TOWARDS THE DEVELOPMENT OF A PLANETARY RESOURCE MANAGEMENT SYSTEM: UNDERSTANDING THE WHY. D. C. Barker, MAXD, Inc., P.O. Box 58915 Houston, TX. 77258; donald.c.barker@att.net).

Introduction: In order for humans to sustainably and permanently venture off Earth, operate in deep space and settle on other worlds, a clear understanding is needed regarding the amount, distribution and accessibility, as well as the prerequisite and precursor prospecting cycles required to locate extractable and usable resources. Off Earth, the play between user needs and resource providers remains a cyclic source of consternation for the development of space resources. Currently, no in-space user base exists whose needs are sufficient to warrant mining resources. Currently, no extraterrestrial resources are needed on Earth given expected costs, time, and risk involved in their acquisition and return. Will the seriousness of some 100 year estimates of threatened terrestrial reserves of He, Zn, Ga, Ge, As, Ag, In, Te and Hf, with many others under pressure [1], be sufficient to drive extraterrestrial resource prospecting and extraction in the near term? What is really needed to spur mining off Earth?

Understanding the "need" for a new focus in space. Currently, only government sponsored space programs exist regarding extraterrestrial exploration, and human space programs are even less evolved and only marginally goal oriented. Combined with the lack of the foreseeable returning of resources to the surface of Earth, the human-space focus needs to change from its historical goal of scientific exploration towards that of permanent and sustainable settlement. Assuming such a potential customer base is established, the question then turns to the multifaceted process of identifying and acquiring resources within an economically viable and safe process. These two ingredients, the changing of goals and focused prospecting for resources must co-occur in a timely manner. Thus the need for developing an efficient and evolving resource assessment methodology [2].

Prospecting for viable volumes of resources in space, in light of uncertain profits, is a tethered problem between the pursuit of basic scientific understanding, fiscal sustainability, technology, risk, and user availability. To date, all potential extraterrestrial resource sources, Moon [3], Mars [4] and all minor and small solar system-bodies, remain rooted in the lowest categories regarding resource location and volume knowledge. Additionally, access and extraction technologies remain at low Test Readiness Levels (TRL, see Fig. 1) [5]. Systems and project engineering cycles (Fig. 2), including timing and risk, need to also be included in order to assure quality and safety, and are usually time consuming [6]. A timeline of actual Mars spacecraft, Table 1, provides a history of Mars mission life cycles and costs. Given an average cycle of more than 4.6 years from inception to landing, add a year for initial data analyses, and one can see that prospecting for even the first sustainable landing site would take decades given the current sequential mission and exploration paradigms. This drives a need for adopting a dedicated and parallel mission prospecting model.

Defining a resource prospecting strategy. On Earth, concerns over mineral reserves and the development of economically viable petroleum resources, in the early 1970's [7], led to an evolving classification scheme relating the degree of recoverable certainty, including technological ability, known existence and extractability of a given resource, and all bound by the technical and economic feasibility of recovery. Development of a Planetary Resource Management System (PRMS) for extraterrestrial resources (see Fig. 3) applies and incorporates the pragmatic, evolved and categorical resource feasibility system began by McKelvey (1972). This ranking system includes Prospective and Contingent Resources and Reserves (Proved-Probable-Possible) resources [8, 9, 10, 11].

Conclusions. By understanding and combining historical resource management schemes with systems engineering cycles, driven by technology readiness levels and a historical understanding of lengthy space systems development cycles, a clear picture of the required increase in scale and timing of needed prospecting requirements becomes clear. Given a well-defined and fiscally protected vision and goal for humans in space, the only way to enable extraterrestrial mining is to develop an in-space user base, requiring a massive, goal directed effort to adopt settlement as the preeminent focus of human space efforts.

References: [1] Schulz K. J. et. al. (eds) (2017) Professional Paper 1802, *U.S. Dept. Interior & Geo. Survey*, A1-V26. [2] Goudarzi G. H. (1984) Open-File Report 84-787. *U.S. Dept. Interior & Geo. Survey*, 1-25. [3] Anand et al. (2012) *Planet and Space Sci.* 74, 42-48. [4] West M. D. and Clarke J. D. A. (2010) *Planet. and Space Sci*. 58, 574-582. [5, 6] NASA Sys. Eng. Handbook, NASA/SP-2016-6105 Rev 2. [7] Taylor R. B. and Steven T. A. (1983) *Economic Geol*. 78, 1268-1270. [8] McKelvey V. E. (1972) *Ameican Scientist*, 60 (1), 32-40. [9] Brobst D. A. and Pratt W. P. ed. (1973) *Geo. Survey Professional Paper 820*, 1-713. [10] Pratt W. P. and Brobst D. A. ed. (1974) Geo. Survey Circular 698. *U.S. Dept. Interior & Geo. Survey*, 1-20. [11] Bureau of Mines and Geological Survey (1980) Geo. Survey Circular 831. *U.S. Dept. Interior & Geo. Survey*, 1-5.

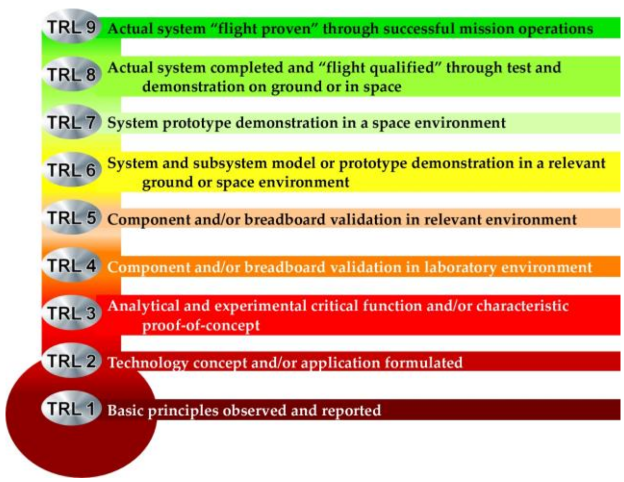

Fig. 1. NASA Test Readiness Levels.

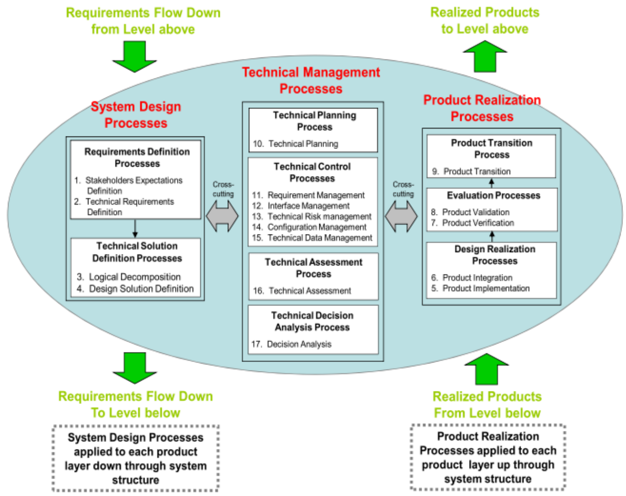

Fig. 2. NASA Systems Engineering Engine.

Table 1. Mars Vehicle Mission History

	Mariner 4	Mariner 9	Viking 1 (L/O)	Viking 2 (L/O)	Mars Observer	Mars Pathfinder	MGS	Mars Climate Orbiter	Mars Polar Lander	2001 Mars Odyssey	MER Spirit	MER Opportunity	MRO	Phoenix	MSL Curosity	Maven	Insignt
Selected or first $	1961	1967	1969	1969	1985	1994	1994	1995	1995	2000	2000	2000	2000	2005	2004	2008	2011
Launch	11/28/1964	5/30/1971	8/20/1975	9/9/1975	9/25/1992	12/4/1996	11/7/1996	12/11/1998	1/3/1999	4/7/2001	6/10/2003	7/7/2003	8/12/2005	8/4/2007	11/26/2011	11/18/2013	5/5/2018
Died	12/21/1967	10/27/1972	11/13/1982	4/11/1980	8/21/1993	9/27/1997	11/2/2006	9/23/1999	12/3/1999	6/12/2018	3/22/2010	6/12/2018	6/12/2018	11/2/2008	6/12/2018	6/12/2018	6/12/2018
Total Ops Days	1118	516	2642	1676	330	297	3647	286	334	6275	2477	5454	4687	456	2390	1667	38
Cradle-Launch (dy)	1427	1610	2422	2442	2824	1068	1041	1440	1463	462	1104	1131	1898	793	2795	1860	2561
Cradle-Launch (yr)	3.9	4.4	6.6	6.7	7.7	2.9	2.9	3.9	4.0	1.3	3.0	3.1	5.2	2.2	7.7	5.1	7.0
Cost ($mil)	554	137	500	500	813	175	154	193.1	110	297	400	400	720	386	2500	671	829

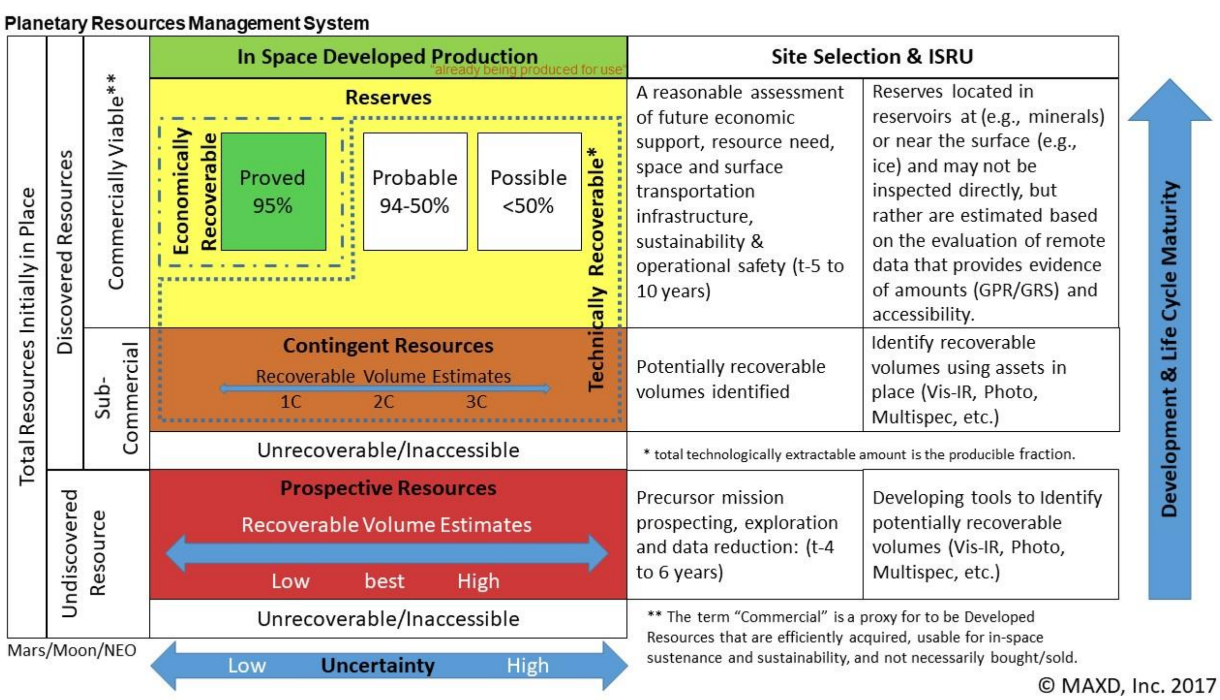

Fig. 3. Planetary Resources Management System for resource prospecting and development, as adopted from McKelvey (1972). Time estimates are based on current mission development and flight rates.