Integrating Space and Mining Engineering: A System Engineering Perspective

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INTRODUCTION

The space industry and the mining industry are both very large, led by sizable multinational corporations and have a very well established way of doing business. With the advent of space resources, possibly for the first time, the two industries are being forced to consider working together. However, their long-established methods of going about their business are not necessarily compatible with each other and there are ample opportunities for miscommunication at several levels, particularly communicating to resources companies in a manner that allows them to make decisions.

The author has for some time been working on an approach to space resources research that "reduces the risk perceived by an investor in a space resources venture". One of the key assumptions on which that work has been based is that such an investor will need to be a very large company, and because of the nature of the business to be pursued, that company is likely to be an existing mining company.

Preliminary work has been carried out. For instance, in (Hadler, 2020), the authors start to address some issues of language, and propose a "framework", but because the authors only address how agencies would pursue resource utilisation, it does not progress the problem of communicating with resources companies.

This paper examines one element of the communication disconnect: the high-level approach to project life cycle, sometimes described by the space industry as Systems Engineering. The two industries have very well established approaches to the development of projects and these are contrasted with each other, with the aim of extracting a common approach.

LIFE CYCLE APPROACHES

Space

The approach to life cycle by NASA is contained in its Systems Engineering Handbook (NASA,2016). Phases A to F are separated by key decision points associated with specific reviews. From (NASA,2016), "Key Decision Points … *are the events at which the decision authority determines the readiness of a program/project to progress to the next phase of the life cycle (or to the next KDP).* Phase boundaries are defined so that they provide natural points for "go" or "no-go" decisions." [italics in the original].

These phases are nearly identical to those used by the European Space Agency (ECSS,2009), with the minor modification that pre-phase A is called phase 0. This close convergence in approaches is an example of effective standardisation of the sector across international borders, which allows companies of different nationalities to work together, and for clients in different countries. This represents great *coherence*, i.e. the ability for cooperation within the industry, but not great *adherence*, the ability to work with industries that have different but similarly well developed and entrenched life cycle approaches.

These agency-driven approaches are very *design*-oriented, e.g. (NASA,2016), on p72, states "Most of the major system decisions (goals, architecture, acceptable life cycle cost, etc.) are made during the early phases of the project". Note that delivering stakeholder outcomes, and how that is to be achieved are listed before cost is mentioned.

Key decisions points follow reviews, of which there are many. To take the first, the Mission Concept Review, as an example, its purpose is "The MCR will affirm the mission need and evaluates the proposed objectives and the concept for meeting those objectives" (NASA,2016; p 161) and the criteria for success at the MCR are listed emphasise technical and logistical feasibility, mission "need", and "cost".

The life cycle maps very readily onto the classic system engineering "V-model" (Forsberg, 2000). Phase A and B are in the descending, design arm of the V, C is along the bottom and D and E are in the ascending arm. So the management of life cycles as understood for space systems is very closely aligned with system engineering approaches.

Mining

The comparable life cycle process in mining is less well documented. The process is relatively well agreed and "standardised" but there is no real "standard". In fact "there is no ready-made recipe that applies in all situations" (Scott, 2008). The key decision points in the life cycle of a mine relate to feasibility studies, and are based on commercial considerations. The role of each study is to improve the degree of certainty about the cost and viability of the opportunity. As more money is spent on each study, more knowledge and certainly are gained.

It makes sense that "study stages are defined by a set of objectives at the start, a set of work programs designed to achieve these objectives, and a decision point at which the project may progress to the next stage" (Scott, 2008). There are decision points after each phase and using as a criterion net present value (NPV) or other valuation methods, all investment-based (Scott, 2008).

The phases progress through inferred to indicated to measured resources as defined by the JORC Code (JORC 2012). The JORC Code is primarily concerned with standards of reporting about the state of a mineral deposit to regulatory bodies such as the Australian Securities Exchange or the New Zealand Stock Exchange. Processes improve knowledge (what is the state of the geology?) in the and each study also examines the "modifying factors" (how can that geology be exploited, all things being considered?).

The JORC Code does not deal with life cycle issues such as decision criteria arising from those feasibility studies. The UN Framework (UN, 2020) provides a very useful way of categorising projects using three criteria: technical feasibility, degree of confidence, and environmental-socio-economic viability. The feasibility study approach to project life cycle navigates between these categories, but the framework itself does not define such life cycle activity.

CONCLUSION

This paper proposes no solutions, but defines a particular problem that is hampering developing resources in space – that very large project life cycles are approached from completely different directions by the space and mining industries.

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