National Aeronautics and
Space Administration

NASA's Space Technology EDL Investments: Path For Enabling Human Mars Missions

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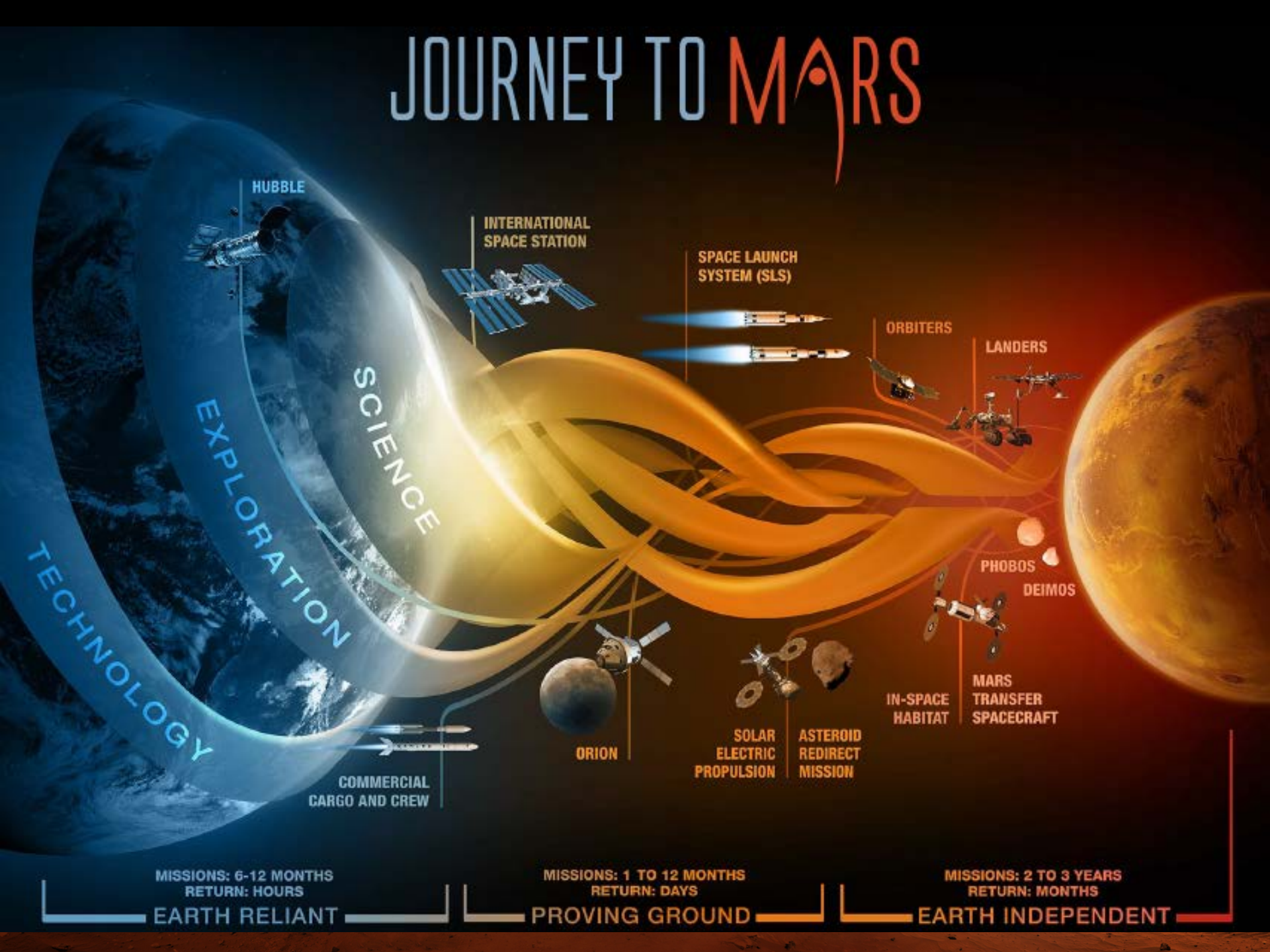
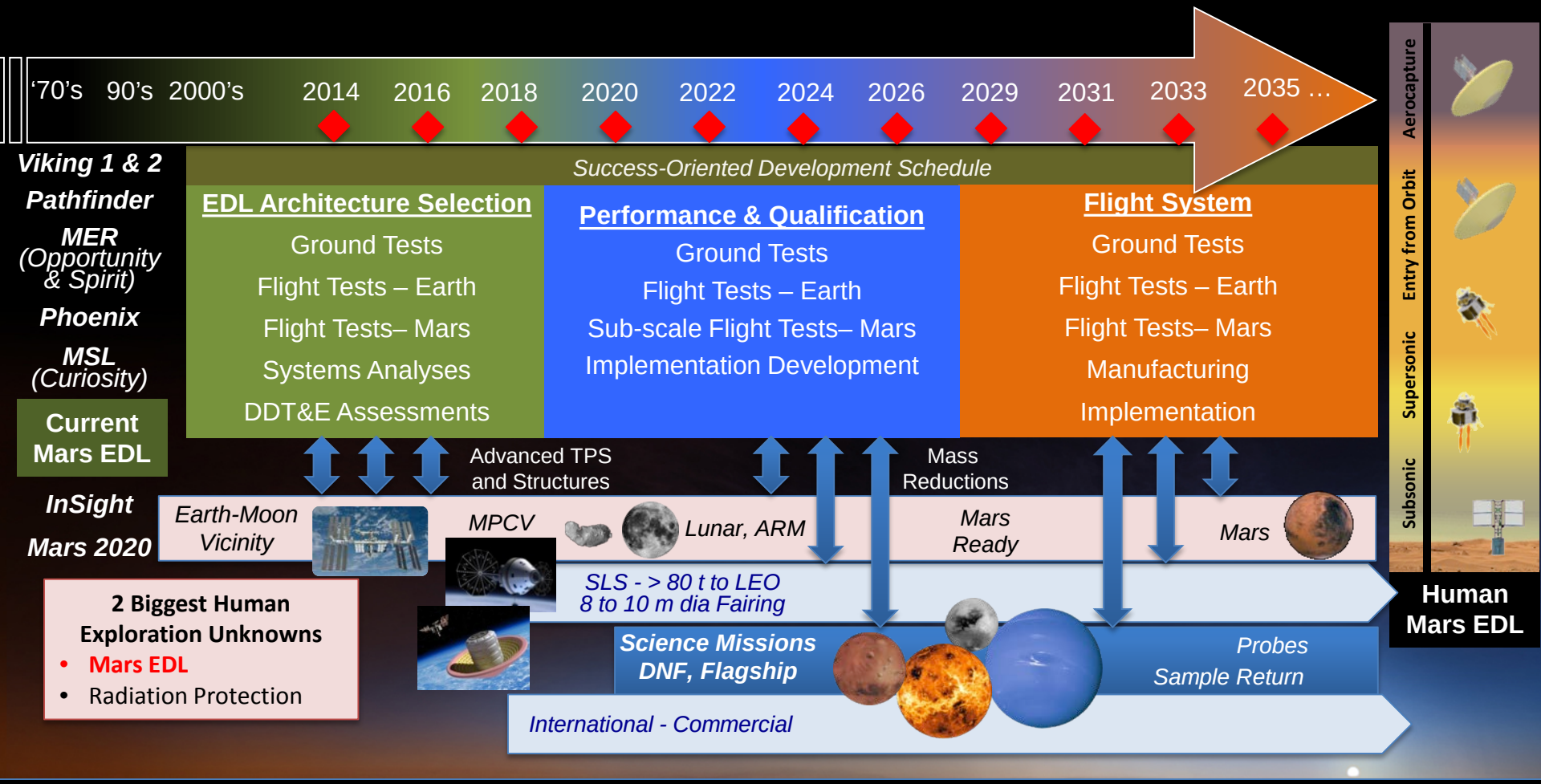
Presentation to IPPW-12
Cologne, Germany
June 17, 2015


JOURNEY TO MARS
HUBBLE
INTERNATIONAL SPACE STATION
SPACE LAUNCH SYSTEM (SLS)
ORBITERS
LANDERS
SCIENCE
EXPLORATION
TECHNOLOGY
PHOBOS
DEIMOS
MARS TRANSFER SPACECRAFT
IN-SPACE HABITAT
SOLAR ELECTRIC PROPULSION
ASTEROID REDIRECT MISSION
ORION
COMMERCIAL CARGO AND CREW
MISSIONS: 6-12 MONTHS
RETURN: HOURS
EARTH RELIANT
MISSIONS: 1 TO 12 MONTHS
RETURN: DAYS
PROVING GROUND
MISSIONS: 2 TO 3 YEARS
RETURN: MONTHS
EARTH INDEPENDENT

EDL is a Long-Term Challenge



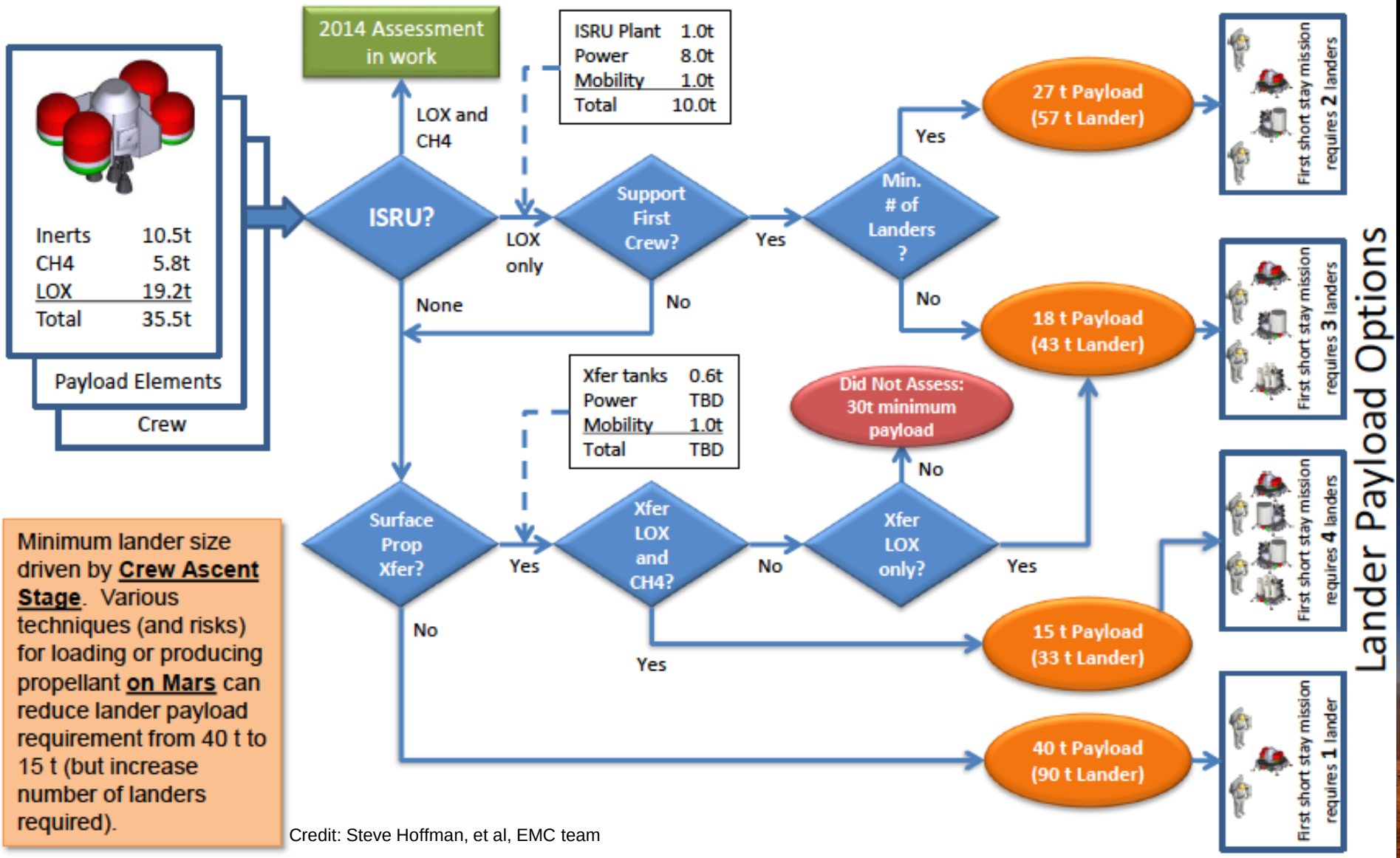
2 Biggest Human Exploration Unknowns

- Mars EDL
- Radiation Protection

Mars			
Landed Mass:	1 t	3-10 t	15-30 t
Precision:	10-25 km	5-10 km	<0.1 km
Planet Access:	~40%	~75%	Near global

Slide credit: Jeff Herath/NASA-LaRC

Evolvable Mars Campaign Landers



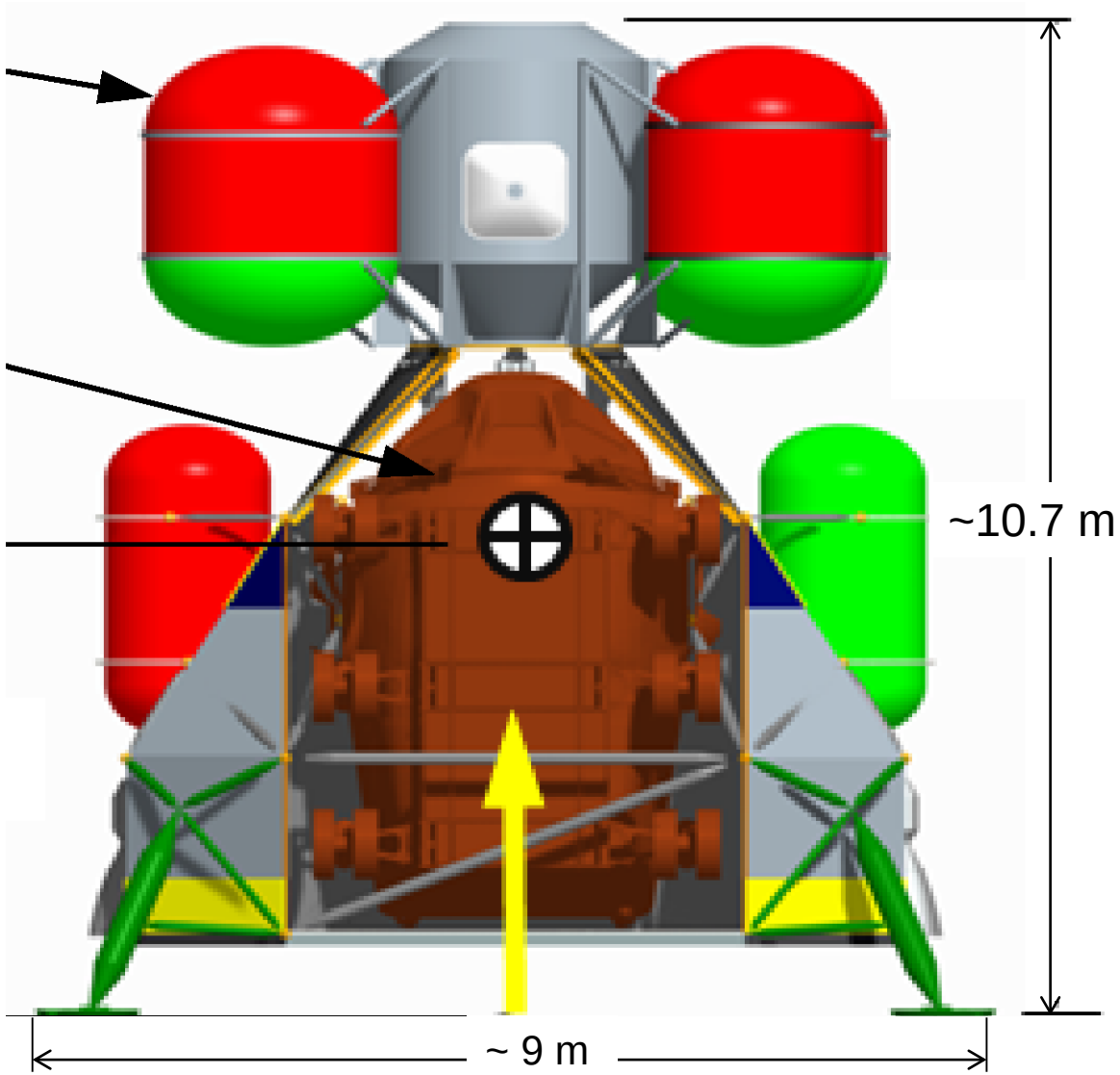
Minimum lander size driven by **Crew Ascent Stage**. Various techniques (and risks) for loading or producing propellant **on Mars** can reduce lander payload requirement from 40 t to 15 t (but increase number of landers required).

Credit: Steve Hoffman, et al, EMC team

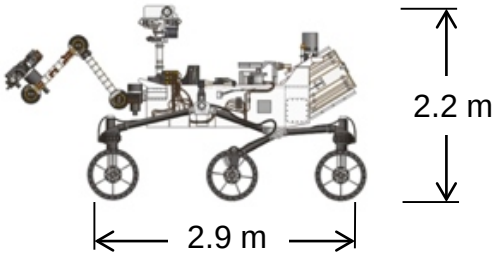
Human Mars: A Leap in Scale

Notional Human Mars Payload

Human Mars Payload:
> 20x more massive
5x taller
12x larger footprint

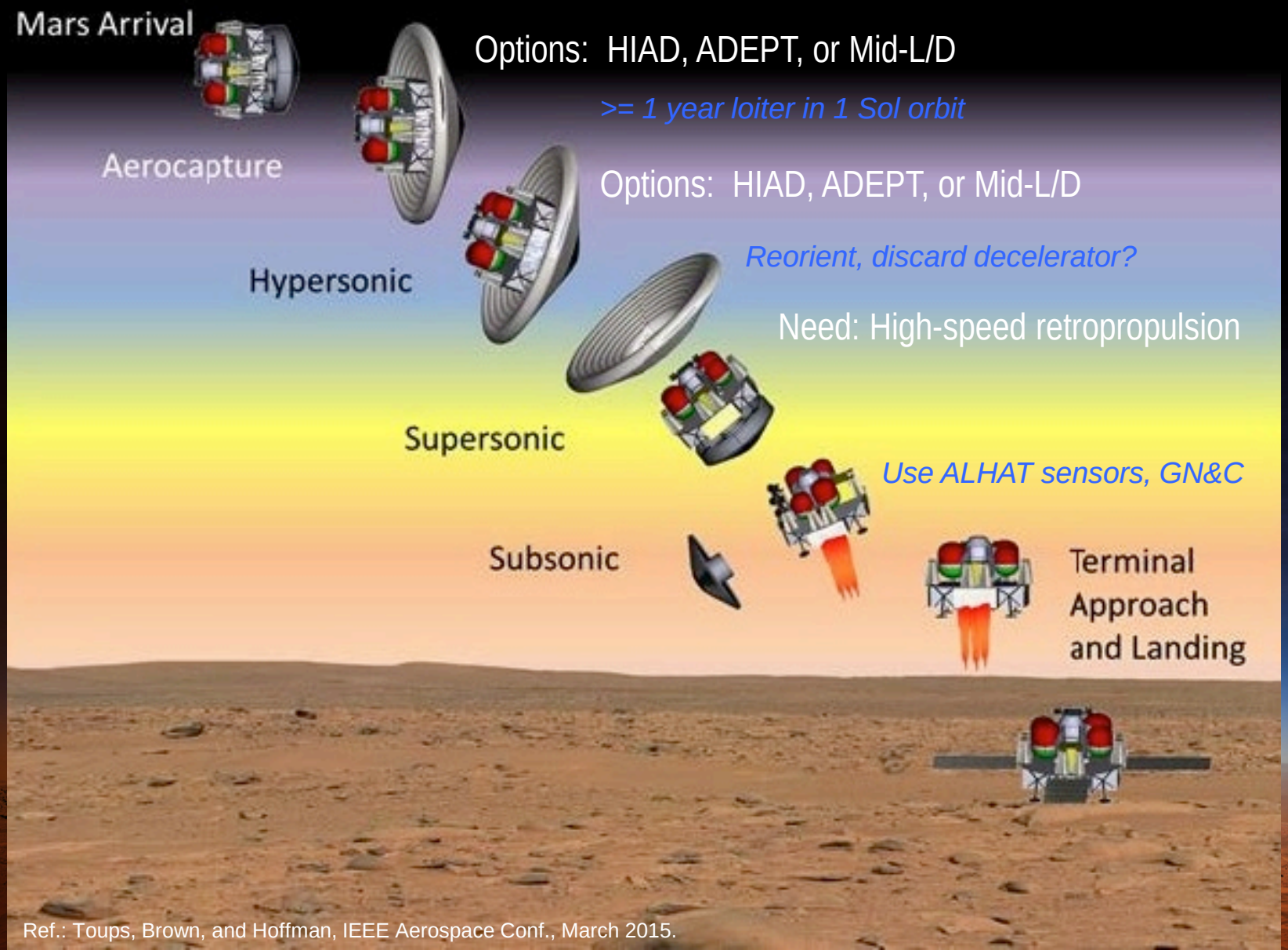


Mars Science Laboratory



Source: historicspacecraft.com, Credit: Richard Kruse

EDL for Human Mars Missions: Multiple Challenges



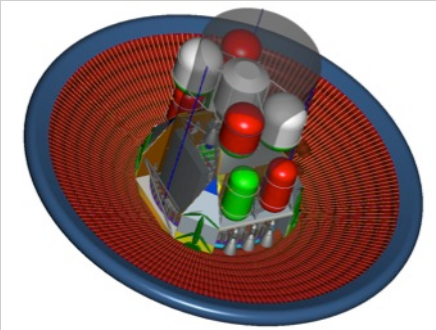
Ref.: Toups, Brown, and Hoffman, IEEE Aerospace Conf., March 2015.

Mars EDL Pathfinder Study Overview

- **Landing humans on Mars in the 2030's implies that subscale prototypes or technology demonstrations to inform these designs need to be completed by the mid-2020's (including flight demonstrations at Mars, if any)**
  - The first full-scale cargo mission is treated as the qualification flight prior to humans
  - A "full scale" demonstration, in effect, is the same as accepting the risk of full-scale development without the benefits (or costs) of sub-scale prototype development
- **There are multiple approaches to entry, descent and landing that are applicable to 20+ metric tons of usable payload on the surface of Mars**
  - Different approaches have different "scalability" characteristics
  - There is not adequate funding available to demonstrate all of the candidates
- **Objectives for FY15 study are to:**
  - Evaluate (for each concept) the benefits of flight demonstration at Mars (relative to terrestrial test + modeling), and at what min / max scale these should be done
    - What "must" be tested at Mars, for risk reduction
    - Minimum scale where results are still valid / useful
    - Maximum scale where test is still cost effective relative to proceeding with full-scale development
- **Results could influence future technology investments**

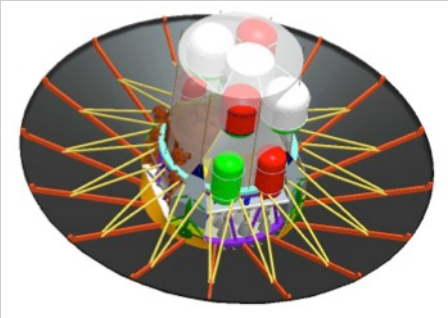
Technology Investments for Human Mars Missions: FY15-16

Hypersonic Inflatable Aerodynamic Decelerator (HIAD)



- Inflatable high-temp tori with overlaid Thermal Protection System
- 6 m wind tunnel, deployment tests; flight tested at 3 m scale (IRVE-II,3)
- ~TRL 4 for human scale

Adaptable, Deployable Entry and Placement Technology (ADEPT)

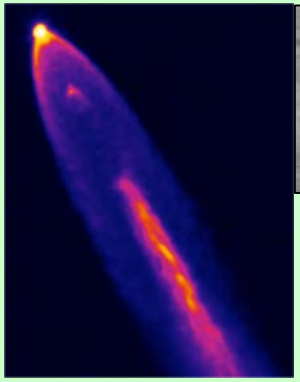


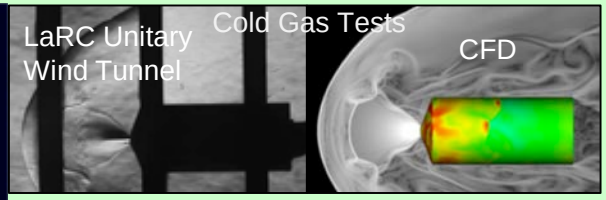
- Mechanically-deployed structure with carbon fabric tensioned "skin"
- Arcjet, deployment, and wind tunnel tests (up to 2 m scale)
- ~TRL 2 for human scale

Mid-Lift-to-Drag Ratio Vehicles (Mid-L/D)

- Historical choice for Human Mars aeroshell (DRA 5.0)
- ISS Return concept (~1 x 2-3 m) in development through CASIS
- ~TRL 3 for human scale

Supersonic Retropropulsion (SRP)

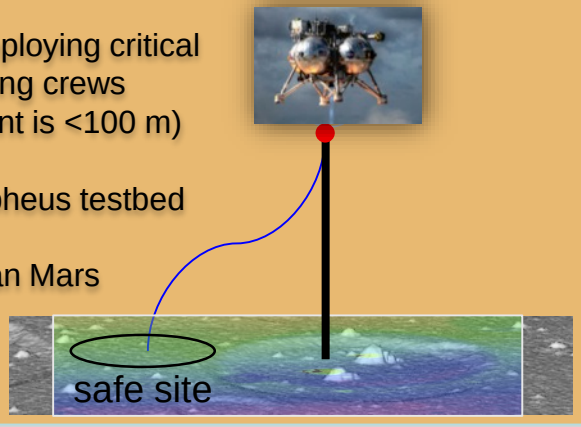




- Engines fire at Mach 2.5-3 for human Mars EDL
- SpaceX stage ignites at conditions similar to Mars, proving startup
- NASA leveraging flight data to improve modeling capabilities
- ~TRL 2-3 for human Mars application

Precision Landing, Hazard Detection & Avoidance (HDA)

- Required for predeploying critical assets and delivering crews (current requirement is <100 m)
- ALHAT/Lander Technologies/Morpheus testbed all applicable
- ~TRL 3-4 for human Mars application

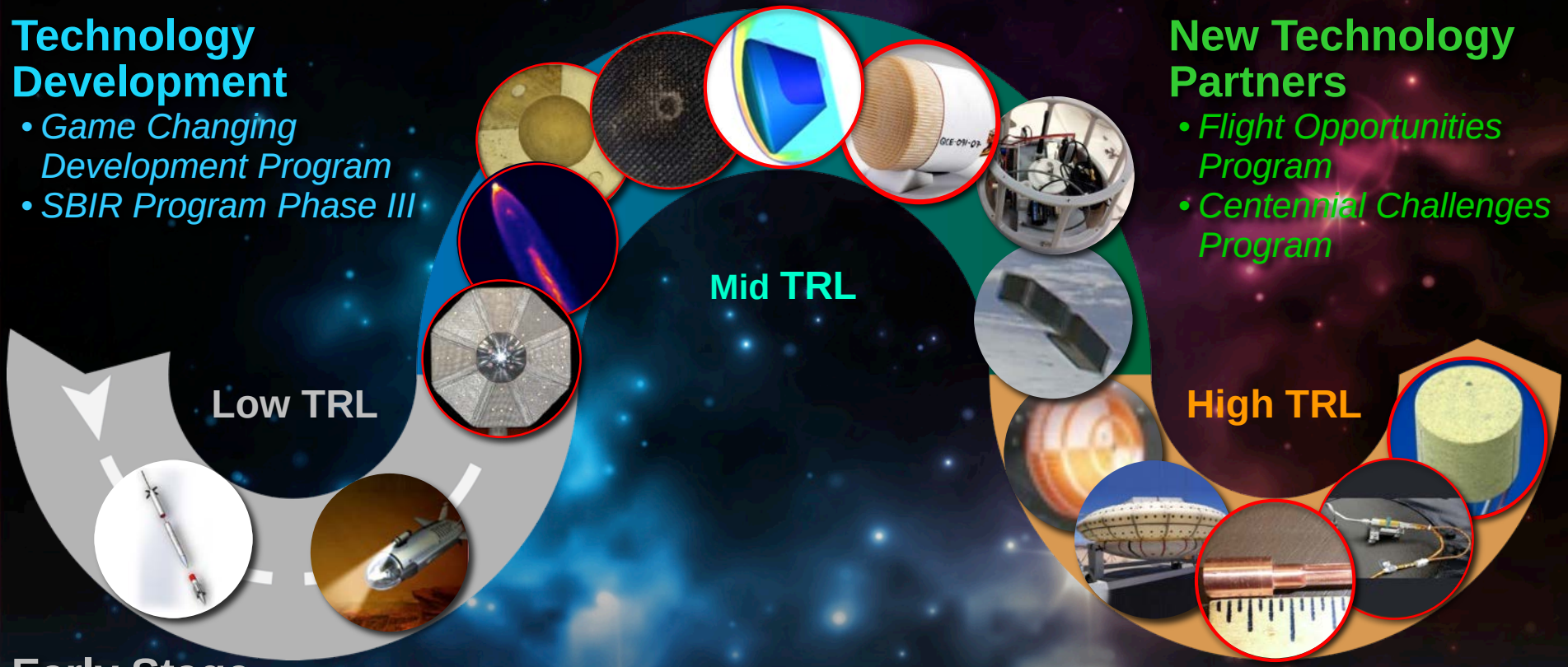


STMD EDL Technology Pipeline

◯ = applicable to Human Mars Missions

Technology Development
- *Game Changing Development Program*
- *SBIR Program Phase III*

New Technology Partners
- *Flight Opportunities Program*
- *Centennial Challenges Program*



Early Stage
- *NASA Innovative Advanced Concepts Program*
- *Space Tech Research Grants Program*
- *Center Innovation Fund Program*
- *SBIR Program Phases I & II*

Technology Demonstrations
- *Technology Demonstration Systems*
- *Small Spacecraft Technologies*

TECHNOLOGY PIPELINE

Summary

- **NASA's Space Technology EDL investments are aligned with NASA's Journey to Mars**
- **The Journey to Mars initiative is a driving and unifying goal for STMD's EDL investments**
  - Architecture and systems analysis is being applied, to assess candidate technologies and maturation plans
  - Strong customer engagement with studies and results
- **Maturing human Mars EDL systems will require significant time and sustained resources**
  - This will challenge current investment strategies
- **A current study is investigating the need for a mid-2020's Mars Pathfinder mission to demonstrate/qualify EDL**