System Case Study:

MARS ONE PROGRAM

EMSE 6801:
Systems Engineering I

Presented By: Kafi A. Joseph

Problem Statement

Mission:

To **establish a human settlement on the planet Mars**; the mission plan **integrates technology components that are readily available** from industry leaders worldwide to enable travel *to* and settlement *on* Mars (Mars One)

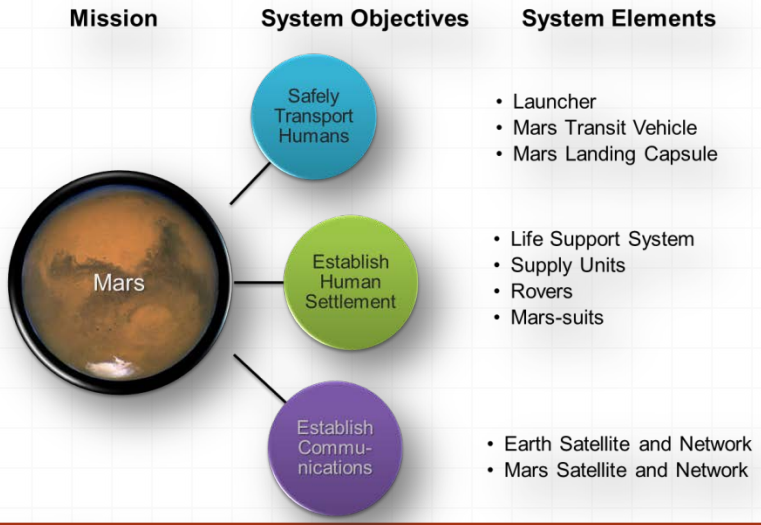
Program Needs:

"[T]o satisfy good old fashioned curiosity"; the inherent human need to explore…

1997 Mars Exploration Study…

- Human Exploration
- Comparative Planetology
- International Cooperation
- **Technological Advancement**
- Inspiration

System Objectives & Elements:



Capability Gaps:

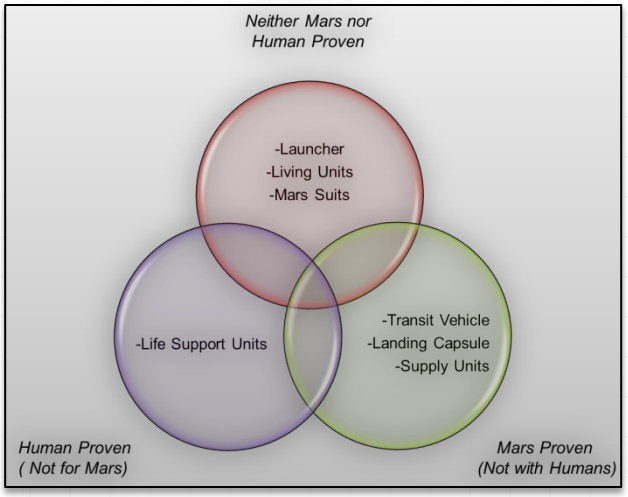


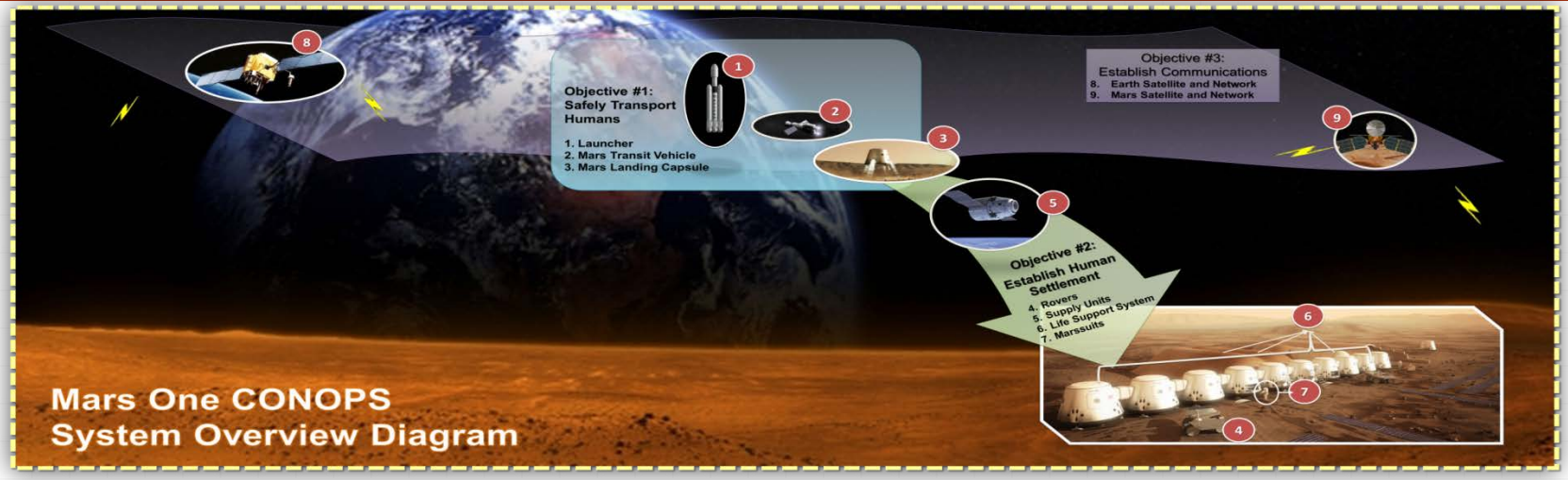
Image from www.nasa.gov Image of the Day Gallery

CONOPS

Roadmap

2011	2013	2015	2016	2018	2020	2021	2022	2023	2024
Mars One Founded	Start Crew Selection	Start of Crew Training	Demo&Comsat Mission	Rover Mission Launched	Cargo Missions Launched	Outpost Operational	Departure Crew One	Landing Crew One	Departure Crew Two

CONOPS System Overview Diagram:



System Boundaries & Interfaces:

Boundaries:

- Space (Earth Orbit / Mars Orbit)
- Mars Planetary Surface

Interfaces:

- Transmission of satellite communications and remote instruction to / from the Earth
- Interactions and construction in reduced gravity
- Navigation and construction in/on the Martian terrain and atmosphere
- Excavation / mining of Mars surface
- Leveraging Solar Power

System Requirements

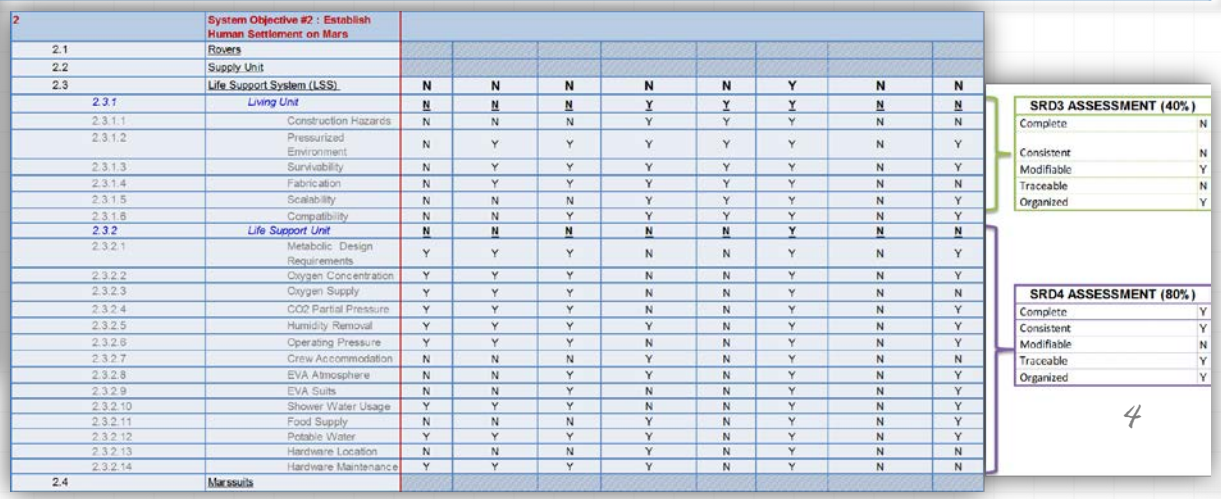
Requirement Identifier	
1	System Objective #1: Safely Transport Humans to Mars
1.1	Launcher
1.1.1	Booster-Core Interface
1.1.2	Booster-Ground Interface
1.1.3	Load Path
1.1.4	Height
1.1.5	Vehicle Width
1.2	Transit Vehicle
1.3	Lander
1.3.1	Entry
1.3.2	Descent and landing
2	System Objective #2 : Establish Human Settlement on Mars
2.1	Rovers
2.2	Supply Unit
2.3	Life Support System (LSS)
2.3.1	Living Unit
2.3.1.1	Construction Hazards
2.3.1.2	Pressurized Environment
2.3.1.3	Survivability
2.3.1.4	Fabrication
2.3.1.5	Scalability
2.3.1.6	Compatibility
2.3.2	Life Support Unit
2.3.2.1	Metabolic Design Requirements
2.3.2.2	Oxygen Concentration
2.3.2.3	Oxygen Supply
2.3.2.4	CO2 Partial Pressure
2.3.2.5	Humidity Removal
2.3.2.6	Operating Pressure
2.3.2.7	Crew Accommodation
2.3.2.8	EVA Atmosphere
2.3.2.9	EVA Suits
2.3.2.10	Shower Water Usage
2.3.2.11	Food Supply
2.3.2.12	Potable Water
2.3.2.13	Hardware Location
2.3.2.14	Hardware Maintenance
2.4	Marssuits

SRDs:

No Mars One Program requirements documentation.

Leveraged 5 Documents as Proxies for SRDs:

- Launcher Requirements (SRD #1): A 2011 Space Launch System NASA Research Announcement for Advanced Booster Engineering Demonstration and/or Risk Reduction
- Lander (SRD #2): A 2009 Preliminary Study on Lander System and Scientific Investigation for the Next Mars Exploration
- Life Support System – Living Unit (SRD #3): A 2005 Paper on In Situ Resource-Based Lunar and Martian Habitat Structures Development at NASA/MSFC
- Life Support System – Life Support Unit (SRD #4): A 1998 NASA Technical Manual on the Design and Operation of the Life Support Systems on the International Space Station
- Communications System – Earth Satellite and Network & Mars Satellite and Network (SRD #5): A 2004 NASA Technical Manual on Developing Architectures and Technologies for an Evolvable NASA Space Communication Infrastructure



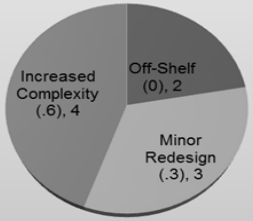
2	System Objective #2 : Establish Human Settlement on Mars								
2.1	Rovers								
2.2	Supply Unit								
2.3	Life Support System (LSS)	N	N	N	N	N	Y	N	N
2.3.1	Living Unit	N	N	N	Y	Y	Y	N	N
2.3.1.1	Construction Hazards	N	N	N	Y	Y	Y	N	N
2.3.1.2	Pressurized Environment	N	Y	Y	Y	Y	Y	N	Y
2.3.1.3	Survivability	N	Y	Y	Y	Y	Y	N	Y
2.3.1.4	Fabrication	N	Y	Y	Y	Y	Y	N	N
2.3.1.5	Scalability	N	N	N	Y	Y	Y	N	Y
2.3.1.6	Compatibility	N	N	Y	Y	Y	Y	N	Y
2.3.2	Life Support Unit	N	N	N	N	N	Y	N	N
2.3.2.1	Metabolic Design Requirements	Y	Y	Y	N	N	Y	N	Y
2.3.2.2	Oxygen Concentration	Y	Y	Y	N	N	Y	N	Y
2.3.2.3	Oxygen Supply	Y	Y	Y	N	N	Y	N	N
2.3.2.4	CO2 Partial Pressure	Y	Y	Y	N	N	Y	N	Y
2.3.2.5	Humidity Removal	Y	Y	Y	N	N	Y	N	Y
2.3.2.6	Operating Pressure	Y	Y	Y	N	N	Y	N	Y
2.3.2.7	Crew Accommodation	N	N	N	Y	N	Y	N	N
2.3.2.8	EVA Atmosphere	N	N	Y	Y	N	Y	N	Y
2.3.2.9	EVA Suits	N	N	Y	N	N	Y	N	Y
2.3.2.10	Shower Water Usage	Y	Y	Y	N	N	Y	N	Y
2.3.2.11	Food Supply	N	N	N	Y	N	Y	N	Y
2.3.2.12	Potable Water	Y	Y	Y	Y	N	Y	N	Y
2.3.2.13	Hardware Location	N	N	N	Y	N	Y	N	N
2.3.2.14	Hardware Maintenance	Y	Y	Y	Y	N	Y	N	N
2.4	Marssuits								

SRD3 ASSESSMENT (40%)	
Complete	N
Consistent	N
Modifiable	Y
Traceable	N
Organized	Y

SRD4 ASSESSMENT (80%)	
Complete	Y
Consistent	Y
Modifiable	N
Traceable	Y
Organized	Y

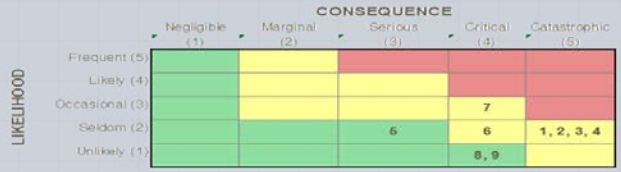
Technical Risk & Technology Readiness Assessment

Mars One Program Risk Profile



	Key Technologies	Readiness Assessment	Risk (L, M, H)	Risk Profile
1	Launcher - Falcon Heavy	• TRL 7	M	• Off-the-Shelf (0)
2	Transit Vehicle - Dragon*	• TRL 9	H	• Moderate / Significant Complexity Increase (.6)
3	Landing Capsule	• TRL 9	M	• Minor Redesign (.3)
4	Life Support System*	• TRL 7 (Life Support Unit)	M	• Minor Redesign (.3)
		• TRL 7 (Living Unit)	M	• Moderate / Significant Complexity Increase (.6)
5	Supply Units	• TRL 9	L	• Off-the-Shelf (0)
6	Rovers*	• TRL 3	M	• Moderate / Significant Complexity Increase (.6)
7	Marssuits*	• TRL 6	H	• Moderate / Significant Complexity Increase (.6)
8	Earth Satellite & Network	• TRL 9	M	• Minor Redesign (.3)
9	Mars Satellite & Network	• TRL 9	M	• Minor Redesign (.3)

**Weight of 2 applied due to potential and significant cost & schedule impacts of technology development*



Consequences		Probability: Frequent (H) .7<P<1.0	Probable (M) .4<P<.7	Improbable (L) 0<P.4	Impossible P=0
Catastrophic	1 - .9		2, 4, 7	1, 3	
Critical	.8 - .7		6	8, 9	
Marginal	.6 - .4			5	
Negligible	.3 - 0				

Technology Readiness:	Technical Risk:
• 4 technologies are at TRL 9; 2 at TRL 7; 1 at TRLs 6 and 1 at TRL 3. • Only 2/9 of those are considered to be in the "off-the-shelf" risk profile	• Used the risk profiles: probability of achieving performance vs. technology options • Overall risk of .6 probability of not achieving program performance success.

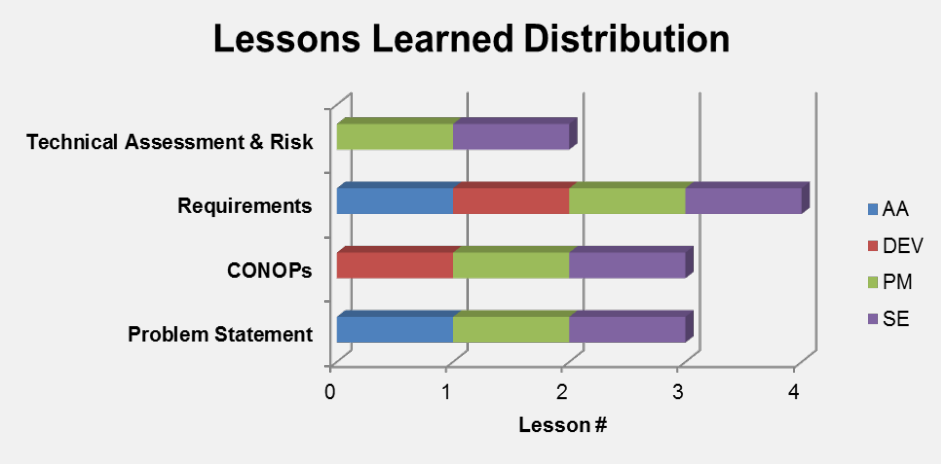
Lessons Learned

Iterations of Lessons Learned:

AUDIENCE	ITERATION: Problem Statement	CONOPs	Requirements	Technical Assessment & Risk
AA	●		●	
DEV		●	●	
PM	●	●	●	●
SE	●	●	●	●

Lesson 1:	Capability gaps and technology readiness are closely interrelated
Lesson 2:	A (CONOPs) picture is worth a thousand words
Lesson 3:	Reliance on 'existing technology' does not alleviate the need to develop requirements
Lesson 4:	Objective risk assessment models should be utilized

- Yielded four lessons learned that can be applied to acquisition agents, users, developers and program managers (PMs) and/or systems engineers (SEs).
- Interestingly, I found that the requirements iteration lessons learned is applicable to ALL audiences, reinforcing the importance requirements.
- Additionally, the all four lessons learned were applicable to the PMs and SEs.



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