

Alternate Approaches to Exploration

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Alternate Approaches to Exploration

- Is there a better way to conduct exploration
 - Apollo approach to minimize return mass
 - New initiatives can result in better mission approaches
 - The SCM approach as an example
 - What ideas do you have for organizing and conducting exploration?
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Alternate Approaches to Exploration

Synopsis:

The Cx Program envisioned exploration of the moon and mars using an extrapolation of the Apollo approach. If new technology development initiatives are successful, they will provide capabilities that can enable alternate approaches. This presentation will provide a brief overview of the Cx approaches for lunar and Mars missions and some of the alternatives that were considered. Then an alternative approach referred to as a Single Crew Module approach is described. The SCM concept employs new technologies in a way that could reduce exploration cost and possibly schedule. Options to the approaches will be presented and discussed.

Biography:

Joe Chambliss serves in the EC Thermal Systems and Engineering Support branch on special projects. He has worked on shuttle, ISS, technology development, and Constellation programs. He was the system manager for ISS Thermal Systems development for its first 6 years of the ISS program. He received his BSASE from UT Austin, a MS in ASE from Rice and a MS in Space Physics and Astronomy from Rice. Recently he has managed efforts in technology development for life support and thermal control and provided support for Cx Orion, Altair and Lunar Surface Systems projects.

Cx Approach for Lunar Exploration

- Lunar program Sortie missions
 - Ares 1 launch of the Orion CEV
 - Ares 5 launch of the Altair vehicle and a Earth departure stage
 - All Elements of the mission were to be discarded during the mission
 - Orion CEV might be reusable
- Other Lunar missions of CX were directed at developing a base on the moon as directed in 2004
- 2010 presidential direction was to focus on exploration
 - It is expected that several exploration missions would be conducted prior to new direction to establish a base at a location selected based on exploration findings



DRMs/Mission Key Driving Requirements Mapping

Lunar Sortie Design Reference Mission



◆ A TBD or TBR is associated with this requirement

- Multi-Mission Phase Requirements**
- Anytime Abort
 - LOC ≤ 1 in 100
 - LOM ≤ 1 in 20

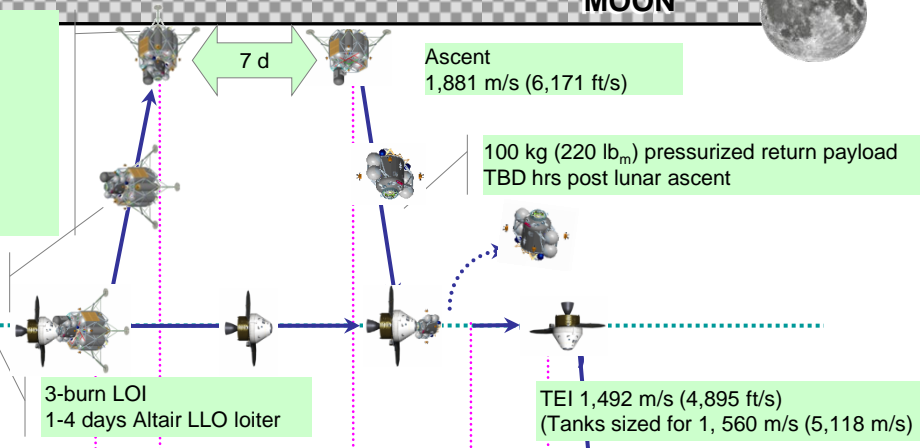
- Altair**
- Crew of 2-4 + 500 kg (1,102 lb_m) cargo
 - Global Access
 - Landing accuracy ≤ 100 m (328 ft) with 95% accuracy (◆)
 - 373 (◆) hrs crew support
 - Airlock functionality
 - LOC ≤ 1 in 250 (◆)
 - LOM ≤ 1 in 75 (◆)

Descent ΔV 2,030 m/s (6,660 ft/s)
LH2/LO2 descent engine restartable/throttleable

LLO 100 km (54nm)

Altair Performs LOI
1,000 m/s (3,281 ft/s)
(Propellant load for 950 m/s)

Altair ΔV for LOI
1,000 m/s (3,281 ft/s)



- Orion**
- Orion TLI Control Mass 20,185 kg (44,500 lbm)
 - FCE & EVA Mass Allocation 675 kg (1,488 lbs)
 - Orion 382 kg (842) unpressurized cargo
 - 21.1 days crew support
 - LOC ≤ 1 in 200
 - LOM ≤ 1 in 50

Altair TLI Injected Control Mass 45 t (99,200 lb_m)
EVA Mass Allocation 171.5 kg (378.0 lbm)
FCE Mass Allocation 133.8 kg (295.0 lbm)

EDS TLI Injection Capability 66.1 t (145,726 lb_m) + 5 t reserve
EDS Performs TLI 3,175 m/s (10,417 ft/s)

ERO 241km (130nm)

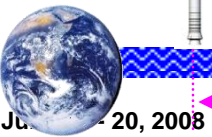
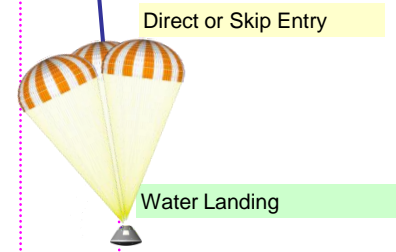
-20x185 km (-11x100 nm), 29°

Ares-I Delivered Mass 23.6 t (52,070 lb_m)
4 days LEO loiter

905 t (2M lbm)

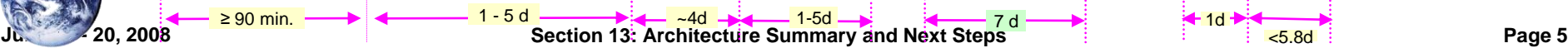
3,698 t (8.2 Mlb_m)

- Ares V**
- 4 launches per year (6 launches per year)
 - Weather exclusive launch availability TBD
 - 2 5.5 segment SRBs; 6 RS-68B
 - LOC ≤ 1 in 37,000
 - LOM (vehicle) ≤ 1 in 125



EARTH

MOON



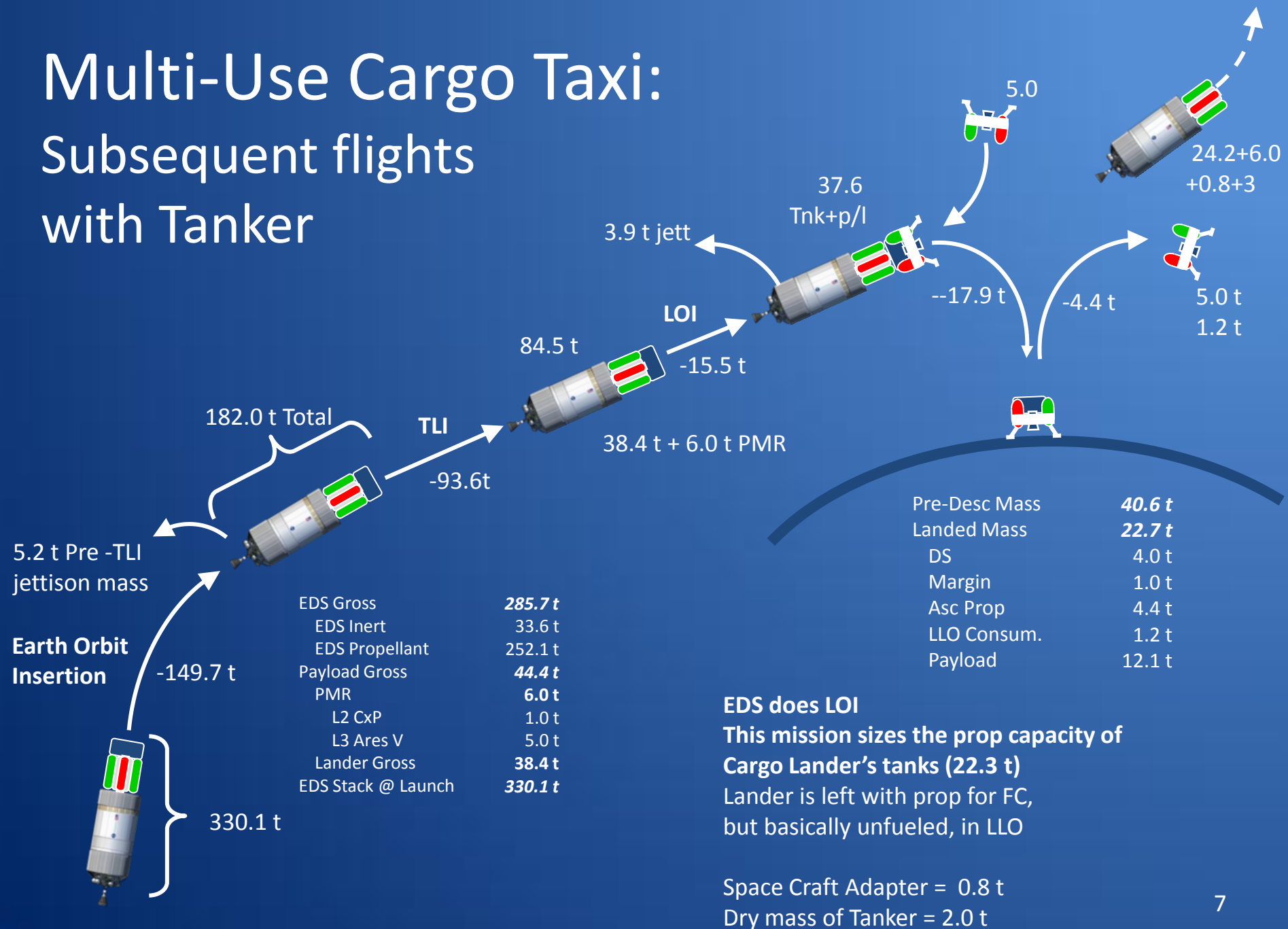
LSS Scenario 10

Evolvable LOX/CH₄ Crew and Cargo Taxi with Tanker with In-Flight Refuel

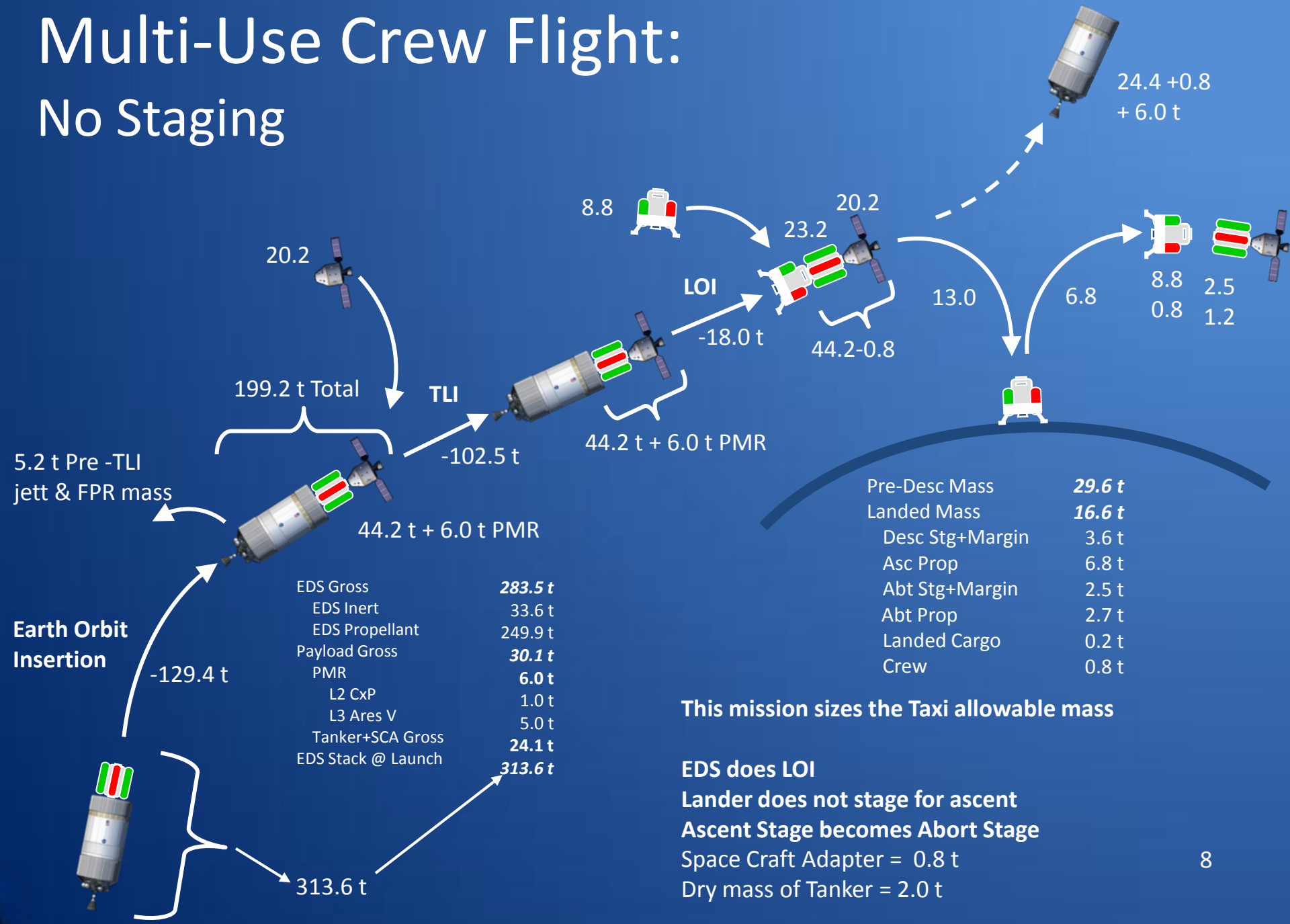
- Started with LCCR architecture and implemented the capability to refuel both cargo and crew missions to reuse the surface delivery systems
 - Eliminated nearly all the graveyard of used vehicles
 - Much more efficient Lunar scenario when plan is to establish lunar base of operations
 - LCCR infrastructure with as few changes as practical to enable reuse of elements
 - Added a refueling module capable of delivering fuel and providing a pressurized module with resupplies of consumables
 - Added an abort capability to crew landers
 - Altair, SEVs and Habitats based on other Cx designs
 - LCCR = Lunar Capability Concept Review

Multi-Use Cargo Taxi:

Subsequent flights with Tanker



Multi-Use Crew Flight: No Staging



Cx Approach for Mars Exploration

- Defined in the 2007 Mars DRM document
- Launches a base that is prepositioned
- Crew returns to Earth via a MPCV
- All mission elements are discarded
 - Possible exception is the MPCV



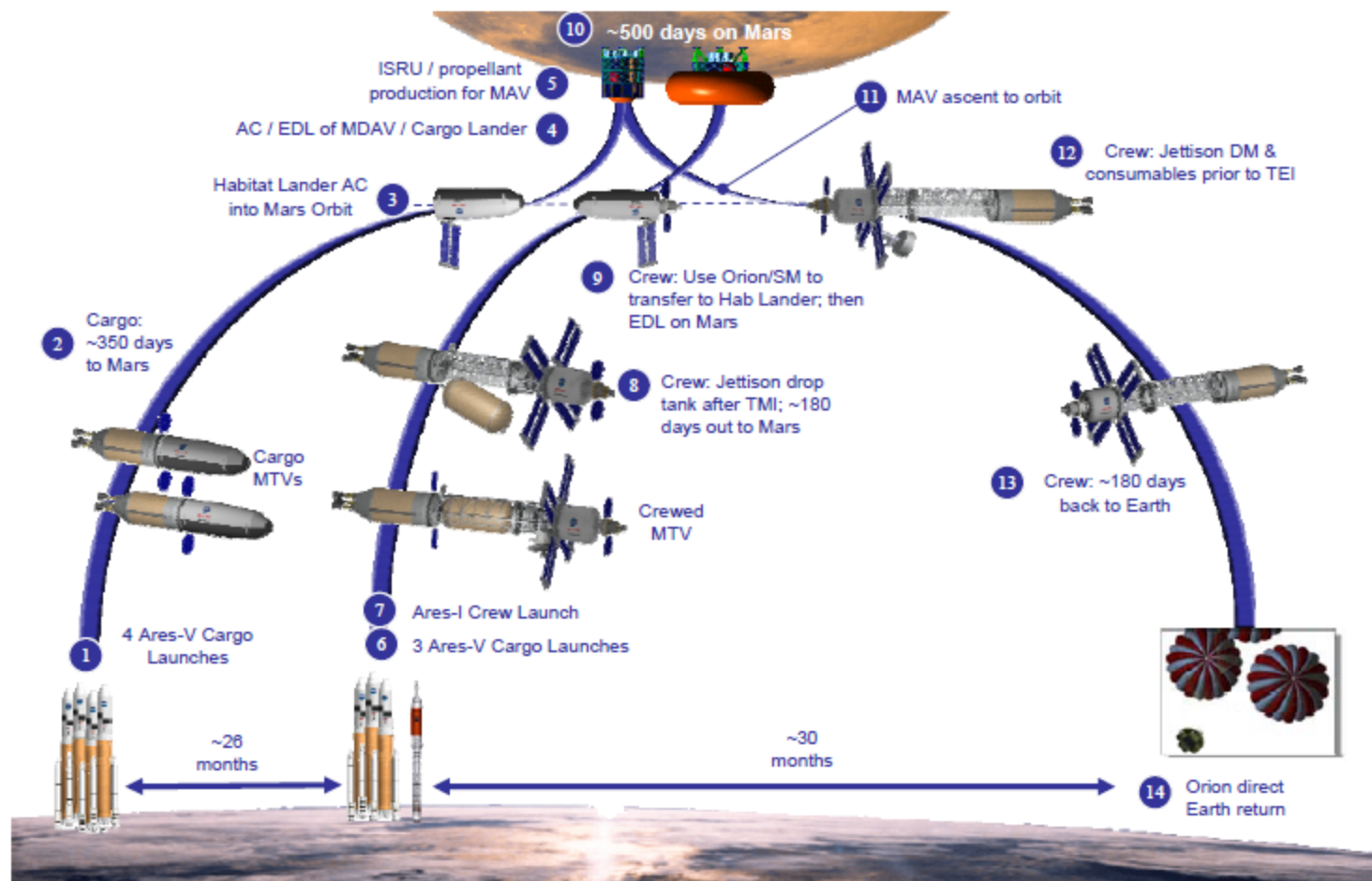


Figure 2-2. Mars Design Reference Architecture 5.0 mission sequence summary (NTR reference).

2.1 Surface Reference Mission

Several different surface architectures were assessed during the formulation of the Mars DRA 5.0, each of which

The Single Crew Module Concept

- Based on presidential direction of 2010 that directed development of new technologies, focus on exploration and cancelation of Cx
 - CCDev access of crew to LEO
 - Heavy Lift Vehicle launch of large payloads to LEO
 - Fueling (later refueling) (and assembly at an in-space assembly base)
 - Closed Loop Life Support (CLLS)
 - Interplanetary space propulsion (probably nuclear powered)
 - Green technology (reuse mission assets)
 - Aero-braking
 - Possibly ISS utilization
- Recognize that deep space missions require long duration crew support for both transit and while at destination
 - Requirements are nearly the same - one system could address both needs
- The SCM concept puts those parts of the direction together in a way that could make exploration more affordable and possibly realizable sooner
 - Proposed to the HEFT as a concept with a request to perform assessments of its feasibility and practicality

An Alternative Approach to Exploration

A Single Crew Module for Transit and Surface Operations

Single Crew Module Concept



MMSEV Or SEV

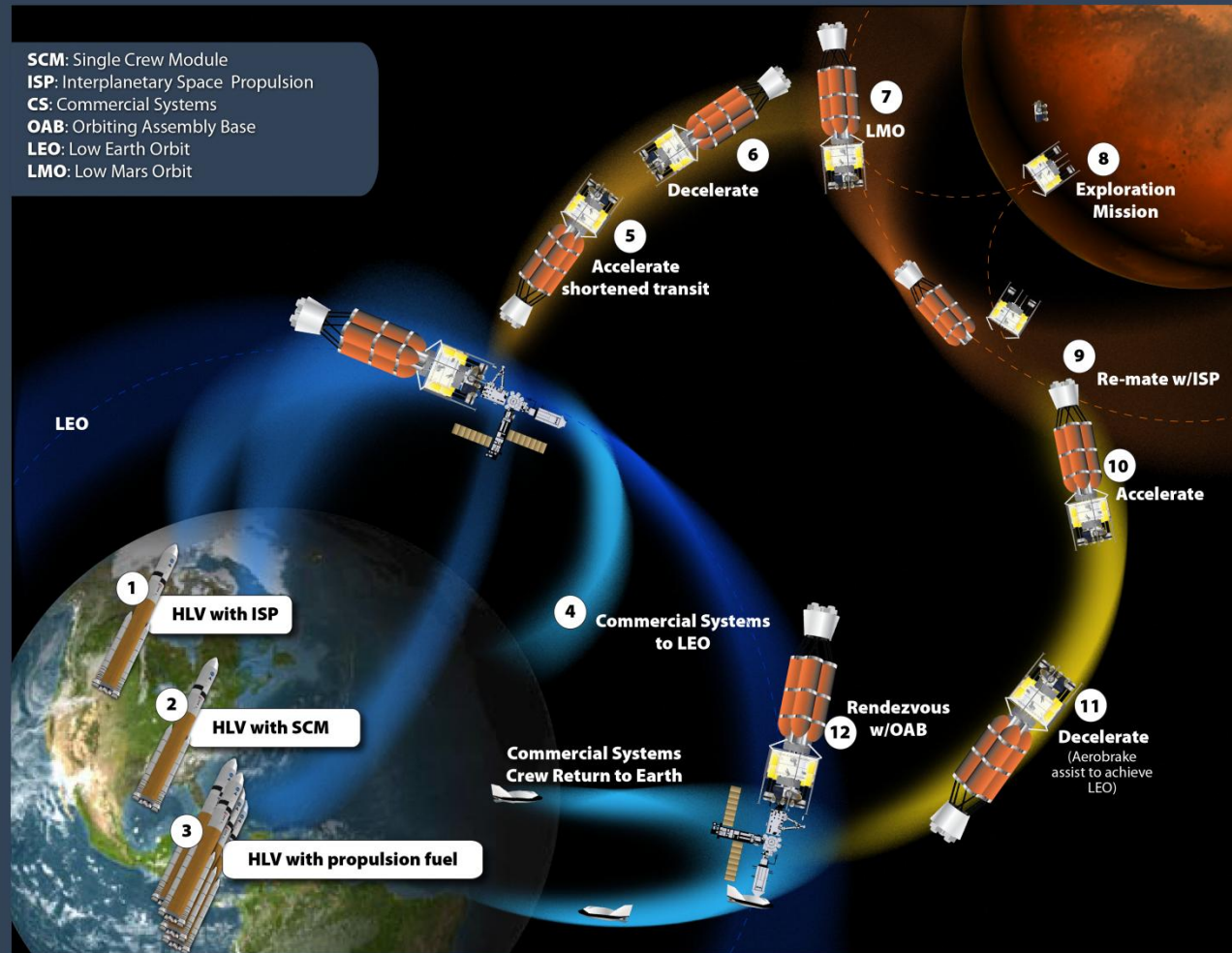
Descent and
Ascent Rockets

Habitat for
transit and
surface
operations

Single Crew Module Approach

- Recognize that crew support requirements are nearly the same for transit and for surface operations
- Propulsion capability can be fully fueled before start of the mission
- Propulsion for landing of the habitat on the surface can be fueled to allow return to orbit
- Focuses on exploration rather than colonization (colonize after exploration has identified a great place for a colony)
- MMSEV for NEA, SEV when to a surface

SCM: Single Crew Module
ISP: Interplanetary Space Propulsion
CS: Commercial Systems
OAB: Orbiting Assembly Base
LEO: Low Earth Orbit
LMO: Low Mars Orbit



Single Crew Module Concept for Transit and Surface Operations

SCM Assumptions

- New initiatives are realized
 - HLLV and Commercial Crew to orbit
 - Makes it possible to deliver major elements and fuel to assemble in space
 - Commercial infrastructure delivers the crew
 - Fueling or refueling in space
 - Makes starting a mission fully fueled possible
 - High Specific Impulse (isp) In Space Propulsion (ISP)
 - Makes acceleration and deceleration to and from destination practical
 - Shortens time to and from destination
 - Dramatically reduces propellant required
 - Increases isp from below 500 to around 5000
 - Chemical propulsion can address getting SCM habitat and SEV to and from destination surface (from low destination orbit)
- Focus for exploration is on NEAs and Mars
 - Mars is the ultimate destination
 - Lunar exploration pursued only as validation of readiness to go to Mars
 - Habitation of space after exploration has established the best location

SCM Features

- Single habitat module for crew during transit and at destination
 - Eliminates the need to have separate vehicles
 - SCM habitat would provide functions Cx approach provided in CEV, Altair, surface habitat
 - Commercial provides capability to get crew to and from assembly base
 - Includes a SEV or MMSEV
 - Safe haven for habitat contingencies
 - Provides efficient EVA capabilities for contingency and exploration via suit ports
- One vehicle departs from and returns to Earth vicinity
- Reuse the habitat and the ISP for subsequent exploration
 - Refurbish and resupply the SCM
 - Refuel the SCM descent and ascent propulsion system
 - Refuel the ISP

SCM Approach

- Develop an Orbiting Assembly Station --- Just Do It !
 - A significant step but one that can rely heavily on ISS heritage for OAS habitat, truss, power and RMS
 - ISS itself could evolve to be the OAS
- Launch major elements without fuel
 - Assemble at OAS then launch fuel to maximize the capability of major elements
- Sequential Exploration to establish confidence
 - Go to NEA first with SCM, ISP and MMSEV
 - Replace MMSEV with SEV and explore the moon to confirm readiness for Mars
 - Use proven SCM complex with SEV to explore Mars
 - Then repeat to go to another place to explore
- Reuse each element by refurbishing between missions and refueling
- Use OAS for other Earth vicinity purposes during exploration missions
 - Construction of solar power satellites
 - Staging and assembly of other missions
 - House experiments or production facilities that use the space environment

Single Crew and Command Module Concept

SCCM: Single Crew Command Module

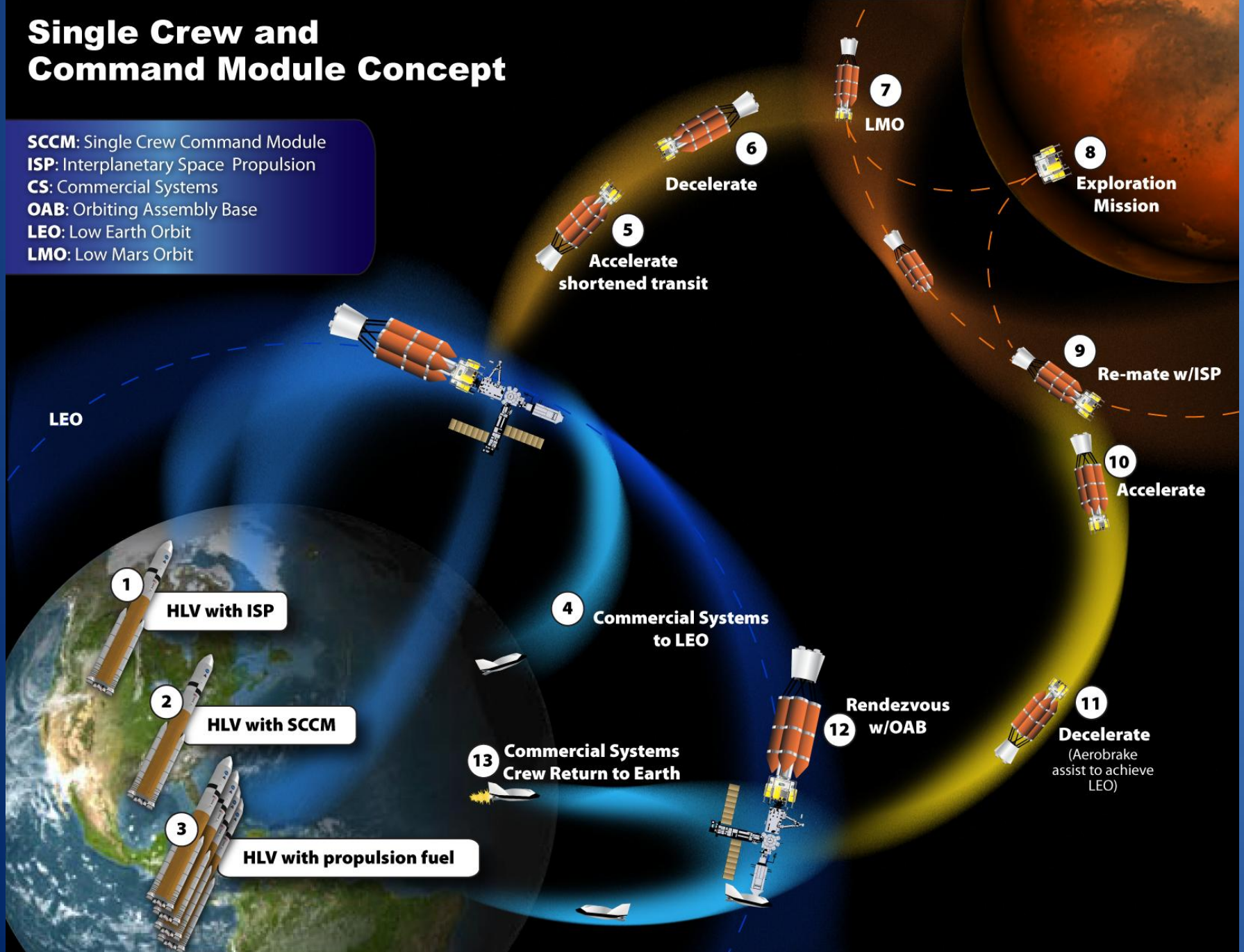
ISP: Interplanetary Space Propulsion

CS: Commercial Systems

OAB: Orbiting Assembly Base

LEO: Low Earth Orbit

LMO: Low Mars Orbit



SCM Advantages

- A single module addresses crew functions for all mission phases
 - Eliminates separate crew support modules that currently address:
 - Transit to a destination (in Cx the CEV);
 - Transit from orbit around a destination to the surface (in LSS the Altair vehicle);
 - Another (or a derivative of the orbit to surface vehicle) that would return to destination orbit
 - In LSS the Altair Ascent module)
 - The habitat for operations at the destination (LSS habitat module)
- Significantly less mass to destination than other approaches
 - Fully uses regenerative technologies to minimize mass by using those for the entire mission
- Eliminates the need to develop new vehicles for subsequent missions
 - The same SCM can address those functions for subsequent missions
 - The cost of exploration should be significantly reduced
 - Replacement HW for subsequent missions is not required

SCM Advantages Continued

- No prepositioning of assets is required
 - Versus Mars DRMs that require that assets be prepositioned
 - Reduces landing accuracy requirements
 - Crew arrives at location not previously explored via prepositioned assets
- Shortens mission duration via use of ISP
 - Several months vs year or more for Mars DRM
 - Could result in reduced volume and consumables – thus a lighter vehicle
 - Would help in addressing radiation exposure
- Vehicle dimensions are not constrained by launch vehicle
 - Allows architectural freedom to arrange mission elements
 - Positioning prop around SCM (instead of beneath) could mitigate radiation exposure
- Allows exploration that can address exploring many sites
 - The exploration program becomes robust due to focus on exploration

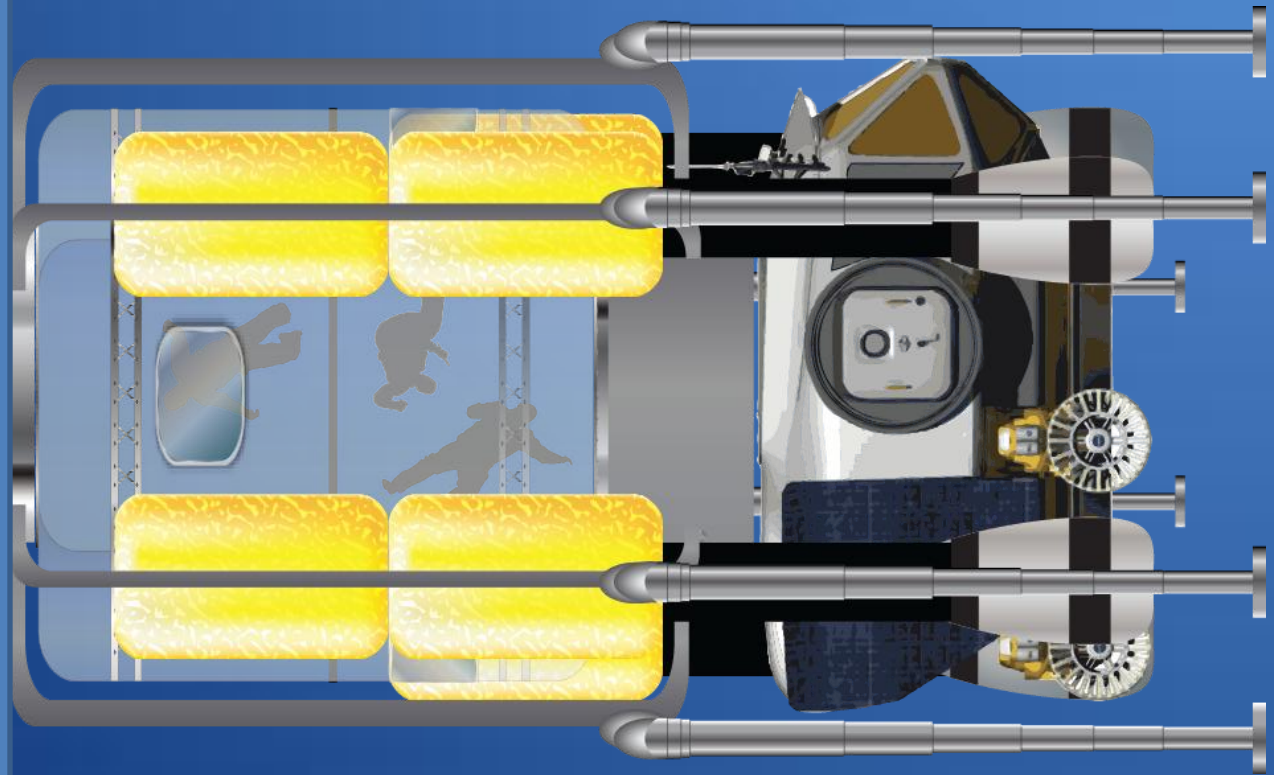
SCM Challenges

- For SCM-to-planetary surface missions
 - Prop is required to land the habitat and SEV and then return both to rendezvous orbit
 - Both are required for return transit
 - Trade versus Mars DRM is the SCM habitat propulsion system versus prepositioned assets and dedicated descent and ascent vehicles
- Reuse makes the SCM life requirements longer than for single use vehicles
- Requires infrastructure for assembly near Earth
 - Most exploration concepts will probably require this

SCM Concept Study

- Estimate the mass of SCM mission elements – Habitat, MMSEV (or SEV), Habitat propulsion system, Landing system, ISP (with propellant)
 - A habitat that can support a crew for an envisioned exploration mission
 - Structure
 - Systems
 - Consumables
 - Contingency items
 - The propellant system that has to lift the habitat to low destination orbit
 - The prop system that is needed to land the habitat + its prop system
 - The habitat prop system with fuel for both landing and to rendezvous with the ISP
 - Using combined habitat and habitat prop system mass - determine what the mass of the ISP is that is needed to take the combined vehicle from Earth to destination vicinity and return the SCM to Earth vicinity
- Compare the SCM integrated mass to the Mars DRM mass
- Assess savings on subsequent exploration missions

SCM Habitat and SEV



Habitat Mass Estimate

- Best available estimate - the May 2011 Deep Space Habitat
 - Total mass for a 4 crew 365 day mission is 27,930 kg
 - Uses ISS derived Technologies for ECLSS
 - Mass could be saved via several refinements
 - Can save over 1000 kg if advanced ECLSS closure is used (for 1 year)
 - Inflatable structure would reduce structural mass
 - Water wall provisions might be reduced related to shorter mission
 - If ISP realizes short mission transits
 - Mass and potentially the volume of the habitat could be reduced
 - Consumables need would be less
 - Includes a power system for independent operation
 - Could provide power via ISP for transit phases

Other SCM Element Mass Estimates

- Habitat landing system –estimate would be from Cx Altair estimates (est 2000 kg)
- SEV would be based on Lunar estimates ~ 4000 kg
 - Addresses EVA for exploration and contingencies
- Propulsion for habitat landing – x kg
 - Likely MOX – to address long term prop storage
 - Probably leave behind after rendezvous with ISP
- Target for defining the capability of habitat propulsion
 - From LMO to surface
 - Mass of habitat, landing system, SEV and Prop system
 - $28,000 + 2000 + 4000 + x = 34,000 + x$ kg
 - From surface to LMO
 - Habitat, SEV, and partially fueled prop system
 - $28,000 + 4000 + x$ (-prop used in descent) = $32,000 + x$ (-prop used in descent) kg
- Prop system must be capable of delivering a habitat + prop system to surface
 - Difference is added prop required to launch the full habitat
 - Thrust required is nearly the same

Alternatives to Reduce Mass

- A primary concern with the SCM approach is propulsion capability required to return the SCM habitat from Mars
 - Design the habitat prop system to meet that requirement
 - Envision habitat prop system launched as 4 modules
 - Each module with prop tanks and rocket and attached to quadrants of the SCM Habitat
 - Provides some contingency capability
- Several modifications could reduce the mass
 - Leave the landing gear on the surface
 - Requires supplying new landing gear for the next mission
 - Leave the SEV on the surface
 - Compromises redundancy on return trip
 - Jettison SCM habitat propulsion after rendezvous with ISP
 - SCM habitat prop system is envisioned to be modular so easily accomplished
 - Segment ISP propellant tanks and jettison tanks when emptied
 - Replace ISP fuel tanks as simpler way to refuel
 - Other uses for large empty fuel tanks?

SCM Options

- Develop and fuel in LEO to maximize mass to space
 - Use OAS or space tug propulsion to raise orbit to depart from HEO outside LEO areas of concern (like radiation belts)
 - Use LEO high thrust system to start mission then lower thrust ISP for remainder of the mission
- Use space tug to transition SCM to outside radiation belts
 - Crew uses space tug to start exploration outside radiation belts
- Use MPCV instead of MMSEV or SEV
 - Provides direct to SCM crew delivery at start of the mission
 - MPCV could be used late in the mission to speed return crew directly to Earth
 - To be reusable the ISP and SCM would return to OAS via longer return trajectory
 - Use of ISP to reduce vehicle velocity during return may make MPCV reentry less challenging
 - Reduces mass of SCM to surface and back to destination orbit (habitat only)
 - Reduces exploration capability at destination
- Other options?

Discussion

- Comments on the SCM concept?
 - Technology use – CLLS, advanced regenerable EVA, TCS tuned to deep space environment?
- Alternatives that should be considered?

Alternate Approaches to Exploration

- What other mission architectures should be considered
- What space infrastructure makes sense
 - How should launch to LEO be managed
 - In space assembly at LEO, HEO, Lagrangian points
 - Fueling or refueling – a solution or a problem? Implications on exploration
- What is the best mix of exploration, operations, commercial and colonization
 - PhotoVoltaics for Earth power
 - Materials from Moon or asteroids
- What is the best way to introduce new concepts
 - How can architecture ideas be introduced so that they get considered
 - How can NASA organize to ensure ideas get fleshed out so that they can be fully be considered
 - What are the best ways to make a module do all mission functions
- Can we afford to start over (with a new approach)
 - Redirect or disruption organization
 - Should currently planned infrastructure be assumed as a starting point
 - Orion, HLLV
- How can mission costs be reduced
 - How can alternate acceleration (launch) approaches contribute
 - Space Elevators, Linear accelerators
- Is life preservation off Earth the main goal of Space Exploration/Colonization

Backup

Comments and Feedback on SCM?

- Reusability of the habitat and ISP
- Propulsion for descent from then return to ISP
- Mission cost lowered, schedule reduced
- How to get into the mix of concepts
 - Proposed the concept to HEFT
 - Advocated a study to establish credibility
 - Advocated to OCT via Game Changing Approach

Taxi-Evolvable Lander

- If a tanker and fuel are carried to LLO with EDS doing LOI, then refuel and reuse of crew or cargo lander in LLO become possible
 - ~ 7.0 t payload with crew and single use lander
 - ~ 0.2 t payload with crew and reuse of Lander
 - ~ 7.0 t cargo, and single use of cargo lander (fly 2 on each Ares V to get ~14.0 t)
 - ~ 12.0 t cargo only, with reuse of cargo lander
- Landers operated in 'conventional' mode initially
 - Staging for crew Lander, one time use then discarded
- Landers evolve into reusable mode after flight heritage established,
 - First with cargo, then with crew
 - Full flight range abort capability becomes available
- EDS refuel in LEO not required. Lander refueled in LLO only (tank exchange?)
- Sortie strategies need to be developed
- This is a challenging mass design for the crew Lander, but
 - Landers do not need to accommodate CEV loads during TLI
 - Landers do not necessarily need to be designed for 5g launch loads fully loaded with cargo and propellant
- Benefits to overall surface campaign need assessment (cost of new landers versus new Ares V's)