Mars 2040 Optimization: Assignment 1, Section B

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1 Project Proposal

1.1 Project Introduction

Our team has decided to do optimization on the Mars 2040 project that Eric worked on in Spring 2015 as the SDM term project. This project generated a model of a Mars outpost architecture including the Transportation Logistics, Surface Habitation, ISRU and Exploration aspects. The model was run through a Tradespace exploration to identify architectures that minimized the IMLEO (initial mass to low-earth orbit, i.e. the total payload launched from the Earth surface each synodic period) while attempting to maximize the Ścientific Valueás defined as the crew-hours per synodic period available for exploration and research, multiplied by a rank scoring of the landing sites based on an independant study performed early on in the term.

We only have one modification to the model currently planned; to make a small improvement on the utility metric for this project. Instead of using the more subjective site scoring from the SDM term project, we will formalize the utility as suggested by Ward et. al.[1] to consider quantitative scientific value.

Since the tradespace exploration has already been performed, we will focus this project on more in depth aspects. We will re-run the tradespace exploration with the improved utility metric on the same design space as setup by the SDM term project. From that point, we will select and baseline the architectures in the fuzzy pareto-optimal region, as defined by Smaling and deWeck[2]. This should give us approximately 300 baseline architectures. as the starting point for our optimization.

The first portion of our optimization will focus on technology road-mapping. We will convert some of the parameters in existing model into design variables, based on the possibilities for technological development. For example, we might take the $LOX/LH_2 I_{sp}$ from a parameterized 448 [seconds] and turn it into a variable across the range of $(448, 480)$ that we could correlate with a development cost estimate for the improvement in I_{sp}. Once we do this for multiple technologies, we can run an optimization of development spending across the portfolio of technologies for the baselined architectures and determine where the money would be best spent in order to improve the future exploration campaign.

If the first portion goes well, and time permits, we would also like to investigate the build-up campaign as well. With a baselined technology capability roadmap, we could run through the 300 candidate architectures from a null-infrastructure to the full 20 person outpost, looking for a sub-game perfect campaign that would optimize not only the steady-state re-supply missions, but the entire campaign from the beginning.

1.2 Formal Problem Statement

To optimize the improvements to a campaign to setup a permanently inhabited outpost on the surface of Mars from a technology development budget, **by** altering the design variables associated with technological performance across pre-selected architectures, **using** systems design optimization methodologies.

1.3 Design Variables, Parameters, Constraints, Bounds and Objectives

Objective Function

$$\text{minimize } J(\mathbf{x}) = \begin{bmatrix} \text{Campaign Utility} \\ \text{Resupply Cost} \\ \text{Technology Development Cost} \end{bmatrix}$$

Design Variables

$$\mathbf{x} = \begin{bmatrix} Isp_{LH_2} \\ Isp_{NTR} \\ \epsilon_{ISRU} \\ \alpha \\ C_{surf} \\ C_{transit} \end{bmatrix} = \begin{bmatrix} \text{LH}_2 \text{ Isp} \\ \text{Nuclear Thermal Rocket Isp} \\ \text{ISRU efficiency} \\ \text{Architecture} \\ \text{Surface Crew Size} \\ \text{Transit Crew Size} \end{bmatrix}$$

Parameters

Most of the architecture selection variables from the SDM term project model have been effectively parameterized. The architectural variables are no longer independently enumerated, instead, the have been conglomerated into a single design variable of α which selects a single complete architecture from the pre-selected pool of architectures in the fuzzy pareto-optimal region of the initial tradespace study.

See the Master Table in the Appendix for the complete list of parameters.

Constraints

$$frac3 * C_{crew}C_{surf} \geq 1 \tag{1}$$

Bounds

$$Isp_{LH_2} = [430, 480]$$

Typical Isp, to a little more than the highest recorded

$$Isp_{NTR} = [800, 1500]$$

Isp recorded under development in the 1960's, to the theoretical maximum

$$\alpha = \{\text{Fuzzy Pareto-Optimal Architectures}\}$$

2 N^2 Diagram

N2.jpg N2.jpg

Earth Entry														
	Descent						142	36, 37, 38, 39				255, 257, 262		125
165, 166		Ascent	167											
165, 166			Return Transit	162, 160, 158										
				Transit Habitat										
	53				Outgoing Transit									
					62	Lunar ISRU								
		186, 187	171, 172, 173				Mars ISRU					255		125
							140	ISFR and Sparing		27	221	259		
									Astronaut Time					
										Surface Power	223	260		125
							142				Surface Habitat			
											221, 222	ECLSS		
	53				62	69							Staging	
														Site Selection

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N2.jpg N2.jpg

Transit Habitat														
	Earth Entry													
162, 160, 158	165, 166	Return Transit												
	165, 166	167	Ascent											
				Surface Habitat										
				221, 222	ECLSS									
						Site Selection								
		171, 172, 173	186, 187		255	125	Mars ISRU							
				223	260	125	142	Surface Power						
				221	259		140	27	ISFR and Sparing					
										Astronaut Time				
					255, 257, 262	125	143		36, 37, 38, 39		Descent			
											53	Outgoing Transit		
												62	Lunar ISRU	
											53	62	69	Staging

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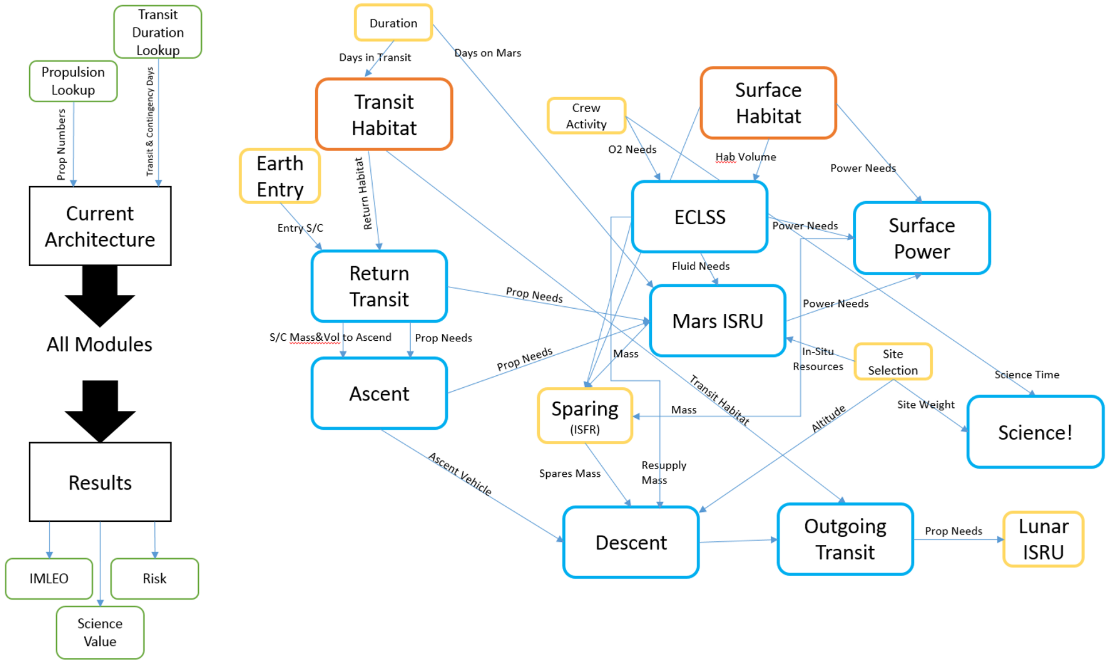

Figure 1: Block Diagram of Model from the Mars2040 Project Spring 2015

3 Block Diagram

Figure **??** shows the model layout from the Mars 2040 SDM term project from the Spring term of 2015. This will be the starting point for our model for MSDO. Throughout the semester, the model may require some modifications based on the changes in scope (going from a tradespace exploration to a development optimization.) However, we feel like this arrangement does a good job setting up the project, and the changes will not likely require massive rearrangements.

References

[1] Eric D. Ward, Ryan R. Webb, Olivier L. deWeck, *A Method to Evaluate Architectural Comparisons for a Campaign to Explore the Surface of Mars*. Manuscript submitted for publication, Acta Astronautica. 2016.

[2] Smaling R., de Weck O., "Assessing Risks and Opportunities of Technology Infusion in System Design", *Systems Engineering*, 10 (1), 1-25, Spring 2007