

National Aeronautics and Space Administration



August 2006

Final Environmental Assessment for the Development of the Crew Exploration Vehicle



FINAL ENVIRONMENTAL ASSESSMENT FOR THE DEVELOPMENT OF THE CREW EXPLORATION VEHICLE

ABSTRACT

LEAD AGENCY: National Aeronautics and Space Administration, Washington, DC
20546

PROPOSED ACTION: To develop the Crew Exploration Vehicle, which would be a new, human-rated space vehicle to transport humans to Low-Earth Orbit, the International Space Station, the Moon, Mars, and destinations beyond.

**FOR FURTHER
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ABSTRACT: This Final Environmental Assessment has been prepared in support of NASA's decision-making process with respect to whether-or-not to move forward with the Proposed Action, the development of a new human-rated spacecraft, the Crew Exploration Vehicle (CEV). The No Action Alternative would be to not develop the CEV.

The CEV, a reusable Apollo-like capsule, would be the U.S. vehicle to transport up to six humans and cargo to space after the Space Shuttle is retired. First human flight is planned for no later than 2014 with initial access to Low-Earth Orbit and to the International Space Station. Human missions to the Moon are planned for no later than 2020 with missions to Mars and other destinations in the following decades.

Design, fabrication, and assembly activities for the CEV would occur at multiple NASA and commercial facilities.

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EXECUTIVE SUMMARY

This Final Environmental Assessment (EA) for the proposed development of the Crew Exploration Vehicle (CEV) has been prepared by the National Aeronautics and Space Administration (NASA) to assist in the decision-making process as required by the National Environmental Policy Act, as amended (NEPA) (42 U.S.C. 4321 *et seq.*); Council on Environmental Quality Regulations for Implementing the Procedural Provisions of NEPA (40 CFR parts 1500–1508); and NASA NEPA policies and procedures at 14 CFR subpart 1216.3.

CEV development activities include design, fabrication, and assembly of the CEV. The alternatives evaluated in this Final EA are the Proposed Action (develop the CEV) and the No Action Alternative where NASA would not develop the CEV. Upon completion of this Final EA, NASA will decide whether to issue a Finding of No Significant Impact (FONSI) and proceed with development of the CEV or issue a Notice of Intent (NOI) to prepare an Environmental Impact Statement (EIS).

PURPOSE AND NEED FOR THE ACTION

The President in his January 14, 2004 address to the Nation announced a new vision for space exploration with the goal of advancing the Nation's scientific, security, and economic interests through a robust space exploration program. This vision encompassed a plan to explore space and extend human presence across the Solar System; return humans to the Moon by 2020 in preparation for missions to Mars and to other destinations; develop innovative technologies, knowledge, and infrastructure both to explore and to support decisions about the destinations for human exploration; and promote international and commercial participation for space exploration. In pursuing this new vision, the President has tasked NASA with the following undertakings:

- Exploration Activities in Low-Earth Orbit: return the Space Shuttle to flight, complete the International Space Station, and retire the Space Shuttle no later than 2010.
- Space Exploration Beyond Low-Earth Orbit: undertake Lunar exploration activities directed at enabling human and robotic exploration of Mars and destinations beyond, conduct the first extended human exploration mission to the Lunar surface by the end of the 2020, and utilize the knowledge gained from successful sustained human exploration of the Moon and robotic exploration of Mars to conduct human exploration expeditions to Mars and, ultimately, other destinations in our Solar System.
- Space Transportation Capabilities Supporting Exploration: develop a new human-rated spacecraft, the CEV, to transport humans and cargo for space missions.

To determine the best exploration architecture and strategy to fulfill these goals, the NASA Administrator chartered the development and preparation of *NASA's Exploration Systems Architecture Study* (ESAS). One of the keystone tasks in developing the ESAS was to define the requirements of the CEV and develop a vehicle configuration capable of meeting those requirements. The CEV configuration specified in the ESAS would be capable of delivering both crew and cargo to and from the International Space Station, missions to the Moon, and would also be adaptable to crewed missions to Mars.

DESCRIPTION OF THE PROPOSED ACTION AND THE ENVIRONMENTAL IMPACTS OF IMPLEMENTING THE PROPOSED ACTION

NASA proposes to develop a new human-rated vehicle to transport cargo and crew on Low-Earth Orbit, Lunar, and Mars missions. This new vehicle, the CEV, would provide human access to the International Space Station and make possible human return to and exploration of the Moon. Subsequent Lunar missions eventually would lead to human missions to Mars and, ultimately, other destinations in our Solar System.

The ESAS considered mission options such as crew transport and cargo supply missions to and from the International Space Station, crew and cargo missions to the Moon, and Mars exploration missions while developing the concept for the CEV. The CEV design would be a modular system based upon the needs of a crewed Lunar mission, capable of being adapted to meet new requirements and incorporating technological advances that may evolve over the service life of the spacecraft.

The CEV would consist of a Crew Module, a Service Module, and a Launch Escape System. The Crew Module, a conical Apollo-like capsule, provides habitable volume for up to six crew members, life support, pressurized space for cargo during uncrewed missions, docking with other space vehicles, and atmospheric entry and landing capabilities. The Service Module, a cylindrical structure attached to the bottom of the Crew Module, would contain the propulsion and power generating systems and the thermal control elements for the Crew Module. Power would be generated via two deployable solar arrays attached to the Service Module. The CEV Service Module would be similar in design to the Apollo Service Module. The Launch Escape System would be mounted on top of the Crew Module and would be similar in design to the Apollo Launch Escape System. The Launch Escape System would be activated in the event of an emergency during launch or ascent operations, separating the Crew Module from the remainder of the launch vehicle stack.

CEV development activities addressed within this Final EA would be expected to be performed at a number of existing NASA facilities (*e.g.*, Lyndon B. Johnson Space Center (JSC), Joseph S. Ames Research Center (ARC), Langley Research Center (LaRC), John H. Glenn Research Center (GRC), John F. Kennedy Space Center (KSC)) and commercial facilities throughout the United States, and possibly abroad. If NASA proceeds with CEV development, the Agency would contract with a commercial firm to serve as the prime contractor, with specific design, fabrication, and assembly activities to be clarified as the development process matures. These activities would be expected to be consistent with the mission statement and scope of normal operations at each facility and would be subject to applicable Federal environmental regulations and those of the respective States and localities. In addition, each facility would have the necessary environmental approvals, permits, and licenses (*e.g.*, air operating permits, wastewater discharge permits) to conduct designated operations and would follow accepted procedures and practices. These include, but would not be limited to, the implementing regulations for the Clean Air Act, the Clean Water Act, and the Resource Conservation and Recovery Act.

It is expected that CEV activities addressed within this Final EA would not require the construction of major new buildings at any NASA or commercial facility; however, additions or modifications to existing buildings or to testing areas may be undertaken. These activities would be evaluated and a determination made regarding measures needed to comply with applicable

Federal, State, and local environmental requirements, or if new or revised environmental permits would be necessary. In addition, a determination also would be made regarding the need for additional NEPA documentation. Environmental impacts associated with the development of the CEV would be expected to be minor (*i.e.*, within the permitted airborne emissions, waterborne effluents, and waste quantities and waste types at each of the involved facilities) and subsequently both the short- and long-term environmental impacts are expected to be within the limits of all applicable environmental laws, regulations, permits, and licenses. No adverse impact on the local infrastructure (*e.g.*, utilities, roadways) near the involved facilities is anticipated. There would be little incremental impact on employment levels at the facilities involved in CEV development. It is expected that many NASA and contractor personnel currently involved in the Space Shuttle Program would be transferred to the CEV Project once the Space Shuttle ceases operations, which is currently planned for no later than 2010. Therefore, little or no incremental socioeconomic impacts to regional economies would be anticipated.

If and when developed, the CEV would undergo testing and flight certification prior to operational use. These actions would be the subject of future environmental documentation. Other NASA activities associated with implementing human exploration of space, such as the development of the Crew Launch Vehicle, the Earth Departure Stage, the Lunar Surface Access Module, the Cargo Launch Vehicle, and the Mars Transfer Vehicle would be addressed in future environmental documentation.

Extending the operational life of the Space Shuttle in lieu of delaying the development of the CEV was considered but was not evaluated further as it was considered to be impractical for several reasons: it would be difficult to implement a crew escape system for the Space Shuttle due to design limitations; the Space Shuttle was not designed for the higher Earth re-entry speeds of a Lunar mission; a costly and a lengthy recertification process for the Space Shuttle would be required if operational life were to be extended beyond 2010; and the President determined that the Space Shuttle would not be used beyond the completion of the International Space Station. In addition, as a matter of public policy, the United States does not plan to abandon its capability to place humans in space. Purchasing space transportation services from foreign governments is viewed as an enhancement to, but not a substitute for, U.S. space exploration capability.

The CEV would have an operational life of no less than 20 years from the first human flight, currently envisioned for 2014. Although decommissioning the CEV would occur in a horizon too distant to address in this Final EA, as with previous programs, environmental documentation would be prepared at the appropriate time. Existing CEVs would be “safed” by removal of remaining hazardous materials such as residual propellant and would be most likely displayed in public settings or dismantled for appropriate disposal. The infrastructure for the CEV Project would most likely be redirected to other programs.

DESCRIPTION OF THE NO ACTION ALTERNATIVE AND THE ENVIRONMENTAL IMPACTS OF IMPLEMENTING THE NO ACTION ALTERNATIVE

Under the No Action Alternative, NASA would not develop the CEV. The United States would not have a spacecraft capable of transporting humans to space or to service the International Space Station after the Space Shuttle is retired. The United States would have to rely on foreign space programs (*e.g.*, Russia) or commercial initiatives to provide International Space Station

resupply and crew transport missions. The United States also would have no capability to undertake human missions to the Lunar surface, missions to Mars, or to destinations beyond.

Not developing the CEV would preclude the potential environmental impacts that would be associated with design, fabrication, and assembly of the CEV. No natural resources would be irretrievably dedicated to developing the CEV. NASA and contractor personnel slated for redeployment into the CEV Project upon retirement of the Space Shuttle would become displaced and would need to seek other employment. Businesses currently supplying the Space Shuttle Program would not have the opportunity to compete for similar CEV-related services. Taken together, the loss of jobs and business opportunities could result in substantial localized adverse socioeconomic impacts on some communities.

PUBLIC AND AGENCY INVOLVEMENT

NASA published the Draft EA in the *Federal Register* on July 20, 2006 (71 FR 41260) and mailed it to Federal, State, and local agencies and organizations, and interested parties. The Draft EA was also available via the worldwide web (http://exploration.nasa.gov/documents/cev_draftea.html). The CEV Draft EA public review period closed on August 25, 2006. NASA received eight comment letters, all from Federal and State agencies. These comments did not raise any substantial issues and were confined to relatively minor factual errors or regulatory requirements in the event that CEV activities were to take place in a specific State. This EA has been modified from the Draft EA in response to those comments to the extent applicable.

If the reader should wish to see the detailed comments and NASA's specific responses, please contact Mario Busacca at 321-867-8456.

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ABBREVIATIONS AND ACRONYMS

	A		JSC	NASA Lyndon B. Johnson Space Center
ac	acres			
ARC	NASA Joseph S. Ames Research Center		K	
			km	kilometer(s)
	C		KSC	NASA John F. Kennedy Space Center
°C	degrees Celsius			
CAIB	Columbia Accident Investigation Board		L	
CEV	Crew Exploration Vehicle		LaRC	NASA Langley Research Center
cm	centimeters			
CO	carbon monoxide		M	
CFR	Code of Federal Regulations		m	meter(s)
			mi	mile(s)
	D		MSFC	NASA George C. Marshall Space Flight Center
DOI	U.S. Department of the Interior			
			N	
	E		NAAQS	National Ambient Air Quality Standards
EA	Environmental Assessment		NASA	National Aeronautics and Space Administration
EIS	Environmental Impact Statement		NEPA	National Environmental Policy Act
EPA	U.S. Environmental Protection Agency		NO ₂	nitrogen dioxide
ESAS	Exploration Systems Architecture Study		NOI	Notice of Intent
			O	
	F		O ₃	ozone
°F	degrees Fahrenheit		OEPA	Ohio EPA
FONSI	Finding of No Significant Impact		P	
ft	foot/feet		Pb	lead (metal)
FR	Federal Register		PBS	NASA GRC Plum Brook Station
			PM	particulate matter
	G			
GRC	NASA John H. Glenn Research Center		S	
			SO ₂	sulfur dioxide
	H		SSC	NASA John C. Stennis Space Center
ha	hectares			
			T	
	I		TPS	The Planetary Society
in	inches		TWH	The White House
			U	
	J		U.S.C.	U.S. Code
JPL	California Institute of Technology Jet Propulsion Laboratory		USCB	U.S. Census Bureau

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1 PURPOSE AND NEED

This Final Environmental Assessment (EA) has been prepared by the National Aeronautics and Space Administration (NASA) to assist in the decision-making process as required by the National Environmental Policy Act (NEPA), as amended (42 U.S.C. 4321 *et seq.*); Council on Environmental Quality Regulations for Implementing the Procedural Provisions of NEPA (40 CFR parts 1500-1508); and NASA NEPA policies and procedures at 14 CFR subpart 1216.3. This Final EA provides information on the environmental impacts associated with development of the Crew Exploration Vehicle (CEV). Development activities include design, fabrication, and assembly of the CEV. This EA supports NASA decision-making with respect to whether-or-not to move forward with development of the CEV with a Finding of No Significant Impact (FONSI) or issue a Notice of Intent (NOI) to prepare an Environmental Impact Statement (EIS).

1.1 PURPOSE AND NEED FOR THE ACTION

On January 14, 2004, the President announced a new vision for space exploration setting the long-term goals and objectives for the Nation's space exploration efforts. The underlying goal of the President's vision is to advance the Nation's scientific, security, and economic interests through a robust space exploration program (TWH 2004). In achieving this goal, the United States will pursue the following initiatives:

- Implement a sustained and affordable human and robotic program to explore the Solar System and beyond;
- Extend human presence across the Solar System, starting with a return of humans to the Moon by 2020 in preparation for human exploration of Mars and other Solar System destinations;
- Develop innovative technologies, knowledge, and infrastructure both to explore and to support decisions about the destinations for human exploration; and
- Promote international and commercial participation in this new space exploration program.

The President tasked NASA as the lead agency in developing the plans, programs, and activities required to implement the Nation's space exploration efforts. NASA was directed to undertake activities in three major areas:

- Exploration Activities in Low-Earth Orbit;
- Space Exploration Beyond Low-Earth Orbit; and
- Space Transportation Capabilities Supporting Exploration.

In pursuit of these major activities, NASA is to undertake the following key actions:

- Return the Space Shuttle to flight;
- Complete assembly of the International Space Station and retire the Space Shuttle by 2010;

- Undertake Lunar exploration activities directed at enabling human and robotic exploration of Mars and beyond;
- Conduct the first extended human exploration mission to the Lunar surface by the end of the next decade; and
- Utilizing the knowledge gained from successful sustained human exploration of the Moon and robotic exploration of Mars, conduct human exploration expeditions to Mars and, ultimately, other destinations in our Solar System.

To determine the best strategy for the President's vision, the NASA Administrator chartered the development and preparation of the *Explorations Systems Architecture Study* (ESAS) (NASA 2005b). The ESAS Team, comprised of an Agency-wide NASA team of employees and consultants, defined the technical requirements for new space exploration vehicles and technologies. A new, multi-functional, human-rated space vehicle, the CEV, would be a key element needed to successfully implement these actions. The CEV would have an operational capability for missions beyond Low-Earth Orbit and would be able to transport cargo and crew to and from the International Space Station (NASA 2006c; NASA 2005b; NASA 2004).

1.2 NEPA PLANNING ACTIVITIES

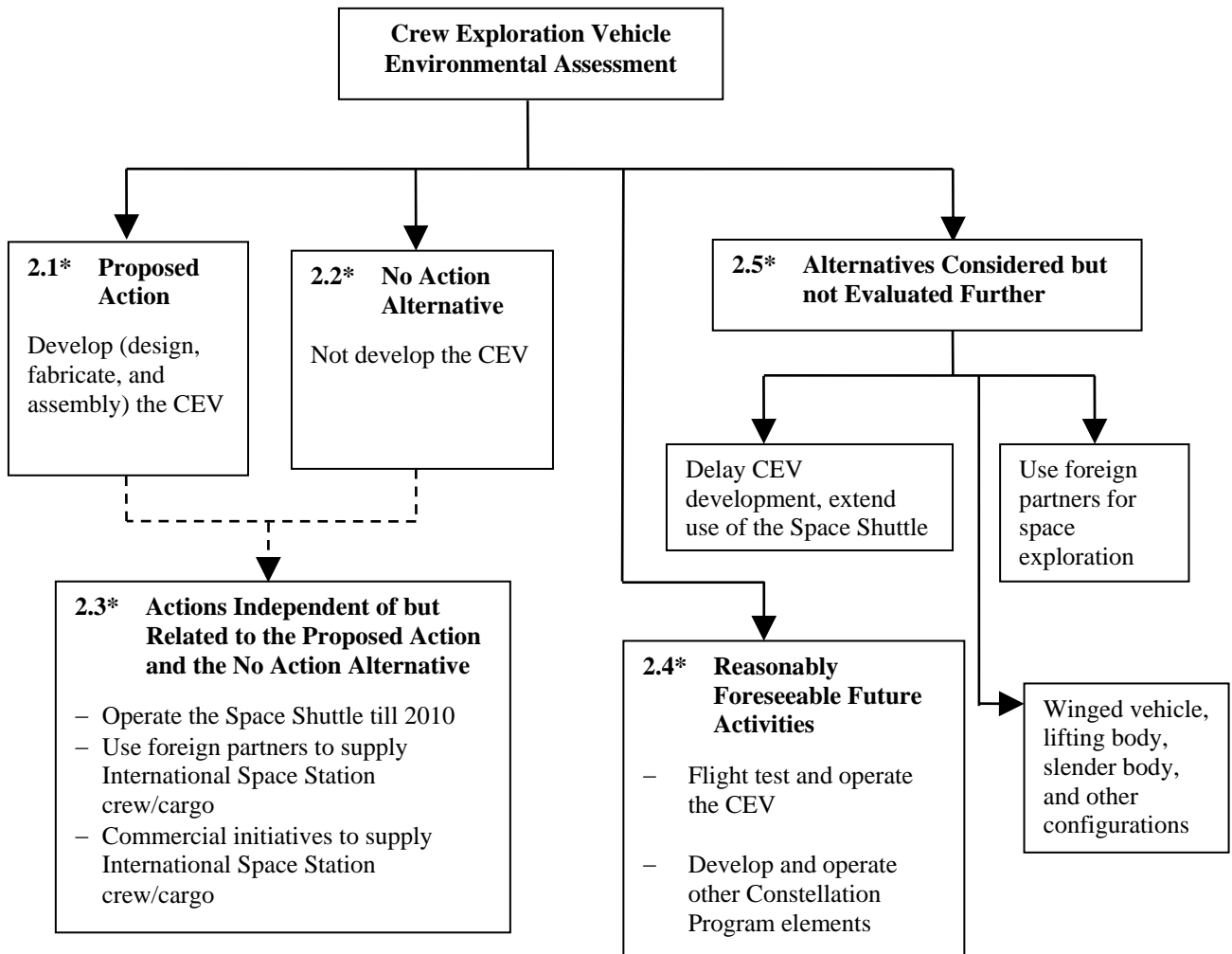
The development activities addressed in this Final EA are limited to design (involving computer-generated graphics and simulations and possibly creating full-scale prototypes for design validation), fabrication (manufacturing and testing CEV components), and assembly (system assembly and system-level ground testing). NASA is planning to address CEV flight testing, ground operations associated with flight testing, recovery of the CEV and its associated hardware after flight testing, flight operations, Earth return, and the development of the crew and cargo launch vehicles in additional NEPA documentation.

NASA published the Draft EA in the *Federal Register* on July 20, 2006 (71 FR 41260) and mailed it to Federal, State, and local agencies and organizations, and interested parties. The Draft EA was also available via the worldwide web (http://exploration.nasa.gov/documents/cev_draftea.html). The CEV Draft EA public review period closed on August 25, 2006. NASA received eight comment letters, all from Federal and State agencies. These comments did not raise any substantial issues and were confined to relatively minor factual errors or regulatory requirements in the event that CEV activities were to take place in a specific State. This EA has been modified from the Draft EA in response to those comments to the extent applicable.

If the reader should wish to see the detailed comments and NASA's specific responses, please contact Mario Busacca at 321-867-8456.

2 ALTERNATIVES EVALUATED

This Section of the Final Environmental Assessment (EA) for the development of the Crew Exploration Vehicle (CEV) describes two alternatives, the Proposed Action and the No Action Alternative. Activities associated with the Proposed Action would occur at multiple National Aeronautics and Space Administration (NASA) and commercial facilities in the United States, and possibly abroad. This Final EA also describes other alternatives examined but not considered further, and provides a side-by-side comparison of the environmental consequences of the Proposed Action and the No Action Alternative. Figure 2-1 diagrams the CEV alternatives, actions, and activities described in this Section.



*Final EA Section heading

FIGURE 2-1. CEV EA ALTERNATIVES, ACTIONS, AND ACTIVITIES ROADMAP

2.1 DESCRIPTION OF THE PROPOSED ACTION

NASA proposes to fund the development of a new human-rated space vehicle to transport cargo and crew on Low-Earth Orbit, Lunar, and Martian missions. This new vehicle, the CEV, would provide human and cargo access to the International Space Station and make possible human return to and exploration of the Moon. Human missions to the Moon eventually would lead to human missions to Mars and, ultimately, to other destinations in our Solar System (NASA 2004).

Developing the CEV, as addressed in this Final EA, would entail design, fabrication, and assembly activities resulting in the production of a limited number of CEVs (NASA 2005b). Design activities primarily would involve computer analyses and simulations and possibly creating full-scale prototypes for design validation. Fabrication activities would involve manufacture and testing of CEV components. Assembly would involve system assembly and system-level ground testing. The Constellation Systems Program Office within the Exploration Systems Mission Directorate at NASA Headquarters would provide oversight of management of the CEV Project. CEV Project Management would be provided by the NASA Lyndon B. Johnson Space Center in Houston, Texas. NASA would provide the basic design requirements as well as limited CEV components (*e.g.*, outer mold line (dimensional envelope), aerodynamic and aerothermal databases, docking component, parachute system, pyrotechnic initiators). The CEV prime contractor would be responsible for delivery of the detailed CEV design that meets NASA requirements (NASA 2006a).

The CEV is one of the key components of the Constellation Program, NASA's overarching program to develop an infrastructure of vehicles and technologies that would provide a foundation for extended human presence in space. The plan to enable the Constellation Program is described by *NASA's Exploration Systems Architecture Study (ESAS)* (NASA 2005b). The ESAS represents the culmination of a comprehensive effort by an agency-wide NASA team to define the technical requirements for new space exploration vehicles and technologies, including the CEV. Figure 2-2 is a top-level Constellation Program implementation schedule.

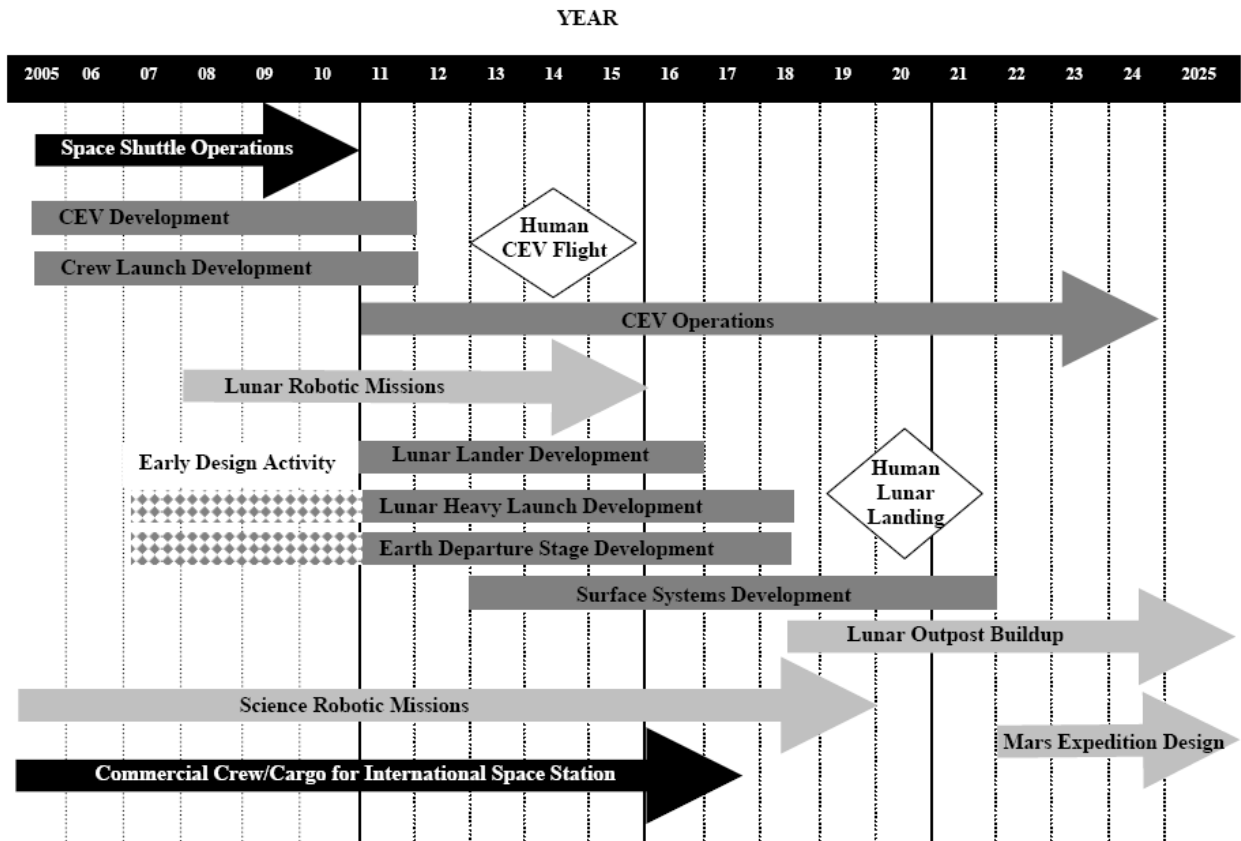
2.1.1 Description of the Crew Exploration Vehicle

2.1.1.1 Overview

The ESAS team established a series of Design Reference Missions to serve as start-to-finish mission baselines against which different approaches and criteria could be compared. Design Reference Missions describe the duration, destination, flight sequence, systems, and technologies required to undertake and complete a particular mission. They lay at the heart of NASA's ESAS development and the configuration of the CEV.

There are six Design Reference Missions applicable to the Proposed Action:

1. Crew Transport to the International Space Station: transportation of crew to and from the International Space Station; specifically, transport three crew members and up to three additional temporary crew members to the International Space Station for a six-month stay and return them to Earth at any time during the mission.



Notes: Specific dates and milestones not yet established. Crew Exploration Vehicle/Crew Launch Vehicle availability planned for no later than 2014, and potentially much sooner. Return to the Moon as early as 2018, but no later than 2020. The Commercial Crew/Cargo for International Space Station is not a Constellation Program Element.

Source: Adapted from NASA 2006d

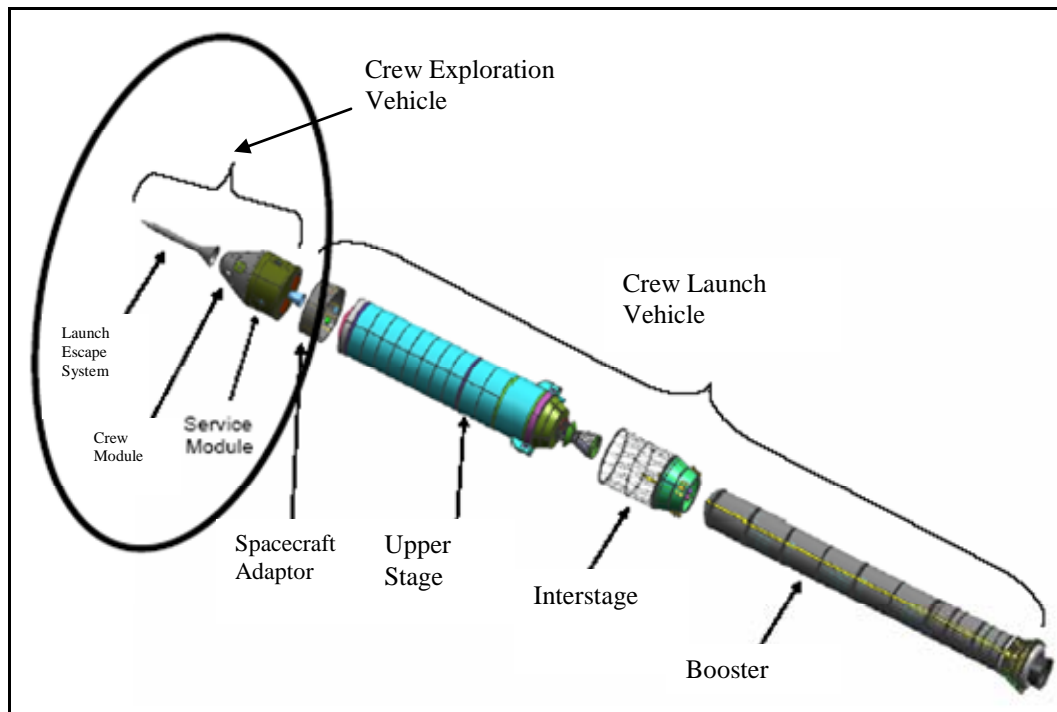
FIGURE 2-2. TOP-LEVEL CONSTELLATION PROGRAM IMPLEMENTATION SCHEDULE

2. Cargo Transport to the International Space Station: transportation of pressurized cargo to and from the International Space Station, returning to Earth after 90 days at the International Space Station using a cargo version of the CEV.
3. Crew and Cargo Transport to the Moon for Short-Term Missions: transportation of crew and cargo to and from anywhere on the Lunar surface; specifically, transport up to four crew members to any site on the Moon (*i.e.*, global access) for up to seven days and safely return the crew to Earth.
4. Cargo Transport to the Moon: transportation and delivery of up to 20 metric tons (22 tons) of cargo (*e.g.*, surface infrastructure needed for Lunar outpost buildup such as habitats, power systems, communications, *in-situ* resource utilization pilot plants, as well as periodic logistics re-supply) to the Lunar south pole in separate missions.
5. Crew and Cargo Transport to the Moon for Long-Term Missions: transportation of up to four crew members and supplies in a single voyage to a Lunar south pole outpost site for an expedition lasting up to six months with a crew exchange mission every six months.

6. Crew and Cargo Transport to Mars: transportation of crew and cargo to and from the surface of Mars for an 18-month stay to establish a continuous human presence on the surface of Mars. This mission sequence would involve a split-mission concept in which cargo is first transported in manageable units to the surface of Mars, or into Mars orbit, and tested in advance of committing the crews to the mission.

See Appendix A of this Final EA for a detailed description of these Design Reference Missions.

The ESAS team evaluated a large number of candidate approaches and design concepts for a CEV capable of meeting the challenges presented by these six Design Reference Missions. Overall, NASA determined that the well-known and understood Apollo-like blunt body would provide the greatest reliability at the lowest technological cost and schedule risk. The basic design of the CEV consists of a Crew Module, a Service Module, and a Launch Escape System and would be approximately 5 meters (m) (16.4 feet (ft)) in diameter and 15.3 m (50.3 ft) in length (Figure 2-3).



Source: NASA 2005c

FIGURE 2-3. CEV IN LAUNCH CONFIGURATION

The CEV as envisioned by the ESAS would be a modular system, capable of adapting to meet new requirements and incorporating technological advances that may evolve over the service life of the spacecraft. The CEV would be developed in a progression of versions, or “Blocks.” The fundamental CEV design was keyed upon the needs of crewed Lunar missions (designated as Block 2). This CEV design was then adapted to meet the requirements of crewed and cargo-only International Space Station missions (Blocks 1A and 1B, respectively). A third variant of the CEV was conceptualized on a less detailed basis for Mars missions (Block 3), employing the principle that International Space Station and Lunar mission experiences would provide the

information necessary to guide the exact design of the Mars-mission CEV (NASA 2005b). CEV variants, with mass summaries for each block, are shown in Table 2-1.

TABLE 2-1. CEV VARIANTS WITH MASS SUMMARIES

	Block 1A International Space Station Crew	Block 1B International Space Station Cargo (pressurized)	Block 2 Lunar Crew	Block 3 Mars Crew
Crew Size	3 (up to 6)	0	4	6
Launch Escape System Required (kg)	4,218	None	4,218	4,218
Cargo Capability (kg)¹	400	3,500	Minimal	Minimal
Crew Module (kg)	9,342	11,381	9,506	To Be Determined
Cargo Module (kg)	13,558	11,519	13,647	
Total (Crew+Cargo Modules) Mass (kg)	22,900	22,900	23,153	

Source: NASA 2005b

Note: 1 kg = 2.2 pounds

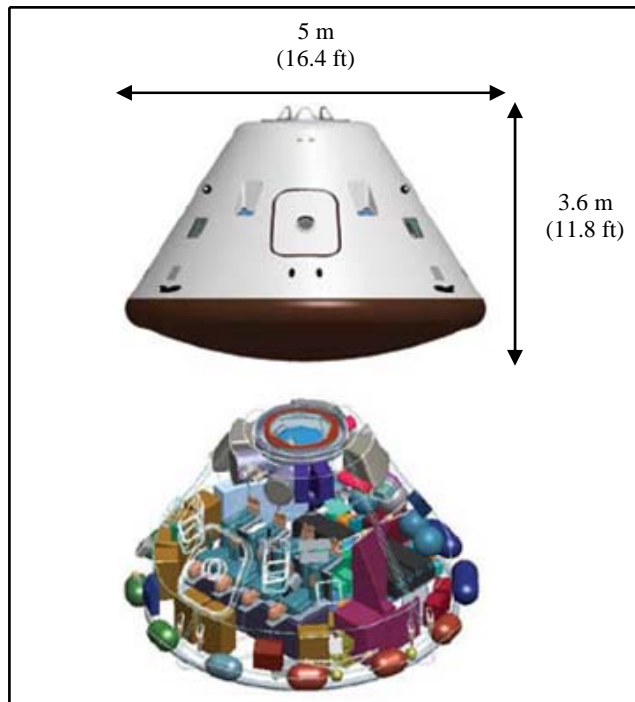
1. Cargo capability is the total cargo capability of the vehicle including Flight Support Equipment and support structure. Crew and cargo mass are approximate values.

2.1.1.2 Crew Module

The Crew Module (Figure 2-4) would provide habitable volume for up to six crew members (approximately 20 to 25 cubic m (706 to 883 cubic ft)), life support, pressurized space for cargo during uncrewed missions, docking with other space vehicles, and atmospheric entry and landing capabilities. Upon return, after friction slows the descending spacecraft, the Crew Module would deploy its parachutes and jettison the heat shield during the final approach. The primary landing mode, terrestrial or water, and the mechanism for landing is currently undefined; however, it could consist of a combination of systems, including retro-rockets, airbags, and/or water flotation devices. After recovery, the Crew Module would be refurbished and reflight multiple times (NASA 2005b).

For the Crew Module physical profile (known as the Outer Mold Line), NASA chose a scaled-up Apollo Command Module shape. The CEV Crew Module would be much larger than the Apollo Command Module, providing more than twice the interior pressurized volume. The Crew Module support structure would be fabricated from aluminum, and its outside skin panels would be composed of a carbon-fiber composite similar to that developed previously for NASA's X-37 Approach and Landing Test Vehicle. The Crew Module's windows would be made from fused silica similar to the windows on the Space Shuttle.

The Crew Module thermal protection system would consist of an expendable heat shield on the bottom of the spacecraft, reusable external insulation, and internal insulation. A number of candidate materials are available for use in the Crew Module thermal protection system (e.g., silica, carbon fibers, metals, ceramics, or combinations of these materials). Many of these have been deployed previously on NASA spacecraft, including the Space Shuttle (JSC 2005). The thermal protection system materials would be selected as the result of a NASA-led trade study.



Source: NASA 2005b

FIGURE 2-4. CEV CREW MODULE REFERENCE DESIGN

The Crew Module reaction control system would provide vehicle control following separation from the Service Module in preparation for reentry. Propulsion would be provided by a gaseous-oxygen and liquid ethanol bipropellant system selected for its relative non-toxicity and commonality with the oxygen supply in the Crew Module's life support system. A similar system has been developed and ground-tested for potential use on the Space Shuttle and commercial spacecraft.

Four rechargeable lithium-ion batteries aboard the Crew Module, in conjunction with two solar arrays mounted on the Service Module, would provide CEV electric power during Low-Earth Orbit, Lunar orbit operations, and during transfer between Earth and the Moon. These batteries would also power the CEV during Lunar orbit eclipse periods and provide Crew Module power following separation from the Service Module prior to re-entry (NASA 2005b).

The Crew Module environmental control and life support system would include gaseous nitrogen and oxygen for the cabin atmosphere, halon fire suppressant, water supply, wastewater storage, and a propylene glycol fluid loop and Freon evaporator system for temperature control (NASA 2005b).

Other Crew Module systems would include a parachute deceleration system, a landing loads attenuation system (airbags) to facilitate a terrestrial touchdown, a water flotation system for water landing, and a docking mechanism for mating with the International Space Station and other space vehicles.

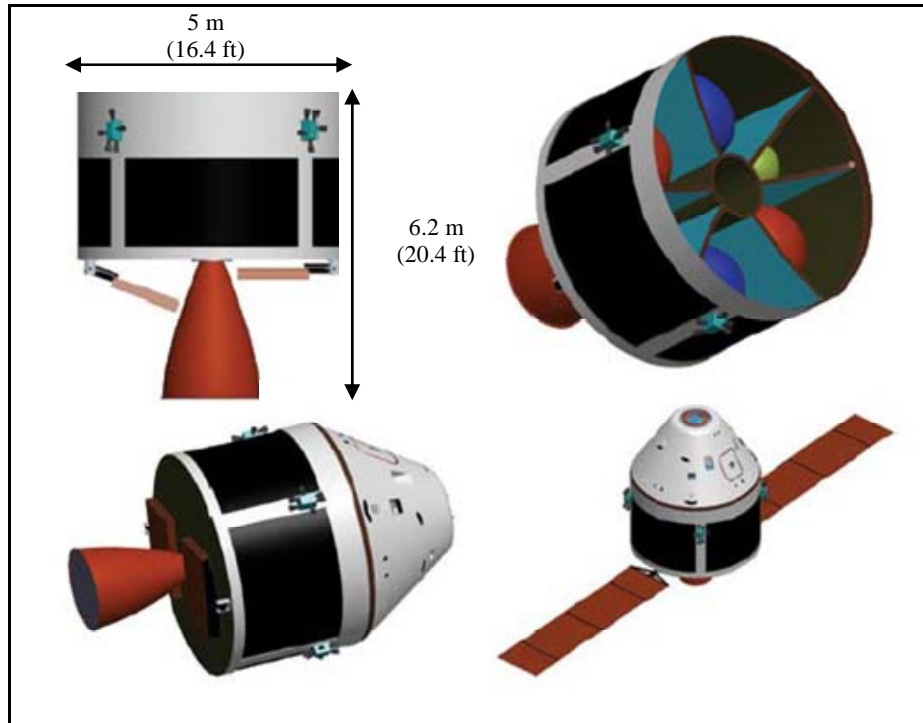
Table 2-2 summarizes candidate materials that may be used in major Crew Module subsystems and components. A majority of these materials have been deployed in NASA human space-flight missions.

TABLE 2-2. CANDIDATE MATERIALS FOR USE IN MAJOR CREW MODULE SUBSYSTEMS AND COMPONENTS

Subsystem or Component	Candidate Materials	Materials Heritage
Pressure Vessel	May be composed of aluminum honeycomb sandwich core and aluminum face sheets	Used in Apollo Command Module
Outer Mold Line	A carbon-based resin composite may be used; other materials considered (<i>e.g.</i> , aluminum)	A similar composite system was developed for X-37 (Approach and Landing Test Vehicle) and X-33 (Reusable Launch Vehicle)
Windows	May be composed of double-paned fused silica panels	Used in Apollo Command Module, similar to the Space Shuttle
Heat Shield	May be composed of phenolic impregnated carbon-based ablator; other materials to be studied	Carbon/phenolic system used in Apollo Command Module
External and Internal Insulation	May be composed of silica and nylon-based materials for external use; other external materials studied; internal insulation may be fibrous alumina	Silica and nylon-based insulation products used in the Space Shuttle; fibrous alumina developed for X-33 (Reusable Launch Vehicle)
Propulsion	Primary and backup reaction control system may be gaseous oxygen and liquid ethanol; other propellants considered	A similar system has been developed and ground tested for potential use on the Space Shuttle and a commercial launch vehicle
Electric Power	Lithium-ion batteries assumed for primary and backup power	Deployed in the Mars Exploration Rovers (Spirit and Opportunity)
Environment	Fire suppression assumes halon; active thermal control assumes propylene glycol loop plus a dual fluid loop (water or Freon) for peak loads	Halon fire suppression and Freon-based cooling systems deployed on the Space Shuttle

2.1.1.3 Service Module

The Service Module is a cylindrical structure that would be attached to the bottom of the Crew Module (Figure 2-5). The Service Module would house propulsion and power systems and the radiator panels used to reject heat developed within the Crew Module. The Service Module would be similar in design to the Apollo Service Module. Candidate construction materials include carbon-fiber composites and aluminum alloys (JSC 2005).



Source: NASA 2005b

FIGURE 2-5. CEV SERVICE MODULE REFERENCE DESIGN

The Service Module would have a service propulsion system and reaction control system to perform late-ascent abort, rendezvous and docking maneuvers in Earth orbit, ferry the Crew Module back from the Moon, and carry out self-disposal following separation from the Crew Module. Propellants under consideration for the Service Module include liquid oxygen/liquid hydrogen, hypergolics (which spontaneously ignite when their constituents come into contact with each other), and combinations of liquid oxygen and various hydrocarbons.

Two deployable solar arrays attached to the Service Module, along with the four rechargeable lithium-ion batteries aboard the Crew Module, would be used to generate electric power for the CEV during Low-Earth Orbit, Lunar orbit operations, and during transfer between Earth and the Moon. Solar arrays would provide greater mass savings than fuel cells or other similar power generation options. The solar arrays would use state-of-the-art photovoltaic cells (*e.g.*, gallium-arsenide).

The Service Module also would provide a mounting location for radiator panels. These panels would provide heat rejection capability for the CEV fluid-loop system. The radiator would have a heat-rejecting coating (*e.g.*, silver-Teflon). The Service Module thermal protection system would consist of insulation blankets for passive thermal control. Insulation materials would likely be similar to the Crew Module thermal protection system (NASA 2005b).

Table 2-3 summarizes candidate materials that may be used in major Service Module subsystems and components. A majority of these materials have been deployed in NASA human space-flight missions.

TABLE 2-3. CANDIDATE MATERIALS FOR USE IN MAJOR SERVICE MODULE SUBSYSTEMS AND COMPONENTS

Subsystem or Component	Candidate Material	Material Heritage
Structure	A carbon-based resin composite may be used; other materials considered (e.g., aluminum)	A similar composite system was developed for X-37 (Approach and Landing Test Vehicle) and X-33 (Reusable Launch Vehicle)
Internal Insulation	May be composed of silica, nylon, or alumina-based materials	Silica and nylon-based insulation products used in the Space Shuttle, fibrous alumina developed for Reusable Launch Vehicle
Propulsion	May consist of liquid oxygen/ liquid hydrogen, hypergolics, and different combinations of liquid oxygen and hydrocarbons	Space Shuttle main engines use liquid oxygen/liquid hydrogen; hypergolics used for Apollo Service Module
Electric Power	Gallium-arsenide may be used	Similar cells, part of the Forward Technology Solar Cell Experiment installed outside the International Space Station in 2005.
Environment	May use a radiator system with a silver-Teflon coating	Similar system deployed on the Space Shuttle

2.1.1.4 Launch Escape System

Should an emergency arise during launch or ascent operations, a rapid escape from the launch stack would be made possible by means of the Launch Escape System. The CEV Launch Escape System would likely be similar to the Apollo Launch Escape System, which featured separate motors for tower jettison, launch escape, and pitch-control. The CEV Launch Escape System would be mounted on top of the Crew Module (Figure 2-3). Pyrotechnics would be utilized to separate the Crew Module from the Service Module and a rocket motor in the Launch Escape System would pull the Crew Module away from the remainder of the launch vehicle stack (NASA 2005c).

Under normal conditions, the Launch Escape System would be jettisoned approximately 30 seconds after first stage separation and would land in the deep ocean and would not be recovered. After the Launch Escape System is jettisoned, emergency aborts for the crew would be provided by the Service Module propulsion system. Though specifics of the Launch Escape System are to be determined, it likely would utilize high-energy solid propellants (NASA 2005b; NASA 2005c).

2.1.2 Facilities Involved

Major technical requirements for the CEV were developed by ESAS team experts throughout NASA. Additional CEV requirements would be developed by contractors and evaluated by NASA. Table 2-4 shows the allocation of primary responsibilities between NASA and its

TABLE 2-4. CEV SYSTEM PRIMARY DESIGN RESPONSIBILITIES

NASA Responsibilities	Contractor Responsibilities
<ul style="list-style-type: none"> • Physical shape, known as the “outer mold line”, dimensions of CEV • Aerodynamic and aerothermal databases • Docking system • Parachute system • Pyrotechnic initiators 	<ul style="list-style-type: none"> • Integration of all CEV Systems and Components • Propulsion system/reaction control system • Landing system

contractors for CEV system design. Activities associated with development of the CEV addressed in this Final EA would be performed at a number of existing NASA and commercial facilities with the Lyndon B. Johnson Space Center in Houston, Texas serving as the Project lead. Table 2-5 lists potential development activities and the NASA facilities that could be involved. If NASA proceeds with CEV development, the assignment of specific tasks to specific NASA facilities would be consistent with the mission statement and scope of normal operations at each facility. The Agency would contract with a commercial firm to serve as prime contractor, with design and fabrication tasks to be clarified as the CEV Project matures.

TABLE 2-5. POTENTIAL CEV DEVELOPMENT ACTIVITIES AT NASA FACILITIES

NASA Facilities	Activities
Lyndon B. Johnson Space Center (JSC), Texas Joseph S. Ames Research Center (ARC), California Langley Research Center (LaRC), Virginia John F. Kennedy Space Center (KSC), Florida John H. Glenn Research Center (GRC), Ohio <i>George C. Marshall Space Flight Center (MSFC), Alabama</i> <i>John C. Stennis Space Center (SSC), Mississippi</i> <i>Jet Propulsion Laboratory (JPL), California</i>	<ul style="list-style-type: none"> • Overall CEV Task Lead (JSC) • CEV Subsystems Management • Systems Engineering and Integration Analysis and Support including Requirements Development, Test and Verification, and Hardware Acceptance • Aerodynamic/Aerothermal Database development performed to describe CEV ascent and entry environments (includes wind tunnel testing) • Docking System concept and hardware development for docking to other Constellation System spacecraft elements and the International Space Station • Guidance, Navigation and Control development for the Autonomous Rendezvous and Docking technology • Development of the technology for the Thermal Protection System required to support ascent, on-orbit, and entry environments • Integrated Systems Health Monitoring software development to support vehicle functioning • Structural dynamics work for the landing system development including Parachute system
Notes: At the time of publication of this Final EA, major CEV development activities are identified only for JSC, ARC, LaRC, GRC, and KSC. MSFC, SSC, and JPL are expected to contribute primarily to design and administrative support activities. Other NASA facilities not listed in Table 2-5 (<i>i.e.</i> , those additional facilities listed in Figure 3-1) may be involved as the CEV Project matures. Prime contractor selection is beyond the scope of this Final EA; therefore, identification of specific contractor facilities and their role in CEV development is not analyzed in this document.	

2.2 DESCRIPTION OF THE NO ACTION ALTERNATIVE

The No Action Alternative is the only alternative to the Proposed Action addressed in this Final EA. Under the No Action Alternative, NASA would not develop the CEV. As a consequence, there would be no U.S.-Government spacecraft available to service the International Space Station after the Space Shuttle is retired. Thereafter, the United States would have to rely on foreign governments (*e.g.*, Russia) or commercial initiatives to provide International Space Station resupply and crew change-out missions. In addition, the United States would not have a space vehicle capable of undertaking human missions to the Lunar surface or beyond. If that capability were not developed by another entity and made available to NASA, the United States would be at risk of losing the opportunity to develop and utilize knowledge gained from successful, sustained human explorations of the Moon and apply it toward human expeditions to Mars and, ultimately, other destinations in our Solar System. Under those circumstances, the Constellation Program would be unable to fulfill the vital human component of its mission.

2.3 ACTIONS INDEPENDENT OF BUT RELATED TO THE PROPOSED ACTION AND THE NO ACTION ALTERNATIVE

Independent of CEV development activities, NASA has indicated that it would continue to fly the Space Shuttle in order to complete assembly of the International Space Station, at least through completion of the U.S. core of the International Space Station, and in fulfillment of standing obligations to transport international crew and modules. The Space Shuttle then would be retired no later than 2010. Subsequently, NASA would need to rely upon foreign governments for human access and cargo delivery to the International Space Station until such time as the CEV is ready to be deployed (currently envisioned as no later than 2014 for first human flight).

In order to create an environment in which commercial space transportation services are available to Government and private-sector customers, NASA is initiating the Commercial Orbital Transportation Services Demonstrations Project. Under this project, NASA intends to stimulate commercial interest in developing and demonstrating vehicles, systems, and operations needed to resupply, return cargo from, and transport crew to and from a human space facility. Once demonstrated, NASA would consider purchasing services from commercial providers to support the International Space Station and eventually extend its use of these services to other NASA needs, such as in-space fuel delivery to support human exploration missions beyond the International Space Station. Potential environmental impacts of the Commercial Orbital Transportation Services Demonstrations Project would be addressed in other NEPA documentation (NASA 2006b).

2.4 REASONABLY FORESEEABLE FUTURE ACTIVITIES

After development, the CEV would undergo a program of testing and flight certification prior to its delivery and use for crewed flights. These actions would be the subject of future NEPA documentation.

Future space transportation capabilities to be developed and implemented as part of the Constellation Program would consist of a Crew Launch Vehicle that would carry the CEV into Earth orbit; an Earth Departure Stage that would be used to propel the CEV from Earth orbit to

Lunar orbit; a Lunar Surface Access Module to support human Lunar exploration missions; a Cargo Launch Vehicle that would launch the Earth Departure Stage and Lunar Surface Access Module into Earth orbit; and a Mars Transfer Vehicle to ferry the CEV and its crew between Earth and Mars orbits. The environmental impacts associated with developing, testing, and launching these systems would be addressed in future NEPA documentation.

2.5 ALTERNATIVES CONSIDERED BUT NOT FURTHER EVALUATED

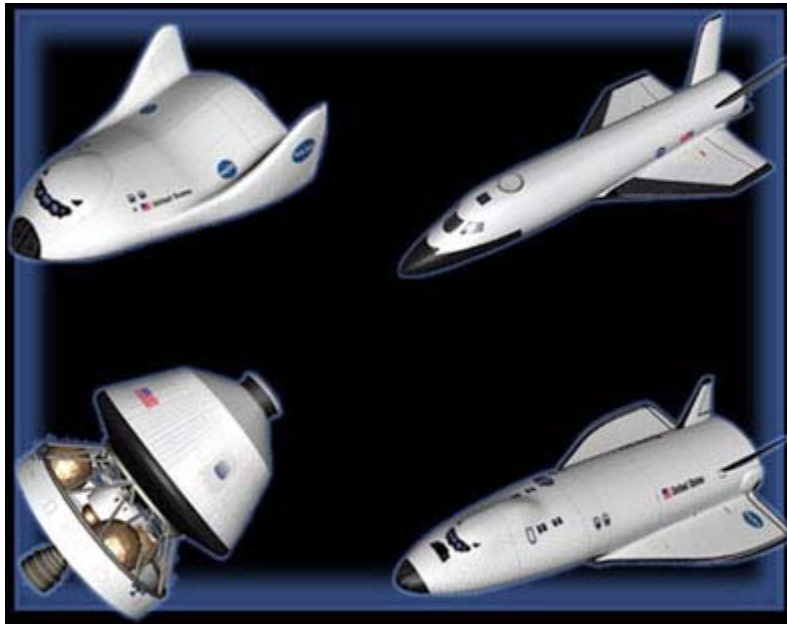
This Section discusses alternatives to the Proposed Action that were considered and eliminated from further consideration.

Modifying/refurbishing the Space Shuttle for long-term cargo delivery and human access to the International Space Station was considered impractical. Limitations in the Space Shuttle's design have raised substantial concerns about its ability to safely operate much further into the future. The Columbia Accident Investigation Board noted that major modifications to the Space Shuttle to significantly improve crew safety (*e.g.*, a crew escape system) cannot be implemented easily (CAIB 2003). Moreover, the Space Shuttle was not designed to withstand the Earth re-entry speeds of a Lunar mission (NASA 2005a). The CAIB report made clear that if the Space Shuttle flights are extended beyond 2010 then the fleet would require recertification — a costly and lengthy process (TPS 2004; CAIB 2003). Finally, the President has made the determination that the Space Shuttle will not be used beyond the completion of the International Space Station.

Purchasing space transportation services from foreign governments is viewed as an enhancement to, but not a substitute for, U.S. human space exploration capability. Since its founding in 1958, NASA has engaged in many cooperative projects with foreign nations, with perhaps none more visible than the ongoing construction of the International Space Station. Further such cooperation will be an important feature of our Nation's renewed commitment to human space exploration. However, as a matter of public policy, the United States does not plan to abandon its capability to put humans in space (TPS 2004; TWH 2004).

Other designs and configurations for the CEV were considered as part of the ESAS report. Winged vehicles, lifting bodies, and slender bodies as well as other approaches were addressed. An evaluation of environmental advantages and burdens of a blunt-body crew module versus a winged/lifting/slender-body vehicle amounts to tradeoffs in noise and upper atmosphere emissions. The entry, decent, and landing trajectory from the blunt body would likely be steeper than the other vehicles resulting in a nominally smaller sonic-boom footprint. Upper atmosphere emissions could result from heat-shield ablation, where a thin portion of the outer layer of heat shield material decomposes in a designed manner due to friction as the vehicle descends through Earth's upper atmosphere. The blunt-body configuration would utilize an ablative heat shield. The other body types would likely deploy refractory materials that would not be consumed. Toxic chemical species could be produced as a result of ablation, depending upon the heat shield material ultimately selected. These compounds would disperse in the large volume of air in the upper atmosphere and would not constitute a danger to health or life on Earth. In summary, there are no significant environmental differences between the proposed blunt-body design and the other vehicle shape classes. Overall, it was determined that the present proposed blunt-body configuration, a legacy of the Apollo Program, was best suited to the long-term safety and success of the human spaceflight systems needed for exploration of near-Earth planetary bodies (*i.e.*, the Moon and Mars). Therefore, none of these other vehicle-shape

systems will be considered further for the purposes of this analysis. Figure 2-6 depicts examples of the CEV configurations evaluated by NASA.



Source: KSC 2004

FIGURE 2-6. EXAMPLES OF CEV CONFIGURATIONS EVALUATED BY NASA

2.6 COMPARISON OF ALTERNATIVES INCLUDING THE NO ACTION ALTERNATIVE

This section compares the potential environmental impacts of the Proposed Action and the No Action Alternative addressed in this Final EA. This comparison is summarized in Table 2-6.

Implementation of the Proposed Action would entail the design, fabrication, and assembly of the CEV and its components. Fabrication would be undertaken at NASA and commercial facilities where such actions would be considered routine and within the normal scope of activities at these facilities. Under the No Action Alternative, NASA would not design and, consequently, not fabricate or assemble the CEV. It is anticipated that the existing conditions and potential environmental impacts at NASA and commercial facilities would not change significantly with implementation of either the Proposed Action or the No Action Alternative, with one exception. Localized but substantial adverse socioeconomic impacts could be anticipated at certain potential project sites as a result of retiring the Space Shuttle and not proceeding with CEV development.

TABLE 2-6. SUMMARY COMPARISON OF THE ENVIRONMENTAL IMPACTS OF IMPLEMENTING THE PROPOSED ACTION OR THE NO ACTION ALTERNATIVE

Impact Category	Implementation of the Proposed Action	Implementation of the No Action Alternative
Land Use Air Quality Noise Water Resources Geology and Soils Ecological Resources Cultural Resources Socioeconomics Site Infrastructure Waste Management Human Health Consequences	Little if any change to existing environmental conditions expected. No adverse impacts within any impact category would be anticipated at any CEV project site. Pollutants released (<i>e.g.</i> , air emissions, wastewater discharge) would be expected to be within existing permit limits. Local economies at certain project sites could be expected to experience short-term positive impacts with the overlap of Space Shuttle operations and CEV development activities; however these short-term impacts would not be expected to impact any regional economies.	No change from existing baseline environmental conditions. Localized but substantial adverse socioeconomic impacts could be anticipated at certain potential project sites as a result of retiring the Space Shuttle and not proceeding with CEV development.

3 DESCRIPTION OF THE AFFECTED ENVIRONMENT

The Crew Exploration Vehicle (CEV) development activities addressed in this Final Environmental Assessment (EA) would entail design, fabrication, and assembly of the CEV, and would occur at various National Aeronautics and Space Administration (NASA) (see Table 2-5) and commercial facilities throughout the United States. The design primarily would involve computer analyses and simulations, and possibly, manufacture of full-scale prototypes for design validation. Fabrication would involve manufacture of components. Assembly would involve assembly of components with system-level testing and final assembly and testing prior to launch.

Figure 3-1 provides the locations of major NASA facilities. Some of these may not be involved in the development of the CEV. The alignment of specific tasks with specific NASA facilities would occur as the CEV Project planning matures. Sections 3.1 through 3.5 present information on the affected environments at the NASA facilities where fabrication and assembly of the CEV would be expected to occur (in bold in Figure 3-1). Commercial facilities that would be engaged in the development of the CEV and its various systems and subsystems have not yet been designated by the contractor-competitors currently involved in the CEV Project. NASA, however, would require as a matter of contract that the successful competitor and its subcontractors ensure that its facilities and those of are in compliance with applicable Federal, State, and local environmental laws, regulations, and permit requirements (see Section 3.6).



FIGURE 3-1. LOCATION OF MAJOR NASA FACILITIES

3.1 LYNDON B. JOHNSON SPACE CENTER, HOUSTON, TEXAS

The Lyndon B. Johnson Space Center (JSC) is devoted to research and development activities related to NASA's human space activities. JSC is the lead NASA facility for management of the CEV development program. In addition to overall management of CEV development, JSC also would have principal responsibility for a number of specific activities including but not limited to the development of the docking system for servicing the International Space Station and the development of the CEV parachute system. All of the CEV activities that would be implemented at JSC would be within the scope of activities normally undertaken at JSC.

JSC encompasses approximately 650 hectares (ha) (1,606 acres (ac)) in Harris County, Texas, approximately 40 kilometers (km) (25 miles (mi)) southeast of central Houston. JSC adjoins public access areas, commercial and industrial sites, and residential areas of Clear Lake City. Land use at JSC primarily includes a commercial/industrial site with facilities, open space, utilities, and roads (JSC 2004).

JSC is set in a landscape with many tidal streams and estuaries of Galveston Bay. Clear Lake is at the southeast corner, Mud Lake and Armand Bayou are northeast, Cow Bayou is southwest, and Horsepen Bayou is north of JSC. Clear Lake and ultimately Galveston Bay receive silt and urban runoff from JSC. Galveston Bay is recognized by the U.S. Environmental Protection Agency (EPA) as an estuary of national significance and was included in the National Estuary Program in 1989. Clear Lake and Armand Bayou are classified by the Texas Natural Resource Conservation Commission as "water quality limited" (JSC 2004).

The primary source of potable water at JSC is the Clear Lake City Water Authority. Domestic wastewater at JSC is transported by underground pipe to the Clear Lake City Water Authority treatment plant. Photographic laboratory wastes and oil-water wastes from garage and shops are treated and disposed of by a licensed contractor approved by the State. Blow-down wastewaters from cooling towers and the thermochemical test area are aerated and chemically treated at JSC before discharge to the Clear Lake City Water Authority plant under pollution control regulations. Non-hazardous wastes are sent to the city of Houston landfill and some classified wastes (*e.g.*, paper, microfilm, and microfiche) are incinerated on-site. Hazardous and radioactive wastes are shipped off-site to a permitted disposal site. Several closed and graded landfills are located at JSC (JSC 2004).

The majority of JSC lies outside the 100- and 500-year floodplain and several types of wetlands have been identified within JSC. The groundwater at JSC is within a shallow confined aquifer which is contaminated with Freon 112. Remediation activities are ongoing (JSC 2004).

The climate at JSC can be classified as warm subtropical with hot summers and mild winters. Annual temperatures range from about 7 to 33° Celsius (C) (45 to 92° Fahrenheit (F)). Average annual rainfall is about 117 centimeters (cm) (46 inches (in)), and the relative humidity is more than 50 percent most of the year. Air quality models indicate that the concentrations of all criteria pollutants generated by JSC are relatively low as compared to the National Ambient Air Quality Standards (NAAQS) (JSC 2004). The six criteria pollutants regulated under NAAQS are carbon monoxide (CO), lead (Pb), nitrogen dioxide (NO₂), ozone (O₃), particulate matter (PM₁₀/PM_{2.5}), and sulfur dioxide (SO₂). Harris County is currently designated as a moderate nonattainment area for the eight-hour O₃ NAAQS (EPA 2005).

JSC is the largest employer of the Clear Lake area, which covers approximately 65,000 ha (160,000 ac) and includes parts of two counties and ten cities. The population of the Clear Lake area is estimated to reach 210,000 by 2010. The Clear Lake area employment base, income level, and education profile are above the regional average because of JSC (JSC 2004).

Neither threatened nor endangered species and critical habitats for Federal or State threatened or endangered species exist at JSC (JSC 2004). The Apollo Mission Control Center, the Space Environment Simulation Laboratory, and the Saturn V Launch Vehicle are listed on the National Register of Historic Places (DOI 2005). The Apollo Mission Control Center and the Space Environment Simulation Laboratory, Chambers A and B, are designated National Historic Landmarks (DOI 2006).

3.2 JOSEPH S. AMES RESEARCH CENTER, MOFFETT FIELD, CALIFORNIA

The Joseph S. Ames Research Center (ARC) primarily engages in the areas of information technology, nanotechnology, fundamental space biology, biotechnology, aerospace and thermal protection systems, and human factors research. ARC would be involved in a number of CEV development activities including the development of the thermal protection system. All of the CEV activities that would be implemented at ARC would be within the scope of activities normally undertaken at ARC.

ARC encompasses approximately 800 ha (2,000 ac) in the northern portion of Santa Clara County, California, approximately 56 km (35 mi) south of San Francisco and 16 km (10 mi) north of San Jose. ARC adjoins public access and wildlife protected areas, commercial and industrial sites, and residential areas of the cities of Mountain View and Sunnyvale. Land use at ARC is classified as industrial and is composed of the Ames Research Campus, the NASA Research Park, an airfield and support facilities, barracks, support facilities (active and inactive) for military personnel, and open space (ARC 2005).

The climate at ARC is characterized by warm, dry summers and cool, wet winters with average annual temperatures ranging from 6 to 25°C (42 to 75°F). The average annual rainfall is approximately 35 cm (13.5 in). ARC is within the Bay Area Air Quality Management District and is designated as a nonattainment area for the State O₃ and PM₁₀ air quality standards (ARC 2005). Furthermore, the Bay area has been designated as a marginal nonattainment area for the eight-hour O₃ NAAQS (EPA 2005).

The ARC site is located on nearly flat topography at the north end of the Santa Clara Valley, one of the most seismically active regions of the United States. Much of the land and soils have been substantially altered by land uses during the past 100 years. ARC is in the Stevens Creek watershed, a tributary to South San Francisco Bay, but historical surface water drainage patterns at the site have been modified substantially to manage runoff from impervious surfaces. Surface water flowing adjacent to ARC reflect water quality typical of urban or developed streams, where various types of point- and non point-source pollutants affect water quality. Groundwater beneath the site has been substantially affected by the Middlefield-Ellis-Whisman Superfund site in neighboring Mountain View, and by chemical spills and releases associated with U.S. Navy and NASA operations. The main contaminants are volatile organic compounds, among them trichloroethene, 1,1,1-trichloroethane, cis- and trans-1,2 dichloroethene, 1,1-dichloroethane, 1,1-dichloroethene, dichlorobenzene, chloroform, Freon 113, phenol, and vinyl chloride.

Consequently, NASA and the U.S. Navy currently are working with the private companies identified as responsible for the bulk of the Middlefield-Ellis-Whisman site contamination to remediate area groundwater. The northernmost portion of the ARC site is within the 100-year tidal floodplain (ARC 2005).

ARC receives its potable water supply from the San Francisco Water Department. Domestic wastewater at ARC is discharged to a sanitary sewer system and transported to an off-site treatment facility. An on-site industrial wastewater treatment facility is used to remove metals and dissolved solids from industrial wastewater and treated groundwater. Hazardous and non-hazardous wastes are collected and hauled by a contractor to EPA-approved off-site disposal facilities. ARC has no active landfills (ARC 2005).

In 2004, the population of the ARC area, encompassing the cities of Sunnyvale and Mountain View, was 197,023 persons, or approximately 12 percent of Santa Clara County residents (USCB 2004). Almost 20 percent of all jobs in the county exist in the ARC area, 44 percent of which are in the manufacturing and wholesale sector. In December 2004, 6,037 people were employed by ARC, 3,962 of whom were employed by NASA and 2,075 by resident agencies (ARC 2005).

No special-status plants are known to occur in the ARC area. In addition, no designated critical habitat areas are within or near ARC. Approximately 14 State and federally endangered or threatened animal species are known to frequent ARC. However, only one special-status animal, the western burrowing owl (listed as a California Species of Concern), is known or expected to occur within ARC in the developed areas that make up the NASA Research Park and Ames Research Campus (ARC 2005). The Unitary Plan Wind Tunnel Complex is a designated National Historic Landmark and is listed on the National Register of Historic Places (DOI 2006; DOI 2005).

3.3 LANGLEY RESEARCH CENTER, HAMPTON, VIRGINIA

The Langley Research Center (LaRC) is the lead NASA center for research in airframe systems and atmospheric sciences. LaRC is on a coastal plain in the northeastern portion of the city of Hampton, Virginia, approximately 240 km (150 mi) south of Washington DC and 80 km (50 mi) southeast of Richmond, Virginia and occupies 327 ha (808 ac) of Federal land (LaRC 2005). LaRC would be involved in a number of CEV development activities including the development of the landing system. All of the CEV activities that would be implemented at LaRC would be within the scope of activities normally undertaken at LaRC.

LaRC is divided into two areas, the West Area and the East Area, separated by the runway facilities of Langley Air Force Base. The majority of LaRC facilities, 319 ha (788 ac) of land, are located on the West Area. The West Area is bound by the Brick Kiln Creek to the north, State Route 172 to the west, and Langley Air Force Base to the south and east. The East Area is an additional 8-ha (20-ac) area situated on Langley Air Force Base property. About 220 buildings are located on the two areas, the majority of which are in the West Area. To the south and north of LaRC are the densely developed residential communities of Hampton and Poquoson, respectively (LaRC 2005).

LaRC is in close proximity to several surface water bodies within the tidal zone of the Chesapeake Bay. Although several surface water sources are within LaRC, the water supply for LaRC is obtained from Newport News Water Works. There are no water production or

treatment facilities at LaRC. Non-hazardous industrial wastewater and sanitary sewage is discharged by permit to the Hampton Roads Sanitation District sanitary sewer system. LaRC is permitted by the Virginia Department of Environmental Quality to discharge to surface waters within permit limitations. Water pollution sources at LaRC are limited due to the relatively low level of industrial operations at the Center. In 2000, LaRC completed clean-up of polychlorinated biphenyl and polychlorinated terphenyl contaminated sediments in a local creek. There is no indication of contamination of the groundwater (LaRC 2005).

Approximately one-third of LaRC is within the 100-year floodplain (LaRC 2005). LaRC does not dispose of solid or hazardous wastes on-site. Non-hazardous wastes are sent to the local incinerator or landfill and hazardous wastes are sent to a permitted hazardous waste disposal facility (LaRC 2005).

The climate in the LaRC area is modified continental with generally mild winters and warm, humid summers. LaRC is within the Hampton Roads Intrastate Air Quality Control Region and is designated as an attainment area for all criteria pollutants except for O₃ (LaRC 2005). Furthermore, the Hampton Roads area has been designated as a marginal non-attainment area for the eight-hour O₃ NAAQS (EPA 2005). LaRC has a State Air Operating Permit limiting air emissions; a Federal Title V Permit is not required.

The cities of Hampton, Poquoson, Newport News, and Williamsburg, and York County, form a major metropolitan area surrounding LaRC. The total population of this area in 2000 was 1,551,351. LaRC employs approximately 2,272 civil service employees and approximately 1,576 contractors (LaRC 2005).

There are three federally-listed threatened or endangered species believed to exist at LaRC, including the Kemp's Ridley sea turtle, bald eagle (currently proposed for delisting (71 FR 8238)), and piping plover. In addition, there are seven species listed as endangered or threatened by the Commonwealth of Virginia, including the canebrake rattlesnake, eastern glass lizard, Wilson's plover, gull-billed tern, loggerhead shrike, peregrine falcon, and Henslow's sparrow. The Lunar Landing Research Facility/Impact Dynamics Facility, Rendezvous Docking Simulator, Eight-Foot High Speed Wind Tunnel, Full Scale Wind Tunnel, and Variable Density Wind Tunnel are designated as National Historic Landmarks and are listed on the National Register of Historic Places (LaRC 2005).

3.4 JOHN H. GLENN RESEARCH CENTER, CLEVELAND, OHIO

The John H. Glenn Research Center (GRC) consists of two sites in Ohio, the Lewis Field in western Cuyahoga County (near Cleveland) and Plum Brook Station in west central Erie County, approximately 80 km (50 mi) west of Lewis Field. Lewis Field and Plum Brook Station would be involved in a number of CEV activities, including the design, development, test, and evaluation of the Service Module. Most of the CEV activities that would be implemented at GRC would be within the scope of activities normally undertaken at GRC. Any activities determined to be outside the scope of activities normally undertaken at GRC would be subject to additional environmental documentation.

Lewis Field

Lewis Field supports NASA's research, technology, and development programs in the areas of aero-propulsion, space flight systems, space propulsion, space science applications, and space power. Lewis Field encompasses nearly 148 ha (365 ac) of land predominantly within the City of Brook Park, approximately 32 km (20 mi) southwest of downtown Cleveland. Lewis Field borders the Cleveland Hopkins International Airport to the east and to the north and west is the Rocky River Reservation, a part of the Cleveland Metropolitan Park District. The southern boundary of Lewis Field is adjacent to highly urbanized and developed residential, commercial, and industrial complexes. The recreational park and the Rocky River Reservation next to Lewis Field are considered a protected environment. There are no national or state parks in the immediate vicinity of Lewis Field (GRC 2005).

The climate at Lewis Field is characterized by warm and humid summers and cold and cloudy winters, with average annual temperatures ranging from -2 to 21° C (28 to 70° F). Precipitation averages 89 cm (35 in) per year and prevailing winds are from the south to southwest (GRC 2005). Cuyahoga County is currently designated as an attainment area for NAAQS criteria pollutants: lead, nitrogen dioxide, particulate matter-10 (PM₁₀) and sulfur dioxide. Cuyahoga County is designated as a nonattainment area for PM_{2.5} and 8-hr ozone and is a maintenance area for carbon monoxide (EPA 2005; OEPA 2006). Lewis Field operates under a Title V Operating Permit issued in 2004 (GRC 2005).

Surface water features at Lewis Field include the Rocky River and its tributary, Abram Creek. The Rocky River flows northward along the western edge of Lewis Field, separating Lewis Field from the Rocky River Reservation and discharging into Lake Erie. Abram Creek crosses Lewis Field and discharges to the Rocky River. Lake Erie, located 8 km (5 mi) to the north, is an important fresh water fishery and a recreational resource. The Rocky River is not a designated wild or scenic river, but it is considered a wildlife refuge by local jurisdictions. (GRC 2005).

Abram Creek is an area of special flood hazard (defined as an area of land that would be inundated by a flood having a one percent chance of occurring in any given year). No other mapped floodplains occur at Lewis Field, and no facilities are present in the 100-year floodplain. The 500-year floodplain for Lewis Field has not been mapped. Although wetlands at Lewis Field have not been officially delineated, a study performed in 2002 identified four areas as probable wetlands (GRC 2005). There is activity occurring currently in one of these areas which involves relocating two storage facilities and capping an on-site landfill. The wetlands in this area have been delineated, and GRC is in the process of applying for a permit from the Army Corps of Engineers to demolish those wetlands. GRC is under EPA order to cap the landfill.

All water used by Lewis Field comes from the City of Cleveland's municipal water supply system (GRC 2005). There are separate collection systems for sanitary sewage, stormwater, and industrial wastewater. The sanitary sewer system discharges by permit to the Southerly Wastewater Treatment Plant of the Northwest Ohio Regional Sewer District. The stormwater sewer system discharges to surface waters within permit limitations. After on-site settling and oil separation, industrial wastewater is discharged by permit to the sanitary sewer system. Lewis Field uses hazardous materials for various institutional activities, which in turn generates hazardous wastes. Such waste is managed in accordance with applicable Federal, State, and

Local rules and regulations and the GRC Environmental Programs Manual for managing hazardous material (GRC 2005).

In 2000, the population of Cuyahoga County was 1,393,978 persons, a decrease of 1.3 percent from 1990. During the same period, Ohio population increased 4.7 percent, to 11,353,140 persons (USCB 2004). As of October 2004, Lewis Field employed 1,937 civil servants and 1,130 contractors (GRC 2005).

There is no evidence of any federally threatened or endangered animal species at Lewis Field. Two State-listed potentially threatened plant species, the pigeon grape and American chestnut, are found at Lewis Field. Lewis Field has no known adverse affects on endangered species beyond its borders (GRC 2005). Portions of Lewis Field are considered sensitive for potential archeological resources. Two Lewis Field facilities (the Rocket Engine Test Facility - now demolished - and the Microgravity Research Laboratory) are designated National Historic Landmarks. The American Society of Mechanical Engineers considers the Icing Research Tunnel an International Historic Mechanical Engineering Landmark. In addition, the Central Area at Lewis Field is eligible for listing on the National Register of Historic Places as a Historic District (GRC 2005). The Altitude Wind Tunnel and Propulsion Systems Laboratory (Test Cells 1 & 2) are also eligible for listing on the National Register of Historic Places.

Plum Brook Station

The Plum Brook Station (PBS) is operated as a satellite facility (component installation) of GRC and performs various research related to space applications. PBS encompasses approximately 2,614 ha (6,454 ac) of land, located approximately 6 km (4 mi) south of Sandusky. Several Federal agencies lease space at PBS from GRC (GRC 2005).

The climate at PBS is characterized as moderately warm and humid in summer, with temperatures occasionally exceeding 32° C (90° F), cold and cloudy in winter, with temperatures falling below -18° C (0° F) an average of five days per year. Average annual precipitation is 88.9 cm (34 in). The Ohio EPA North West District Office conducts air monitoring for the district including Erie County which tracks CO, O₃, NO₂, SO₂, PM₁₀, total suspended particulates, nitrogen oxide, and toxic air pollutants. Erie County is currently designated as an attainment area for all NAAQS. PBS is classified as a minor source under Title III and Title V of the 1990 Clean Air Act Amendments (GRC 2005).

PBS is located in the Lake Erie watershed. The Huron River and its branches constitute the major surface water system. The largest surface water body near PBS is Sandusky Bay on Lake Erie, approximately 6 km (4 mi) to the north. All surface waters at PBS are classified as Warmwater Habitat by the Ohio EPA. Water quality in the streams that originate or flow through PBS is believed to be generally good. PBS has two surface water areas believed to be contaminated as a result of munitions operations in the early 1940s (GRC 2005).

Potable water used at PBS is purchased from the Erie County Water Division. Erie County's primary groundwater source is from the limestone and dolomite aquifer found in the western end of the County. This aquifer also underlies portions of PBS. No groundwater at PBS is used for drinking water. There are no injection wells on-site. Routine groundwater monitoring is not required. Wastewater discharges at PBS include stormwater, non-contact cooling water, cooling

tower and boiler blowdown, and sanitary discharges. Surface discharges occur under permit conditions (GRC 2005).

Although portions of PBS lie within 100-year and 500-year floodplains, no PBS facilities or activities occur in the 100-year floodplain. Wetlands at PBS have not been officially delineated, and PBS relies on studies to indicate the potential or probable location of a wetland. There are no known activities currently located in wetlands (GRC 2005).

The 2000 Census lists the population of Erie County at 79,551. The population of Erie County in the vicinity of PBS increases by 50% in the summer; Cedar Point Amusement Park alone draws approximately 3.6 million visitors each season. As of May 2005, NASA employment at PBS is approximately 100, of which 14 are civil servants (GRC 2005).

Much of PBS is undeveloped natural areas or recovering natural areas previously used for agriculture. PBS supports large numbers of protected plant and animals species, including one Federally-listed species, the bald eagle (currently proposed for delisting (71 FR 8238)), seven State-listed endangered, nine threatened, 11 potentially threatened, and seven species of special concern. The B-2 (Spacecraft Research Facility) is a designated National Historic Landmark and is listed on the National Register of Historic Places. The Plum Brook Reactor Facility was determined not to be eligible for the National Register of Historic Places; however, NASA is in the process of documenting its history and decommissioning the reactor (GRC 2005).

3.5 JOHN F. KENNEDY SPACE CENTER, FLORIDA

The John F. Kennedy Center (KSC) is the launch site for the Space Shuttle. KSC would be used for final assembly and checkout of the CEV. Much of the infrastructure used for the Space Shuttle would be modified for the CEV after the Space Shuttle is retired.

KSC is in Brevard County on the east coast of Florida approximately 242 km (150 mi) south of Jacksonville and 64 km (40 mi) due east of Orlando on the north end of Merritt Island, which forms a barrier island complex with adjacent Cape Canaveral. NASA maintains operational control over approximately 1,806 ha (4,463 ac) of KSC (KSC 2003).

KSC is surrounded by the Indian River Lagoon system and the Atlantic Ocean. The Indian River Lagoon system has been designated an Estuary of National Significance, containing Outstanding Florida Waters and an Aquatic Preserve. The Indian River Lagoon system consists of Mosquito Lagoon to the north, Banana River to the south, and Indian River to the west. Parts of all three lagoons are contained within the KSC boundaries. This aquatic resource is host to rich and productive estuarine faunas. Banana Creek drains numerous wetlands and impoundments within KSC to the Indian River. Surface waters at KSC have special designations and activities in these waters are subject to numerous Federal, State, and regional regulations. Surface water quality at KSC is considered generally to be good. Fresh surface waters within KSC are derived primarily from the surficial groundwater, and shallow groundwater supports fresh water wetlands (KSC 2003).

The climate of KSC is subtropical with hot, humid summers and short, mild, dry winters. The main factors influencing climate at KSC are latitude and proximity to the Atlantic Ocean and the Indian River Lagoon system, which moderate temperature fluctuations. Summer weather, usually beginning in April, prevails for about six months of the year. Average high

temperatures, during summer months, range from 27 to 32°C (80 to 90°F). A typical day is mostly sunny, with scattered white clouds (KSC 2003).

Ambient air quality at KSC is influenced by NASA operations, land management practices, vehicle traffic, and emission sources outside of KSC. All of KSC's air sources are addressed under a Title V Air Operating Permit. Brevard County is in attainment for all six criteria pollutants regulated under NAAQS (EPA 2005).

KSC is Brevard County's largest single employer with over 15,540 employees (in 2006) and a major source of revenue for local firms (NASA 2006e). Operations at KSC have a domino effect through the region. It is estimated that each job created with Brevard County's space industry generates an additional 1.93 jobs within this region. In 2000, Brevard County's population totaled 476,230 persons (KSC 2003).

Many threatened, endangered, or species with special designations have been found at KSC. Amphibians and reptiles include four State species of special concern (Florida gopher frog, American alligator, gopher tortoise, and Florida pine snake), two State and federal threatened species (loggerhead turtle and eastern indigo snake) and four State and federal endangered species (Atlantic green sea turtle, Atlantic hawksbill turtle, Atlantic Ridley sea turtle and the leatherback sea turtle). Protected birds include nine State species of concern (American oystercatcher, black skimmer, brown pelican, little blue heron, reddish egret, roseate spoonbill, snowy egret, tricolored heron, and white ibis), three State and federal threatened species (bald eagle, which is currently proposed for delisting (71 FR 8238)), Florida scrub-jay, and piping plover), and one State and federal endangered species (wood stork). Protected mammals at KSC include one State species of special concern (Florida mouse), six State and federal endangered species (finback whale, Florida manatee, gray bat, humpback whale, North Atlantic right whale, and sei whale), and one State and federal threatened species (Southeastern beach mouse) (KSC 2003).

The following sites at KSC are listed on the National Register of Historic Places: Central Instrumentation Facility, Crawlerway, Headquarters Building, Launch Complex 39 Pads A and B, Launch Control Center, Missile Crawler Transporter Facilities, Operation and Checkout Building, Press Site Clock and Flag Pole, and the Vehicle Assembly Building – High Bay and Low Bay (DOI 2005). Additionally, Pad A and Pad B at Launch Complex 39 are each designated Historic Districts.

3.6 COMMERCIAL FACILITIES

CEV components would be developed at various, yet-to-be named commercial facilities throughout the United States, as defined by the prime contractor that is ultimately selected by NASA.

The existing environments at the commercial facilities are not addressed in detail in this Final EA. It is expected that the activities engaged in by each commercial facility involved in the design, fabrication, and assembly of the CEV would fall within the normal realm of operations at each facility. Further, it is expected that all such facilities would be in compliance with all applicable Federal, State, and local environmental laws, regulations, and permits. NASA would

ensure that this is the case as a matter of contract with the prime contractor selected for development of the CEV.

4 ENVIRONMENTAL CONSEQUENCES

This Section of the Final Environmental Assessment (EA) for the Crew Exploration Vehicle (CEV) presents an overview of environmental impacts of implementing the Proposed Action and the No Action Alternative, both discussed in Section 2. Under the Proposed Action, the National Aeronautics and Space Administration (NASA) would proceed with developing the CEV. Under the No Action Alternative, NASA would not proceed with CEV development.

4.1 ENVIRONMENTAL IMPACTS OF THE PROPOSED ACTION

4.1.1 CEV Development

Developing the CEV as addressed in this Final EA would entail design, fabrication, and assembly activities resulting in the production of a limited number of each variant of the CEV. Design activities primarily would involve computer analyses and simulations and possibly the creation of full-scale prototypes for design validation. Fabrication activities would involve manufacture and testing of CEV components. Assembly would involve system assembly and system-level testing.

NASA would provide the basic design requirements (including the outer mold line (dimensional envelope), aerodynamic and aerothermal databases and limited CEV components (*e.g.*, docking components, parachute system, pyrotechnic initiators). The CEV prime contractor would be responsible for delivery of a detailed CEV design that meets NASA requirements (NASA 2006a). Although the selection of a prime contractor is beyond the time frame of this Final EA, it is expected the prime contractor would use NASA and contractor facilities in the United States, and possibly abroad. NASA-provided CEV components would be designed, fabricated, and assembled at both NASA and contractor facilities. All or part of the final CEV may be assembled at a NASA facility.

4.1.2 Environmental Impacts at NASA Facilities Involved in the Development of the CEV

Development of the CEV and other CEV-related activities, as addressed in this Final EA, would be implemented at various NASA facilities throughout the United States. Figure 3-1 provides the locations of all major NASA facilities. Table 2-5 provides a list of CEV development activities and NASA facilities that would be likely to be associated with one or more of these activities. Fabrication and assembly of the CEV would occur at NASA facilities addressed in detail in Sections 3.1 through 3.5. However, as the CEV Project planning matures, activities and responsibilities at any NASA facility could be redefined.

CEV development activities would be performed using mostly existing resources at each NASA facility. All CEV design, fabrication, and assembly activities would be expected to be within the mission and normal scope of activities at each facility. Design, fabrication, and assembly of CEV components and subsystems at NASA facilities would be expected to result in air emissions and waste streams at levels within environmental permit limitations at each facility. During CEV fabrication and assembly, the potential for substantial adverse environmental impacts from liquid propellants may well be confined largely to spills, depending on the propellants ultimately selected. Workers handling propellant (*e.g.*, hydrazine) during component testing would be

equipped with protective clothing and breathing apparatus and uninvolved workers would be excluded from the area during loading operations. Propellant loading would occur only shortly before component testing, further minimizing the potential for accidents. Facilities involved in fuel loading during component testing would have safety policies and procedures in place to ensure worker safety during liquid propellant fueling operations. Table 4-1 compares reportable quantities of potential propellants under the Comprehensive, Environmental, Response, Liability, and Compensation Act. Releases of substances in quantities equal to or greater than their reportable quantity are subject to reporting to the National Response Center under this Act.

TABLE 4-1. REPORTING REQUIREMENTS FOR POTENTIAL CEV PROPELLANT RELEASES

Chemical	Chemical Abstract Service No.	Reportable Quantity (pounds)
Ethanol	64-17-5	None established
Hydrazine	302-01-2	1
Hydrogen	1333-74-0	None established
Hydrogen peroxide	7722-84-1	None established
Hydroxyl ammonium nitrate	13465-08-2	None established
Nitrogen	7727-37-9	None established
Nitrogen tetroxide	10102-44-0	10
Nitrous oxide	10024-97-2	None established
Methane	74-82-8	None established
Oxygen	7782-44-7	None established
Propane	74-98-6	None established

Note: 1 pound = 0.454 kilograms

The environmental impacts associated with ongoing activities similar to those required for the CEV have been addressed at each involved NASA facility in existing environmental documentation (*e.g.*, Environmental Resources Document). These activities would not entail substantial environmental impacts in any environmental media, including but not limited to:

- Land Use
- Air Quality
- Noise
- Water Resources
- Geology and Soils
- Ecological Resources
- Cultural Resources
- Socioeconomics
- Site Infrastructure
- Waste Management

It is expected that the environmental compliance status of each involved NASA facility would not be adversely affected. While development of the CEV at the various NASA facilities would not be expected to require construction of new buildings, additions or modifications to some existing buildings or testing areas may be necessary. In such cases, the affected NASA facility would prepare appropriate environmental documentation and obtain the appropriate environmental permits, as required.

4.1.3 Environmental Impacts at Commercial Facilities Involved in the Development of the CEV

The CEV components would be developed at various commercial facilities as defined by the prime contractor.

It is expected the CEV design, fabrication, and assembly activities addressed in this Final EA would be performed using mostly existing resources at each commercial facility. Activities are expected to be performed at existing facilities and are expected to be similar in effect to on-going activities at these facilities. It is expected the design, fabrication, and assembly of the CEV would not require construction of new buildings at any commercial facility. Additions or modifications to existing buildings or to testing areas may be needed, and in such cases, the involved facility would be required to obtain the necessary environmental permits.

The commercial facilities that would be used for the design, fabrication, and assembly of the CEV would be typical industrial facilities. These facilities would have the necessary approvals, permits, and licenses (*e.g.*, air operating permits, wastewater discharge permits) to conduct designated operations and would follow accepted procedures and practices. During CEV fabrication and assembly, it would be expected that the potential for substantial adverse environmental impacts may well be confined largely to spills as described in Section 4.1.2. Commercial facilities involved in fuel loading during component testing would have policies and procedures in place to ensure worker and public safety during liquid propellant handling operations.

CEV activities would be performed within the scope of these approvals, permits, and licenses and would be subject to Federal environmental regulations and those of the respective states and localities in which the facilities are located. These include, but would not be limited to, the implementing regulations for the Clean Air Act, the Clean Water Act, and the Resource Conservation and Recovery Act. Design, fabrication, and assembly of the CEV would not entail substantial impacts in any of the following environmental media, including but not limited to:

- Land Use
- Air Quality
- Noise
- Water Resources
- Geology and Soils
- Ecological Resources
- Cultural Resources
- Socioeconomics
- Site Infrastructure

- Waste Management

Environmental impacts associated with the design, fabrication, and assembly of the CEV as addressed in this Final EA would be expected to be minor (*i.e.*, within the permitted quantities of airborne emissions, waterborne effluents, and waste disposal at each of the involved facilities) and subsequently both the short-term and long-term environmental impacts are expected to be within the limits of all applicable environmental laws, permits, and licenses. No adverse impact on the infrastructure (*e.g.*, utilities, roadways) would be anticipated. Specifically:

- Any increases in air emissions would be expected to be minimal or non-existent and would be within existing permits.
- No direct adverse effects would be anticipated on either aquatic or terrestrial ecosystems as no major construction activities would be anticipated.
- Impacts on water quality would be minimal and would be expected to be within the scope of existing permits.
- Employment at project sites would be expected to change from present levels and could introduce localized beneficial impacts; however, it should have little or no incremental socioeconomic impacts to the regional economy.

Should NASA decide to proceed with the Proposed Action and a prime contractor is selected, the Agency will prepare additional environmental documentation, if needed.

4.1.4 CEV End-of-Operational Life

The first human flight of the CEV would be planned for no later than 2014, and as currently envisioned, the CEV would have a lifecycle that ends no less than 20 years after the first human flight (NASA 2006a).

The CEV end-of-operational lifetime planning would occur in a time horizon too distant to address in detail in this Final EA, however, decommissioning the CEV can be assessed qualitatively. As with previous programs (*e.g.*, the Space Shuttle Program) environmental documentation would be prepared at the appropriate time.

Decommissioning the CEV would entail cessation of manufacture of the CEV. Existing units would be recovered and would be “safed” by removal of remaining hazardous materials and wastes such as residual propellant. These units then could be either displayed in public settings, dismantled for appropriate disposal or recycling, or refurbished for other uses. The infrastructure used for the CEV Project most likely would be redirected to other programs.

4.2 ENVIRONMENTAL IMPACTS OF THE NO ACTION ALTERNATIVE

Under the No Action Alternative, NASA would not develop the CEV. The United States would not have a human-rated Government space vehicle and may well forego any plans to independently place humans in space. NASA would not be able, independently, to send humans or cargo to the International Space Station following retirement of the Space Shuttle by the end of this decade or to the Moon by the end of the next decade, or to Mars and destinations beyond. NASA would have to partner with foreign governments or rely on commercial initiatives (NASA 2006b) to service the International Space Station, to place humans in space for Lunar missions and for destinations beyond the Moon, if and when these services are developed. Without direct

access to space, the U.S. science and engineering goals of the International Space Station could be jeopardized as well as adversely impacting the ability of the United States to enter into future international cooperative ventures as a reliable partner (NASA 1996).

Not developing the CEV would preclude the potential environmental impacts that would be associated with design, fabrication, and assembly of the CEV. No natural resources would be irretrievably dedicated to developing the CEV.

It is expected that many NASA and contractor personnel currently involved in the Space Shuttle Program would be transferred to the CEV Project. However, if the CEV is not developed, these personnel would need to find other employment, and suppliers of CEV-related products and services would lose a potential source of revenue. Taken together, these outcomes could have substantial localized adverse socioeconomic impacts on the communities supported by NASA and contractor facilities.

Building and operating something as complex as a human-rated launch system entails a substantial knowledge base of engineering and scientific skills. This knowledge base would likely be lost if NASA retired the Space Shuttle and did not pursue development of the CEV. This could have an adverse impact on the long-term ability of the United States to build, launch, and operate human-rated launch systems.

4.3 ENVIRONMENTAL JUSTICE

Executive Order 12898, *Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations*, directs each Federal entity to consider the impacts of its actions on minority populations and low-income populations within a region of influence.

Under the Proposed Action, NASA facilities would be associated with the design, fabrication, and assembly of the CEV. Fabrication and assembly of the CEV would occur at those facilities that are addressed in detail in Sections 3.1 through 3.5. Environmental Justice has been addressed previously in the referenced documents for these facilities (*e.g.*, ARC 2005; GRC 2005; LaRC 2005; JSC 2004; KSC 2003). CEV activities at NASA facilities would be considered to be within the normal scope of activities at each facility, and thus would have no disproportionately high or adverse human health or environmental impacts on low-income or minority populations. Under the No Action Alternative, NASA would not develop the CEV. No activities associated with the CEV would occur at the NASA facilities. Therefore, no disproportionately high or adverse human health or environmental impacts on low-income or minority populations would occur.

4.4 CUMULATIVE IMPACTS

Cumulative impacts are the impacts on the environment that result from the incremental impact of an action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non-Federal) or person undertakes such other actions. Cumulative impacts can result from individually minor, but collectively significant activities that take place within the same period of time and/or within the same geographical area.

The development of the CEV as addressed in this Final EA would occur at various NASA and commercial facilities throughout the United States, and possibly abroad. Cumulative impacts

could be addressed for those facilities where CEV design, fabrication, and assembly would be expected to occur. It is anticipated that the CEV design, fabrication, and assembly activities taking place at NASA and commercial facilities would be a small fraction of overall operations and thus would be within the scope of normal operations at each facility. Therefore, effluents resulting from CEV activities would be within each facility's permit limitations and would not be expected to place any of the involved NASA and commercial facilities into non-compliance with applicable Federal, State, or local environmental laws, regulations, and permits. However, CEV Project planning is in the developmental stages and is not yet fully defined. The roles and responsibilities of NASA facilities (see Table 2-5) associated with the design, fabrication, and assembly of the CEV could be redefined as the CEV Project matures.

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APPENDIX A

DESIGN REFERENCE MISSIONS FOR THE CREW EXPLORATION VEHICLE

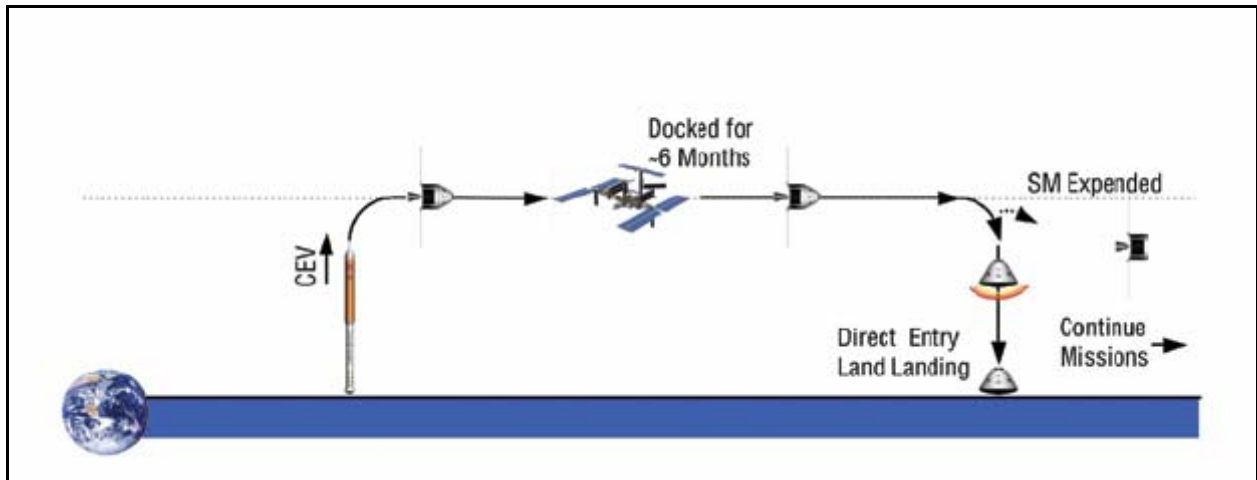
The National Aeronautics and Space Administration (NASA) Exploration Systems Architecture Study (ESAS) team was established to determine the best exploration architecture and strategy to implement The President's new vision for space exploration as announced in his January 2004 address (TWH 2004). This vision encompassed a plan to return humans to the Moon no later than 2020 in preparation for human exploration of Mars. As a part of NASA's future human space exploration strategy, the Space Shuttle would be retired no later than 2010 and be replaced by a new human-rated spacecraft, the Crew Exploration Vehicle (CEV). The CEV would begin operations with first human flights no later than 2014 (NASA 2004). The ESAS team was required to perform four specific tasks:

- Complete assessment of the top-level CEV requirements and plans to enable the CEV to provide crew transport to the International Space Station (ISS) and to accelerate the development of the CEV and crew launch system to reduce the gap between Space Shuttle retirement and CEV initial operational capability;
- Provide definition of top-level requirements and configurations for crew and cargo launch systems to support the Lunar and Mars exploration programs;
- Develop a reference Lunar exploration architecture concept to support sustained human and robotic Lunar exploration operations; and
- Identify key technologies required to enable and significantly enhance these reference exploration systems and reprioritize near- and far-term technology investments.

The ESAS (NASA 2005b) addressed the following four major points: CEV definition, launch vehicle definition, Lunar architecture definition, and technology plan definition. Additional key analysis support areas included cost, requirements, ground operations, mission operations, human systems, reliability, and safety. The ESAS team examined multiple combinations of launch elements (*e.g.*, duration, destination, flight sequence, systems, and technologies required to undertake and complete a particular mission) to establish Design Reference Missions that would facilitate the development of the CEV. There are six Design Reference Missions applicable to the Proposed Action, as summarized below (NASA 2005b).

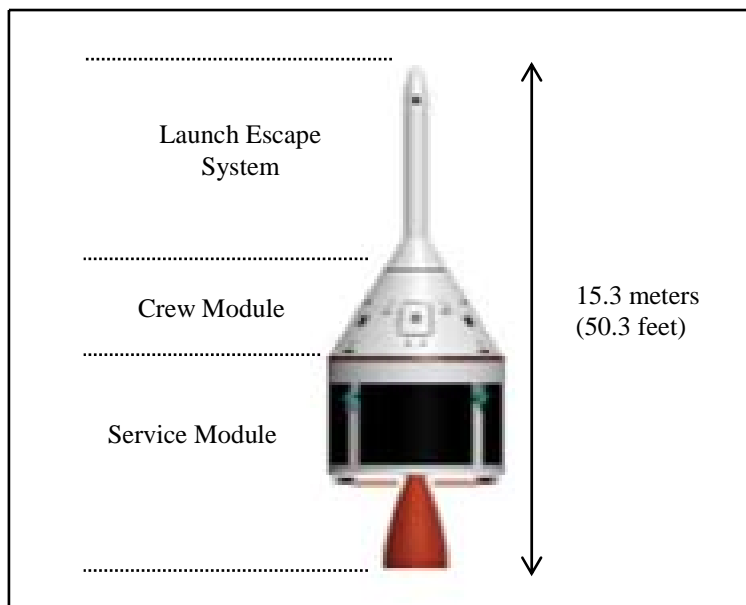
A.1 CREW TRANSPORT TO THE INTERNATIONAL SPACE STATION

The purpose of this mission would be to transport three International Space Station crew members, and up to three additional temporary crew members, to the International Space Station for a six-month stay and return them to Earth at any time during the mission (Figure A-1). The CEV, consisting of a Crew Module (CM), Service Module (SM), and Launch Escape System (LES) (Figure A-2), would be launched by the Crew Launch Vehicle (Figure A-3) into Earth orbit, where the CEV would perform a series of burns and maneuvers to close on and dock with the International Space Station. Once ingress activities are complete, the CEV would be configured to a quiescent state for the duration of the crew's assignment aboard the International Space Station. Periodic systems health checks and monitoring would be performed.



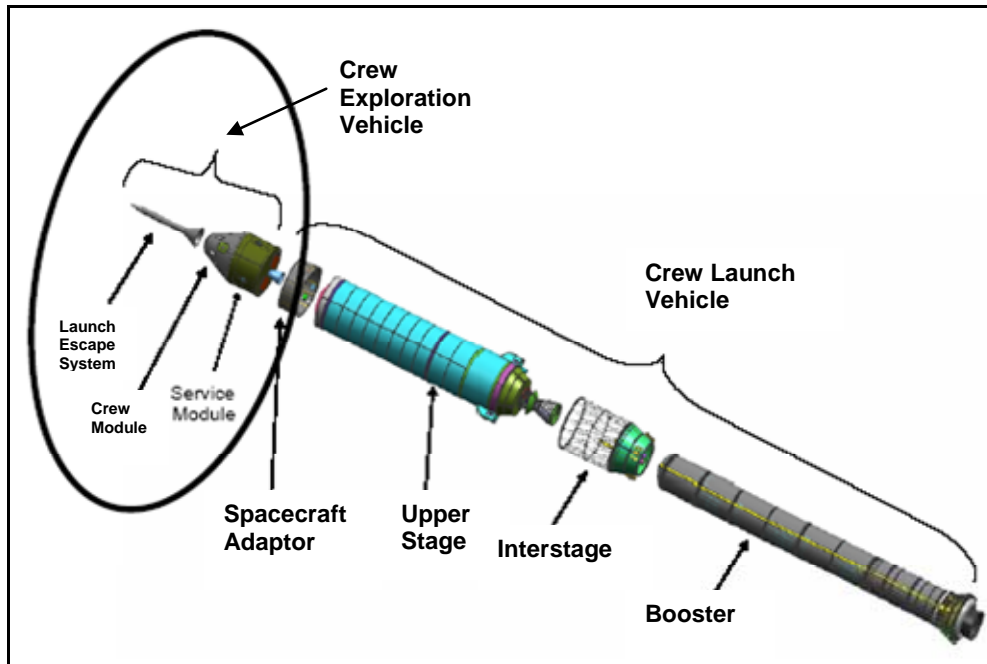
Source: NASA 2005b

FIGURE A-1. NORMAL CREWED MISSION TO THE INTERNATIONAL SPACE STATION



Source: NASA 2005b

FIGURE A-2. CREW EXPLORATION VEHICLE



Source: NASA 2005c

FIGURE A-3. CREW EXPLORATION VEHICLE IN LAUNCH CONFIGURATION

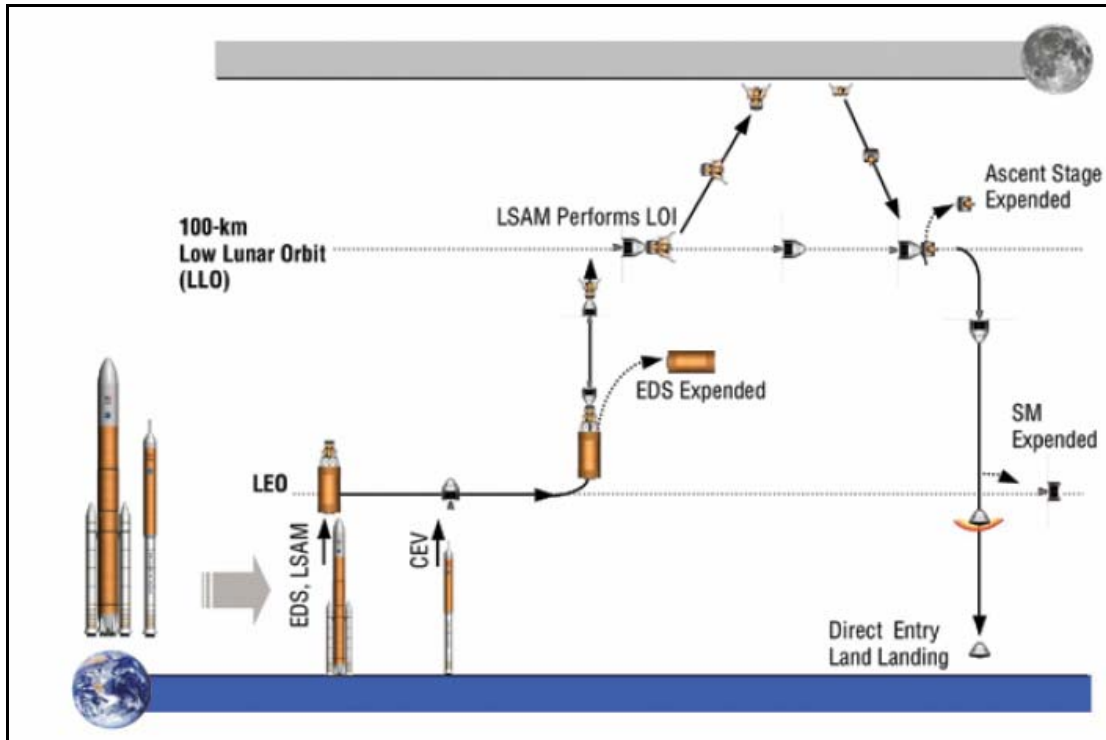
Upon completion of their assignment, the crew would return to the CEV and the CEV would undock from the International Space Station. The CEV would depart the vicinity of the International Space Station and would conduct a deorbit burn. After burn completion, the CEV Service Module would be discarded, and the CEV Crew Module would be maneuvered to the proper re-entry attitude. The CEV would perform a land-based landing at a designated site.

A.2 CARGO TRANSPORT TO THE INTERNATIONAL SPACE STATION

The purpose of this mission would be to transport pressurized cargo to the International Space Station and return pressurized cargo to Earth after 90 days. The general mission sequence is similar to Figure A-1, except the duration is shorter. A cargo version of the CEV would be launched by the Crew Launch Vehicle into orbit filled with up to 3,500 kilograms (7,700 pounds) of materiel. The uncrewed CEV would perform a series of burns and maneuvers to close on and dock with the International Space Station. Once ingress activities are complete, the CEV systems would be configured to a quiescent state and the CEV cargo would be offloaded by the International Space Station crew. Periodic systems health checks and monitoring would be performed. Upon completion of the docked phase lasting up to 90-days, the International Space Station crew would stow any return items in the CEV pressurized cabin, and Mission Control would command the CEV to undock. The CEV would depart the vicinity of the International Space Station and would conduct a deorbit burn. After burn completion, the CEV Service Module would be discarded, and the unoccupied CEV Crew Module would be maneuvered to the proper re-entry attitude and would perform a land-based landing at a designated site.

A.3 CREW AND CARGO TRANSPORT TO THE MOON FOR SHORT-TERM MISSIONS

The purpose of this mission would be to transport up to four crew members to any site on the Moon (*i.e.*, global access) for up to seven days (Figure A-4). This short-term mission would be analogous to the Apollo surface missions. It would demonstrate the capability to land humans on the Moon, operate for a limited period on the surface, and safely return to Earth.



Source: NASA 2005b

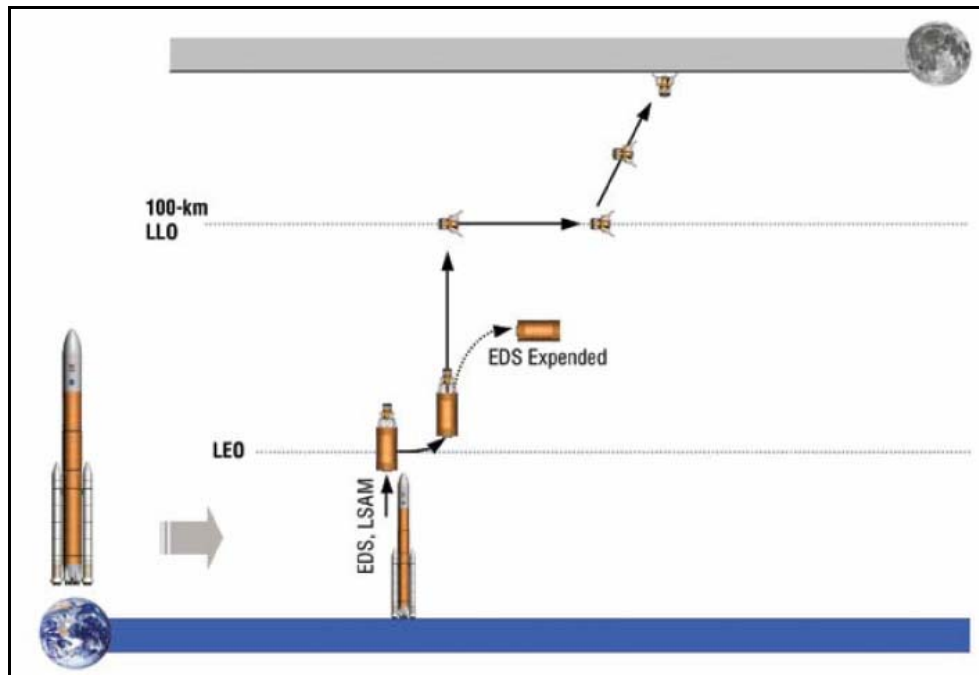
FIGURE A-4. NORMAL CREW AND CARGO SHORT-TERM LUNAR MISSION

The following transportation elements would be required to perform the mission: a Crew Launch Vehicle (CLV), a Cargo Launch Vehicle (CaLV), a CEV, a Lunar Surface Access Module (LSAM), and an Earth Departure Stage (EDS). The mission sequence assumes a combination Earth Orbit Rendezvous (EOR) and Lunar Orbit Rendezvous (LOR). The Lunar Surface Access Module and Earth Departure Stage would be pre-deployed in a single Cargo Launch Vehicle launch to Low-Earth Orbit, and the Crew Launch Vehicle would deliver the CEV and crew to Earth orbit where the Lunar Surface Access Module/Earth Departure Stage and CEV would rendezvous and dock. The Earth Departure Stage would perform a trans-Lunar injection burn and would be discarded. The Lunar Surface Access Module would then perform the Lunar Orbit Injection (LOI) for the CEV/Lunar Surface Access Module. The entire crew would transfer to the Lunar Surface Access Module, would undock from the CEV, and would perform a descent to the Lunar surface in the Lunar Surface Access Module while the CEV orbits the Moon. After up to seven days on the Lunar surface, the Lunar Surface Access Module would return the crew to Lunar orbit where the Lunar Surface Access Module and CEV would dock. The crew would transfer back to the CEV, and the Lunar Surface Access Module would be disposed of via impact

on the Lunar surface. The CEV would then return the crew to Earth with a direct entry and land at a designated land-landing site.

A.4 CARGO TRANSPORT TO THE MOON

The purpose of this mission would be to deliver up to 20 metric tons (22 tons) of cargo to the Lunar surface in a single mission using the elements of the human Lunar transportation system (Figure A-5). This capability would be used to deliver surface infrastructure needed for Lunar outpost buildup (e.g., habitats, power systems, communications, mobility, in-situ resource utilization pilot plants) as well as periodic logistics re-supply packages to support a continuous human presence.



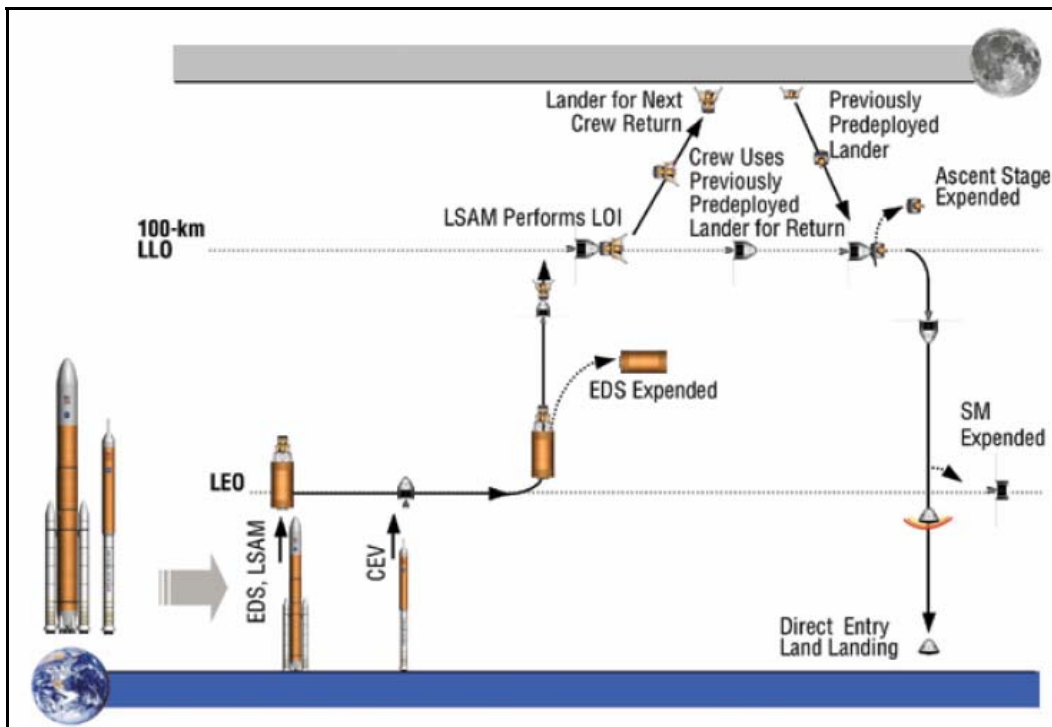
Source: NASA 2005b

FIGURE A-5. NORMAL LUNAR OUTPOST CARGO DELIVERY MISSION

The following transportation elements would be required to perform the mission: the same Cargo Launch Vehicle and Earth Departure Stage as the short-term Lunar mission and a cargo variant of the Lunar Surface Access Module to land the large cargo elements near the Lunar outpost site. The cargo variant of the Lunar Surface Access Module would replace the habitation module with a cargo pallet and logistics carriers. The Lunar Surface Access Module and Earth Departure Stage would be launched to Low-Earth Orbit on a single Cargo Launch Vehicle. The Earth Departure Stage would perform the trans-Lunar injection burn and would be discarded. The Lunar Surface Access Module would then perform the Lunar orbit injection and a descent to the Lunar surface. The cargo would then be offloaded from the Lunar Surface Access Module autonomously or by the outpost crew.

A.5 CREW AND CARGO TRANSPORT TO THE MOON FOR LONG-TERM MISSIONS

The purpose of this mission would be to transfer up to four crew members and supplies in a single voyage to a Lunar outpost site for an expedition lasting up to six months (Figure A-6). Every six months, the crew would change. The entire suite of transportation vehicles developed to support a short-term Lunar mission would also be required for Lunar outpost missions. The mission sequence assumes a similar approach as described for the short-term Lunar mission except for duration.

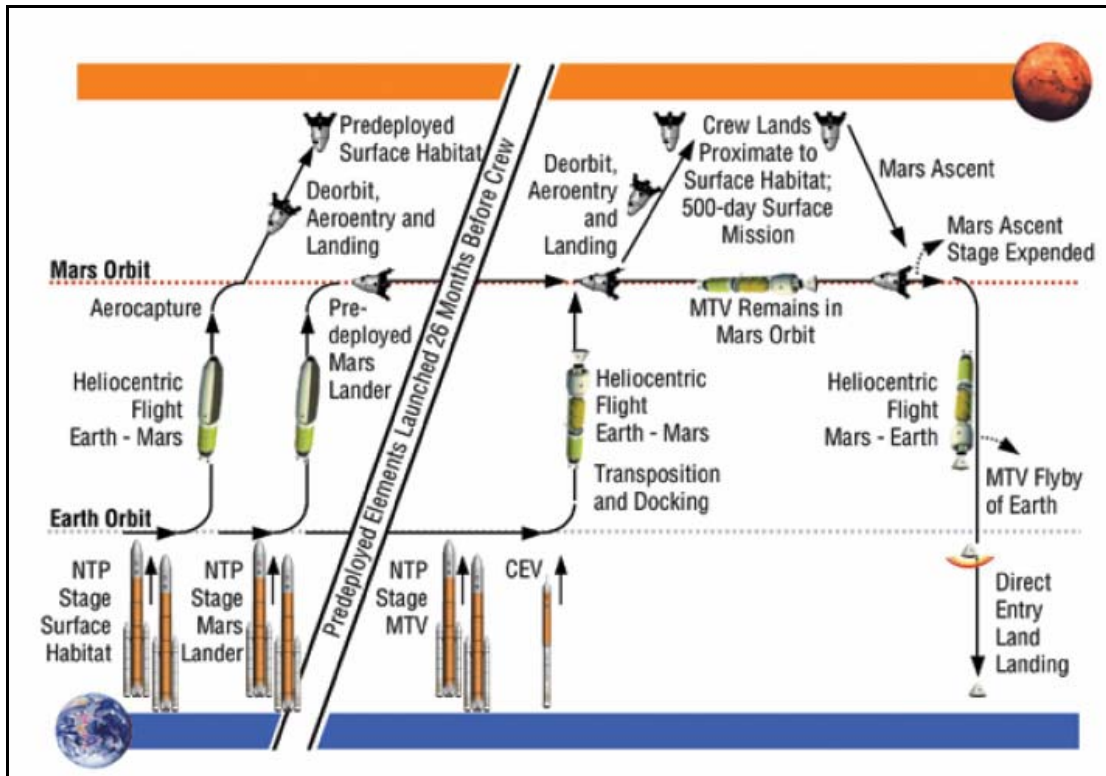


Source: NASA 2005b

FIGURE A-6. NORMAL LUNAR OUTPOST CREW AND CARGO DELIVERY MISSION

A.6 CREW AND CARGO TRANSPORT TO MARS

The purpose of this mission would be to establish a continuous human presence on the surface of Mars. The mission sequence would involve a split-mission concept in which cargo would be transported in manageable units to Mars surface or orbit, and checked out in advance of committing the crews to the mission. The split-mission approach would allow the crew to be transported on faster, more energetic trajectories, minimizing their exposure to the deep-space environment, while the vast majority of the materiel sent to Mars would be sent on minimum energy trajectories. Each human mission to Mars would be comprised of three vehicle sets: two cargo vehicles and one round-trip piloted (crewed) vehicle (Figure A-7).



Source: NASA 2005b

Note: NTP=Nuclear Thermal Propulsion

FIGURE A-7. NORMAL MARS EXPLORATION MISSION

The CEV with a crew of up to six would be launched by the Crew Launch Vehicle into Low-Earth Orbit and would perform a series of burns and maneuvers to close on and dock with the pre-deployed Mars Transfer Vehicle (MTV). Once crew and cargo transfer activities are complete, the CEV would be configured to a quiescent state. Periodic systems health checks and monitoring of the CEV would be performed throughout the Mars transfer mission.

As the Mars Transfer Vehicle approaches Earth upon completion of the (up to) two-and-one-half-year mission, the crew would transfer to the CEV and would undock from the Mars Transfer Vehicle. The CEV would conduct a deorbit burn, would maneuver to the proper re-entry attitude, and would perform a landing at a designated site.

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