Canadian Space Agency
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MULTIPLE-ATV SCALE LUNAR MOBILITY
OPERATIONAL CONCEPT STUDY

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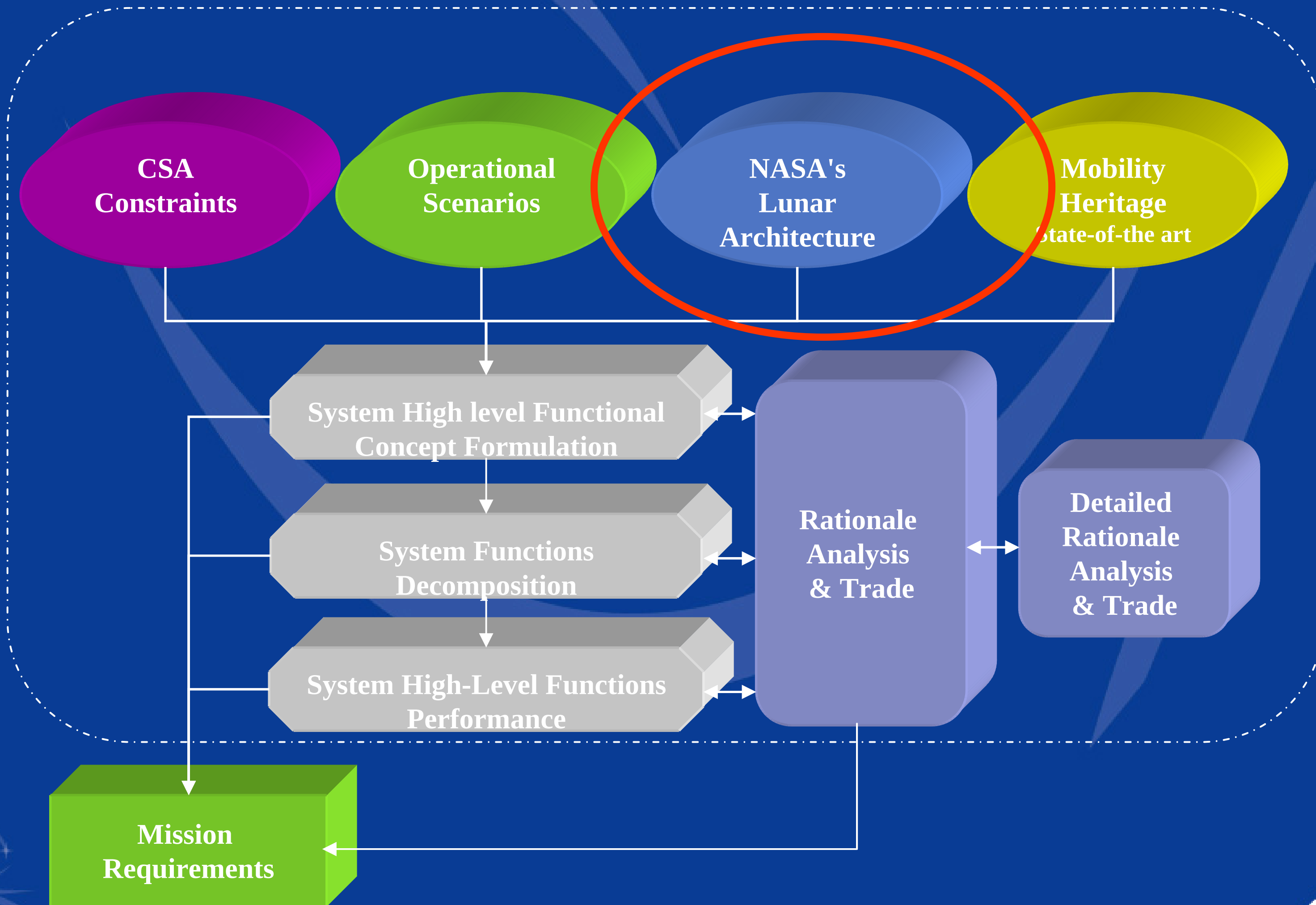
Study Objectives

- Contribute to determining Canada's role in the current NASA's lunar exploration architecture and plans.
- In-depth understanding of what is required to develop a Lunar Surface Mobility infrastructure in terms of function and performance.
- Focus on Multiple ATV scale rovers.

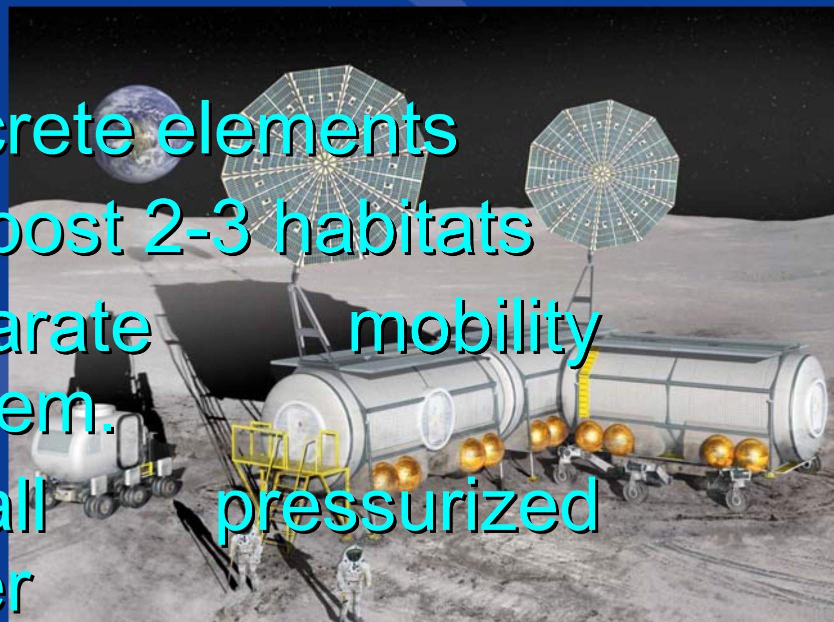
The Process

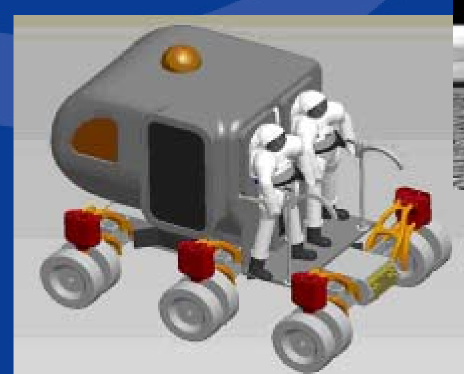


CSA Constraints
Operational Scenarios
NASA's Lunar Architecture
Mobility Heritage
State-of-the art
System High level Functional Concept Formulation
System Functions Decomposition
System High-Level Functions Performance
Rationale Analysis & Trade
Detailed Rationale Analysis & Trade
Mission Requirements

NASA's Lunar Surface & Mobility Architecture

- Discrete elements
- Outpost 2-3 habitats
- separate mobility system.
- Small pressurized rover
- Surface Carrier Concept
- Mobile Habitat





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Operational Scenarios

- Scenarios Were developed by a multi-discipline team
- Many iterations before a simple baseline set was developed
- Scenarios are based on multi ATV scale rovers

- Shackleton crater rim drive
- Sortie out of line of sight
- EVA Scenario
- Excavating a trench

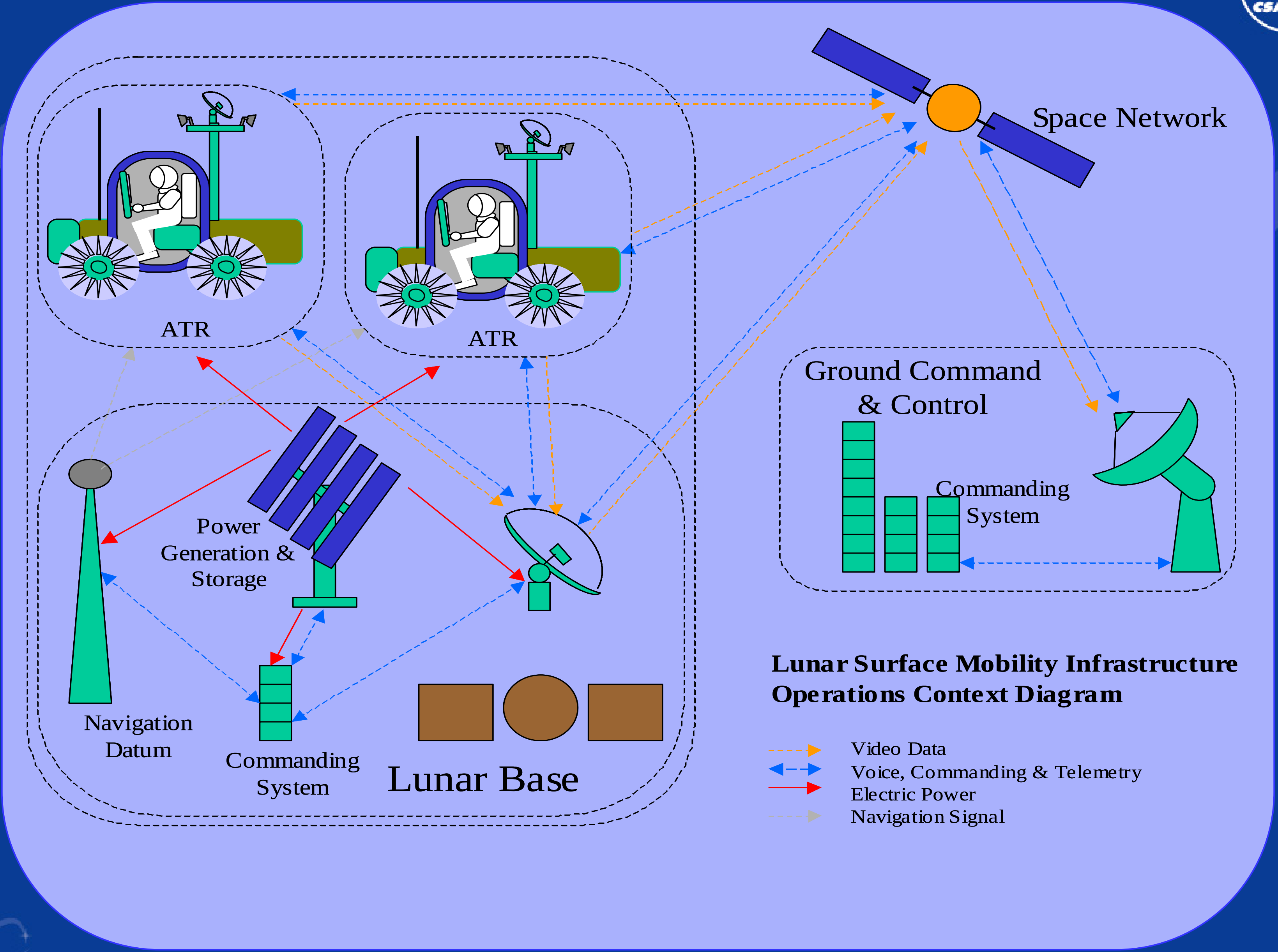
Failure modes:

- Loss of communication;
- Terrain not passable;
- Low Energy Level;
- Solar Flux Low;
- Sun event;
- Failure of vehicle;
- Astronaut incapacitated

Operational Scenarios

- Unmanned and Manned
- Unmanned scenarios showcase the need for variable level of autonomy;
- Manned scenarios highlight the added payload / speed / range and multi rover redundancy requirements to ensure astronaut safety;

Functional Concept Formulation



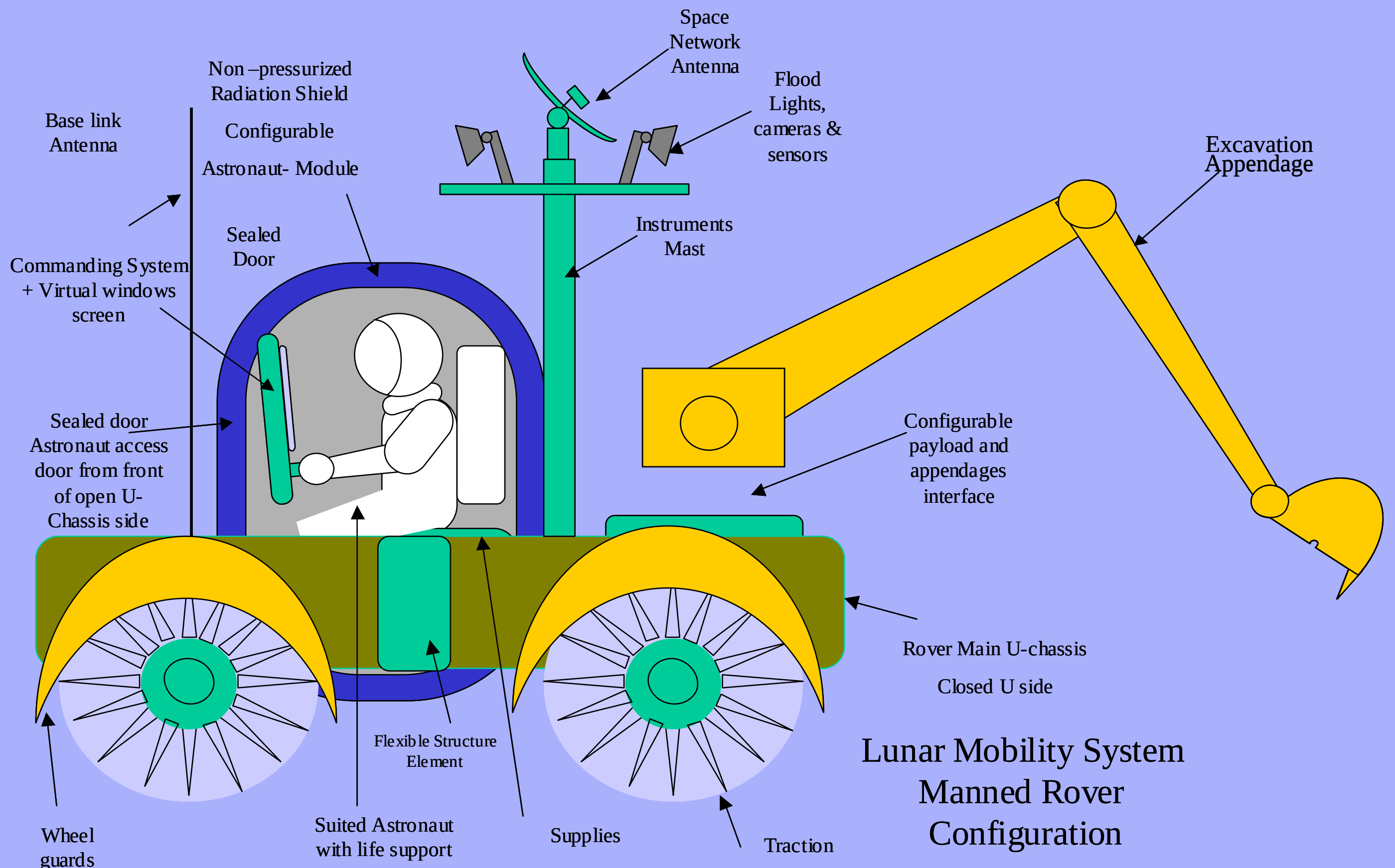
Lunar Mobility Module (LMM) Functions

- All terrain, electrically driven
- Configurable and scalable
- operate in lunar environment
- Specialized Functional Modules
- Self configure
- ATV to a large construction crane

Lunar All Terrain Rover (ATR) Configuration

- LMM based with Astronaut & other Modules
- ATV scale, Single astronaut vehicle
- Non pressurized, radiation protected vehicle
- Second astronaut carried in emergency.
- Various viable vehicle concepts

Study analysis are based on this configuration



Lunar Mobility System Manned Rover Configuration

Lunar Rover System Environment

- Day operation only
- 2 hrs drive in shadow
- Survive lunar night
- Operate anywhere
- 20^{o} max inclination
- Rocky unpacked regolith
- Obstacles height < 20cm
- Radiation protection
- Single Solar Events
- cosmic ray
- Vacuum
- 5 years operation
- Sealed from regolith
- Micrometeorites protection

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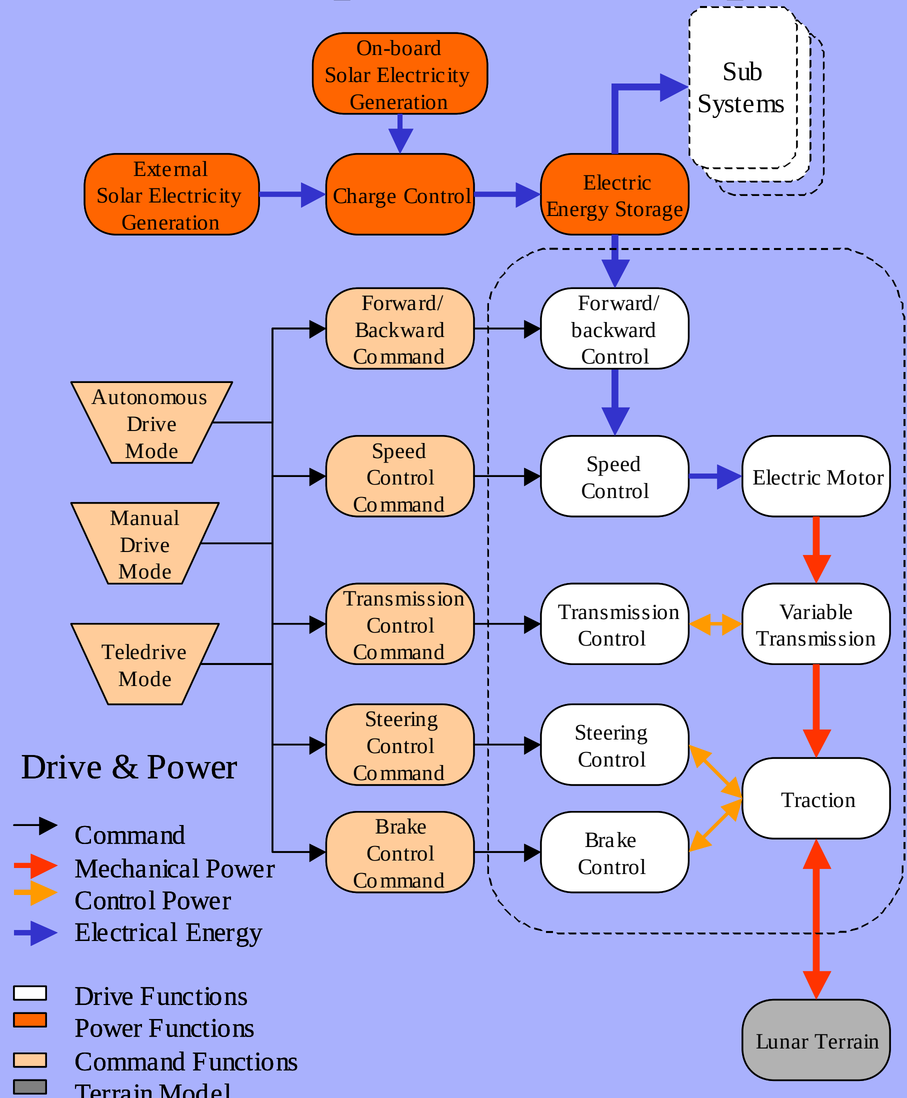
System Functions Decomposition Example



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Rationale Analysis and Trade

- RAT-1: Rover part of lunar base infrastructure (LAT-1, LAT-2)
- RAT-2: Multifunctional vehicle
- RAT-3: Scalable design
- RAT-4: Increase astronaut mobility to 21 km range (3 hr out, 3 hr back @ 7km/h average)

Detailed Rationale Analysis & Trade

- Vehicle Mass Estimate (305, 1100 kg)
- Estimating Lunar Vehicle's Drive Energy
- Lunar Vehicle Shield Mass Estimate
- Lunar Night Heating Power Estimate (10KWhr)
- Analysis of Power Generation & Storage
- Digital Video Data Rate Estimate

Lunar Vehicle Shield Mass Estimate

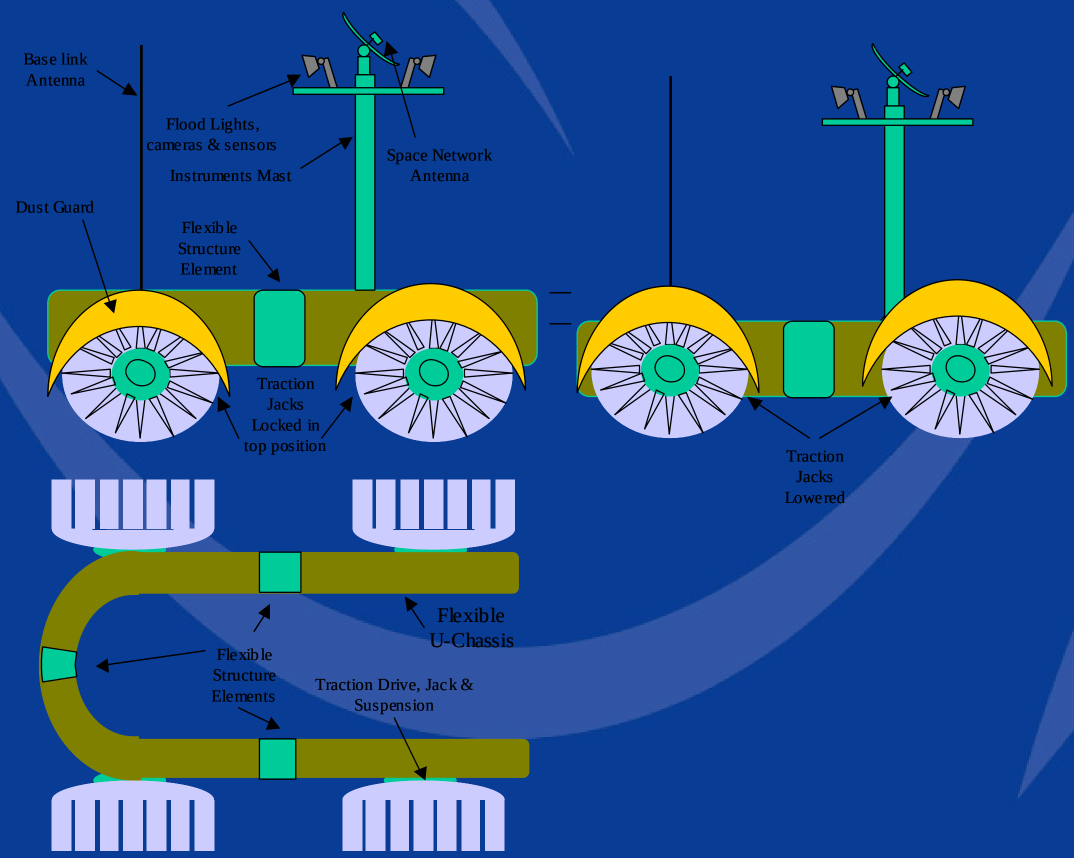
- Based on the CHEERS model data, SPE and GCR
- Body does equivalent at 10 g/cm^2 Aluminum
- Dosage PER YEAR = 94.8 cSv
- Values are within exposure limits of low orbit .
- Total mass estimated of (3.7cmThick) shield ~ 400Kg for one astronaut.
- Chosen value provides the best compromise in terms of radiation protection for astronaut and practical value for vehicle shield mass.

Power Generation & Storage Analysis (2)

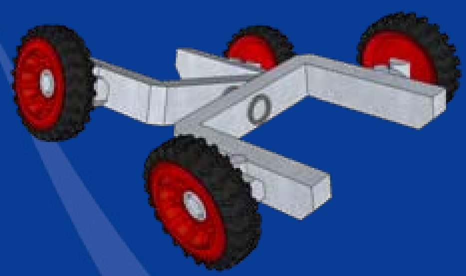
Vehicle Power Consumption Profile -1 Manned vehicle configuration			
Subsystem	**Parameters Values**	**Power Consumption**	
Traction			
Vehicle mass	1100 Kg		
Speed	7 Km/h		
Inclination	0 degree		
# Stops/Km	10		
# Slow downs/Km	20		
Subtotal		309W	
Thermal Night survival Thermal shadow drive	N/A 25 at 20%	5 W	
Comm. HB link Space	Off		
Comm. HB Link Base	Off		
CPU & electronics	Main CPU ON NAV CPU Off	12 W	
Instruments	Nav Inst = OFF Cams = OFF		
Flood Lights	100 W at 20%	20 W	
		P_T	**Range***
Total Power * See range estimate		**346 W**	**162Km**

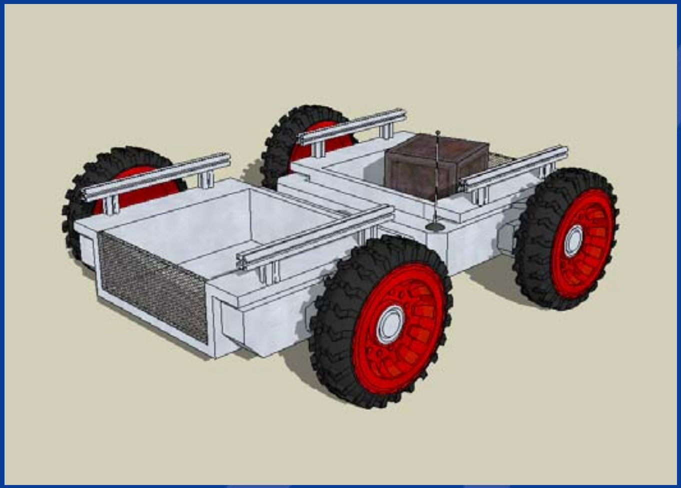
Vehicle Power Consumption Profile -3 Autonomous drive vehicle configuration			
Subsystem	**Parameters Values**	**Power Consumption**	
Traction			
Vehicle mass	1100 Kg or 350 Kg		
Speed	7 Km/h		
Inclination	0 degree		
# Stops/Km	10		
# Slow downs/Km	20		
Subtotal		309W or 98W	
Thermal Night survival Thermal shadow drive	N/A 25 at 20%	5 W	
Comm. HB link Space	Off		
Comm. HB Link Base	Off		
CPU & electronics	Main CPU ON NAV CPU ON	24 W	
Instruments	Scanner = ON Nav Inst = ON Cams = ON	48W	
Flood Lights	100 W at 20%	20 W	
		P_T	**Range***
Total Power * See range estimate	Full payload	**406W**	**127Km**
	LMM + 50Kg payload	**195 W**	**538Km**

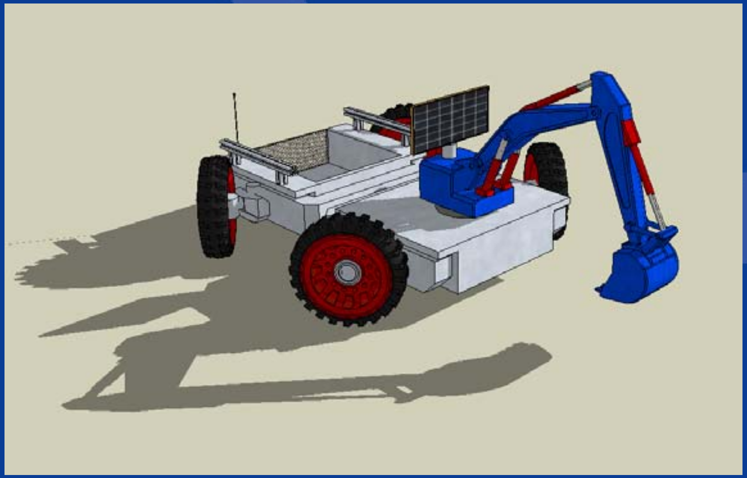
Chassis Concepts
U-Chassis

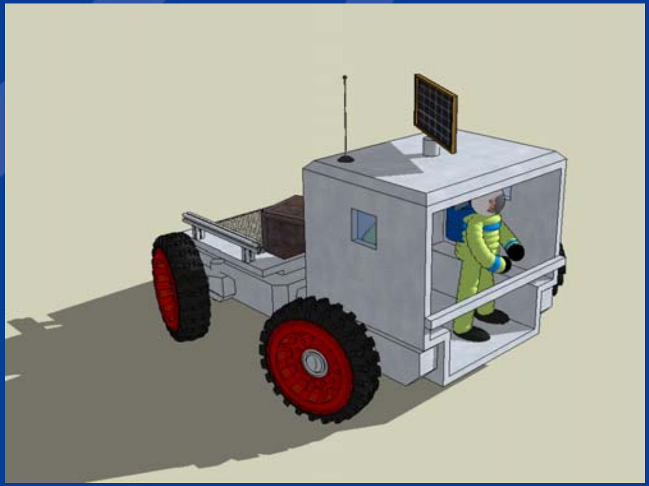


H-Platform concept

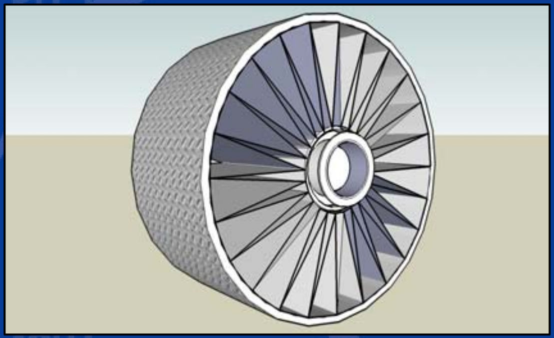


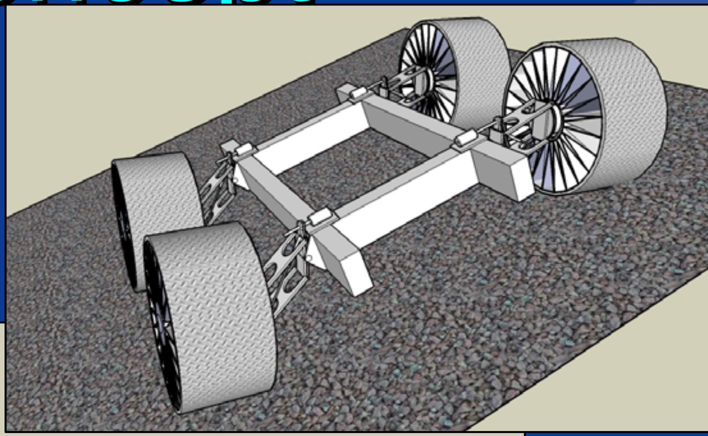


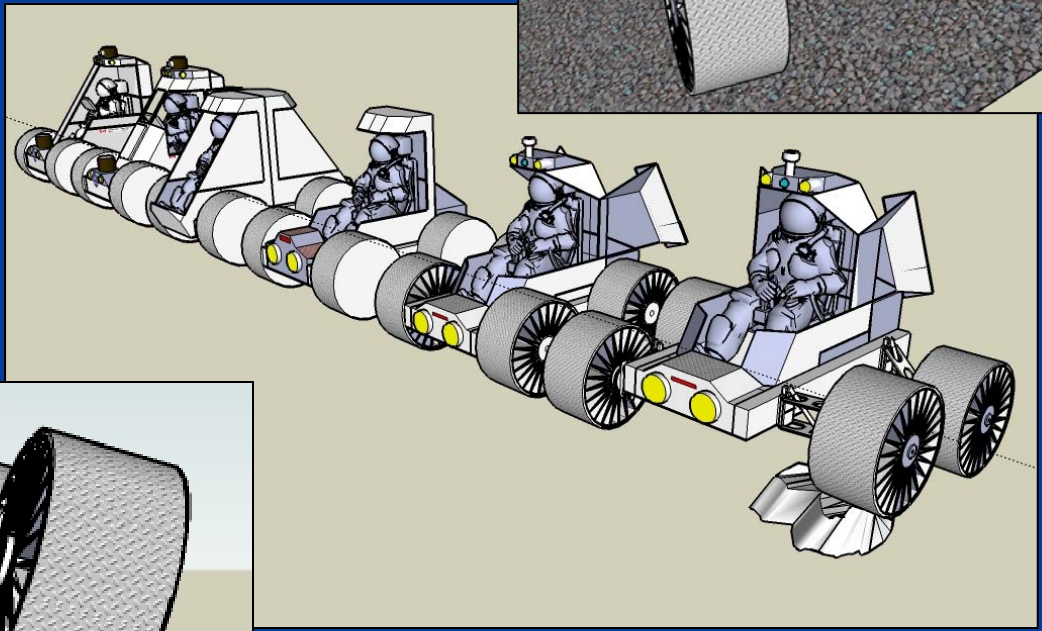


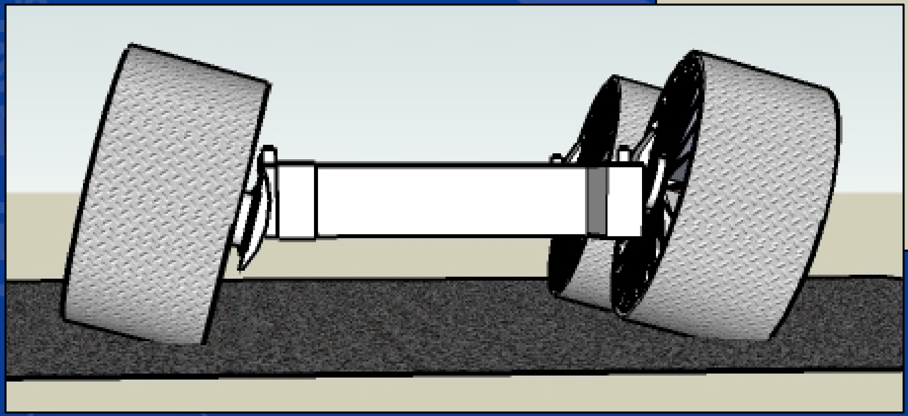


Squat I - Platform concept









Conclusions

- Human radiation protection is a mass driver at the ATV scale.
- Wheels vs tracks
- Safety of EVA astronauts driver (many small vehicle goes around walk-back)
- Power estimates (driving not too bad, night survival a challenge)
- Multi-purpose vehicle interesting