



Modeling Logistics and Supportability for Crewed Missions Beyond Low Earth Orbit

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Overview



- **Logistics and supportability will become more powerful drivers of risk and cost for crewed missions to the Moon and Mars.**
- **This Paper:**
 - Provides an overview of a methodology that is used for space mission logistics and supportability analysis, including key metrics, assumptions, and required inputs.
 - Acknowledges the unique demand from planned dormancy periods in Artemis campaign architecture and the challenges to modeling.
 - Characterizes the differences in lunar and Mars missions and this relationship with supportability analysis.

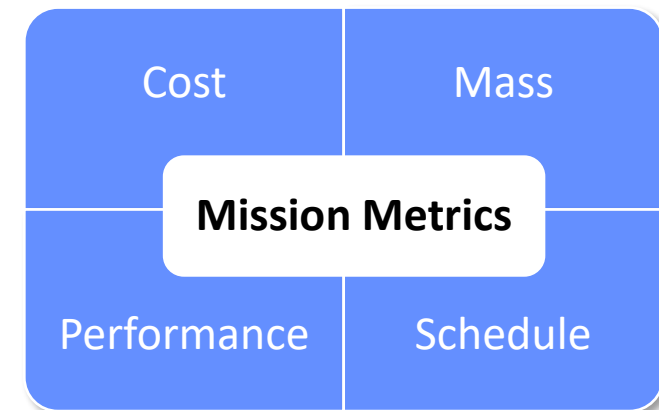
Supportability



- Supportability is a measure indicating how easily a specific system can be supported within a given context
- Comprised of a set of characteristics stemming from design and operational decisions made during system and mission development
- Analyses characterize the trade-offs between mission metrics and their relationship to system architecture and design choices

Supportability Characteristics
Reliability
Availability
Maintainability
Resupply Capability
Commonality
Redundancy
Level of Repair

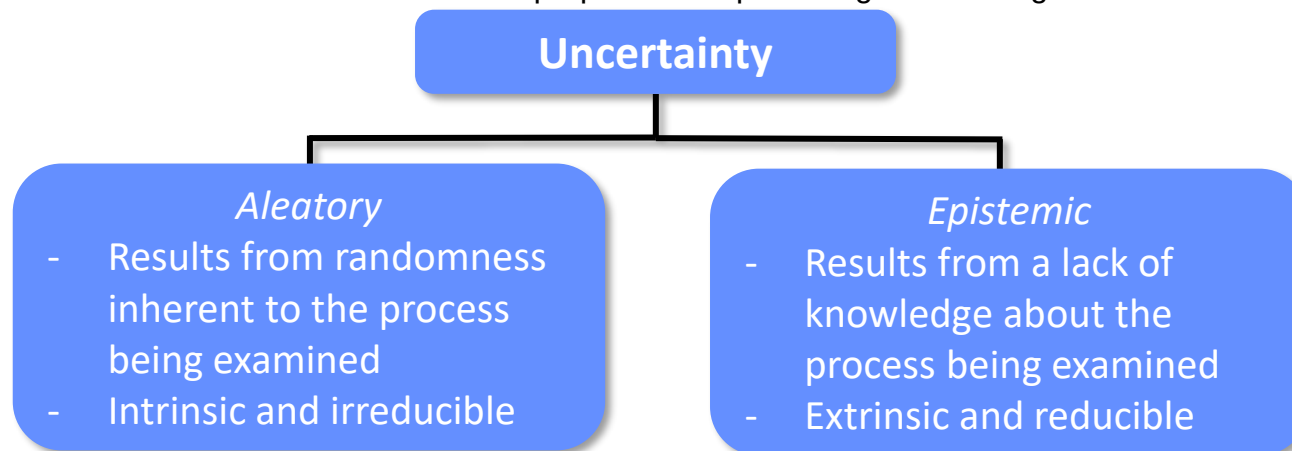
Objective of supportability analysis is to enable informed decision making in the early stages of mission and system design.



Risk



- Risk is defined as the combination of the probability that an event will occur and the impact that will result if that event does occur
- Utilize Probabilistic Risk Assessments (PRAs) to estimate the probability associated with a set of outcomes
- Uncertainty is a facet of risk and can be included when conducting supportability analyses
- In modeling, all the components of risk are quantified in the Probability of Sufficiency (POS)
 - POS is the probability that the amount of maintenance resources provided for a given mission are sufficient to cover all maintenance demands during a mission and is the key risk metric that determines required spares allocations.
- **Supportability analyses alone do not reduce risks, but it does:**
 - Aim to identify and characterize potential risks
 - Provide decision-makers the information to prepare for or plan mitigation strategies for the risks



Risk Dimensions

- Loss of Crew (LoC)
- Loss of Mission (LoM)
- Loss of Vehicle (LoV)



Quantified Risks

- Probability LoC (PLoC)
- Probability LoM (PLoM)
- Probability LoV (PLoV)



Logistics



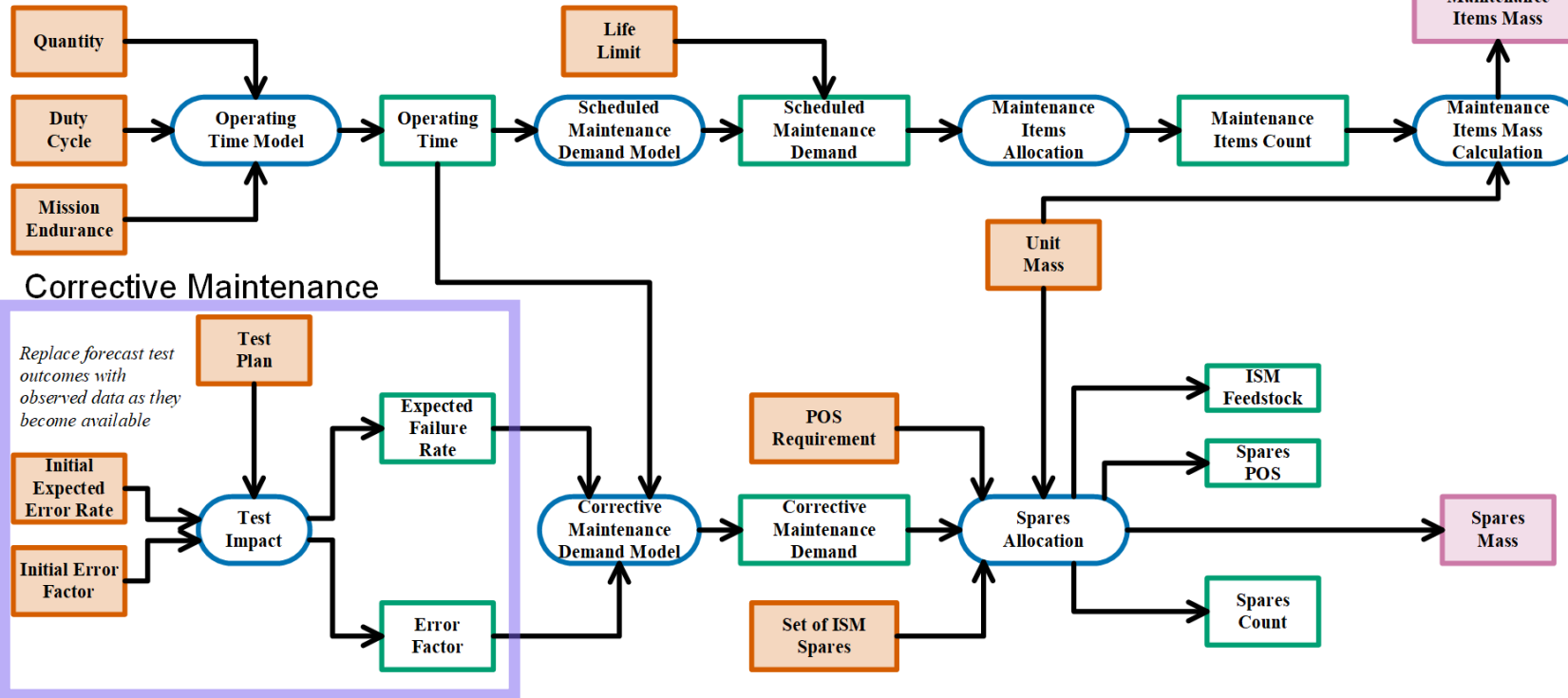
The items for health of the crew, health of the vehicle, and to support mission operations.

Categories of Logistics		
<i>Spares</i>	Used for corrective maintenance	Determined with the spares modeling approach
<i>Maintenance Items</i>	Used for scheduled maintenance	
<i>Consumables</i>	For consumption and/or use by the crew	Determined by the consumable logistics model
<i>Utilization</i>	For mission scientific objectives	
<i>Outfitting</i>	For bringing dormant systems online	
<i>Packaging</i>	Used for safely delivering other logistics items	

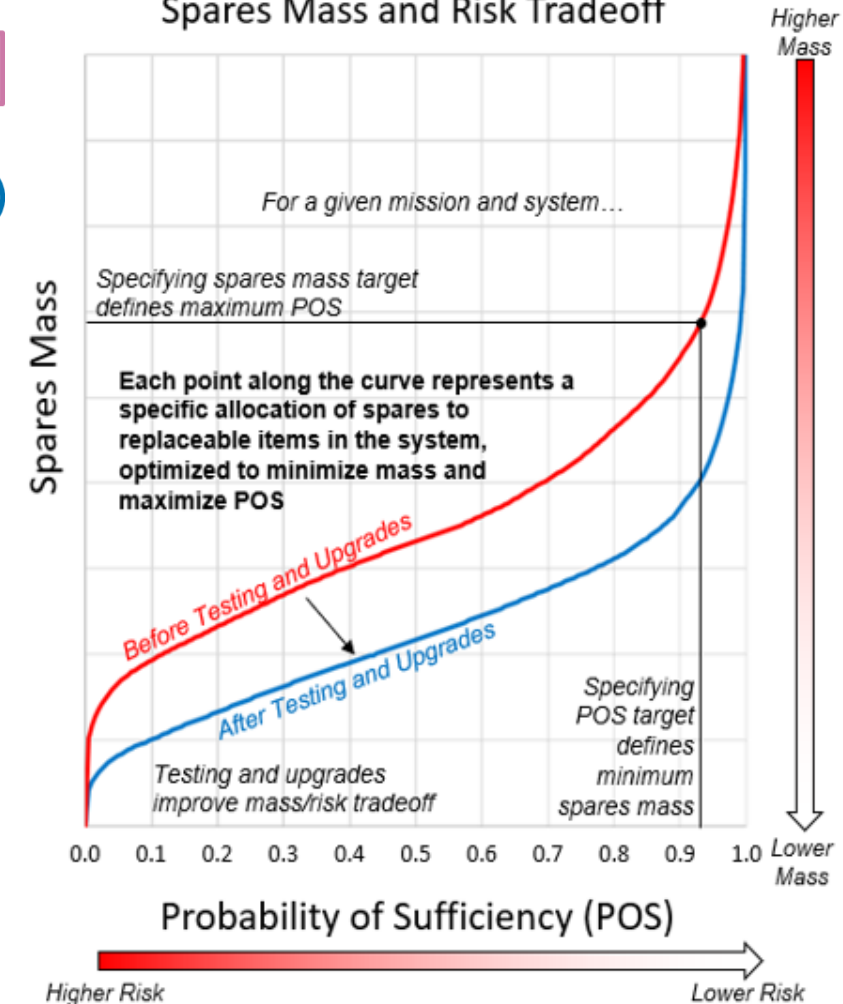
Spares Modeling



Scheduled Maintenance



Spares Mass and Risk Tradeoff

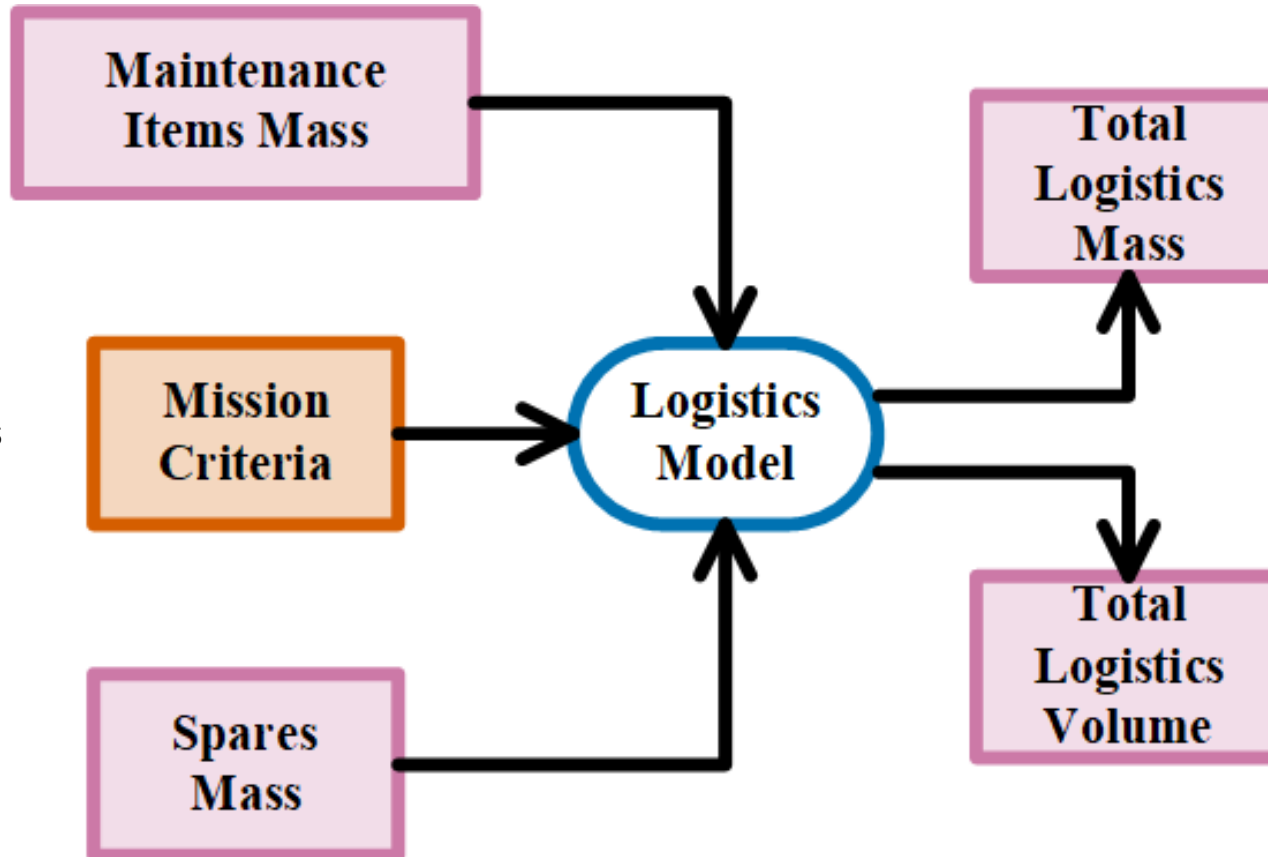


The **Test Plan** reduces the **epistemic uncertainty** of the Failure Rates and Error Factors, producing more accurate results for the spares analysis.

Logistics Modeling



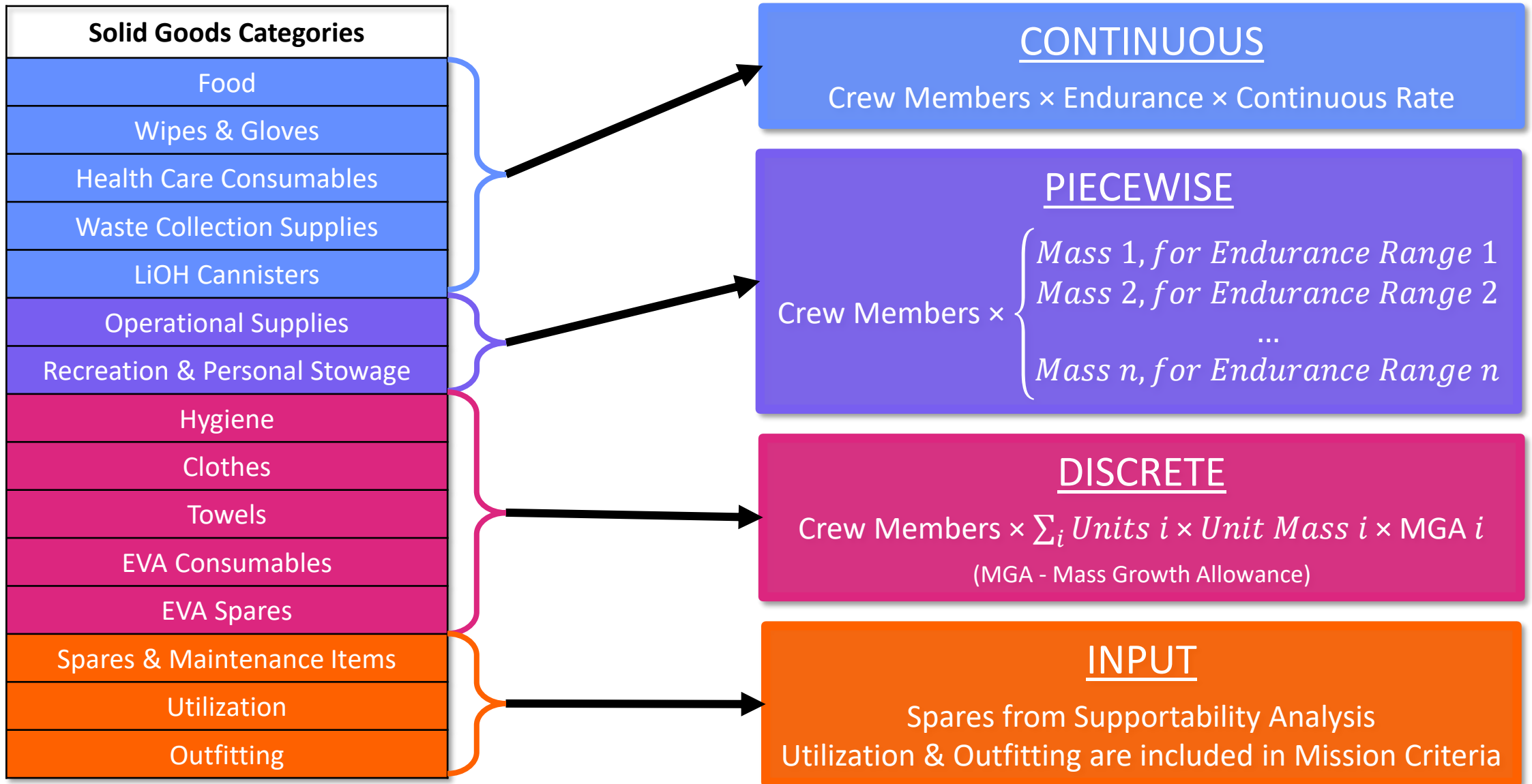
Total mass of all ORUs after
deterministic analysis



- Mission Duration
- Crew Size
- Mission Elements
- Environmental Control and Life Support Systems (ECLSS) Architecture
- Extra-Vehicular Activity (EVA) Cadence
- Transfer Schedule

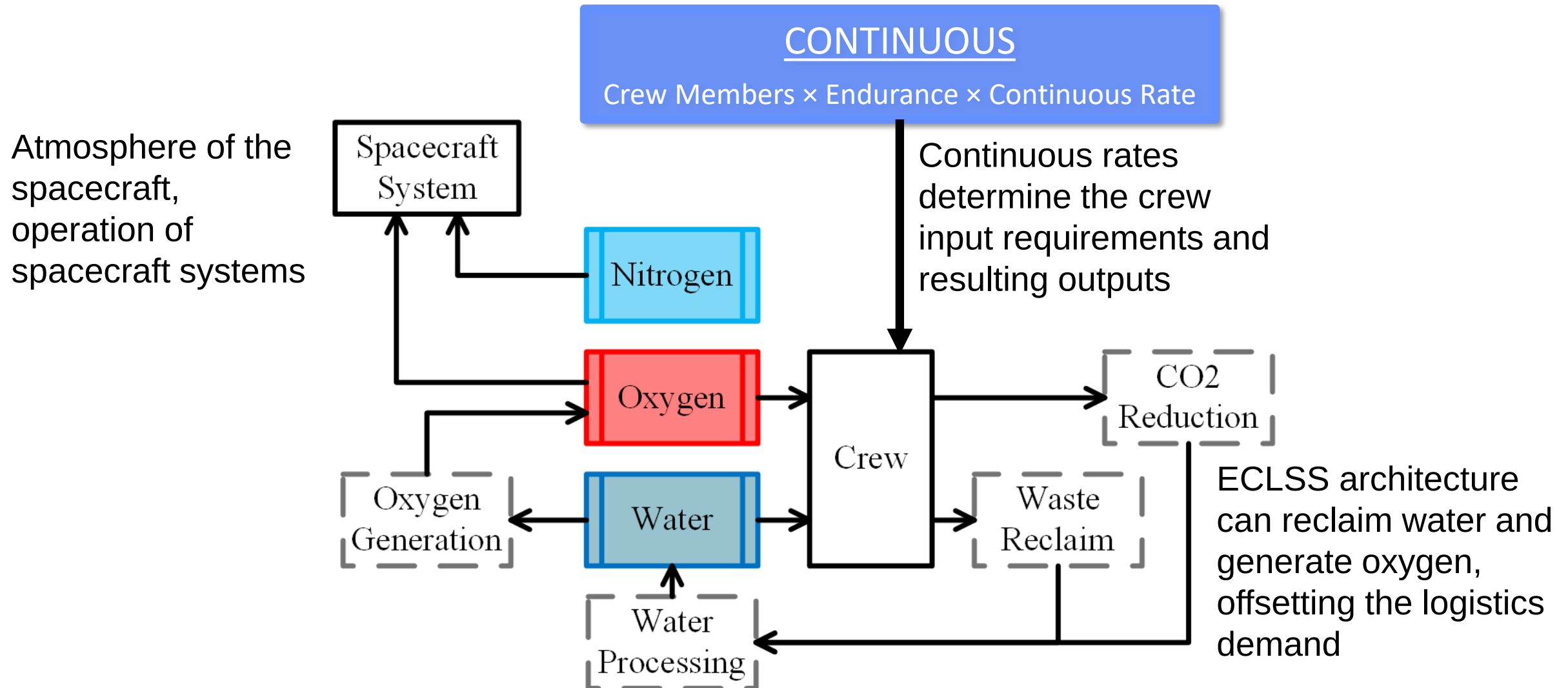
Total mass of all ORUs after
probabilistic analysis

Consumable Logistics Modeling – Solid Goods

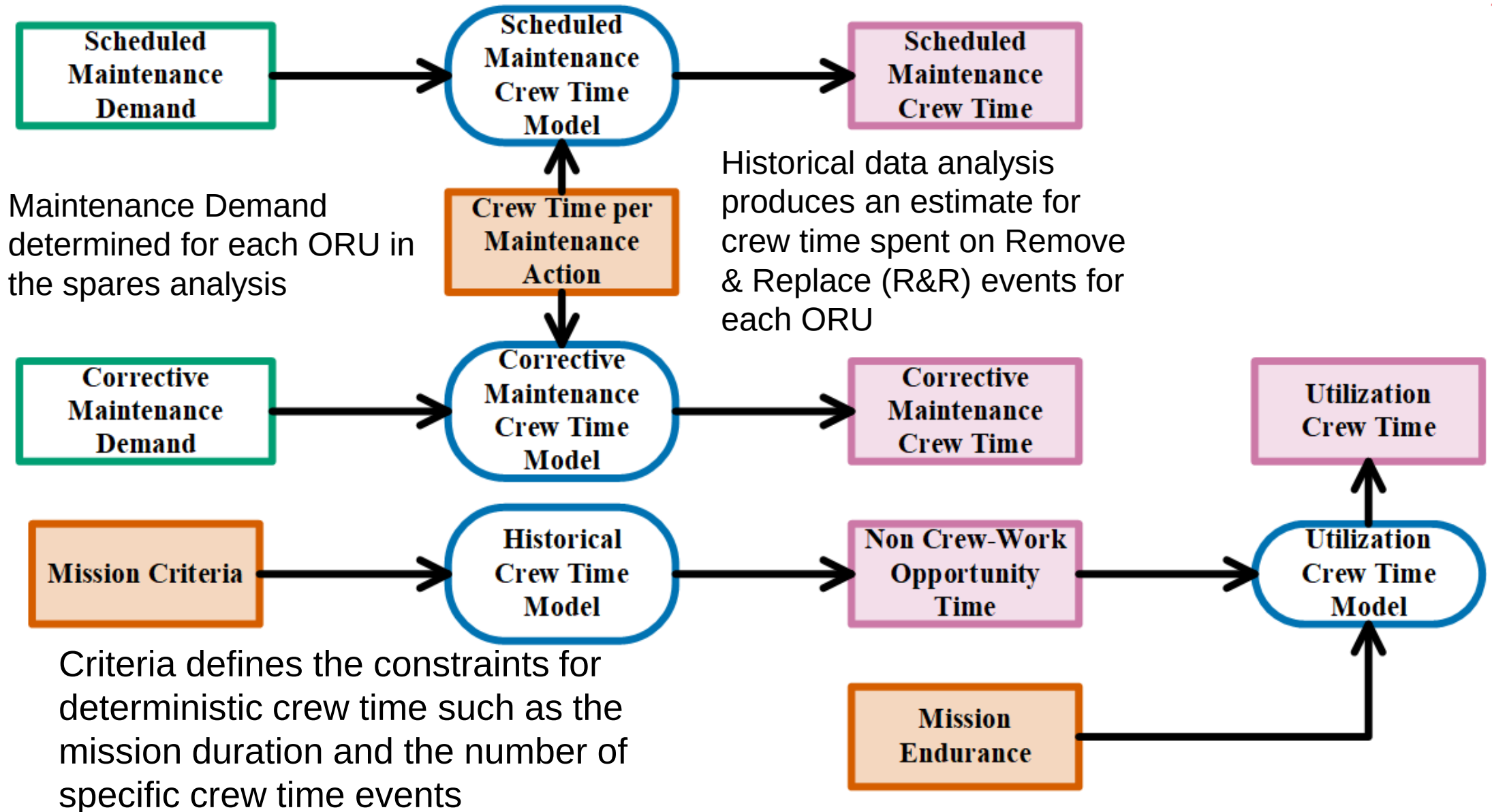


Solid Goods volume is determined with density per category assumption

Consumable Logistics Modeling – Gas & Liquids



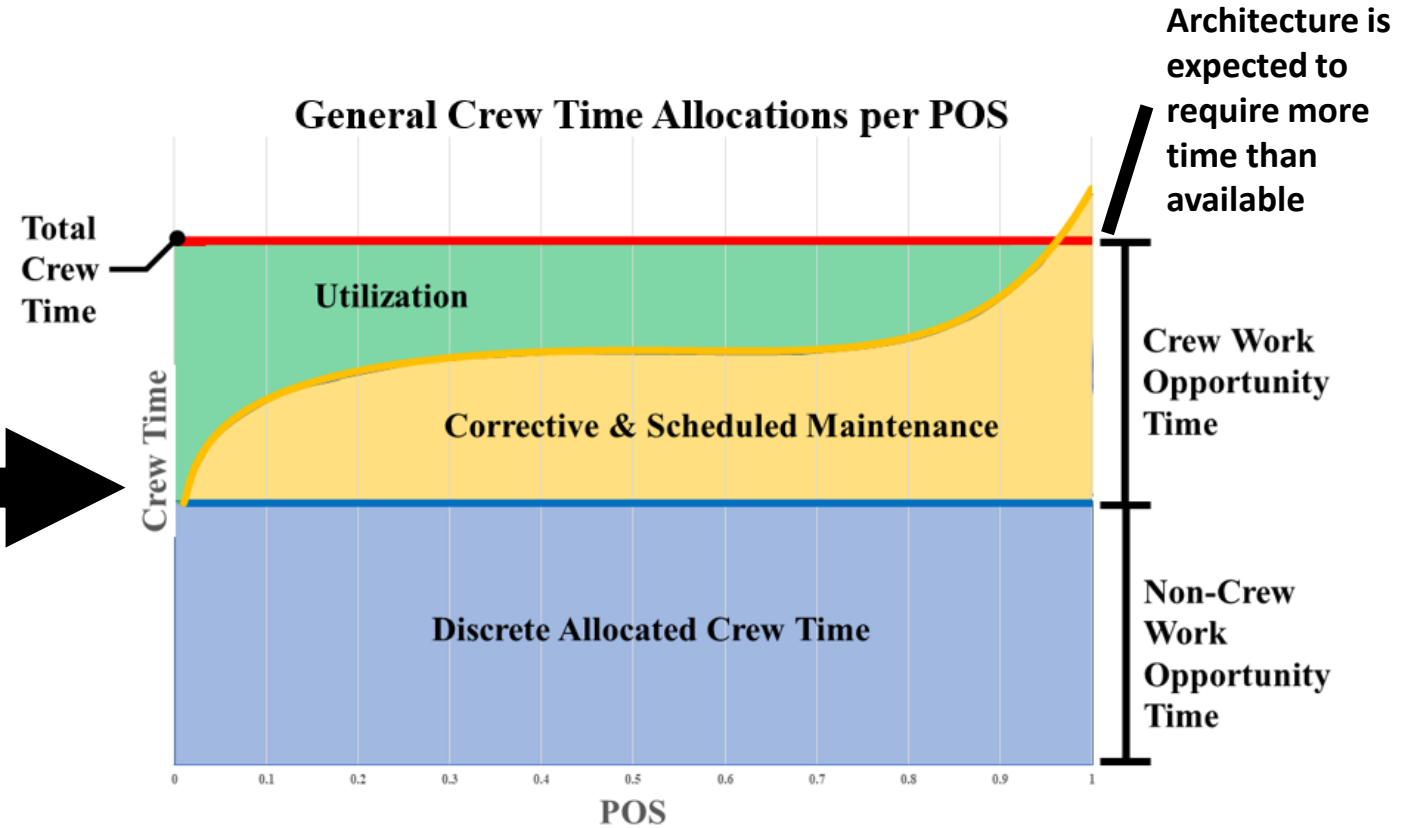
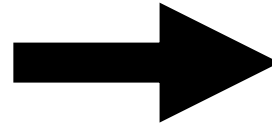
Crew Time Modeling



Crew Time Modeling



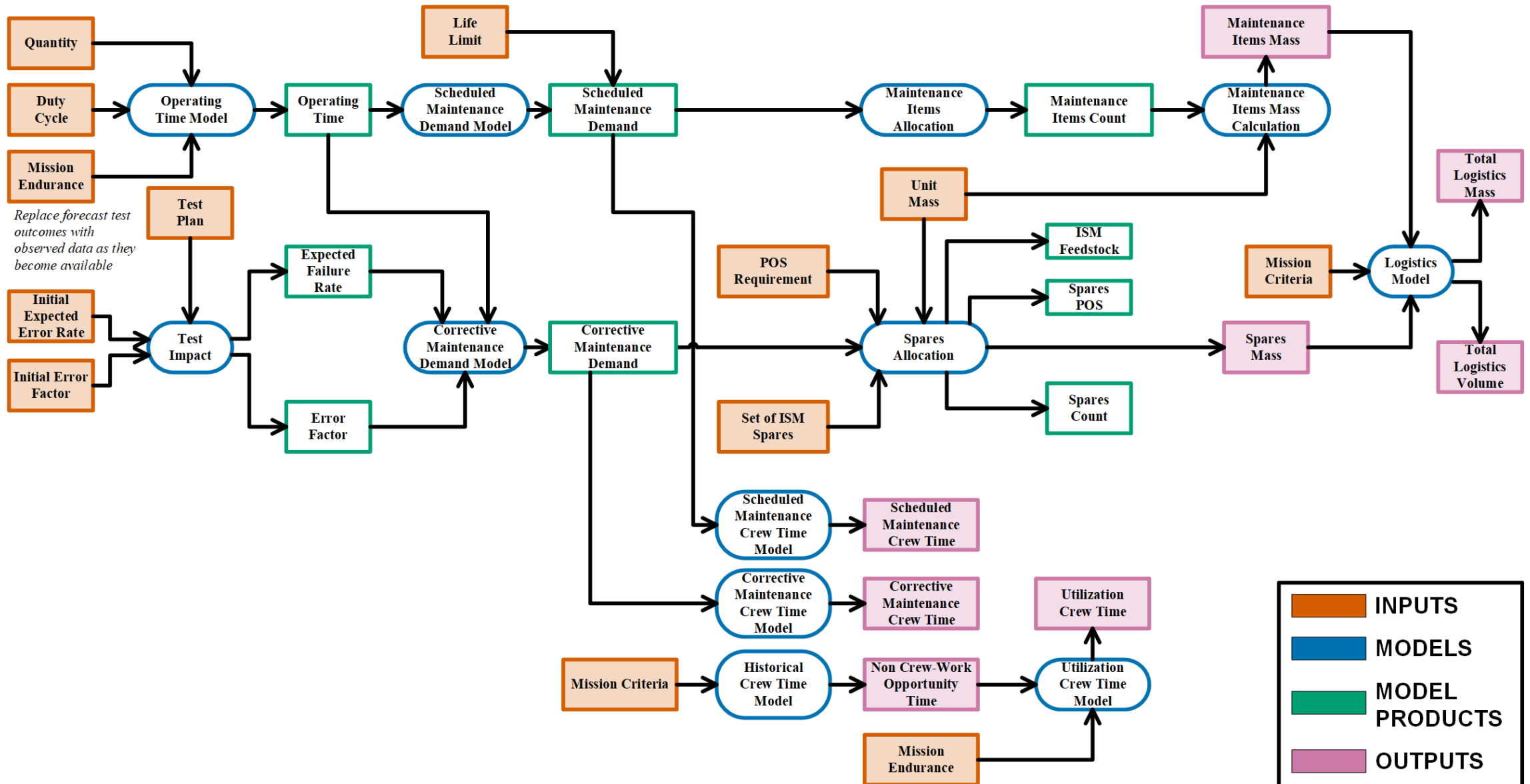
Activity	Sub-Activity	Operation Type
Vehicle Ops	Standup/Closeout	
	Traffic	Docking/Undocking
		Berthing/Unberthing
		Vehicle Relocation
Upkeep Ops	Routine Operations	
	Maintenance	Corrective Repair
		Scheduled Preventative
Outfitting		
Medical		
EVA		Pre-EVA
		EVA
		Post-EVA
Logistics	Vehicle Loading/Unloading	
	Routine Logistics Operations	
Training		
Exercise		
Utilization		
Work Prep		
Public Relations		
Conference		
Tag-Ups		
Personal		
Sleep		
Meals		



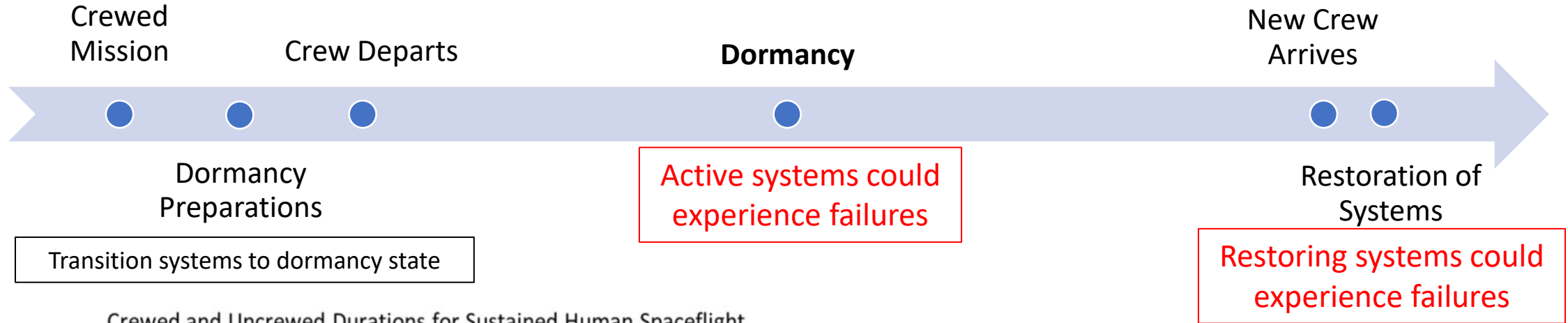
Crew Work Opportunity Time:

Difference of the Total Crew Time and the Discrete Allocated Crew Time.

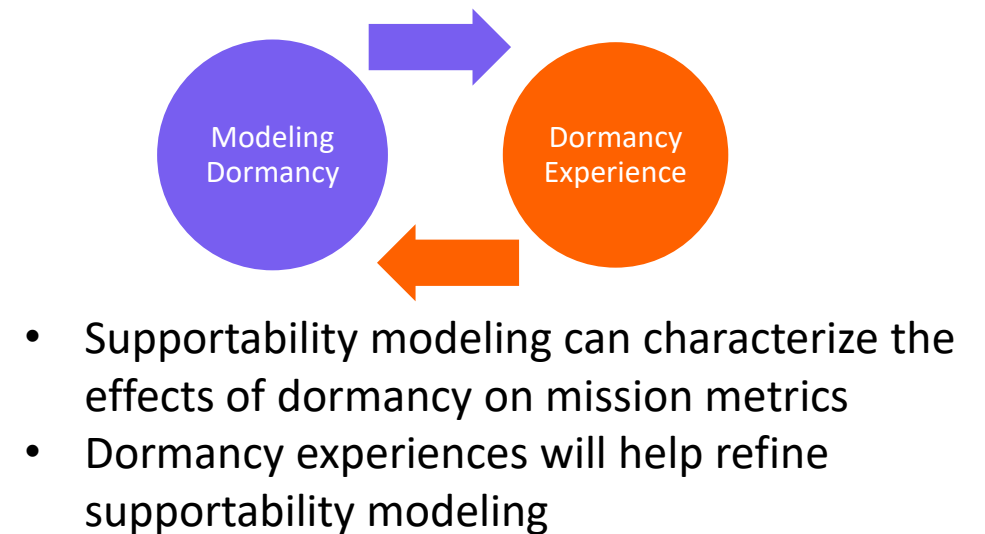
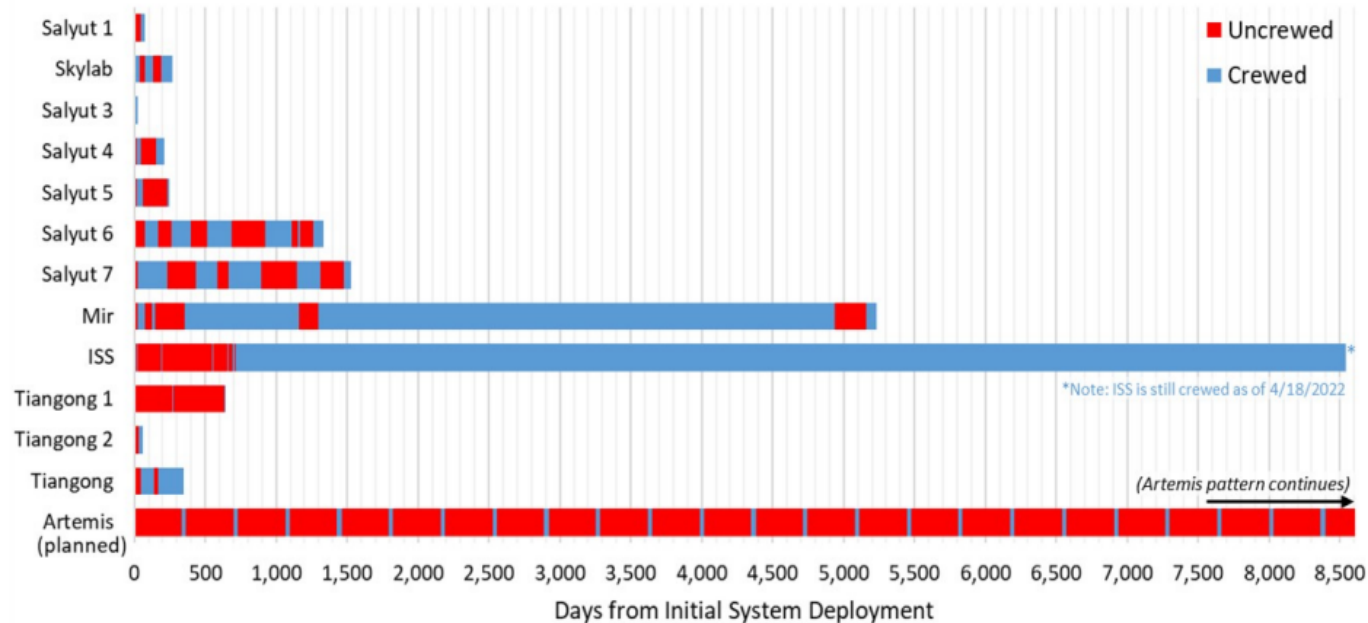
Integrated Supportability Analysis



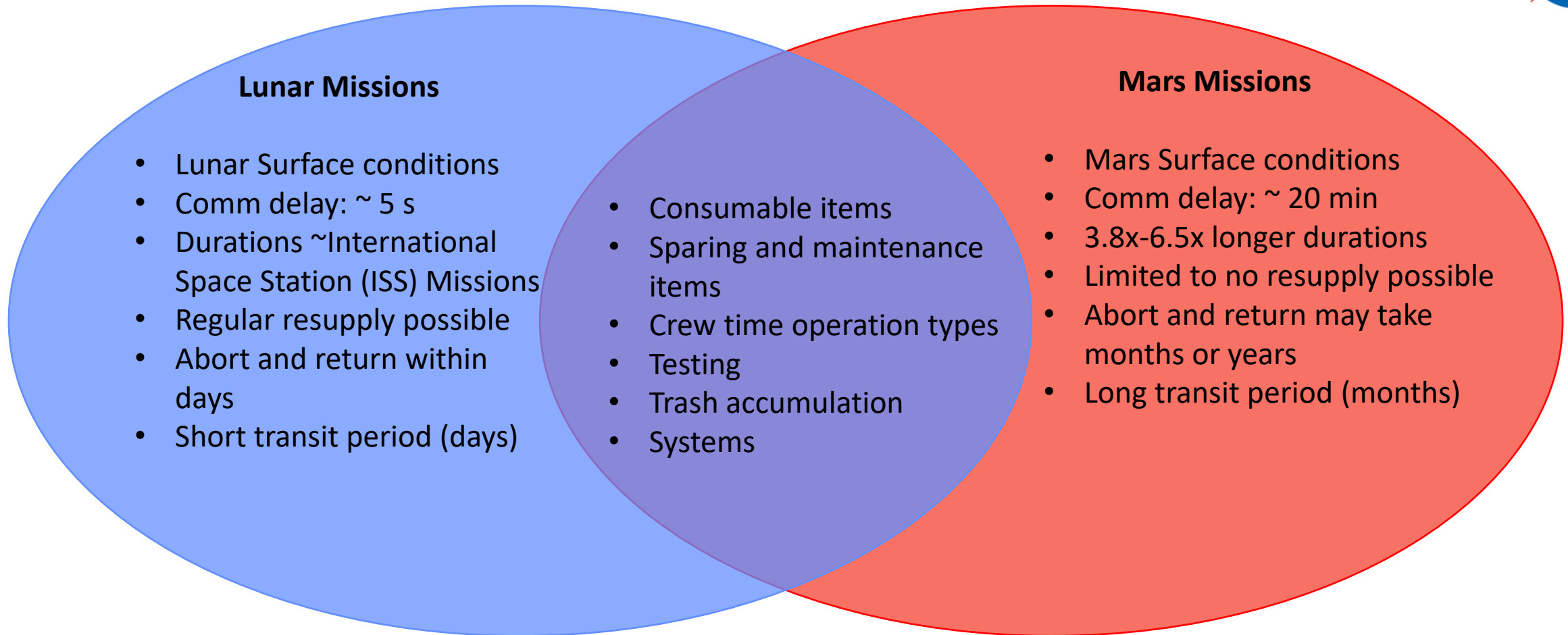
Dormancy Impacts



Crewed and Uncrewed Durations for Sustained Human Spaceflight

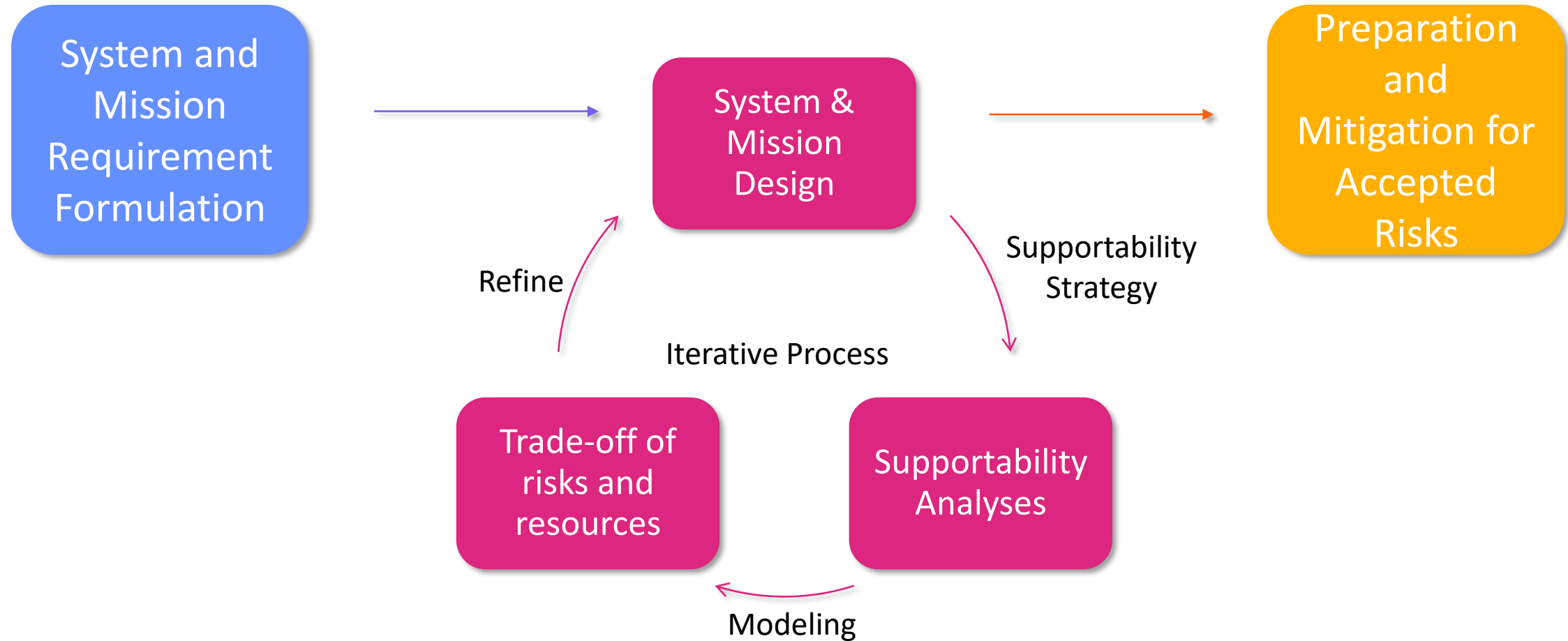


Moon and Mars Differences



Modeling methodology is the same for both lunar and Mars surface missions, however, the parameters used are different

Designing Systems with Supportability in Mind



Supportability analysis characterizes the relationship between system design, mission design, risk, and resource requirements, and can help guide system development and mission planning

Conclusion



- Logistics and supportability will become more powerful drivers of risk and cost as Lunar and Mars missions are developed.
- Supportability analysis characterizes the relationship between system design, mission design, risk, and resource requirements, and can help guide system development and mission planning.
- Supportability modeling uses spares, consumables, and crew time models to characterize the trade-offs between mission metrics and their relationship to system architecture and design choices.
- The same modeling methodology can be used for lunar and Mars missions with different input parameters.
- Analysis alone doesn't reduce risk, but it does enable more informed decision-making during system development, which can enable safer and more effective systems.



Thank You
Any Questions?

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