Project Overview

Lightweight Nonmetallic Thermal Protection Materials Technology (LNTPMT) Project

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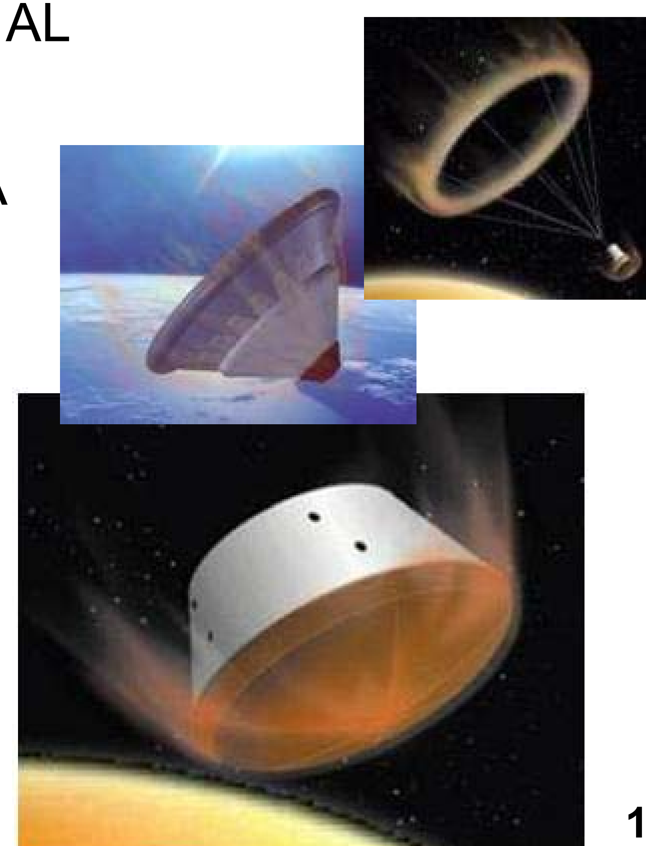


Overview Outline

- Exploration Systems Organization & New TPS Project
- Project Objective
- Team Members
- Overview of Project (tasks, schedule, etc.)
- Definition of Reference Missions & Space Environments
- Technology Performance Metrics & Classes of TPS Materials
- Testing (types of tests)

Exploration Systems Research and Technology (ESR&T) Overview

Explorations Systems Research & Technology
Manager
J. Mankins

Program Integration Team
Team Leader
Richard McGinnis

Advanced Space Technology
Program Manager
Chris Moore

- Advanced Studies, Concepts and Tools R&T Program
- Advanced Materials & Structural Concepts R&T Program
- Communications, Computing, Electronics & Imaging R&T Progr
- Software, Intelligent Systems & Modeling R&T Program
- Power, Propulsion & Chemical Systems R&T Program

Organized by Discipline, Emphasizing the Longer-term

Technology Maturation
Program Manager
Bob Wegeng (act.)

- High Energy Space Systems Technology Demos Program
- Advanced Space Systems & Platform Tech Demos Program
- Advanced Space Operations Technology Demos Program
- Lunar & Planetary Surface Ops Technology Demos Program
- In-Space Technology Experiments Program (IN-STEP)

Organized by Functional-Area, Emphasizing Technology Validation

Innovative Partnerships
Program Manager
B. Neumann

- Small Business Innovative Research
- Small Technology Transfer Research
- Technology Transfer Partnerships
- University Research, Eng, and Technology Institutes
- Space Product Development

Organized by Program Function, Emphasizing Types of Relationships

Project Objective

- **To establish an TPS materials technology roadmap, development methodology plan, characterization plan, and qualification plan to enable the maturation of lightweight nonmetallic TPS materials.**
  - Screening tests will enable the development of a TPS database to enable comparison and assessment of candidate TPS materials by Exploration Systems vehicle designers
    - **Measurement of key TPS material properties**
    - **Assessments of material performance characteristics in relevant planetary gases (both simulated Earth and Mars atmospheres)**
    - **Assessments of material performance characteristics in pertinent space environmental conditions**
  - Project results will allow the early identification of areas that require more focused development efforts by the overall Exploration Systems team
  - Groundwork will be established for eventual qualification and certification of TPS and heatshield materials to be used on Exploration Systems vehicles

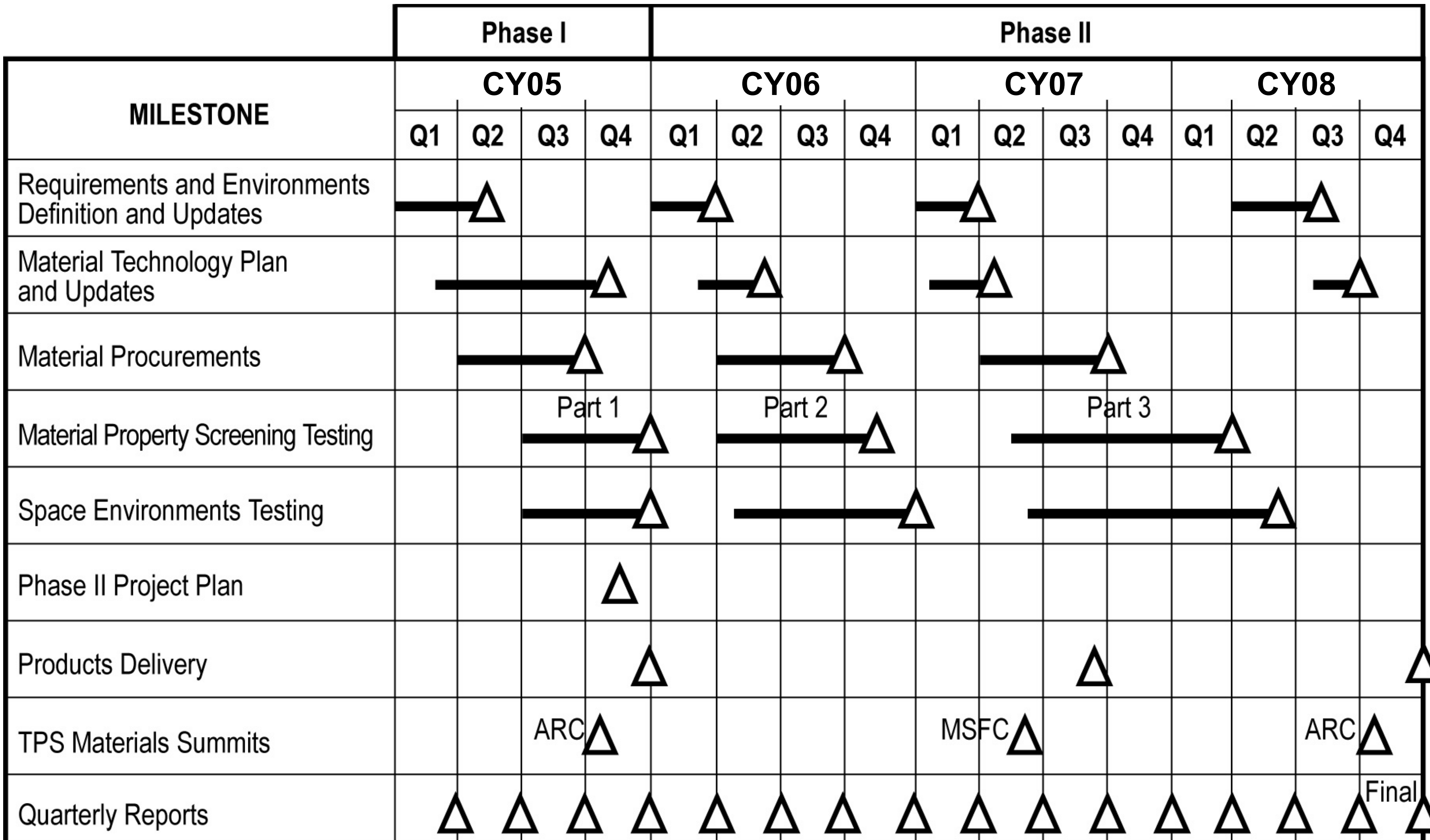
Team Members

- **Primary Organizations Involved In Project:**
  - NASA Marshall Space Flight Center (MSFC)
    - Non-Metals Engineering Branch (EM40)
    - Environmental Effects Branch (EM50)
    - Space Transportation Programs & Projects Office (NP)
    - Engineering Directorate Test Laboratory (ET21 Branch)
    - Natural Environments Branch (EV13)
  - NASA Ames Research Center (ARC)
  - NASA Glenn Research Center (GRC)
  - NASA Langley Research Center (LaRC)
  - Southern Research Institute (SRI)
- **Supporting Organizations & Consultants:**
  - NASA Johnson Space Center (JSC)
  - Air Force Research Laboratory (AFRL) @ WPAFB
  - Naval Surface Warfare Center (NSWC)
  - Redstone Arsenal's AMRDEC (Aviation & Missile Research, Development, & Engineering Center)
- **Industry (Aerospace, Materials, Etc.): TBD**

Overview of Project Tasks

- **Basic tasks to be accomplished in 2 phase project:**
  [1-year Phase I; 3-year Phase II]
  - Definition of mission requirements, applicable environments, & technology advancement roadmaps
  - Determination of specific material properties to be measured & specific environments to be evaluated
  - Determination of materials to be considered & generation of test matrices
    - **Conduct Internal NASA Summit in March 2005 to facilitate this & previous 2 tasks**
    - **Release a Request for Information (RFI) to facilitate industry input and/or involvement in the project**
  - Testing of selected materials according to test matrices developed
    - **Material properties testing**
    - **Space environmental effects testing**
    - **Planetary gases testing in arc jet facilities**
    - **Combined effects & sequential effects testing**
  - Iterate process based upon close coordination with other Exploration Systems projects & industry (both aerospace & materials companies)
    - **Three TPS Materials Summits (one in Phase I --- Oct/Nov 05; two in Phase II)**

Overall Project Schedule



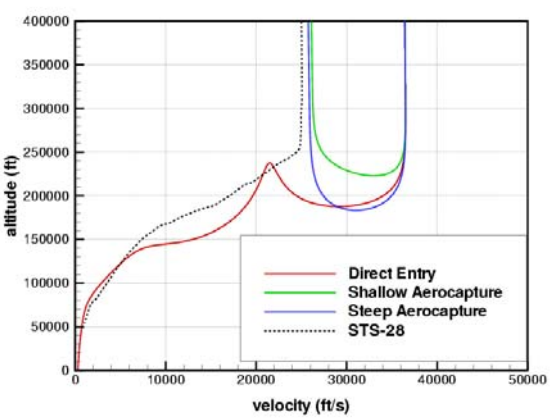
Missions & Environments

♦ **Reference Mission Segments & Environments To Be Considered:**

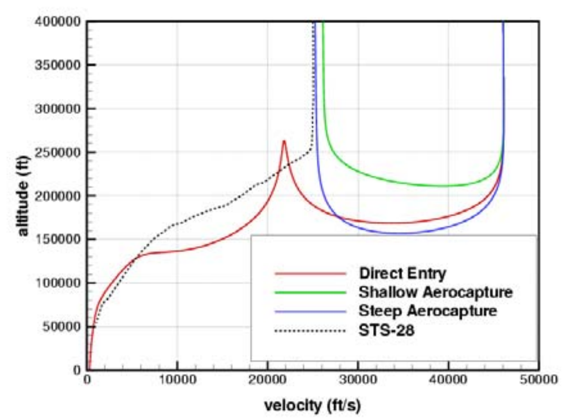
- Aeroentry, aerocapture, & aerobraking for both Earth & Mars
  - **Earth aeroentry/aerocapture upon returning from the Moon of greatest importance**
  - **Mars aeroentry/aerocapture upon arriving from the Earth**
- Long-duration deep space exposures
  - **Transit between Earth & Mars**
  - **Long duration Lunar orbit**
- Long duration low-Earth & low-Mars orbits

Definition & supporting analyses are on-going, for example:

Lunar Return Entry Trajectories



Mars Return Entry Trajectories



Space Environmental Effects

		Low Earth Orbit: Equatorial	Low Earth Orbit: Polar	GEO	Interplanetary
Vacuum	Solar UV	Independent of Orbit			
	Contamination	Independent of Orbit			
Neutral	Drag	Yes	Yes	N/A	N/A
	Sputtering	Yes	Yes	N/A	N/A
	AO Erosion	Yes	Yes	N/A	N/A
	Glow	Yes	Yes	N/A	N/A
Plasma	S/C Charging	Low	Mid	High	High
Radiation	Trapped Belts	Low	Mid	High	N/A
	Solar Particle Event	Low	Mid	High	High
	Galactic Cosmic Rays	Low	Mid	High	High
Micrometeoroid /Orbital Debris	Hypervelocity Impact	MM – Risk decreases with increasing altitude OD – Risk greatest in popular orbits			

- **Moon: -- No atmosphere, high radiation, temps from 400K to 40K, abrasive dust, 1/6 g**
- **Mars: -- CO_2 atmosphere (1% of Earth's density), 38% g, dust, winds, 40% Sun's radiation**

Technology Performance Metrics

TPS Material Application/Reference Mission	Technology Metric	TPM Target	TPM Minimum Success Criteria
Direct Entry • Ablative	Heat rate	600 W/cm2	400 W/cm2
	Heat Load	50 KJ/cm2	30 KJ/cm2
	Density	<300 kg/cm3	<500 kg/cm3
	Loads	5 g's	20 g's
	MMOD	>1 cm	>1 mm
	Shock/Acoustic	20%> Apollo/Mars Viking	Apollo/Mars Viking
	Space Effects (maintain 80% thermal performance)	20%> Apollo/Mars Viking	Apollo/Mars Viking
Aerocapture • Non-ablative Ceramics/CMC's • Non-ablative Ceramics/CMC's w/ ballutes	Heat rate	>100 W/cm2 (>10 W/cm2)	>60 W/cm2 (>5 W/cm2)
	Heat Load	>40 KJ/cm2 (TBD)	>30 KJ/cm2 (TBD)
	Density *	<300 Kg/cm3, CMC<TBD Kg/cm3 (<TBD Kg/cm3)	<500 Kg/cm3, CMC<TBD Kg/cm3 (<TBD Kg/cm3)
	Loads	5 g's	20 g's
	MMOD	>1 cm	>1 mm
	Shock/Acoustic	20%> Apollo/Mars Viking	20%> Apollo/Mars Viking
	Space Effects (maintain 80% thermal performance)	20%> Apollo/Mars Viking	20%> Apollo/Mars Viking

* Density/weight of CMC system TBD due to CMC performing as both TPS and primary structure.

List of Candidate TPS Materials

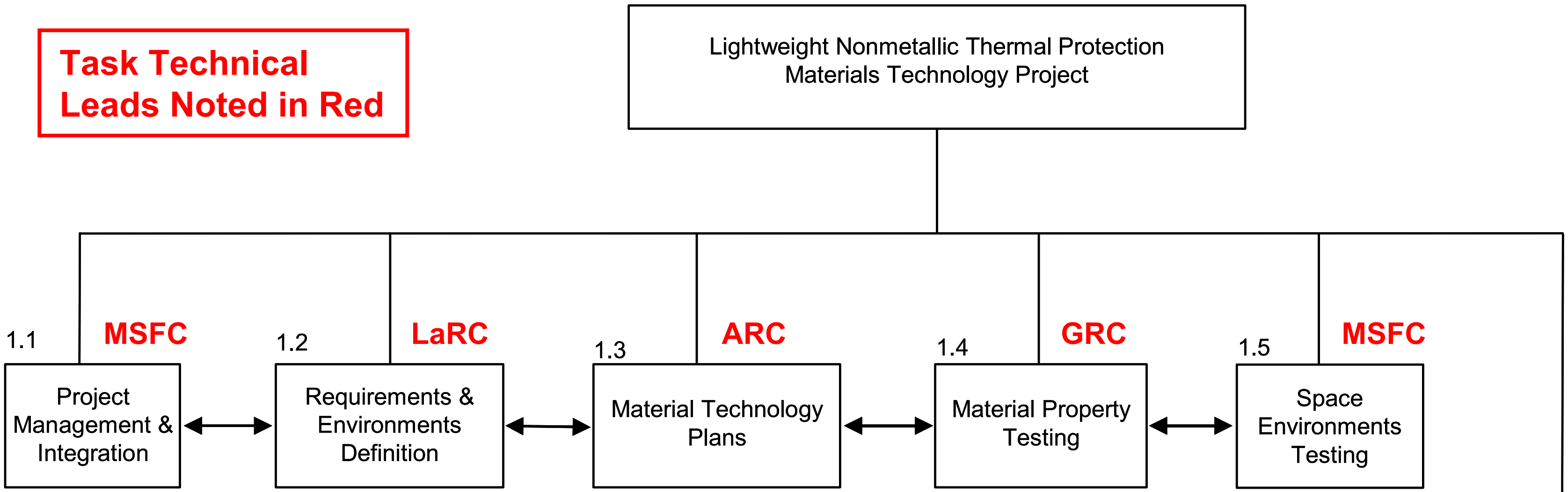
Material Classes	Partial Listing of Candidate Materials Under Consideration	
Lightweight Ablatives	Lightweight Silicone Reinforced Ablators Low & Mid Density DoD Ablators	NASA Ames Silica Impregnated Ceramic Ablators NASA Ames Phenolic Impregnated Ceramic Ablators
Rigid Reusable Ceramics	Shuttle AETB Tiles NASA Ames High Emissivity Tiles	NASA Ames TUFROC Tiles
Ceramic Matrix Composites (CMC's)	DoD 2D/3D Carbon-Carbon DoD 2D/3D Carbon/Silicon-Carbide	2D CMC-Overwrapped Tiles
Ballute Thin Film Materials	In-Space Propulsion Ballutes NASA MSFC SBIR Ballutes	Aerogel Impregnated Films
Baseline/Reference Standard Materials	Mars Viking SLA-561 Ablator Shuttle Orbiter RCG Tile & RCC	Apollo Ablator Minuteman Ablator

NOTES:

- **The TPS materials to be investigated for Phase I are substantially complete or fixed.**
- **Materials to be investigated in Phase II are yet to be determined. Selection will be based upon the Phase I results, teaming arrangements, and the direction Exploration Systems takes.**

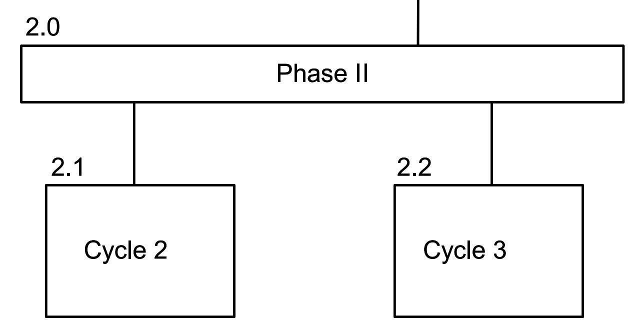
Testing Emphasized in 5-Task Effort

Task Technical Leads Noted in Red



<u>Material Property Testing:</u>

- Physical: density, microstructure, compatibility
- Thermal: conductivity, emissivity, specific heat, CTE
- Mechanical: tension, compression, shear, vibration



<u>Space Environments Testing:</u>

- Solar/radiation: electron & proton fluxes, UV
- Atomic Oxidation
- MMOD: hypervelocity impact
- Arc jet testing: Earth gases, Mars gases
- Multi-parameter: stressed oxidation
- Sequential or combined effects: SEE + arc-jet + residual mechanical properties

Summary of Lightweight Nonmetallic Thermal Protection Materials Technology (LNTPMT) Project

Description

Establish the TPS material technology roadmap, methodology, and screening testing process to mature lightweight nonmetallic TPS materials and demonstrate developed roadmap and methodology

Participants

PI: Tim Lawrence/MSFC
PM: Kevin Flynn/MSFC

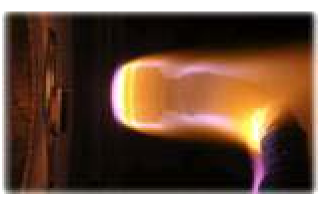
Mike Gubert/MSFC	Peter Valentine/MSFC
James Kiser/GRC	Craig Ohlhorst/LaRC
Frank Milos/ARC	John Koenig/SRI

Work Breakdown Structure

1.1 Project Management & Integration
1.2 Requirements & Environments Definition
  1.2.2 Reference Missions
  1.2.3 Space Environments
1.3 Material Technology Plans
1.4 Material Property Testing
  1.4.2 Physical Property Testing
  1.4.3 Thermal Property Testing
  1.4.4 Mechanical Property Testing
1.5 Space Environments Testing
  1.5.2 Multiparameter Testing Effects
  1.5.3 Acoustic/Vibration/Shock Effects
  1.5.4 Solar/Radiation Effects
  1.5.5 Atomic Oxygen Effects
  1.5.6 MMOD Effects
  1.5.7 Planetary Gases Heat Flux Effects

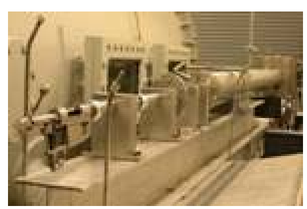
Mechanical tests

Space Effects/Radiation tests



Planetary Gases Thermal tests

Screening of Candidate TPS Materials



Orbital debris impact tests

Major Deliverables & Schedule

Phase I: A TPS reference missions and environments definition report, TPS materials technology plan, TPS materials and space environmental effects test plans, and materials and space environmental test and assessment reports.

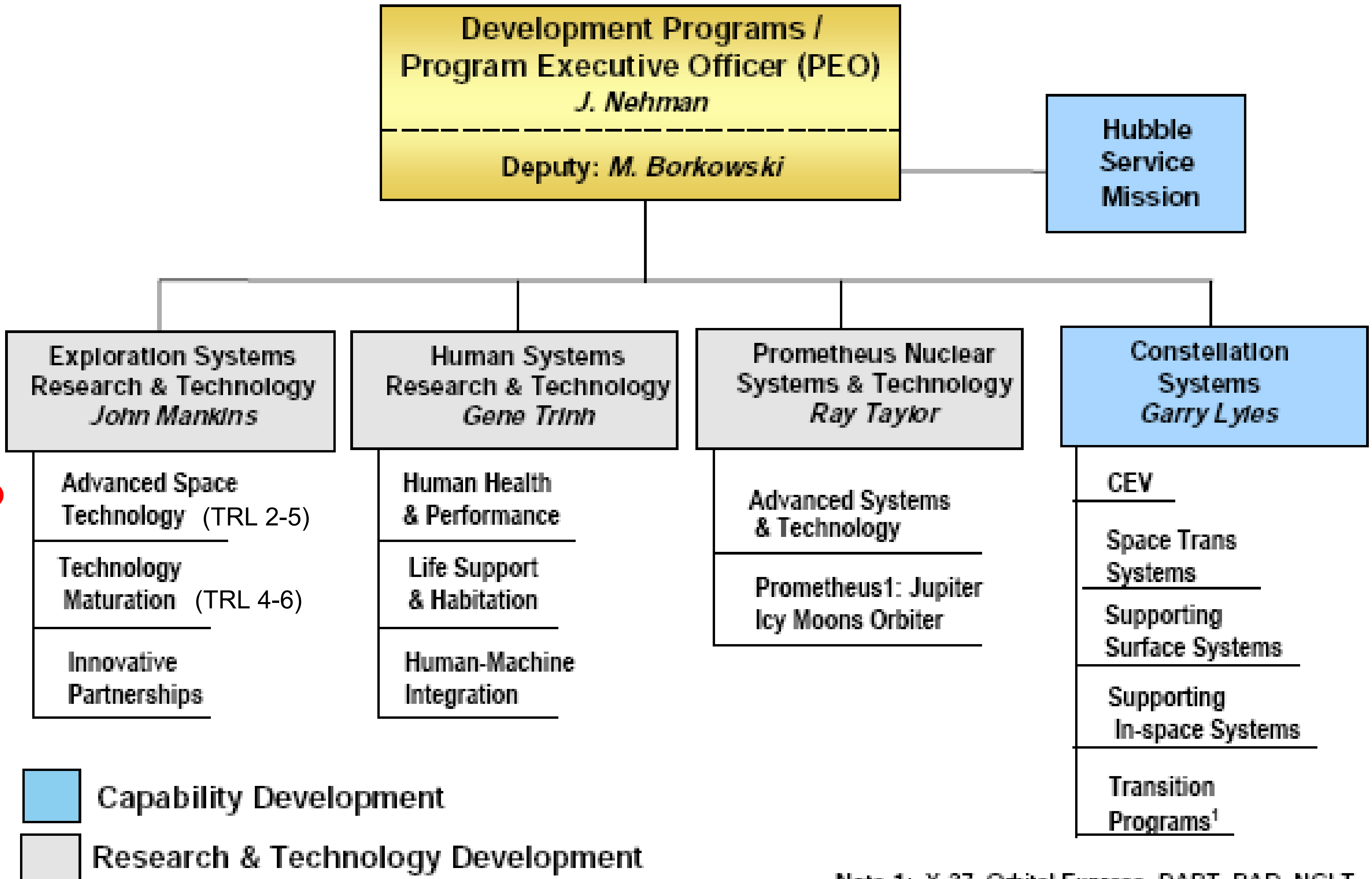
Phase II: Identify TPS materials and provide test data to enable the validation of preliminary thermal predictions, thus allowing the refinement of predictive modeling tools used to: a) design vehicles, b) generate mission scenarios, and c) minimize system mass.

Resources

Phase 1	Phase 2
$ 1.9 M	$ 13.1 M

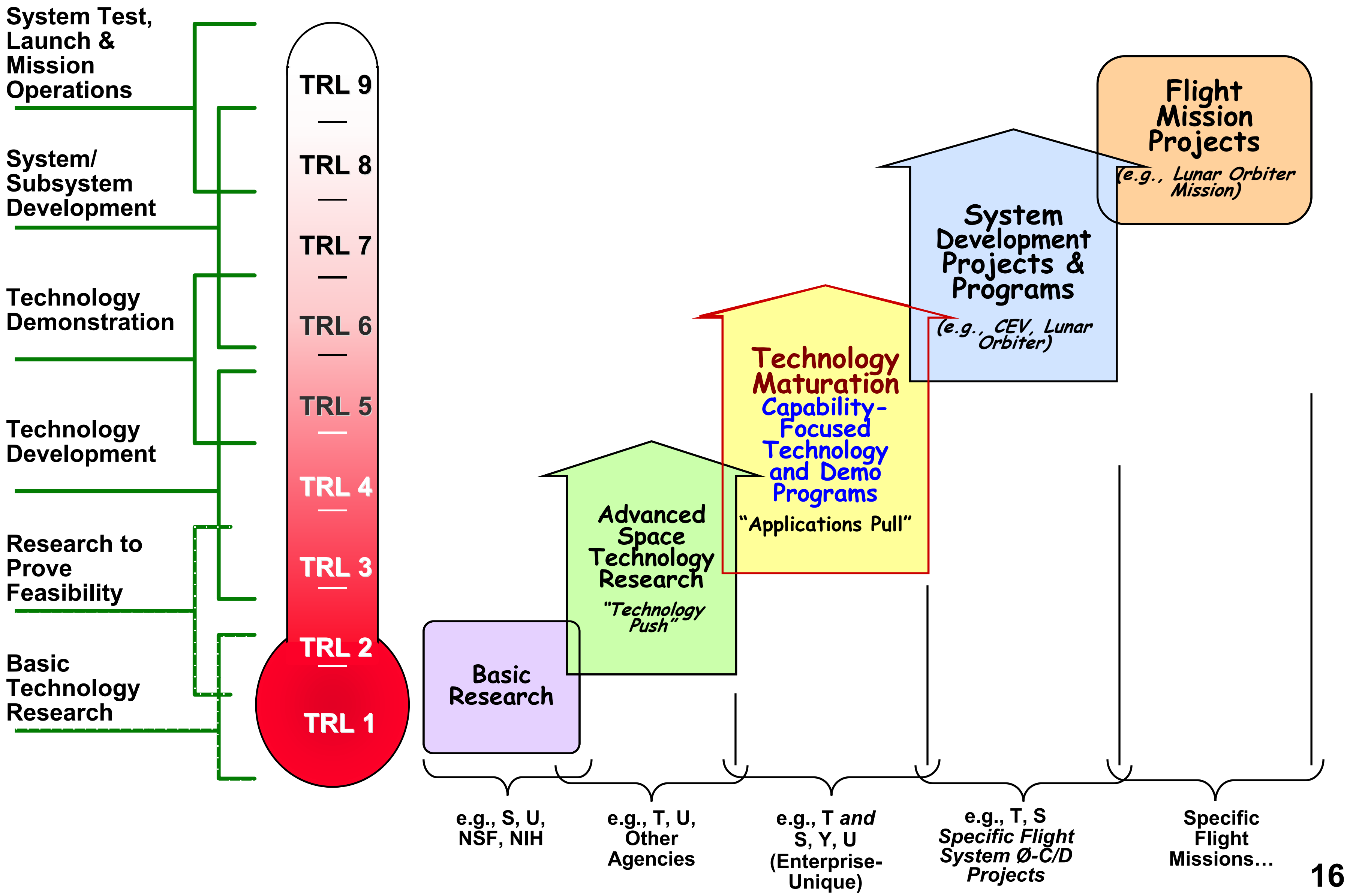
BACK UP Information

ESMD Development Programs

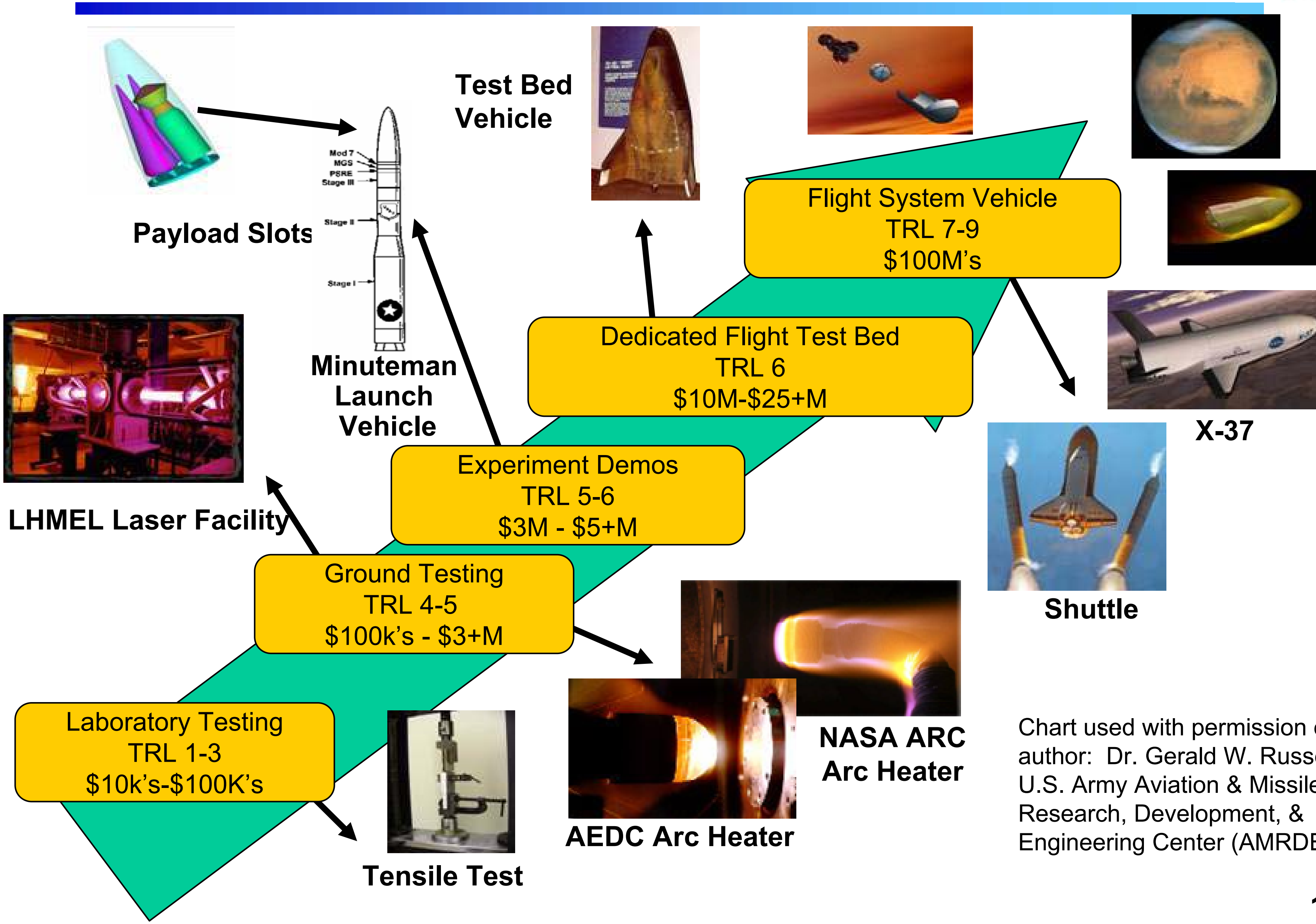


Note 1: X-37, Orbital Express, DART, PAD, NGLT

ESR&T Technology Maturation Model



Technology Maturation & Advancement



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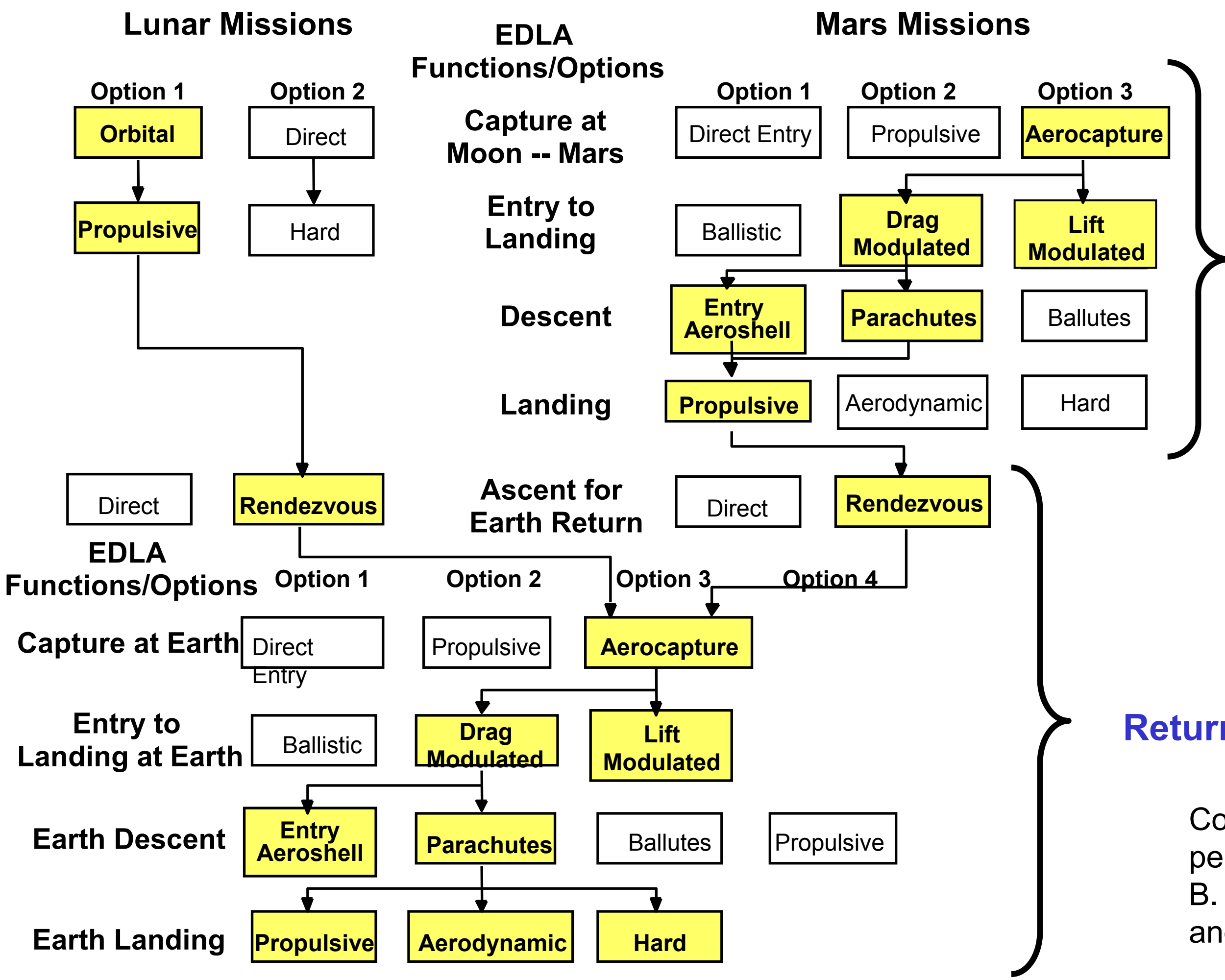
EDLA Mission Trade Space



Arrival at destination

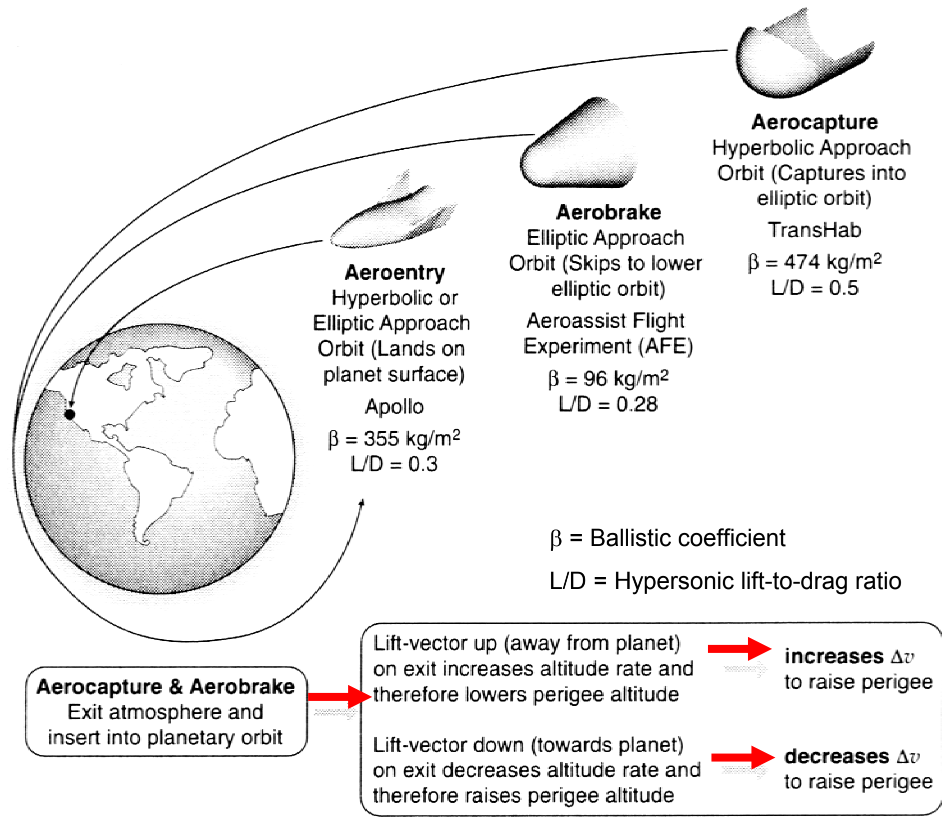
Return to Earth

EDLA = Entry, Descent, Landing, & Ascent

Using the atmosphere of the Earth and Mars for aerocapture and aerobraking results in significant mass savings making the trade choices more obvious

Aerodynamic Braking Maneuvers

- **Three types of aerodynamic braking maneuvers:**
  - **Aerocapture**
    - **Transfers the spacecraft from a hyperbolic approach trajectory to an elliptical parking orbit**
  - **Aerobraking**
    - **Transfers the spacecraft from an initial elliptical parking orbit to a less energetic (i.e., Lower apoapsis) elliptical parking orbit**
    - **Requires small ΔV**
  - **Aeroentry**
    - **Transfers the spacecraft from either a hyperbolic or elliptical approach orbit to the planet surface**
    - **May require a small ΔV**
- **All three involve turning kinetic energy into heat by using the planet's atmosphere as a brake**



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Mass of aerobraking system = 0.15 mass of spacecraft at time of aerobraking.