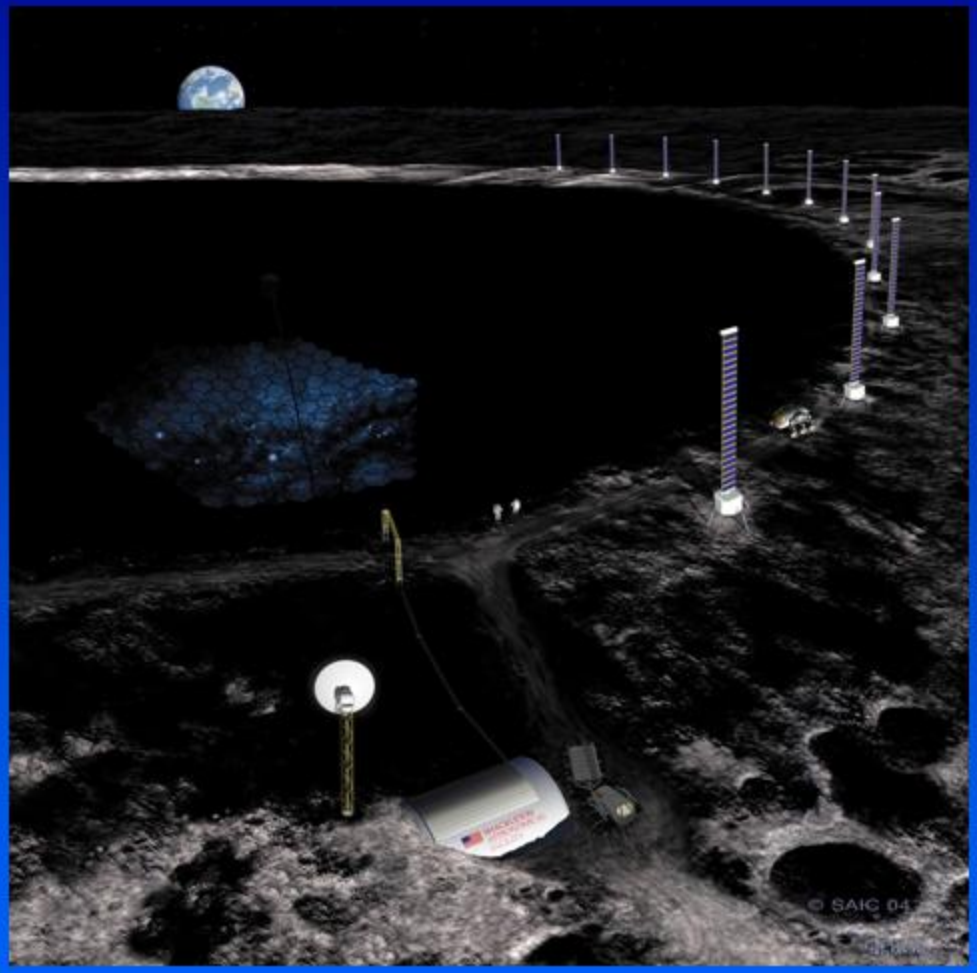

Concept Exploration and Refinement

Kickoff Briefing

September 13, 2004

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From Science to Solutions

Briefing Topics

- Overall Approach
- Initial Concept for Technical Solution
  - Architecture
  - Missions Campaign
- Initial Assessments
- Schedule and Products

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Overall Approach

- Refine a lunar exploration mission architecture and campaign that provides an affordable yet safe and reliable infrastructure for testing systems and operations that will be used on future Mars missions
- Architecture options and system performance options within these architectures have been studied extensively
- Develop FOMs related to safety, risk, reliability, performance, sustainability & evolvability, and cost
- Bring lessons learned from recent program support and relevant studies
- Integrated evaluation of FOMs at architecture level to assess trends and impacts

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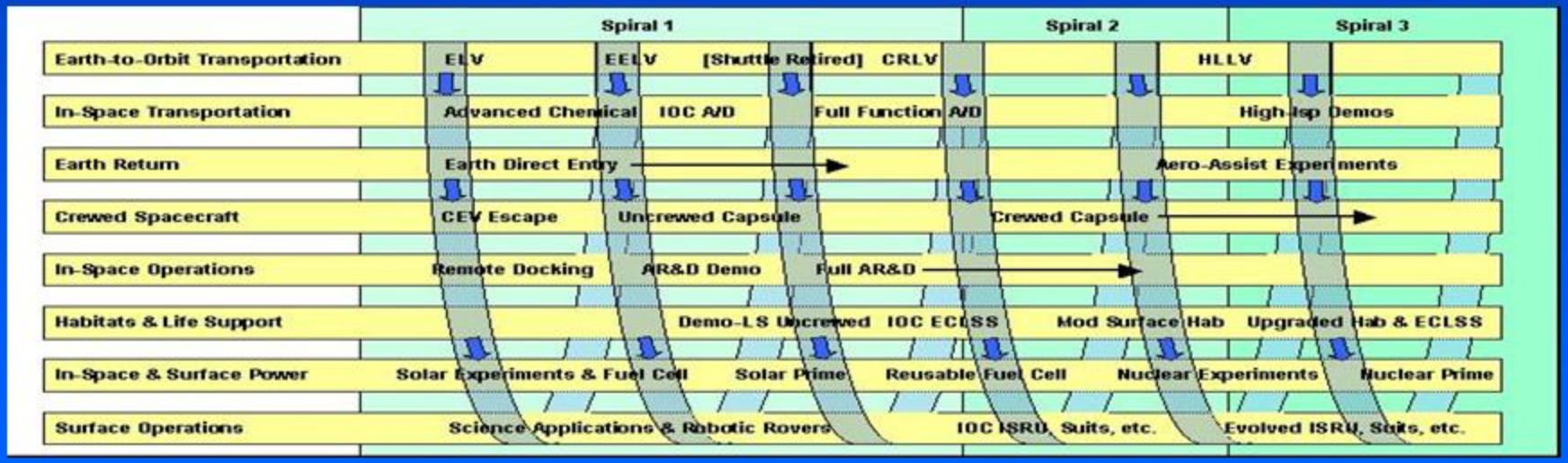
Spiral Development

- Initial assessment of spiral development needs in the context of the recent mandate



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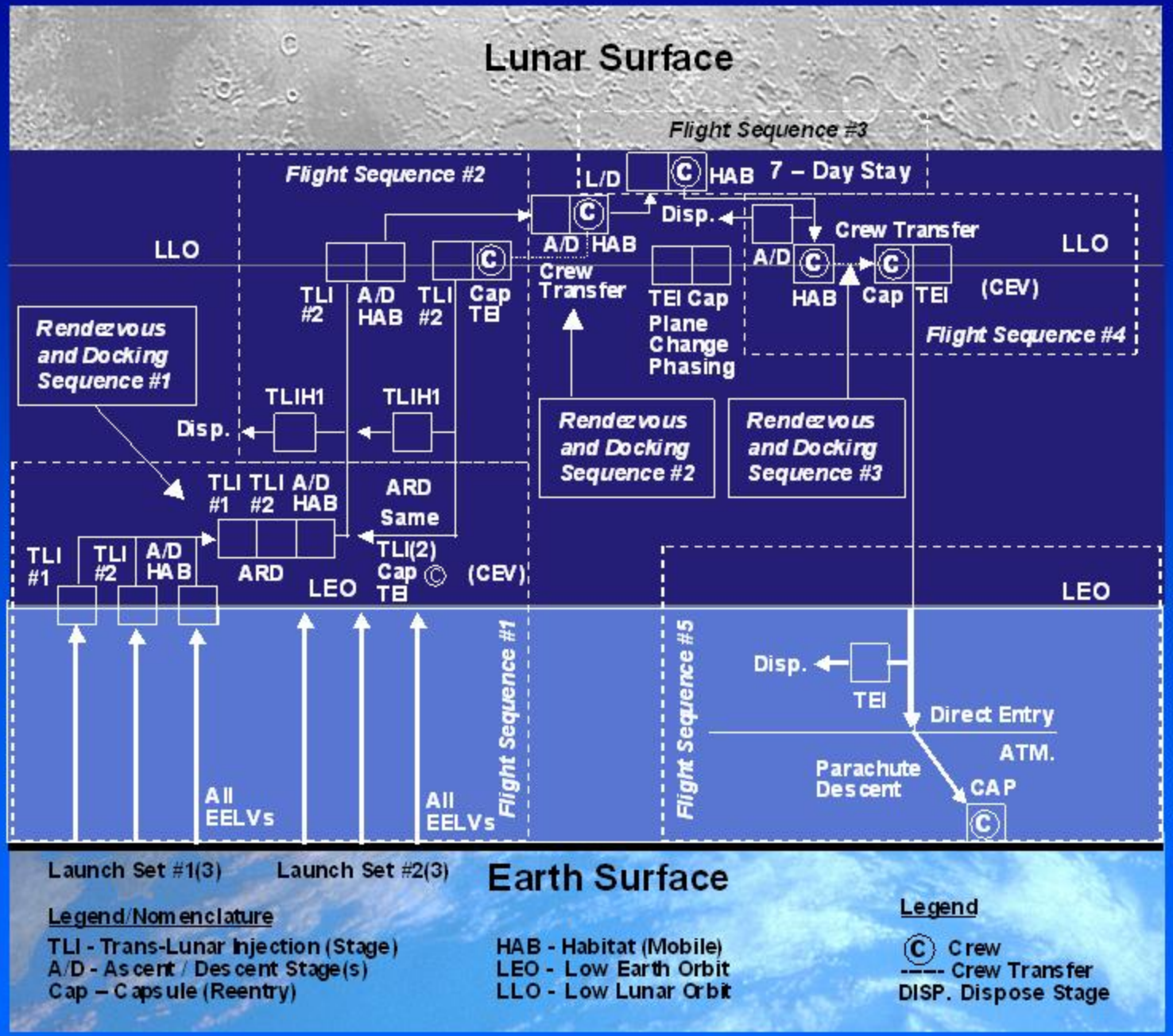
Flight Sequence and Extensibility

	System	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	System Description
Earth-To-Orbit	EELV				1	2	4	5	6		7				9	10	11	12	13	15	16			Delta or Atlas EELV
	Crew Rated Launch Vehicle								6			8			9	10	11	12	13	15	16	17,19	20	Clean Sheet or Evolved Man Rated LV
	Heavy Lift Launch Vehicle																			14,15	16	17-19	20	Clean Sheet or Evolved w/ 50+ MT lift cap.
In-Space Transportation	Descent/Ascent Modules							5			7						11	12	13	15	16	17.19	20	Evolving functions – single non start eng to multi
	Advanced Chemical				1	2	4	5	6		7				9	10	11	12	13	15	16	17.19	20	Low boil-off cryo or adv. storable prop. engines
	High Isp Propulsion																			14		18	20	SEP, NEP propulsion for slow p/d delivery
Earth Return	Earth Direct Entry						4	5	6		7	8			9	10	11	12	13	15	16	17.19	20	Adv. TPS for direct atm. re-entry from LEO/LLO
	Earth Capture - Aero-assist																		13	14			20	Aerobraking or aerocapture in LEO - expen return
Crewed Spacecraft	CEV - Escape System					3	4		6			8			9	10	11	12	13	15	16	17,19	20	Launch escape system for crew safety
	CEV - Capsule					3	4		6			8			9	10	11	12	13	14	16	17,19	20	Capsule for launch, re-entry and crew support
In-Space Operations	Remote Docking				1																			Human manipulated docking done remotely
	AR&D					3			6		7	8			9	10	11	12	13	14	16	17,19	20	Autonomous rendezvous and docking
Habitats & Life Support	Modular Surface Habitat - IOC										7					10	11							Habitat for short stay missions
	Connected/Enlarged Modular Surface Habitat														9			12	13	15		17,19	20	Linked modular surface hab s for extended stay missions
	ECLSS														9	10	11	12	13	15	16	17,19	20	Open-loop life support evolving to Mars-compat.
In-Space & Surface Power	Solar Electric				1		4	5	6		7	8			9	10	11	12	13	15	16	17.19		Photovoltaic power production
	Fuel Cells				1	3	4		6		7	8			9	10	11	12	13	15	16	17,19	20	H2/02 fel power production and storage
	Nuclear																	12	13	15	16	17,19	20	Surface nuclear power for sustained lunar bases
Surface Operations	ISRU															10	11	12	13	15	16	17,19	20	02 generation evolving to mult. Purpose suits
	Surface Navigation															10	11	12	13	15	16	17,19	20	Beacons or inertial ref. systems for surface nav.
	Surface Mobility																11	12	13	15	16	17,19	20	Non-pressurized evolving to pressurized
	EVA Suits - Evolved Lunar Suit														9	10	11	12	13	15	16			Evolved suits - tailored for lunar environment
	EVA Suits - Evolved Mars Suit																			15	16	17,19	20	Evolved suits - tailored for Martian environment
					Spiral 1										Spiral 2					Spiral 3				

Legend: Common system within the lunar mission set; Evolvable system (later lunar mission and/or Mars); Common system extensible to Mars


Lunar Surface
Flight Sequence #3
L/D
HAB
7 – Day Stay
Flight Sequence #2
Disp.
Crew Transfer
LLO
A/D
HAB
Crew Transfer
TEI Cap
Plane
Change
Phasing
A/D
HAB
Cap
TEI
(CEV)
LLO
Flight Sequence #4
TLI #2
A/D HAB
TLI #2
Cap TEI
Rendezvous and Docking Sequence #1
TLIH1
TLIH1
Disp.
Rendezvous and Docking Sequence #2
Rendezvous and Docking Sequence #3
TLI #1
TLI #2
A/D HAB
ARD
Same
TLI #1
TLI #2
A/D HAB
ARD
TLI(2)
Cap TEI
(CEV)
LEO
LEO
Flight Sequence #1
All EELVs
All EELVs
Flight Sequence #5
Disp.
TEI
Direct Entry
ATM.
Parachute Descent
CAP
Launch Set #1(3)
Launch Set #2(3)
Earth Surface
Legend/Nomenclature
TLI - Trans-Lunar Injection (Stage)
A/D - Ascent / Descent Stage(s)
Cap – Capsule (Reentry)
HAB - Habitat (Mobile)
LEO - Low Earth Orbit
LLO - Low Lunar Orbit
Legend
Crew
Crew Transfer
DISP. Dispose Stage

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Initial Risk Assessment (example)

Ref. No.	Risk Statement	Risk Level	Mitigation Outline
			Technical Risks
RT-1	Long duration human missions beyond LEO may not be safe due to radiation effects on human physiology	High	1. Radiation shielding concepts developed and proven in variety of test beds (Earth laboratory, ISS, CEV demonstration flights) to mitigate this Crew health risk 2. High Isp propulsion technology development initiated early in program to reduce mission durations as much as possible
RT-2	Inability to dock critical systems in orbit at LEO and/or LLO aborts key mission	Low	3. Repeated missions demonstrate various docking systems early in campaign to prove capability and add confidence in mission success predictions
RT-3	Crew stranded on lunar surface, unable to return to Earth	Medium	4. Predeployment of additional surface assets and remote monitoring ensures redundant systems available before Crewed mission ever launches 5. System failure tolerance optimized through modularity 6. Abundant operational workarounds built into missions, such as hardware cannibalization and multi-mission/reconfigurable software

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Activities Sequence and Products

	System Concept Architecture Definition	System Analysis	System Integration	Requirement Engineering
		Base		Option
Activities	• Define Mission Objectives • Identify Stakeholders • Define System Boundaries • Identify Constraints & • Driving Requirements	• Define Operational Concepts • Develop Functional Models • Using CORE • Determine Interfaces • Determine Capabilities • Develop Integrated Trade Tool Set	• Develop Enterprise Requirements • Allocate Requirements System Level • Manage Requirements Using Doors	• Identify Capabilities Requirements for Each Mission • Advanced Technology Assessment Using Fast Pact • Requirement Viability Assessment
Products	• Mission Objectives • Schedules/Plans	• Operational Concept Description • FFBD/IDEF0 Models • DRM for Each Spiral • Trade Studies	• Populated Requirements Database with Allocations to Systems	• Systems Simulations • Requirements Analysis Results

Trade Study Areas

- Technology
  - Launch Vehicle, High Isp In-space Propulsion, Lunar Surface Power
- Modularity
  - CEV, Habitation Module
- Reuse
  - CEV Capsule, Lunar Surface Infrastructure Elements, In-space Propulsion
- Campaign
  - Number of Missions, Test Objectives in each Mission, Mission Sequencing; CEV Draft Level I Requirements Impacts

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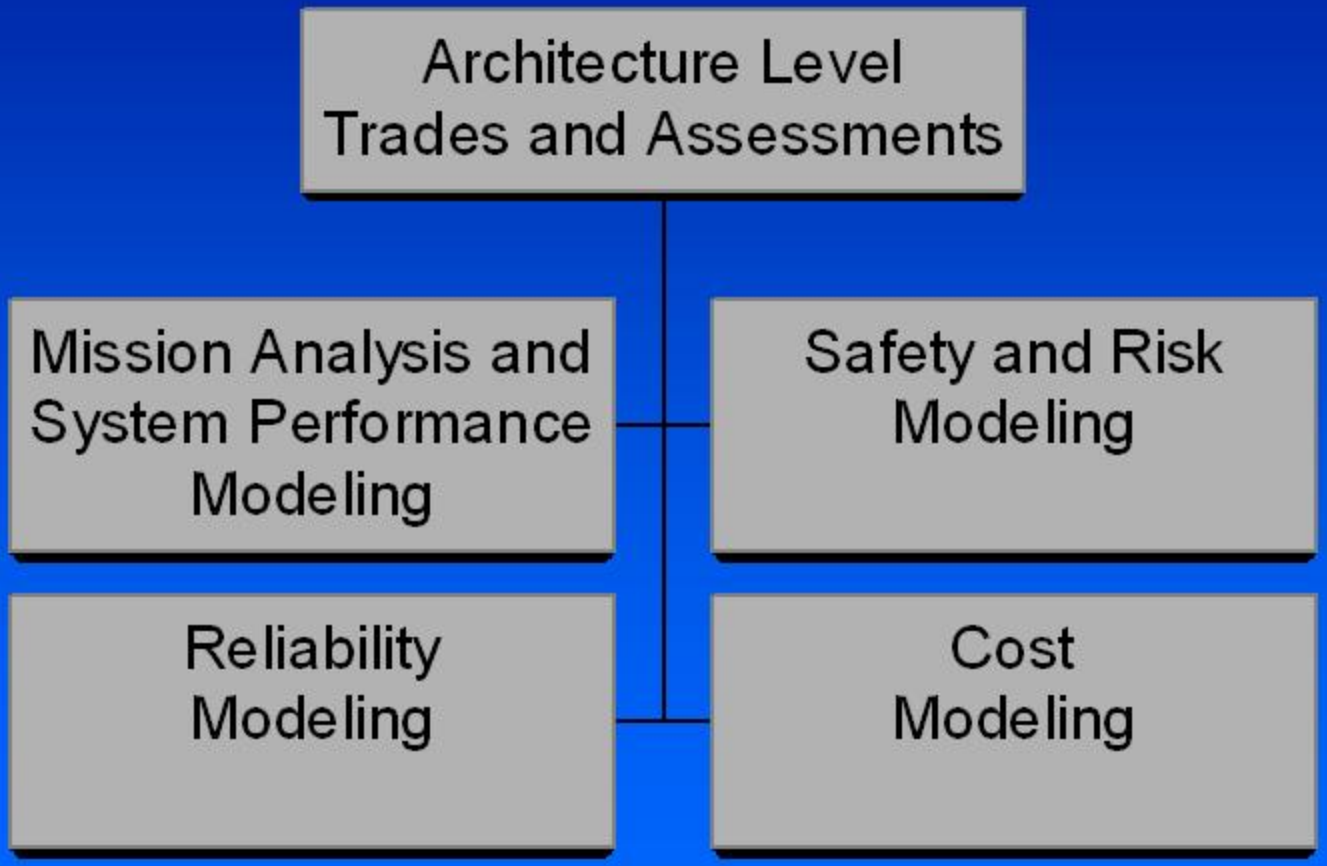
Contributing Analysis Areas



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Safety and Risk Modeling & Analysis

- Lessons Learned
  - Use of probabilistic methods, specifically in relation to cost, safety and reliability where uncertainty may be high, are important for properly characterizing and comparing alternative programmatic and design paths
  - Including the risk and uncertainty associated with advanced or complex technical designs in the architecture assessment allows lower performance but less complex alternatives to be considered and kept as back-up options for risk mitigation purposes
- Modeling Issues
  - Models for extended lunar campaigns not developed but elements to do so already exist
  - Data from Apollo missions is difficult to come by and may not be representative of current capabilities

Reliability Modeling & Analysis

- Lessons Learned
  - STS has surpassed and ISS approaches the program duration projected for these lunar missions; reliability and sparing trend data are available
    - example - ISS MDMs: initially planned as mostly identical with common sparing source; ultimately mostly unique with no common sparing but constrained sparing budget
- Modeling Issues
  - Models for extended lunar campaigns not developed but elements to do so already exist

Cost Modeling & Analysis

- Lessons Learned
  - Ground Rules and Assumptions must be established prior to analysis initiation
    - Phase durations, fiscal year outputs, inflation indices, etc.
  - Cost is dependent on system design input parameters - typically defined close to study deadlines
    - Cost parameters must be received in a timely manner to develop estimates and perform sensitivity/risk analysis
- Modeling Issues
  - Operations models for extended or long duration planetary surface systems (e.g., habitats) not developed to date
  - Similar concerns for systems or technology with low maturity or few historical instances

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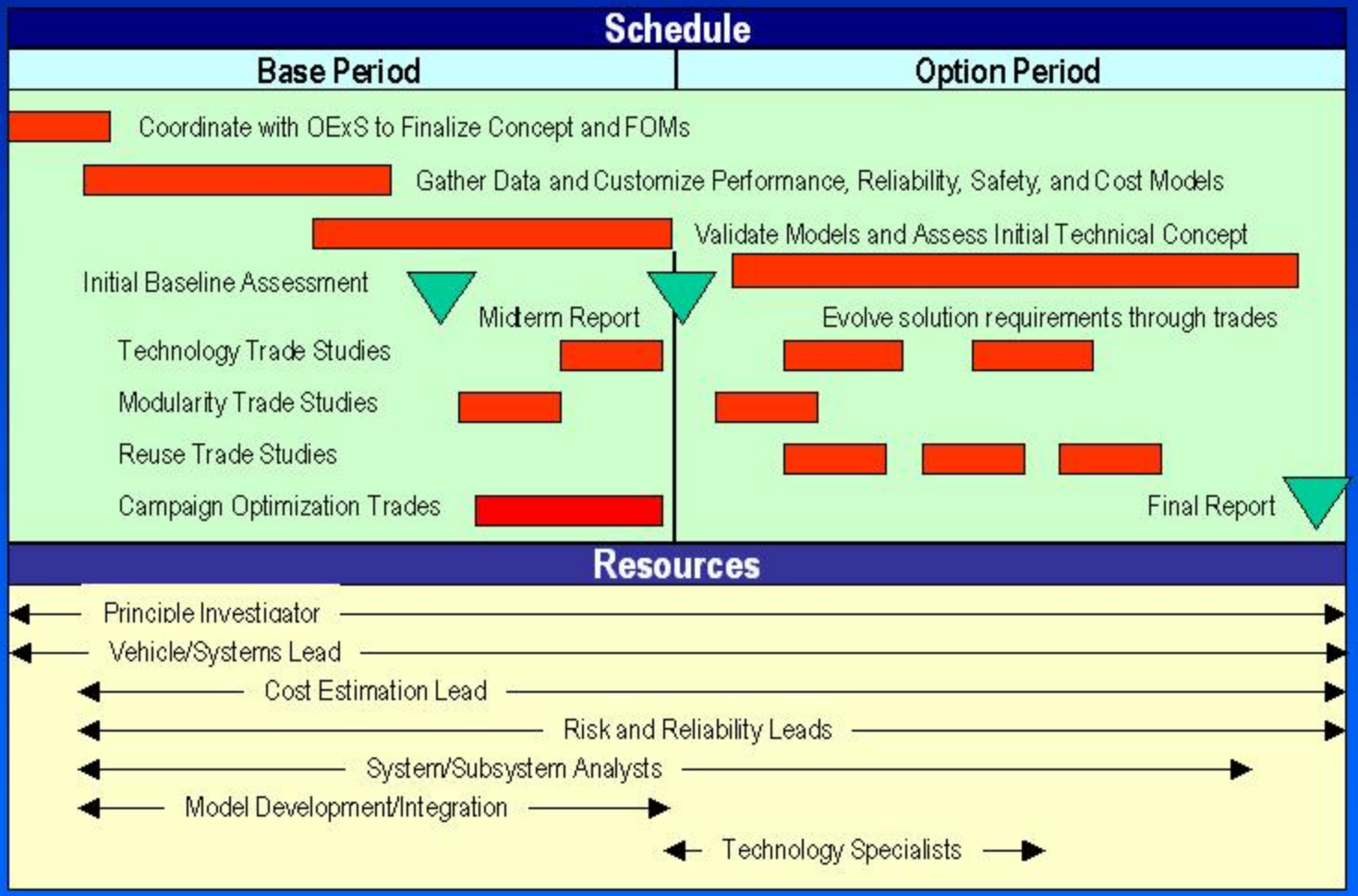
Initial Schedule and Resources



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Summary

- Assess architecture-level FOMs at the system level
- Assembled team with skills in primary areas of interest:
  - system performance
  - safety
  - risk
  - reliability
  - cost
- Building cross-cutting model to evaluate architecture level trends and impacts