Overview of Exploration Program

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The Constellation Program is developing the flight systems and Earth-based ground infrastructure to establish an expanded human presence in the solar system. By building on the achievements of previous lunar exploration efforts and technological advancements made over the past 5 decades, and by conducting enhancing and enabling research and technology development, NASA will provide the foundation for the U.S. to continue to access the International Space Station (ISS), return humans to the moon, and enable human exploration of Mars and beyond.

The first step in this ambitious national undertaking is to formulate a safe, cost-effective, and sustainable strategy or architecture for lunar return. We must then design and develop the building blocks of the vehicles and systems necessary to accomplish this goal. Figure 1 illustrates the basic plan (reference mission) for the first human lunar landings.

The long-term objectives of U.S. space exploration continue to evolve. The near-term goals are well-established and under way: to develop the flight systems and ground infrastructure required to enable continued access to space and to enable future crewed missions to the ISS, the moon, and Mars.

The exploration vehicles we are developing to meet this goal include the Orion Crew Exploration Vehicle (CEV) spacecraft and two new launch vehicles – the Ares I and the Ares V. The Ares I launch vehicle will carry the Orion CEV to low-Earth orbit (LEO) where the CEV will dock with either the ISS or with a payload launched earlier on an Ares V launch vehicle for transit to the moon. For lunar missions, the Ares V launch vehicle will carry an Earth departure stage (EDS) and lunar payload (e.g., a lander) in a single launch. After the Orion CEV docks with the EDS/lunar payload in Earth orbit, the EDS engine will ignite and propel the lunar payload and the Orion CEV to the moon. Ares V launch vehicles will be used to launch the components needed to send and return a crew to Mars. This could include a Mars transfer vehicle, a lander, a surface habitat, and surface equipment. The Ares I and Orion CEV will also be used for crew transport to and from LEO for the Mars missions.

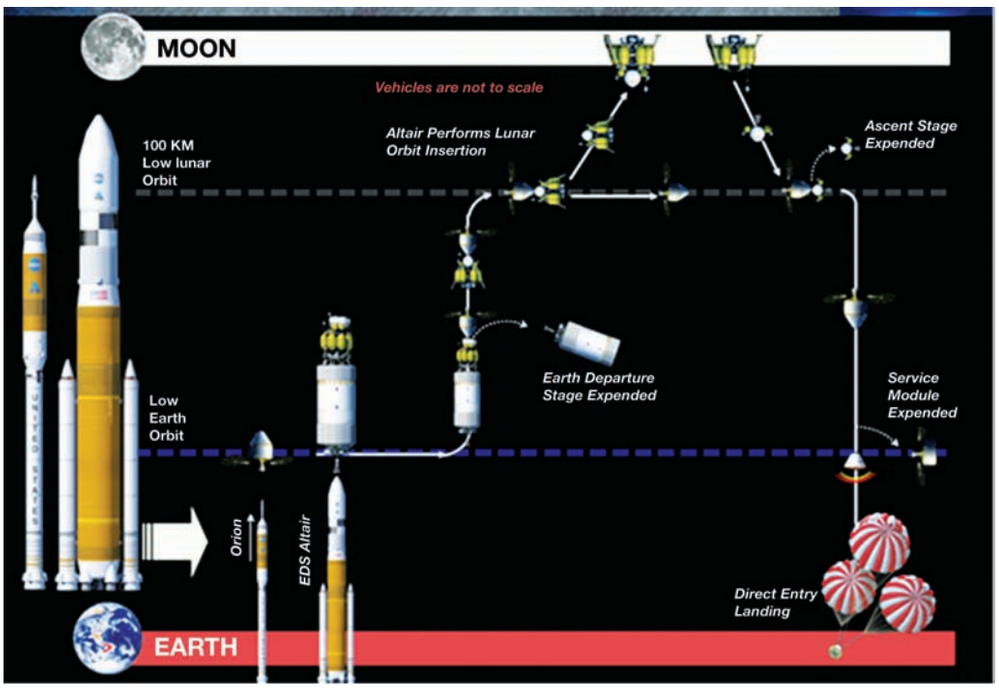

Fig. 1. *Typical lunar reference mission.*

The Constellation flight projects are as follows:

The Orion Crew exploration vehicle

The basic design of the Orion spacecraft consists of the crew module (CM), service module, spacecraft adapter, and Launch Abort System. The Orion spacecraft is approximately 5 m (16.4 ft) in diameter and 15.3 m (50.3 ft) in length with a mass of approximately 14,000 kg (31,000 lbs.). It provides crew habitation in space and docking

capability with other launched components and the ISS; and it performs Earth return, atmospheric entry, and landing. The Orion spacecraft can be configured to carry a crew of up to four to and from lunar orbit and up to six to and from the ISS.

Due to the physics associated with atmospheric entry, the overall shape of the CM is similar to that of the Apollo command module; however, the Orion CM is much larger, providing more than twice the usable interior volume and carrying double the crew size to the moon. The CM includes a pressurized crew transfer tunnel and docking device capable of mating with the ISS and the Altair lunar lander.

The CEV's technologies include: soft capture docking, a phase change material heat exchanger, optical navigation, and lightweight parachute material.

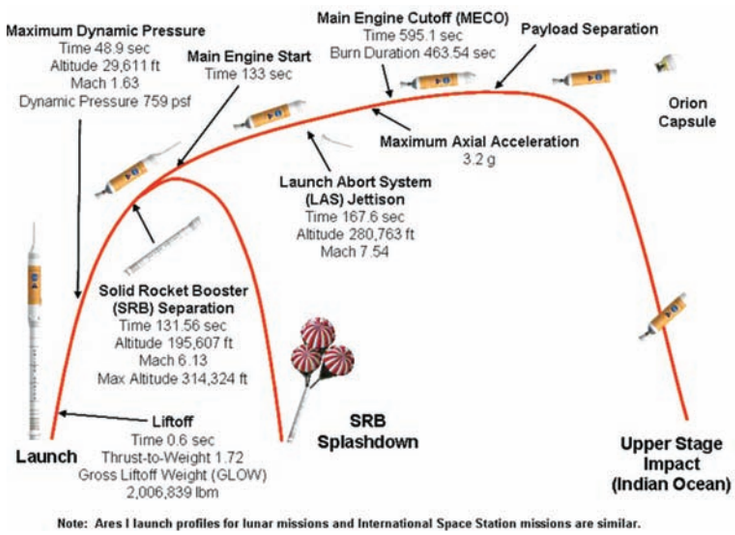

Fig. 2. *The Delta IV program.*

The Ares launch vehicles

The Ares I launch vehicle carries the Orion spacecraft to LEO where it can rendezvous and dock to the ISS or to the Altair lunar module previously launched by an Ares V heavy-lift rocket. We are developing the Ares I and Ares V concurrently with propulsion and structures hardware commonality, which results in significant design and manufacturing cost savings. Common elements being developed for the Ares I and Ares V launch vehicles include the solid rocket motors and the J-2X upper stage engine. Cost and risk reduction are also enhanced by using existing and proven hardware and systems whenever possible. This includes solid rocket booster technology from the Space Shuttle Program used as the basis for the Ares I first stage and Ares V booster rockets. The Ares I upper stage J-2X engine (and the EDS of the Ares V) is a generational upgrade of the J-2 engine used on Saturn V and Saturn IB launch vehicles during the Apollo Program. The RS-68 engines of the Ares V core stage were developed in the late 1990s and early 2000s for the U.S. Air Force's Evolved Expendable Launch Vehicle Program (Delta IV) (figure 2).

The Altair lunar lander

The Altair lunar lander (figure 3) will provide access to the lunar surface for astronaut crews and/or cargo via a descent stage, and will return the crew via an ascent stage to the Orion spacecraft in lunar orbit. A cargo-only version of the lunar lander will be able to transport cargo to the lunar surface; it may not include an ascent stage. Basic elements of the lunar lander will include the propellant tanks and engines associated with the ascent/descent stages, a living module for the crew (i.e., pressure vessel), a landing gear system, internal power supplies (e.g., rechargeable batteries) and provisions for crew access to the lunar surface. Propellants proposed for the lunar lander include liquid oxygen/liquid hydrogen for the descent stage and

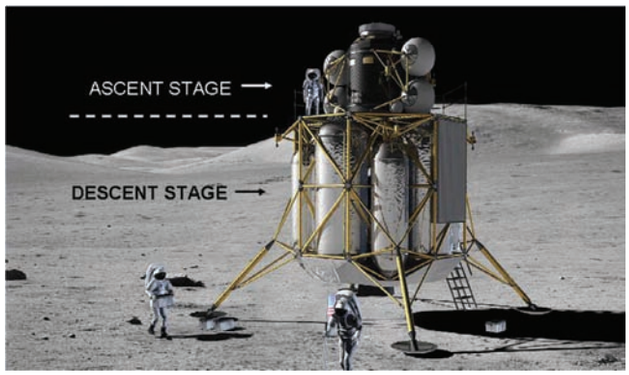

Fig. 3. *Concept design for the Altair lunar lander.*

liquid oxygen/methane for the ascent stage, although we have not made a final decision on propellants.

Altair lunar lander technologies include: autonomous landing and hazard avoidance technology, thermal control, and life support.

Extravehicular activity support equipment

The EVA [Extravehicular Activity] Systems Project provides the spacesuits and necessary tools for astronauts to work outside of the protective confines of a space vehicle. EVAs can be conducted in space or on the lunar surface, and are used for planned activities (e.g., research tasks or site exploration) as well as for contingency tasks (e.g., inspection or vehicle repair).

The EVA Systems Project will develop, certify, produce, and sustain the flight and training hardware systems necessary to support EVA and crew survival during all Constellation mission phases.

We are developing the following spacesuit capabilities:

- Crew protection and survival capability for launch and atmospheric entry, landing, and abort scenarios
- Contingency zero-gravity in-space EVA capability for the Orion spacecraft
- Surface EVA capability for exploration of the moon

The spacesuit – the extravehicular mobility unit, currently being used by the Space Shuttle Program and on the ISS – is not compatible with either the lunar or the martian environments because it was designed for zero-gravity operations in LEO. NASA is developing a new modular spacesuit system that will be used during launch, atmospheric entry, and abort as well as in zero-gravity and lunar environments. The spacesuit will support long-duration (180 days) missions, perform multiple EVAs, and function under conditions expected at lunar exploration sites. Figure 4 illustrates the two basic types of spacesuits being developed: the launch-entry-abort (LEA) suit and the lunar surface suit. These designs share many common elements, but the lunar surface suit provides additional micrometeoroid and dust protection and has an enhanced range of mobility to allow astronauts to work for extended periods of time in the lunar 1/6-g environment. Figure 5 shows engineers testing a prototype lunar surface suit in conjunction with a new lunar rover concept vehicle at the Johnson Space Center in early 2008.

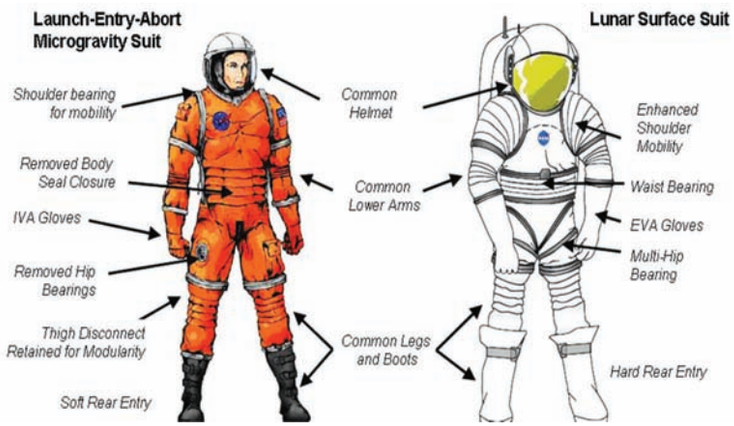

Fig. 4. *Early designs for the LEA suit and lunar surface suit.*

EVA support equipment technologies include: composite bearings, a modular helmet, a suit port, and abrasion-resistant suit material.

Lunar surface systems

Our primary goal in developing all of the launch capability and vehicle and suit infrastructure discussed above is to enable a sustained human presence on the moon. In June 2008, the Constellation Program completed the Lunar Capability Concept Review (LCCR). The LCCR was a major milestone and the result of over 9 months of various lunar exploration-related studies, including:

- Lunar surface infrastructure compatibility and maximum leverage with the Orion, Altair, and Ares vehicles already in development
- Lunar mission concept evaluations
- Habitat and logistics module concepts (hardside and inflatable)
- Lunar rovers and equipment mobility devices
- Construction equipment concepts for lunar soil excavation and movement
- Equipment and processes for oxygen extraction from lunar soil
- Lunar surface communications and navigation services
- Outpost evolution and growth (in both lunar equatorial and polar regions)
- Lunar infrastructure extensibility to Mars exploration

The Lunar Surface Systems Project is tasked with (1) continuing study and definition in all of these areas, and more, to refine an overall architecture for lunar surface operations; and (2) engaging the international community in preliminary discussions about long-term lunar outpost development.

Technologies for the lunar surface systems include: the Lunar Electric Rover gears, wheels, and mechanisms; robots for mobility; habitats; life support water recovery and air revitalization; in-suit resource utilization; habitability and human factors; and thermal control.

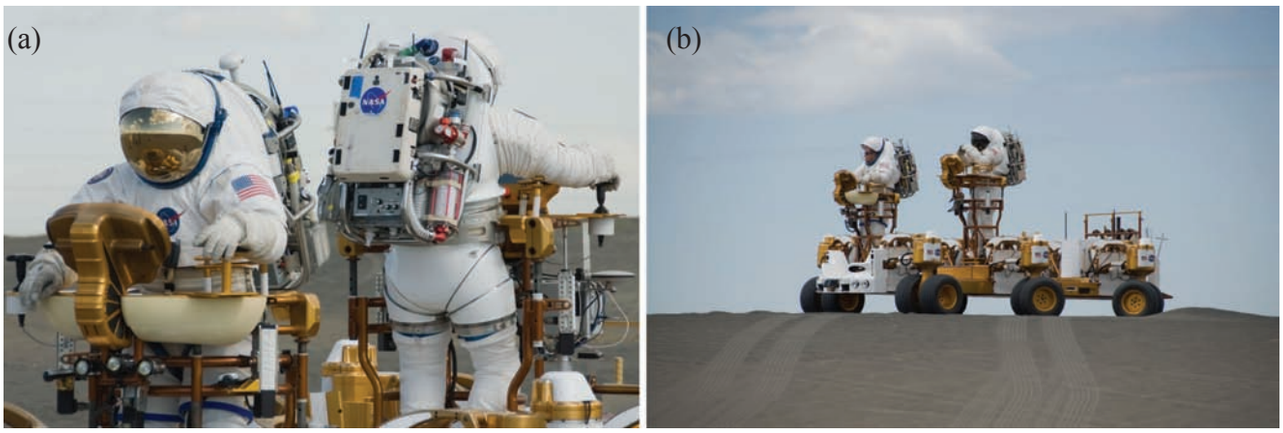

Fig. 5. *Engineers testing (a) prototype lunar surface suit, and (b) lunar rover concept vehicle.*

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