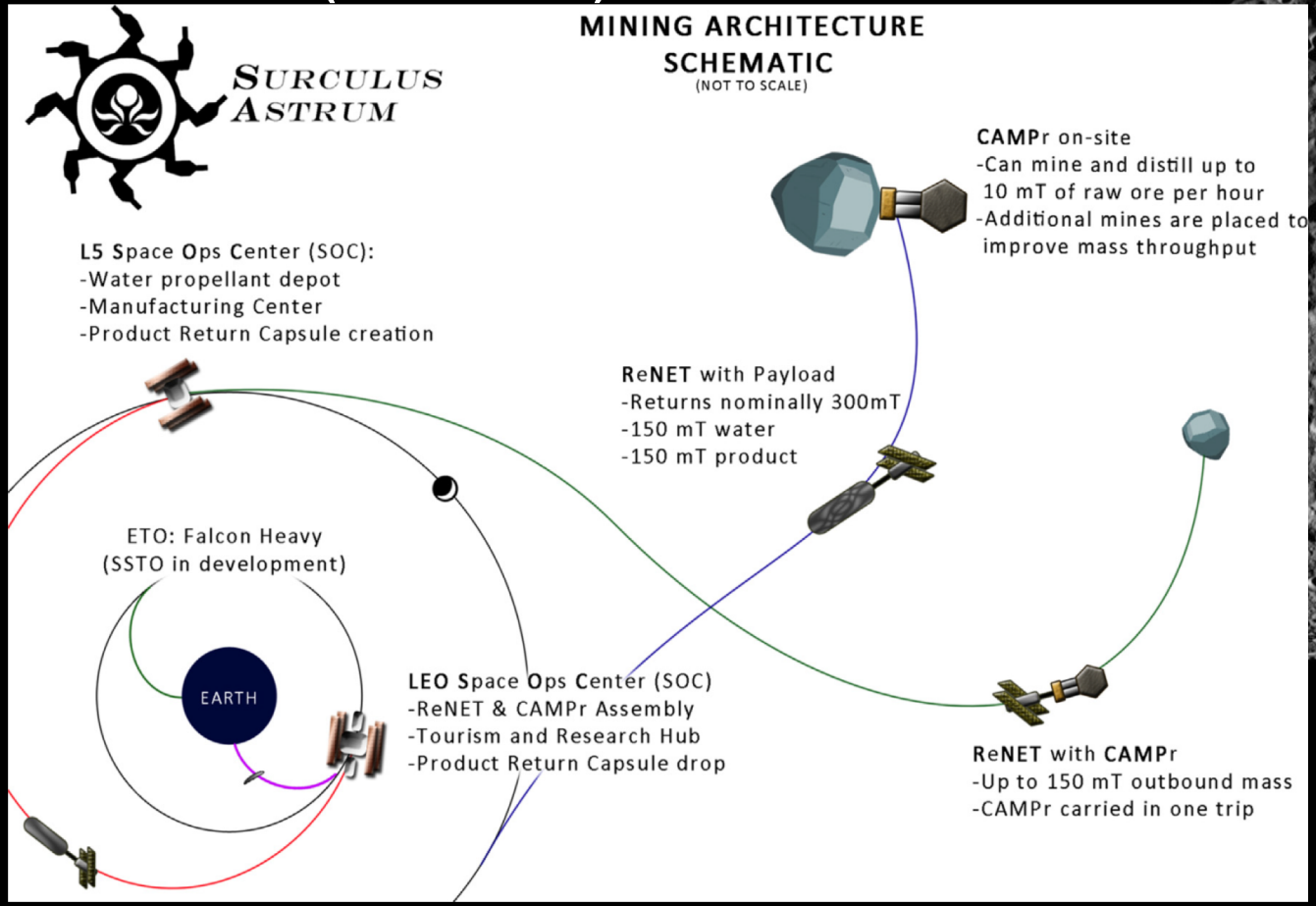
- Based on a commercial asteroid mining architecture developed by the Senior Space Design Class at the University of Washington during the Winter and Spring quarters of 2013. (Andrews et al. 2015)

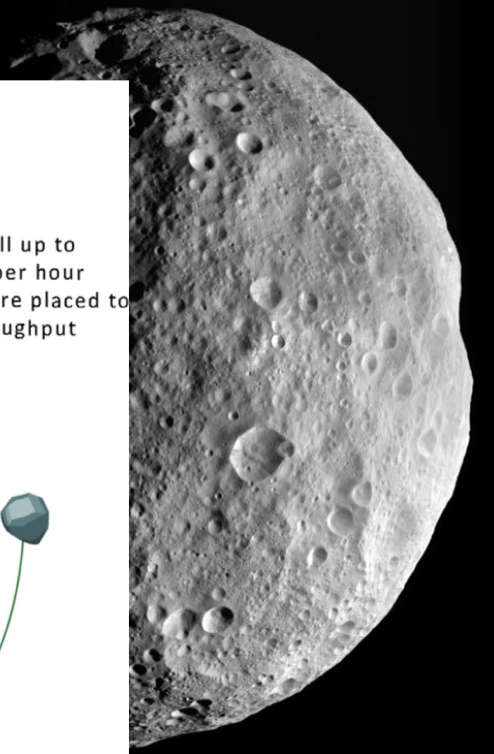
- Focus on technology development

- 20 year project that involves the development of ground-based as well as space-based infrastructure to locate and mine metallic asteroids to recover platinum group metals for sale on Earth commodity markets as well as water for utilization by space-based industry

- Estimated positive net Present Value (NPV) of $14 billion over a twenty year investment and mining period

Business Case (schematic)

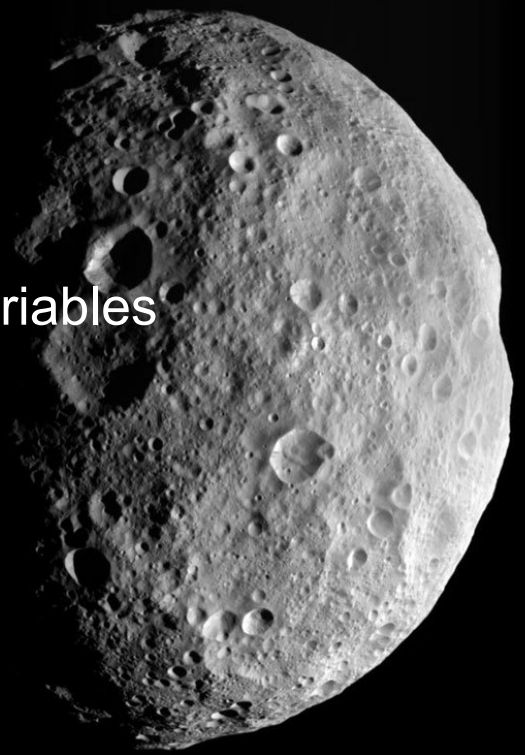




Andrews et al. 2015

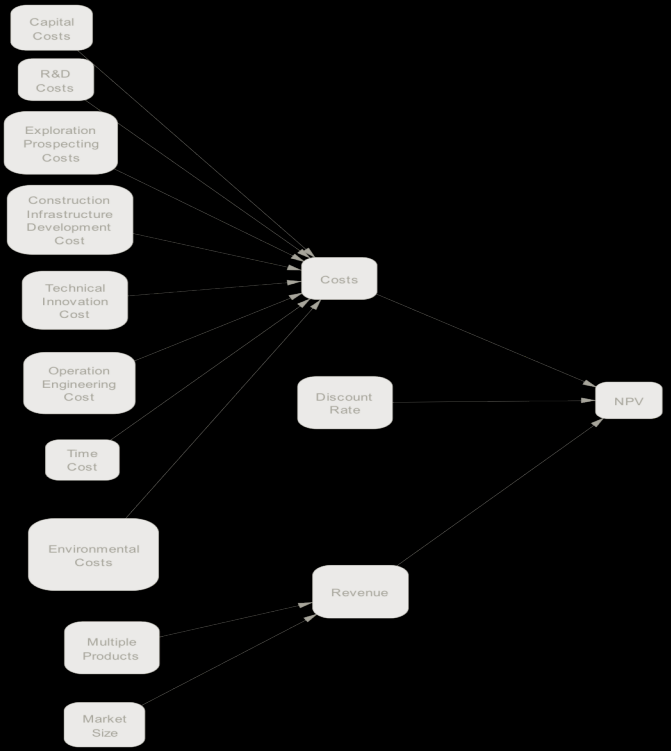
Data Collection

- Use Business Case to define Variables
- Use a Delphi Survey to validate and bound variables
- Compile data and load into decision model

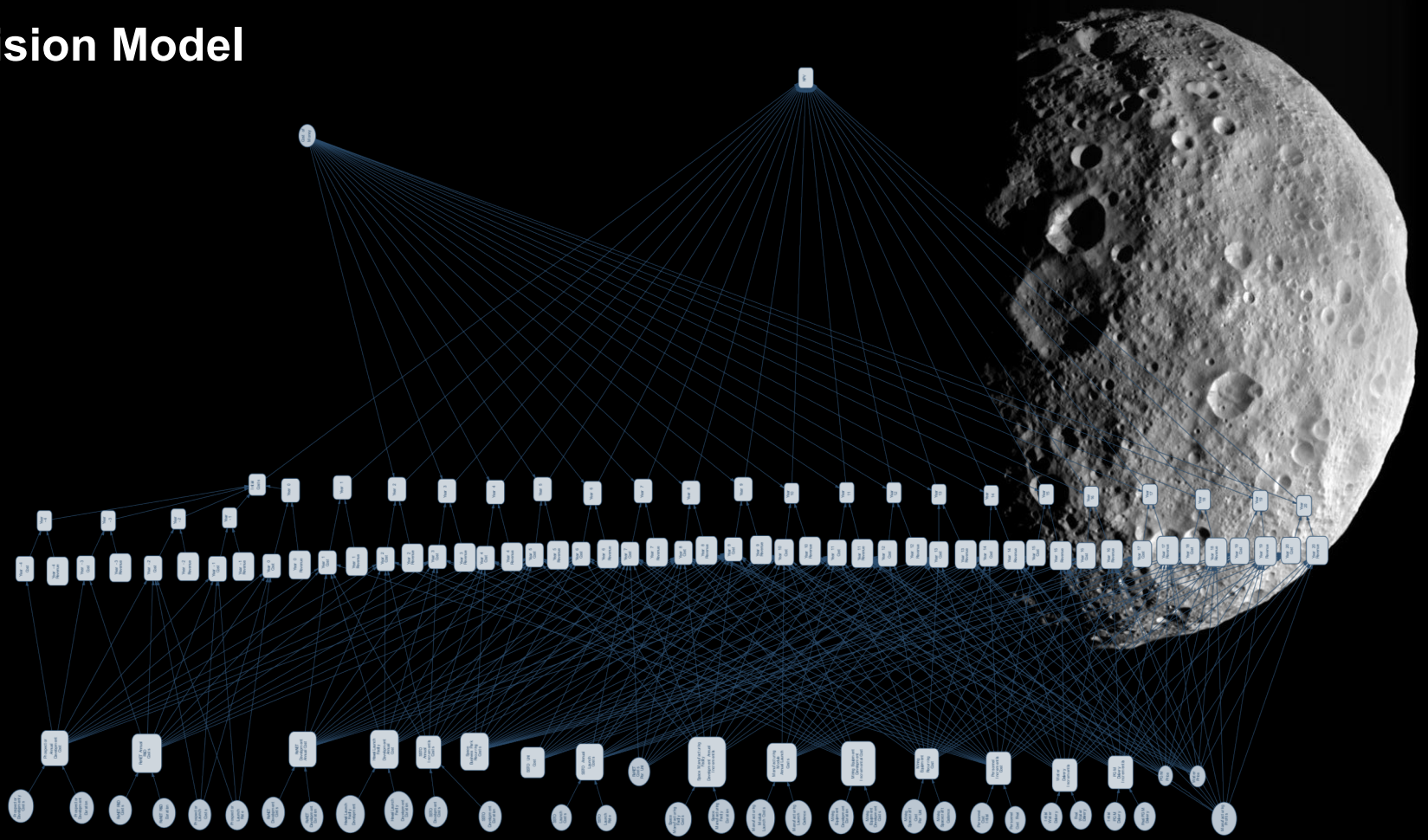


Decision Model

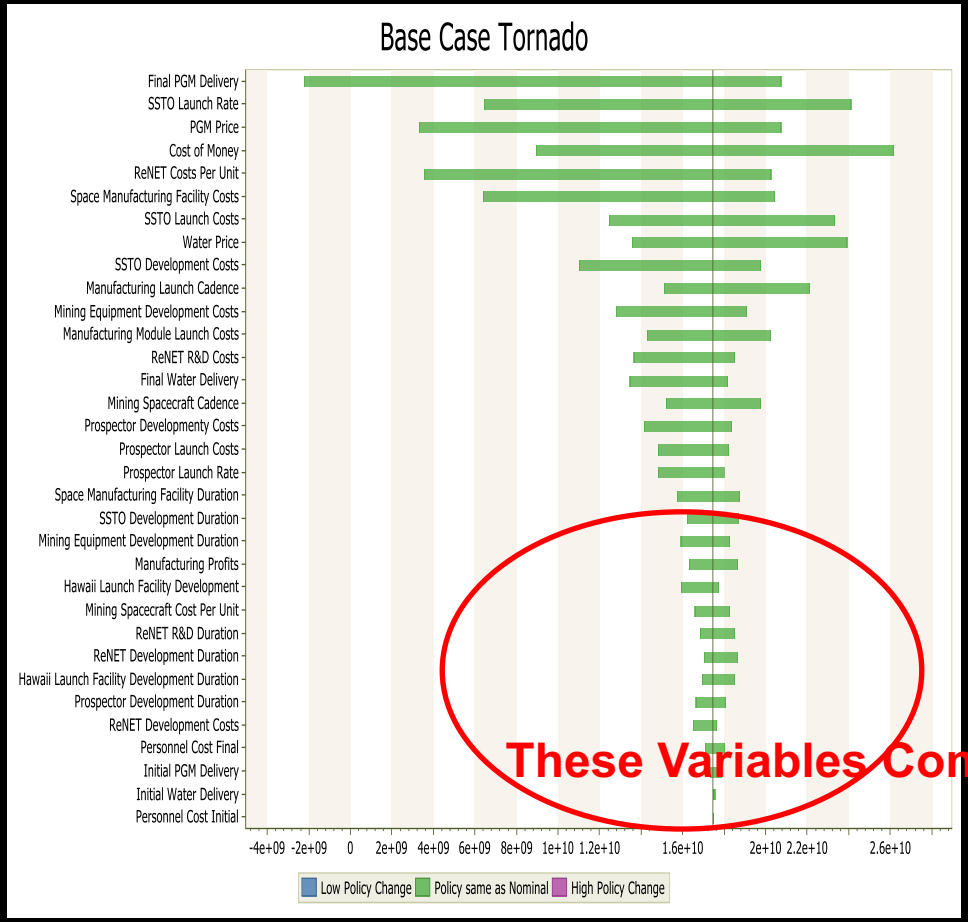
A decision model is a diagram that shows a particular outcome in relation to various input variables.

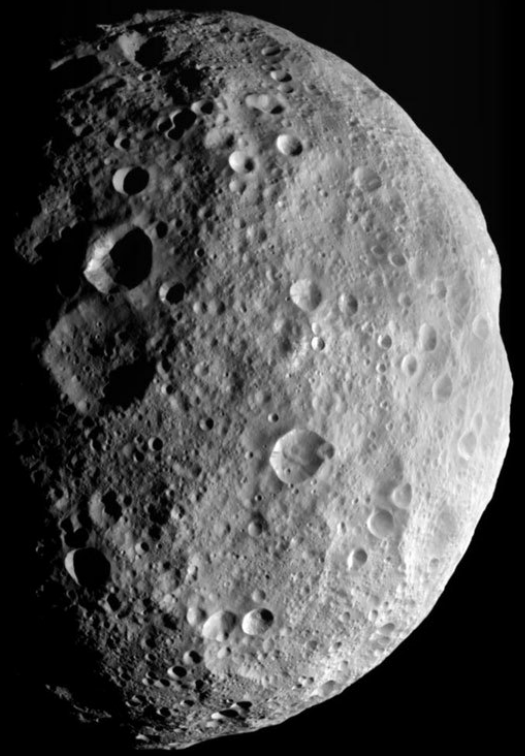


Decision Model



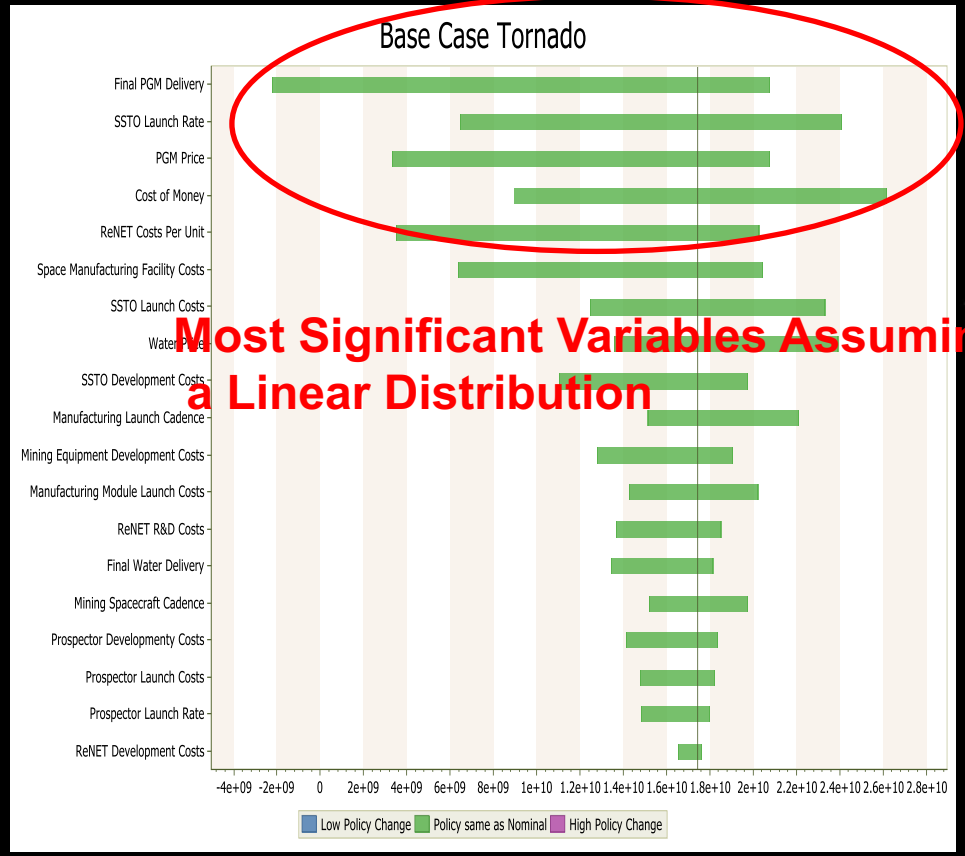
Sensitivity Analysis





These Variables Contribute Little to the Outcome

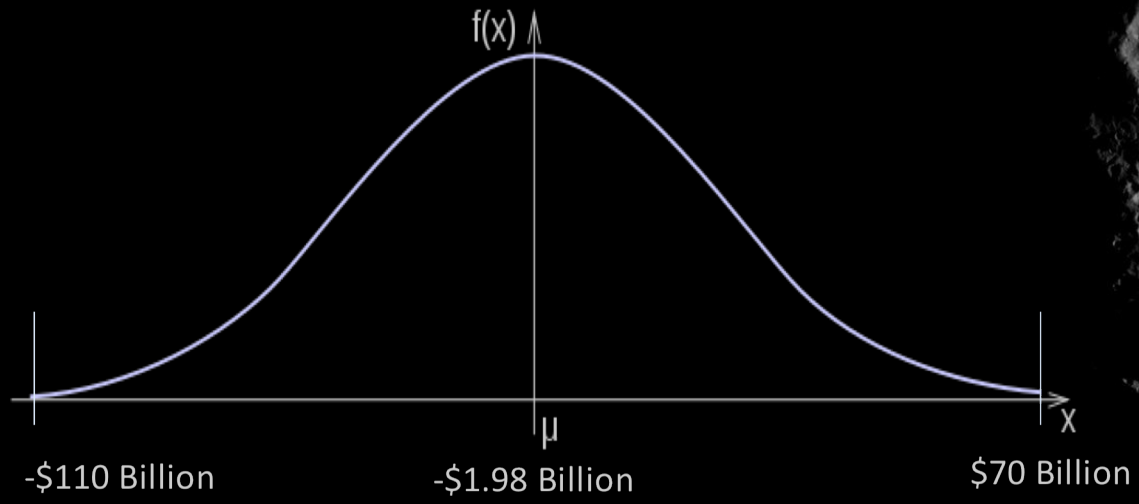
Sensitivity Analysis



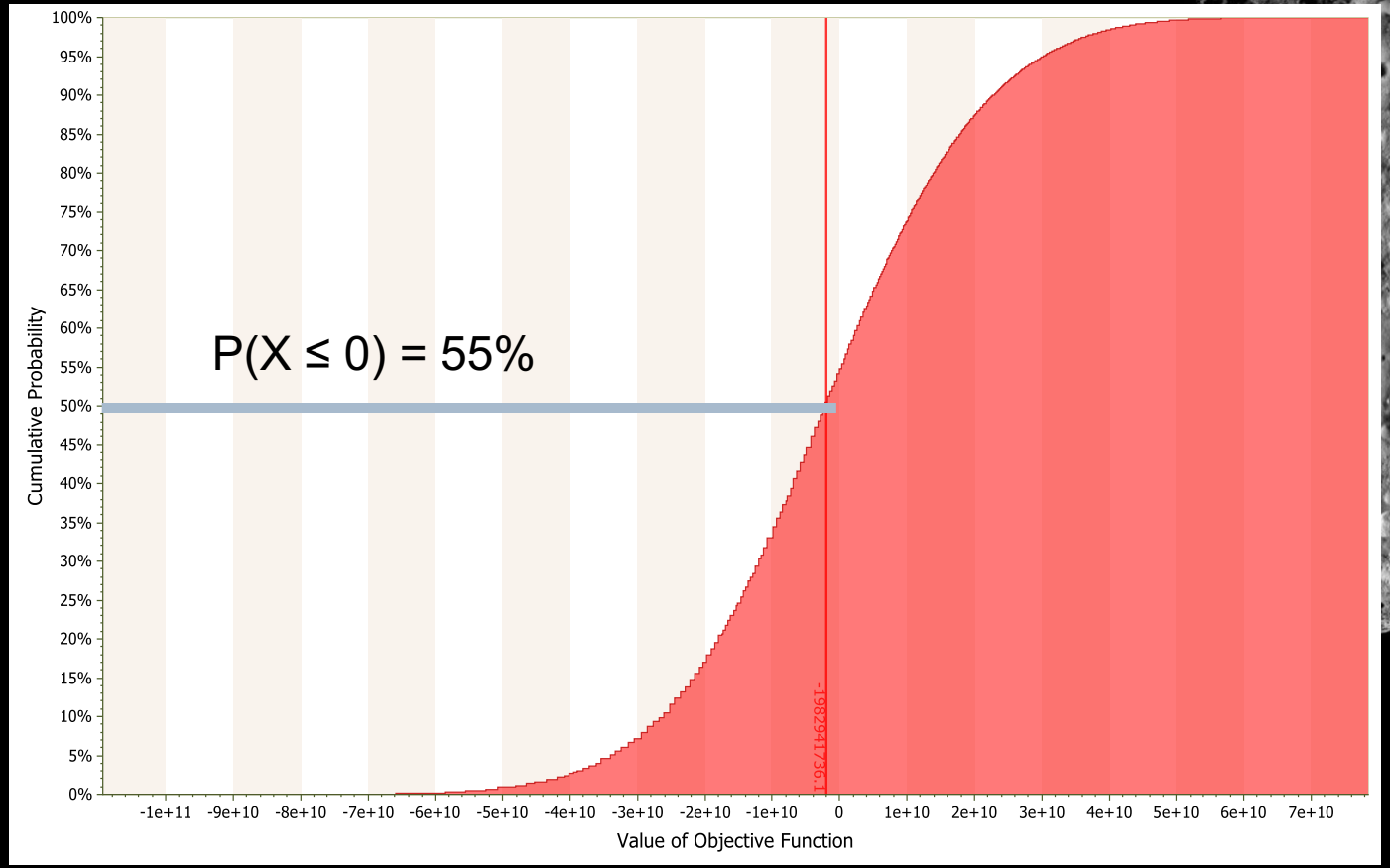
Most Significant Variables Assuming a Linear Distribution

Monte Carlo Simulation

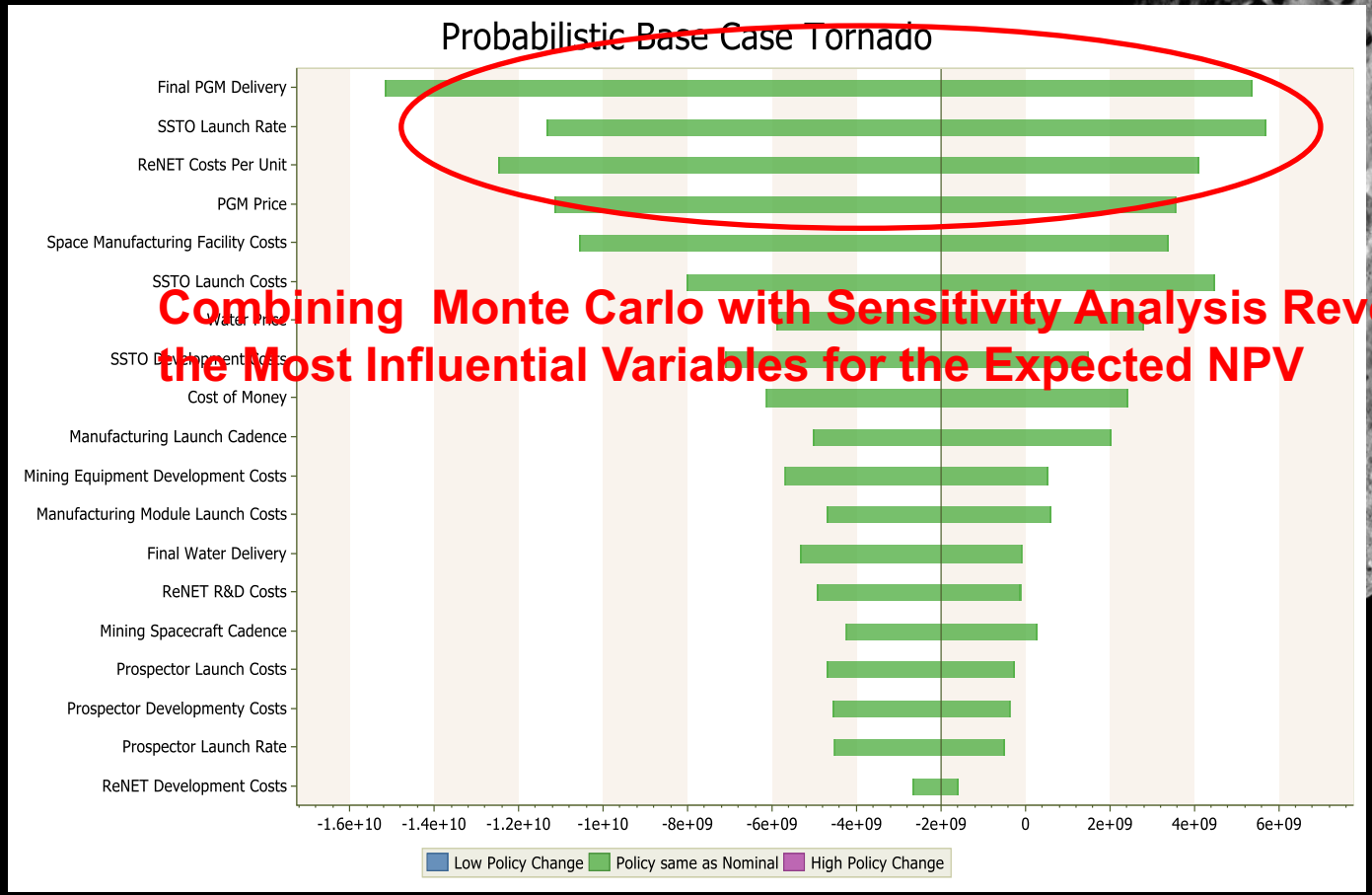
Monte Carlo simply allows each variable to range between its maximum and minimum along some probability distribution



Monte Carlo Simulation



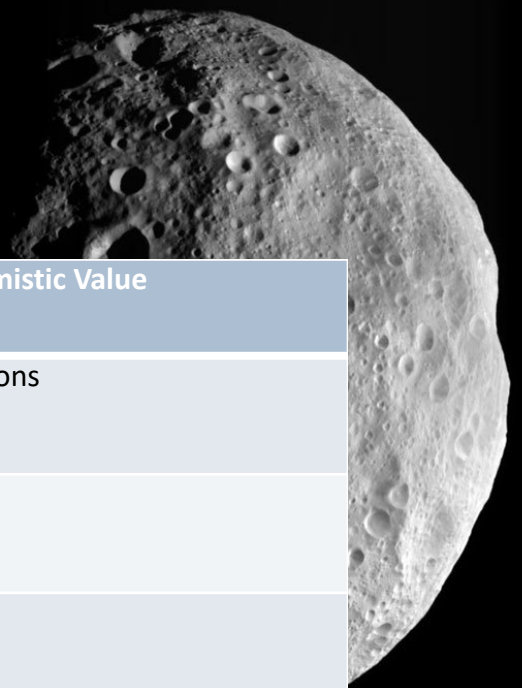
Monte Carlo Simulation



Combining Monte Carlo with Sensitivity Analysis Reveals the Most Influential Variables for the Expected NPV

Risk Assessment

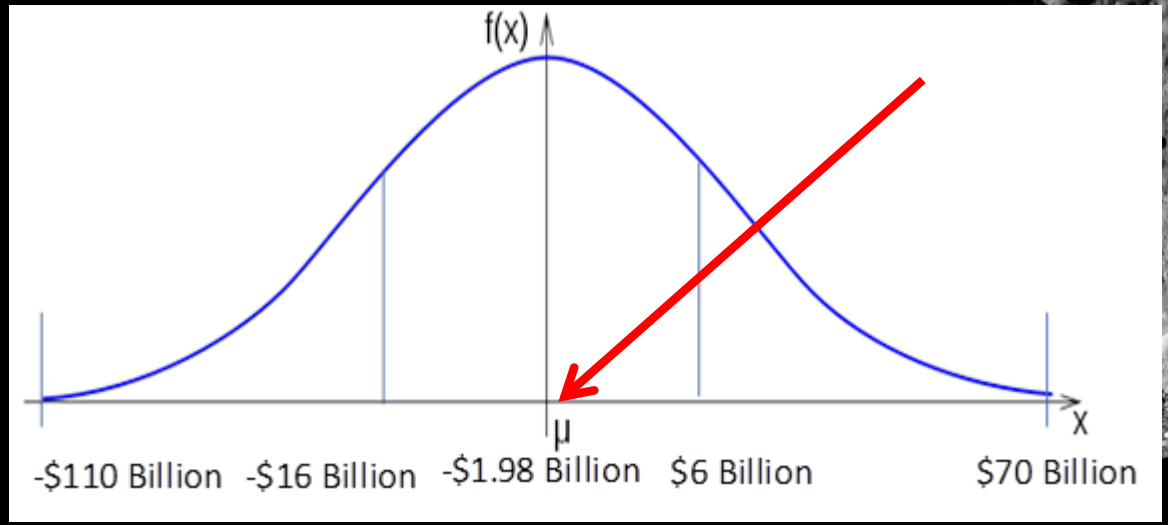
Required for a positive outcome:



Variable	Andrews et al. (2015) Value	Model Optimistic Value
PGM Delivery Final	370 metric tons	370 metric tons
SSTO Launch Rate	88 per year	88 per year
Unit Cost for ReNET	$350 million	$350 million
PGM Price	$1000 an ounce	$1000 an ounce

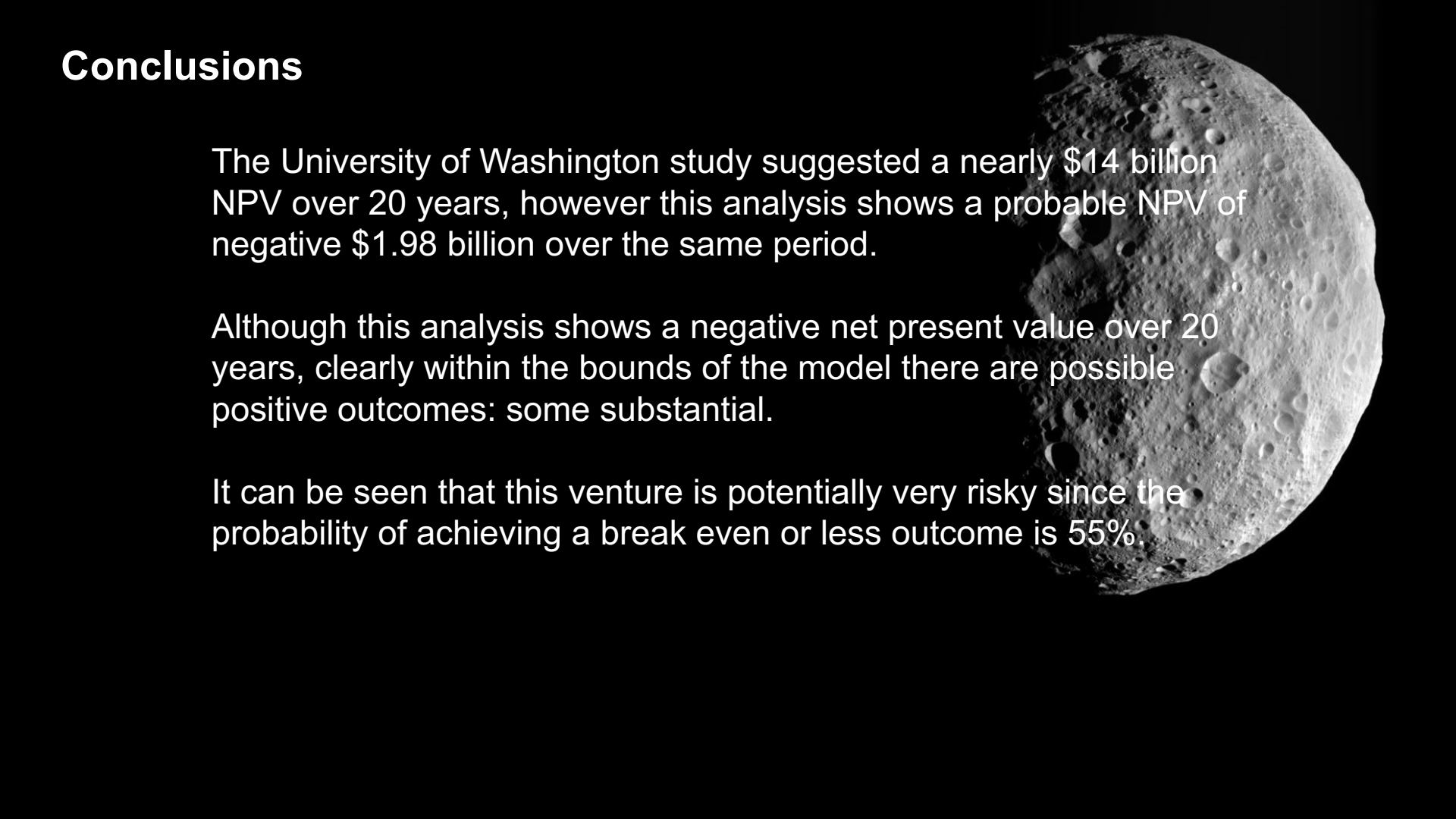
Risk Assessment

Or looking at it another way:



The most probable outcome is that over a 20 year period, the project loses nearly $2 billion.

Conclusions



The University of Washington study suggested a nearly $14 billion NPV over 20 years, however this analysis shows a probable NPV of negative $1.98 billion over the same period.

Although this analysis shows a negative net present value over 20 years, clearly within the bounds of the model there are possible positive outcomes: some substantial.

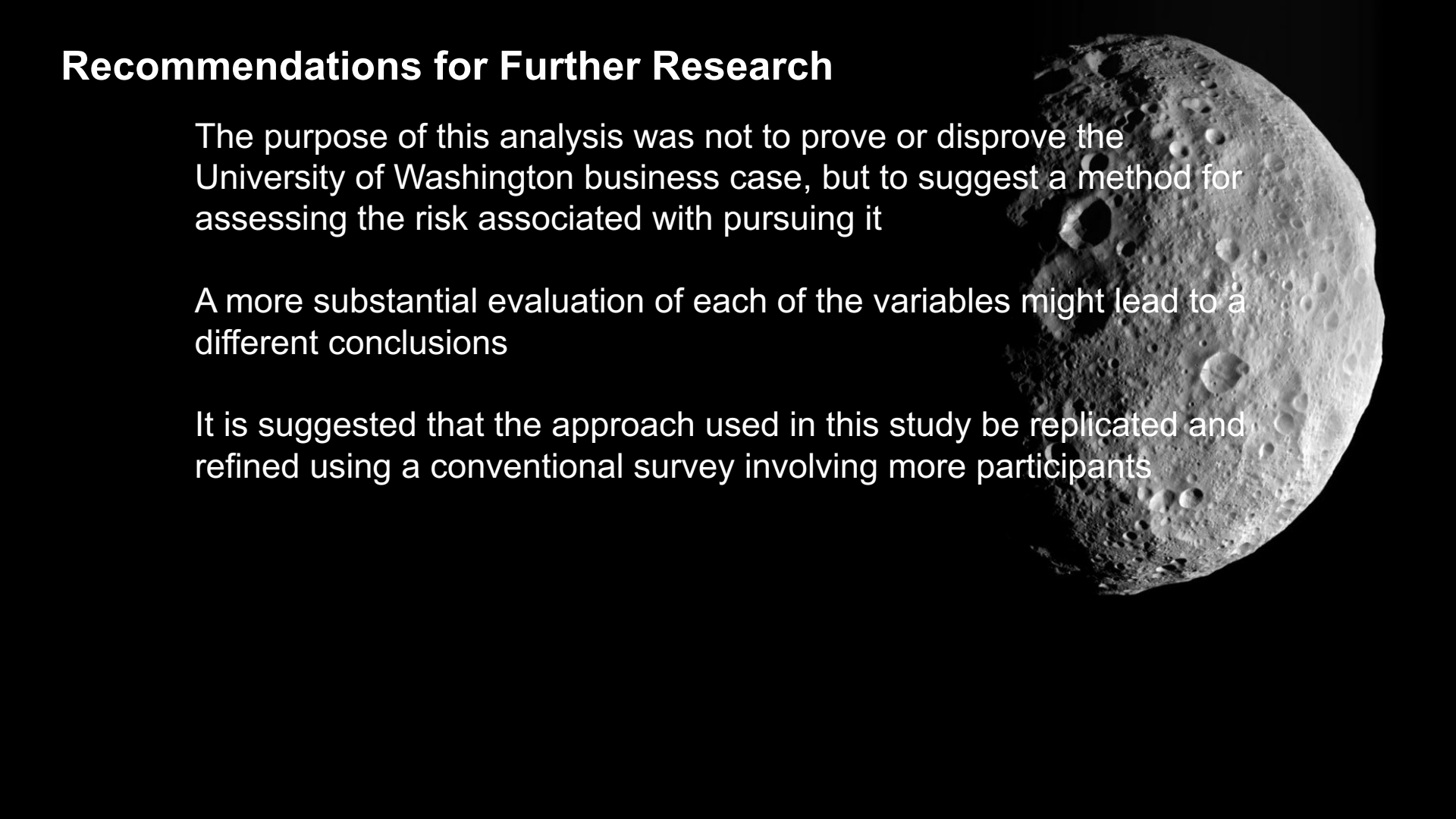
It can be seen that this venture is potentially very risky since the probability of achieving a break even or less outcome is 55%.

Recommendations for Further Research

The purpose of this analysis was not to prove or disprove the University of Washington business case, but to suggest a method for assessing the risk associated with pursuing it

A more substantial evaluation of each of the variables might lead to a different conclusions

It is suggested that the approach used in this study be replicated and refined using a conventional survey involving more participants



Now: If You Could Invest In Asteroid Mining….Would You?

Q&A