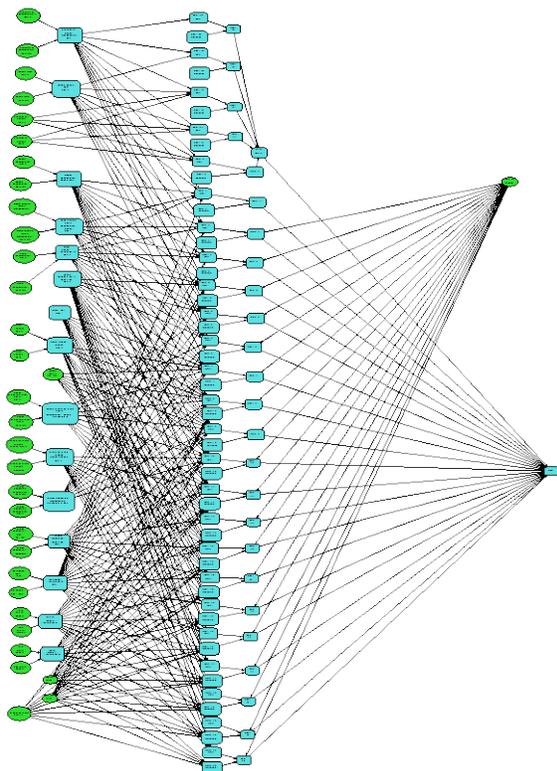


RISK ASSESSMENT OF AN ASTEROID MINING VENTURES USING DECISION MODELING AND MONTE CARLO SIMULATION. M. R. Jude, University of North Dakota, Department of Space Studies, 4149 University Ave. Stop 9008, 510 Clifford Hall, Grand Forks, ND. 58202-9008, mjude@soropro.com

Introduction: Private space exploration is beginning to receive a lot of attention, primarily driven by commercial efforts to mine asteroids. Such endeavors ultimately will require substantial amounts of investment. Yet, potential investors have no way of gauging the risk associated with asteroid mining. The problem statement that drives this study is relatively simple: current estimates of asteroid mining viability do not adequately factor risk into their analysis. Rather than attempting to build a business case for asteroid mining, this research adopts a well-documented business plan and then attempts to assess the risk implicit in that plan. This research is not concerned so much with the rigor of the business case, though, as it is with proposing a way to assess risk within such a plan.

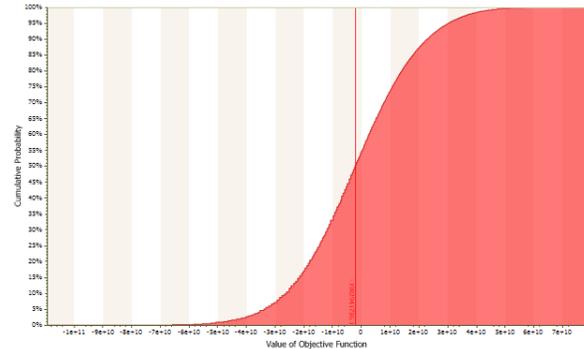
Summary of Analysis: An asteroid mining business case, developed at the University of Washington [1], is utilized to construct a Delphi survey [2] of subject matter experts to gauge the reasonableness of the estimates used in the plan. Once ranges for the important variables are ascertained, a decision model, as suggested by Clemen [3] is constructed as shown in the following figure.



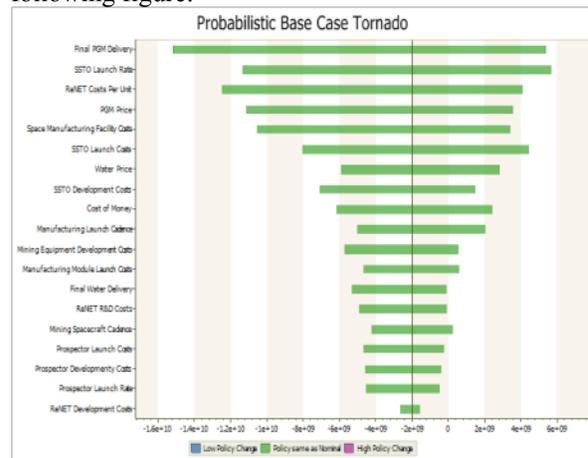
This model's output is in the form of a net present value (NPV) over a period of 20 years with each year's contribution of the form:

$$NPV_{Year\ x} = (Year\ x\ Revenue - Year\ x\ Cost) / (1 + Cost\ of\ Money)^{(X-1)}$$

Then a Monte Carlo simulation is run from the model which generates the following output:



Finally, a Tornado Diagram that assesses the impact of the various input variables is run as shown in the following figure:



Primary variables impacting the viability of the asteroid mining venture are determined to be: platinum group metal delivery rates, single stage to orbit launch rates, cost of reusable space tugs, and platinum group metal market price.

Conclusions: This approach, combining decision modeling with Monte Carlo simulation, indicates that the business case is very risky. Rather than a net present value of more than \$14 billion over twenty years, as estimated by the University of Washington study, this analysis indicates a loss of nearly \$2 billion over the same period. Consequently, the risk of such a business case is assessed to be very high.

References:

- [1] Andrews, Bonner, Butterworth, Calvert, Dagang, Dimond, . . . Yoo. (2015). Defining a successful commercial asteroid mining program. *Acta Astronautica*, 108, 106-118.
- [2] Brown, B. (1968). Delphi Process: A Methodology Used for the Elicitation of Opinions of Experts. RAND Document No: P-3925, 1968, 15 pages. Retrieved November 13, 2016
- [3] Clemen, R. (1996). *Making hard decisions: An introduction to decision analysis* (2nd ed.). Duxbury Press. Belmont, CA.