DEPARTMENT OF DEFENSE
OFFICE OF SECURITY REVIEW
1155 DEFENSE PENTAGON
WASHINGTON, DC 20301-1155

June 22, 2009
Ref: 09-S-1945

Ms. Paula L. Geisz
Export Control and Interagency Liaison Division
National Aeronautics and Space Administration
Headquarters
Washington, DC 20546-0001

Dear Ms. Geisz:

This is in response to the enclosed May 21, 2009, request for security review of the enclosed document titled:

- "Top Level Summary of Technologies"

The Department of Defense has found no classified information in the document and has no issue with its public release, but defers final approval for public release to NASA.

Please direct any questions regarding this case to Mr. Donald Kluzik at 703-696-4709, email: Donald.Kluzik.ctr@whs.mil.

Sincerely,

for M. M. Langerman
Chief

Enclosures:
As stated

Technology			ETDP Project	Funding Status	Benefits Statement	Connectivity to Architecture Elements	Need Date	Architecture Assessed Criticality
Ref #	Title	Brief Description of Capability Need						
STRUCTURES, MATERIALS AND MECHANISMS								
Structures, Materials, and Mechanisms Project								
SMM-1	Friction Stir Welding and Spun Formed Dome	Friction stir welding and spun formed domes could provide a highly reliable and low cost manufacturing approach to manufacture lower mass tanks for Ares I. Current state of the art manufacturing capabilities are exceeded in this technology for Ares I and will be substantially exceeded by the Ares V core stage tanks. Completion is required by Ares I CDR.	Structures, Materials, and Mechanisms (SMM) Project	Funded	Reduces Ares and Altair tank mass by reducing weld mass. Could marginally improve reliability and cost.	Ares I, Ares V, Lander	Ares I FY09 Ares V FY13 Altair FY13	Highly Desirable
SMM-2	CEV Parachute Materials	Lightweight Orion parachute materials are required for re-entry of the lunar Orion Command Module. Lightweight Nylon broadcloth for skirt to shoulder region of main canopies and M5 fiber-based fabrics for structural grids are desired. M5 is a novel fiber with a tenacity (strength-to-weight ratio) approximately twice that of currently available fibers.	Structures, Materials, and Mechanisms (SMM) Project	Funded	Reduces mass of Orion parachute and/or enables landing of heavier Orion CM.	Orion CM	Orion FY13	Highly Desirable
SMM-3	Composite Strut Technology	Structural approaches and techniques are required for the fabrication of lightweight composite struts (including end fittings) for application to Altair primary structure.	Structures, Materials, and Mechanisms (SMM) Project and Advanced Composite Technologies Project	Funded	Reduces mass of Altair structure, allowing increased payload to the surface and/or enabling architecture closure.	Lander	Altair FY13	Critical
SMM-4	Long-Life, Low Temperature Mechanical Systems	Need mechanical and drive control electronic systems that can operate in and out of low-temperature (40K) environments and up to five years without critical failures. This includes motors, actuators, gearboxes, position/speed sensors and distributed electronics.	Structures, Materials, and Mechanisms (SMM) Project	Funded	Improve reliability and life of systems operating during local lunar night	All Surface Systems	Surface Systems FY14	Highly Desirable
SMM-5	Lightweight High-Strength Window Materials	Need alternative technologies to fused silica and aluminosilicate windows. Need windows that are lightweight and resistant to MMOD damage and provide some level of radiation shielding.	Structures, Materials, and Mechanisms (SMM) Project	Funded Outyears	Reduces mass of structure, allowing increased payload to the surface and or enabling architecture closure. Improve crew safety from MMOD impact and radiation.	Orion, Habitat, Lander, Small Pressurized Rover	Orion FY13 Altair FY13 Surface Systems FY14	Highly Desirable
SMM-6	Long-Term Durability and Damage Tolerance for Metallic, Composite, and Inflatable Structures	A wide range metallic, composite, and inflatable materials have potential for being used on the Lunar surface. However the short-term exposure effects, long term durability and end-of-life properties must be established for the lunar environment including: vacuum, thermal cycling, thermal extremes, radiation exposure, dust exposure and micro-meteoroid exposure. Minimum gage and residual strength must also be established for the various material/structural systems and applications for the relevant threat environments.	ETDP is not funding this activity at this time.	Unfunded	Improve reliability and life of surface system structures, thereby improving crew safety and reducing the need for logistics. Could also reduce mass margins required by reducing uncertainty.	All Surface Systems	Surface Systems FY14	Critical
SMM-7	Shell Buckling	Shell buckling rating factors are based on studies from over 40 years ago. Substantial improvements have been made in materials and manufacturing processes which warrants a new baseline be defined for structural knock down factors.	ETDP is not funding this activity at this time.	Unfunded	Reducing uncertainty in knock-down factors will enable lower mass structures.	Ares I, Ares V	Ares I FY09 Ares V FY13	Critical
SMM-8	Lunar Meteoroid Ejecta Environment Model	A new lunar meteoroid ejecta environment model must be developed for use by lunar systems designers.	ETDP is not funding this activity at this time.	Unfunded	Enabling designers to better model the expected micro-meteoroid environment could improve reliability and reduce mass margin.	All architecture elements except Ares I and V.	Orion FY13 Altair FY13 Surface Systems FY14	Highly Desirable

Technology			ETDP Project	Funding Status	Benefits Statement	Connectivity to Architecture Elements	Need Date	Architecture Assessed Criticality
Ref #	Title	Brief Description of Capability Need						
SMM-9	Gas Strut Separation System	Ares I and Ares V require improvement in separation systems to reduce risk of separation failures. Failure of a single separation motor can lead to recontact between stages. Gas struts have been determined to be a technology that can provide needed risk improvement. The technology needs to be provided with extended range for the long nozzles used on Ares vehicles. Required by Ares V PDR.	ETDP is not funding this activity at this time.	Unfunded	Could provide slightly higher level of reliability and mass reduction over SOA separation approaches.	Ares I and Ares V	Ares I FY09 Ares V FY13	Desirable
SMM-10	NASCAP Lunar Update	Constellation system design and requirements verification for successful operation in surface charging environments (radiation belts, lunar orbit, lunar surface) will likely utilize the aerospace industry standard NASA and Air Force Charging Analysis Program (NASCAP). The current version of the code supports analysis in low Earth orbit, geostationary orbit, and interplanetary (solar wind) environments. Updates of the code are required to conduct analyses in the magnetosheath and magnetotail environments where studies have shown severe charging conditions can occur.	ETDP is not funding this activity at this time.	Unfunded	Enabling designers to better model vehicle surface charging related to the local radiation environment could improve reliability and reduce mass margin.	All architecture elements except Ares I and V.	Orion FY13 Altair FY13 Surface Systems FY14	Highly Desirable
SMM-11	Lunar Macroscale Plasma Model	Design and verification that Constellation lunar architecture (Orion, Altair, LSS, EVA) meet spacecraft charging requirements will require tools for evaluating the plasma environments in the lunar wake when the Moon is in the solar wind, magnetosheath, and the Earth's magnetotail. The model also provides the inputs to the microscale plasma models for evaluating charging conditions on the lunar surface.	ETDP is not funding this activity at this time.	Unfunded	Enabling designers to better model vehicle surface charging related to the local plasma environment could improve reliability and reduce mass margin.	All architecture elements except Ares I and V.	Orion FY13 Altair FY13 Surface Systems FY14	Desirable
SMM-12	Radiation Charging Analysis Tool (RCAT)	No NASA standard tool set exists for conducting internal (deep dielectric, bulk) charging analyses of systems exposed to energetic electrons. Constellation systems (Orion, Altair, EVA, LSS) will be exposed to these environments during transit of the Earth's radiation belts, while in lunar orbit, and on the lunar surface. A tool is required for evaluating electric fields generated by charge densities accumulating in insulating materials when exposed to charging environments.	ETDP is not funding this activity at this time.	Unfunded	Enabling designers to better model vehicle internal charging related to the local radiation or plasma environment could improve reliability and reduce mass margin.	All architecture elements except Ares I and V.	Orion FY13 Altair FY13 Surface Systems FY14	Highly Desirable
SMM-13	Single-Piece Orion CM Conical Structure	Current state-of-the-art for the fabrication of conically shaped CM-like structures is welded, riveted construction. By using innovative, near net shape fabrication methods, single piece conically structures can be produced which eliminates or minimizes welds and rivets thereby increasing safety margins and reliability.	ETDP is not funding this activity at this time.	Unfunded	Reducing number of welds and rivets would decrease system mass and possibly improve reliability and safety.	Orion	Orion FY13	Desirable
SMM-14	Lightweight Motors and Actuators	Actuator and motor weight savings could be realized by using alternative materials such as titanium or ceramics for gearboxes and other motor components. Brushless DC disc motors may also provide weight reductions by eliminating or minimizing gearbox requirements, as well as having benefits for scalability in uses requiring operation over large temperature ranges.	ETDP is not funding this activity at this time.	Unfunded	Reducing actuator and motor component weights could lead to significant architecture weight savings.	All architecture elements except Ares I and V.	Orion FY13 Altair FY13 Surface Systems FY14	Desirable
Advanced Composites Project								
AC-1	Composite Damage Tolerance/Detection	Ares V concept definition has identified composite structures for the shroud, EDS, EDS cryogenic tanks, interstages, and SRM cases, SRB frustums, and skirts to significantly reduce launch vehicle mass. Damage identification during pre-launch servicing and in-flight failure detection is required for safe and reliable vehicle operation. EDS will mate and operate with Orion making the EDS a human rated element. Therefore, failure detection for aborts is necessary. Identification includes recognition of damage and location of damage. NDE techniques are sought for all composite components including engine nozzles. Needed by Ares I CDR.	Advanced Composite Technologies Project	Funded	Improves crew safety and reliability through detection of potential failures prior to launch and in flight.	Ares I, Ares V, Lander	Ares I FY09 Ares V FY13 Altair FY13	Highly Desirable

Technology			ETDP Project	Funding Status	Benefits Statement	Connectivity to Architecture Elements	Need Date	Architecture Assessed Criticality
Ref #	**Title**	**Brief Description of Capability Need**						
AC-2	Composite Joining Technology	Ares I is planning to use composites for dry structure. Ares V concept definition has identified composite structures for the shroud, EDS, EDS cryogenic tanks, interstages, and SRM cases, SRB frustums, and skirts to significantly reduce launch vehicle mass. Joining of composites to metal fittings is critical for reliable implementation of composites structures. Techniques are needed to address large diameter dry structures and solid rocket motor cases. Required by Ares I CDR/Ares V PDR.	Advanced Composite Technologies Project	Funded	Reduces structural mass through enabling the efficient integration of metallic and composite structures.	Ares I, Ares V, Lander	Ares I FY09 Ares V FY13 Altair FY13	Highly Desirable
AC-3	Large Composite Manufacturing	Ares V concept definition has identified composite structures for the shroud, EDS, EDS cryogenic tanks, interstages, and SRM cases, SRB frustums, and skirts to significantly reduce launch vehicle mass. Ares V will have a 10 m diameter which exceeds current SOA composite manufacturing capabilities. Research and technology development is required in the manufacture of large scale composite structures including dry structures, SRM cases, and EDS cryogenic tanks. Solutions are needed in non-autoclave fabrication for large structures as well as solutions for leak-free cryogenic tanks with reduced micro-cracking in cryogenic hydrogen tanks. Required by Ares V PDR.	Advanced Composite Technologies Project	Funded	Significantly reduces Ares V structural mass by enabling large scale manufacturing of ten-meter-diameter composite structures for shrouds, interstages and skirts.	Ares V	Ares V FY13	Critical
AC-4	Lightweight, Impact-Resistant Materials and Structures for Habitable Systems	Use of composites for unpressurized structures to the maximum extent feasible. Possible use of composites for pressurized structures. Integrate MMOD shielding approaches. Develop composite lightweight propellant tanks and dewar technologies. Establish minimum gage requirements.	Advanced Composite Technologies Project	Funded	Reduces mass of structure, allowing increased payload to the surface and/or enabling architecture closure. Improve crew safety from MMOD impact.	Habitat, Small Pressurized Rover, Lander	Altair FY13 Surface Systems FY14	Critical
AC-5	Composite Strut Technology	Structural approaches and techniques are required for the fabrication of lightweight composite struts (including end fittings) for application to Altair primary structure.	Advanced Composite Technologies Project	Funded	Reduces mass of Altair structure, allowing increased payload to the surface and/or enabling architecture closure.	Lander	Altair FY13	Highly Desirable
AC-6	Crewed Composite Pressure Vessel Design and Validation Technologies	Technologies are desired for the validation of design and fabrication techniques for lightweight crewed composite pressure vessels (for the Altair ascent module and air-lock structures). Challenges to be addressed include damage tolerance, leak prevention, protection against MMOD, and maintaining structural integrity in the presence of very large launch and landing loads.	ETDP is not funding this activity at this time.	Unfunded	Could significantly reduce mass of Altair structure, allowing increased payload to the surface and/or enabling architecture closure.	Orion, Altair, Small Pressurized Rover, Habitat	Orion FY13 Altair FY13 Surface Systems FY14	Highly Desirable
Advanced Habitation Project								
AH-1	Certified In-Situ Repair Techniques for Habitat Structures	For long term survivability on planetary surfaces, methods are need to repair holes and breeches in exterior and interior habitat structures. The most likely repair scenario will be for small holes or cracks.	Advanced Habitation Project	Funded	Reduces crew risk and chance for mission abort. Decreases logistics mass resupply requirements by increasing system life.	All Surface Systems, but focused on Habitat.	Surface Systems FY14	Critical
AH-2	Lightweight , Durable Inflatable Habitats	Inflatable shells have the potential for very efficient packaging on the launch vehicle and reducing habitat mass. Packaging concepts, that include internal outfitting must be developed, as well as efficient means for deploying the habitat . Very low permeability bladder materials must be developed that does not become unacceptably brittle at low temperatures.	Structures, Materials, and Mechanisms (SMM) and/or Advanced Habitation Project	Funded	Allow more efficient packaging of habitat within payload shroud. May reduce mass.	Habitat	Surface Systems FY14	Desirable
Advanced Radiation Protection Project								

	Technology		ETDP Project	Funding Status	Benefits Statement	Connectivity to Architecture Elements	Need Date	Architecture Assessed Criticality
Ref #	**Title**	**Brief Description of Capability Need**						
ARP-1	Radiation Shielding Systems	Need capability to protect the outpost crew for at least 6 months from exceeding current standards for radiation dosage on the lunar surface. Current technology requires many layers of heavy shielding structure. There are multiple approaches to address this issue (e.g., materials, water, safe haven, habitat design). Need highly reliable reduced-weight multifunctional structures and blankets. Fixed or portable safe havens could supplement habitat shielding.	Advanced Radiation Protection Project	Funded	Enable crews to stay at least 6 months at a time at the outpost. Significantly reduce mass of radiation shielding required to support crew stays of at least 6 months.	Habitat, Small Pressurized Rover, Lander	Altair FY13 Surface Systems FY14	Critical
PROTECTION SYSTEMS								
Ablative TPS Technology Development Project								
ATPS-1	Robustness Options for Orion Baseline PICA Heat Shield	For Orion lunar return missions, more robust TPS/heat shield solutions in terms of damage tolerance, increased reliability and reduced mass are required.	Ablative TPS Project	Funded	Improve the safety/reliability of Orion heat shield by wrapping the PICA blocks on five-sides with silica-phenolic. Improve heat shield mass through integration of a high-performance insulator beneath a thinner layer of PICA.	Orion CM	Orion FY13	Highly Desirable
ATPS-2	Robust Ablative Heat Shield Architecture	A robust, scalable heat shield TPS architecture is required that can be used for multiple missions.	Ablative TPS Project	Funded	Reduce the mass and improve the safety and reliability of the Orion heat shield through the use of cured ablative TPS blocks bonded to a structural honeycomb lattice.	Orion CM	Orion FY13	Highly Desirable
ATPS-3	PICA Bond System Design for Margin	Design, testing and analysis of PICA carrier structure/ablator alternate bonding system designs are required as a possible block upgrade to Orion for improved safety. Testing and analysis of PICA carrier structure/ablator bonding system to improve the understanding of the design margin in realistic environmental conditions is needed.	Ablative TPS Project	Funded	Improve the safety and reliability of Orion heat shield by designing and testing alternative bonding techniques.	Orion CM	Orion FY13	Desirable
ATPS-4	Free Flying Inspection System for Orion TPS	Inspection capability is needed for micrometeoroid orbital debris (MMOD) damage to Orion exterior using a remotely controlled free-flying inspection system, which provides full coverage (as compared to the limited coverage of fixed external cameras).	ETDP is not funding this activity at this time.	Unfunded	Improve human safety by detecting critical issues with Orion TPS or structure prior to entry.	Orion CM, although could be used to inspect EDS, Lander and Orion SM prior to TLI or during mission.	Orion FY13	Highly Desirable
ATPS-5	Coupling of Aerothermal and TPS Material Response Tools	The current state of the art in TPS design ignores coupling between ablation products, boundary layer gases, and shock layer radiation, leading to potential mis-prediction of flight performance and degraded margin. Tools that enable conservative and accurate prediction of the flight environment, TPS response, and their interaction are required.	Ablative TPS Project	Funded	Reduce the mass and improve the safety and reliability of the Orion heat shield through the use improved design tool integration.	Orion CM	Orion FY13	Highly Desirable
ATPS-6	Improved Aerothermodynamic Modeling for Database Generation Tools	Improved tools are required for the prediction of heat transfer for lunar return. Current radiative heat transfer models rely on many simplifying assumptions which, when taken as a whole, overly penalize the TPS mass. Current convective heating turbulence models are empirically based and are often designed for flow regimes which are not directly applicable to the Orion environment. These two environments (radiation and convective heating) make up the bulk of the margin in the aerothermodynamic design.	ETDP is not funding this activity at this time.	Unfunded	Reduce the mass and improve the safety and reliability of the Orion heat shield through the use improved design tool integration.	Orion CM	Orion FY13	Highly Desirable
ATPS-7	Integrated Aerothermal/TPS Analysis of Arc Jet Testing	The basic process for simulation of arc-jet tests is ad-hoc and based on physical models developed for flight which may be inappropriate for ground test environments. Improved validation of analysis tools is required.	ETDP is not funding this activity at this time.	Unfunded	Reduce the mass and improve the safety and reliability of the Orion heat shield through improved tool validation for arc-jet testing.	Orion CM	Orion FY13	Desirable

Technology			ETDP Project	Funding Status	Benefits Statement	Connectivity to Architecture Elements	Need Date	Architecture Assessed Criticality
Ref #	Title	Brief Description of Capability Need						
ATPS-8	High Temperature Composites for CEV Crew Module Backshell	Develop high temperature composites like Graphite BMI or Graphite Polyimides for Orion CM backshell panels and attach flanges to allow higher temperature bondlines (>500F), thereby saving TPS mass.	ETDP is not funding this activity at this time.	Unfunded	Reduce the mass of the Orion structure, thereby providing additional launch mass margin or payload capability	Orion CM	Orion FY13	Highly Desirable
Dust Management Project								
DM-1	Dust/Regolith Mitigation Techniques	Approaches to prevent regolith/dust from entering habitable volumes from suits and instruments are required. A reliable system for collecting and removing regolith/dust from the habitat is also required. Extensive exposure to lunar dust can lead to respiratory problems. Need dust characterization and establishment of human health standards. Dust-proof connectors, filtering systems, electrostatic curtains and wands, and compressed gas systems are example technologies that need to be developed. Sensor/monitor of dust levels within the airlock and methods for dust removal (e.g., electrostatic methods, nitrogen air shower) are required.	Dust Management Project	Funded	Improve crew health and safety, increase crew functionality, and reduce mechanical maintenance issues through prevention of dust entering habitable areas and improved approaches for detecting and removing dust.	Habitat, Small Pressurized Rover, Lander, EVA Systems	Altair FY13 Surface Systems FY14 EVA Systems FY13	Critical
DM-2	Dust Control and Removal of Airborne Dust	Technologies are needed to remove airborne dust (down to the submicron range) from cabin atmospheres without incurring high expendable filter media resupply burdens.	Dust Management and Exploration Life Support Projects	Funded	Improve crew health and safety, increase crew functionality, and reduce mechanical maintenance issues through prevention of dust entering habitable areas and improved approaches for detecting and removing dust.	Habitat, Small Pressurized Rover, Lander	Altair FY13 Surface Systems FY14	Critical
DM-3	Lunar Regolith and Dust Simulant Development, Evaluation, and Production	For all surface systems, especially ISRU, accurate lunar regolith physical and chemical simulants are required to develop and test hardware. Recent testing comparing JSC-1 to actual lunar material showed drastic differences in performance which would have caused hardware failure to occur under lunar mission conditions. This is especially important with no robotic precursor missions planned.	Dust Management Project	Partially Funded	Enables the simulation of lunar dust environment on Earth to test dust mitigation technologies and effects of dust on critical mechanisms.	All Surface Systems	Surface Systems FY14	Critical
DM-4	Dust Mitigation of PV Array Gimbals and Mechanical Components	Gimbal and drive mechanisms for PV arrays (and other systems) are required with long operational life in the lunar dust environment.	Dust Management Project	Funded	Increase operational life and performance of PV array and other mechanisms. Improved life will reduce mass of logistics resupply required	Power Systems, and potentially other surface systems.	Surface Systems FY14	Critical
DM-5	Dust Mitigation for Thermal Control Systems	Performance degradation assessments and dust mitigation approaches are needed for radiators and thermal control systems.	Dust Management and Thermal Control Systems Projects	Funded	Increase operational life and performance of thermal control systems. Improved life will reduce mass of logistics resupply required	All Surface Systems	Surface Systems FY14	Critical
DM-6	Material Coatings for Dust Mitigation	Coatings that can be applied to or integrated with various materials that make them resistant to sharp lunar dust and its tendency to cling to the materials. Research and test options to provide resistance to lunar dust damage and clinging. Examine potential use of nano-level technologies. Potential applications include IVA/EVA clothing, internal and external structural surfaces, and mechanical equipment/tools.	Dust Management Project	Funded	Improve crew health and safety, increase crew functionality, and reduce mechanical maintenance issues through prevention of dust entering habitable areas.	All Surface Systems	Surface Systems FY14	Critical
DM-7	Dust-Tolerant EVA-Compatible Connectors	Dust tolerant EVA-compatible fluid connectors are required for recharging of fluids when connected to a suitport or suitlock. This capability enables a shorter duration life support system resulting in mass savings.	Dust Management Project	Funded	Improve crew EVA safety and productivity.	EVA Systems	EVA Systems FY13	Highly Desirable
PROPULSION SYSTEMS								
Propulsion and Cryogenic Advanced Development (PCAD) Project								

Technology			ETDP Project	Funding Status	Benefits Statement	Connectivity to Architecture Elements	Need Date	Architecture Assessed Criticality
Ref #	Title	Brief Description of Capability Need						
PCAD-1	High Reliability LOX/LH2 Throttling Engine	High reliability liquid oxygen, liquid hydrogen propulsion is required for the Altair descent module to enable architecture closure. The descent engine must be highly reliable and safe, while providing the required throttle for lunar braking, descent, and landing. Technology development is required to reduce programmatic risk associated with the lunar lander flight engine development.	PCAD Project	Funded	Improve crew safety and reliability, reduce mass and improve performance to enable architecture closure. Enable deep throttling to provide more design/landing flexibility.	Lander	Altair FY13	Critical
PCAD-2	LO2/LCH4 Main Engine and Auxiliary Propulsion Systems	Technology development is required to demonstrate key performance and reliability characteristics for LO2/LCH4 main engine and reaction control system engines, including ignition reliability and main engine performance. Specifically, the main engine and RCS thrusters must demonstrate durability and reliability for full mission duration in representative environment and likely off-nominal propellant conditions and mission needs.	PCAD Project	Funded	Reduce mass and improve performance to significantly aid in architecture closure. Provide technology risk reduction for future Mars missions and propellant ISRU.	Lander	Altair FY13	Highly Desirable
PCAD-3	HTPB Propellant	In order to improve performance margins to meet launch mass requirements for Ares V, HTPB propellant must be matured for application in human rated launch systems. Mixture uniformity must be understood and burn rate differentials between batches must be understood for the twin booster Ares V. Required by Ares V PDR.	ETDP is not funding this activity at this time.	Unfunded	HTPB provides significant improvements in Ares V payload mass to orbit, enabling architecture closure. Could improve performance of Ares I if high dynamic pressures can be accommodated.	Ares V , possibly Ares I	Ares I FY09 Ares V FY13	Critical advanced development and analysis task.
PCAD-4	HTPB SRB Nozzles	HTPB propellants put a much higher heat flux on the SRB nozzle. Research is necessary to characterize and develop nozzle materials and assembly techniques which can operate reliably in the higher heat flux. Required by Ares V PDR.	ETDP is not funding this activity at this time.	Unfunded	HTPB provides significant improvements in Ares V payload mass to orbit, enabling architecture closure. Could improve performance of Ares I if high dynamic pressures can be accommodated.	Ares V , possibly Ares I	Ares I FY09 Ares V FY13	Critical advanced development and analysis task.
PCAD-5	Non-Toxic TVC Actuation Systems	Non-toxic TVC actuation systems are desired to reduce the probability of exposing ground crew to toxic hydrazine and save ground operations costs. Maturation of Electro-Hydraulic Actuator (EHA) technology is required. Required by Ares V PDR.	ETDP is not funding this activity at this time.	Unfunded	Improve ground operations safety and cost.	Ares I and V	Ares I FY09 Ares V FY13	Highly Desirable
PCAD-6	High Performance, Non-Toxic Monopropellant for Orion CM RCS	Demonstration of non-toxic monopropellant propulsion system for Orion CM RCS is desired. Focus should be on candidates that provide increased performance, lower mass and power, reusability and reduced ground ops impacts.	ETDP is not funding this activity at this time.	Unfunded	Improve ground operations safety and cost. May increase mass.	Orion CM	Orion FY13	Desirable
PCAD-7	High Reliability Power Efficient Actuators	High reliability propellant control valve actuators and thrust vector control actuators with low specific power requirements are needed to meet Altair control and mass constraints. The Altair functional requirements and environments are outside the experience base, and technology development is needed to assure low development risk.	ETDP is not funding this activity at this time.	Unfunded	Improve reliability and reduce power of propellant actuators.	Lander	Altair FY13	Desirable
PCAD-8	Orion SM Main Engine Composite Nozzle	Composite nozzles can offer reduced mass and higher resistance to catastrophic failure from MMOD impact relative to metallic nozzles. A hot-fire test of a Snecma-provided Guipex carbon-carbon nozzle extension with an existing heritage OMS engine is proposed.	ETDP is not funding this activity at this time.	Unfunded	Significantly reduce nozzle mass, adding much needed launch mass margin.	Orion SM	Orion FY13	Highly Desirable
Cryogenic Fluid Management Project								
CFM-1	Long-Term On-Orbit Cryogenic Storage	The Earth Departure Stage (EDS) may be required to loiter up to 14 days to support Orion rendezvous and Trans-Lunar Injection (TLI). Cryogenic Fluid Management techniques to maintain the cryogenic fuel and oxidizer for the TLI burn is required for mission success. Required by Ares V PDR.	Cryogenic Fluid Management (CFM) Project	Funded	Reduce or eliminate boil-off of cryogenic propellant thereby enabling architecture closure and improving mission success.	EDS, Lander	Ares V FY13 Altair FY13	Critical
CFM-2	Liquid Level Measurement	Improved liquid level measurements are necessary for on-orbit cryogenic fluid management and state determination functions. The EDS tanks will be approximately 50% full and must be maintained during loiter. Techniques to measure liquid levels in these conditions must be defined and demonstrated. Required by Ares V PDR.	Cryogenic Fluid Management (CFM) Project	Funded	Higher certainty in amount of propellant remaining reduces propellant mass margin requirements, thereby improving performance.	EDS, Lander	Ares V FY13 Altair FY13	Desirable

Technology			ETDP Project	Funding Status	Benefits Statement	Connectivity to Architecture Elements	Need Date	Architecture Assessed Criticality
Ref #	Title	Brief Description of Capability Need						
CFM-3	Leak Detection	Leaks are a major concern for both on-orbit cryogenic fluid maintenance and for abort detection. Leak detection is not currently reliable, and techniques which can operate from launch pad to orbit are necessary. Small, undetected leaks can result in significant fluid losses resulting in failure of the EDS to successfully complete the TLI burn. Required by Ares V PDR for EDS. Technologies related to Ares I abort detection needed for Ares I CDR.	Cryogenic Fluid Management (CFM) Project	Funded	Improve safety and reliability through knowledge of and elimination of leakage sources.	Ares I and V, EDS, Lander	Ares I FY09 Ares V FY13 Altair FY13	Highly Desirable
CFM-4	Cryogenic Fluid Management for Lander Propulsion Systems	High reliability liquid oxygen, liquid hydrogen propulsion systems are required for the Altair descent stage to enable architecture closure. The descent propulsion system must be highly reliable and safe, while providing the required throttle for lunar braking, descent, and landing. Technology development is required to reduce programmatic risk associated with the Altair propulsion system development.	Cryogenic Fluid Management (CFM) Project	Funded	Improve crew safety and reliability, reduce mass and improve performance to enable architecture closure. Enable deep throttling to provide more design/landing flexibility.	Lander	Altair FY13	Critical
CFM-5	Oxygen Liquefaction, Storage, and Surface Transfer and Distribution	Ability to liquefy, store, and transfer liquid oxygen (as opposed to high pressure oxygen) could have significant mass, volume, and safety reductions for ISRU, power, life support, and EVA.	Cryogenic Fluid Management (CFM) Project	Funded	Required to enable ISRU for propellant applications, but may not be required for other oxygen ISRU needs (ECLSS, fuel cell reactants, EVA) since these systems can use gaseous inputs. Might reduce storage system mass for these applications, but more analysis is required.	ISRU, Small Pressurized Rover	ISRU FY16 Surface Systems FY14	Desirable
CFM-6	Hydrogen Fuel Cell Reactant Liquefaction	Need lightweight highly efficient cryogenic chillers and storage devices.	Cryogenic Fluid Management (CFM) Project	Funded	Required to enable ISRU for propellant applications. Might be required to enable lunar night exploration using mobile habitat by greatly reducing mass of consumables.	Small Pressurized Rover	Surface Systems FY14	Desirable
CFM-7	In-Flight Scavenging of Cryogenic Propellant Boil-off	Need capability to recover propellant boil-off from main propellant tanks during flight for use as fuel cell reactants or in auxiliary propulsion system.	Cryogenic Fluid Management (CFM) Project	Funded	Reduce or eliminate boil-off of cryogenic propellant thereby enabling architecture closure and improving mission success.	Lander, Possibly for Methane-Fueled Orion SM.	Altair FY13 Orion FY13	Highly Desirable
CFM-8	Cryogenic Scavenging from Lander Descent Tanks on Lunar Surface	Recover residual propellants from Altair for use as fuel cells reactants and/or outpost water to reduce logistics resupply requirements.	Cryogenic Fluid Management (CFM) Project	Funded	Scavenging Altair fluids could significantly reduce logistics mass transportation requirements.	Lander, ISRU, Habitat, Power Systems	ISRU FY16 Surface Systems FY14 Altair FY13	Highly Desirable
CFM-9	Advanced Multi-Layer Insulation (MLI)	MLI is a leading candidate for EDS CFM applications. MLI application to 10 m diameter tanks may require technology development to enable EDS manufacturing to minimize production cost. Required by Ares V PDR.	Cryogenic Fluid Management (CFM) Project	Funded	Reduce boil-off of cryogenic propellant thereby enabling architecture closure and improving mission success.	EDS, Lander	Ares V FY13 Altair FY13	Critical
CFM-10	Scaling of Large Low- G Cryogenic Storage Systems	Determine non-dimensional scaling relationships, perform CFD analysis, and perform sub-scale testing of tanks of two different sizes, but geometrically similar, to enable validation of design.	ETDP is not funding this activity at this time.	Unfunded	Reduces uncertainty in CFM systems modeling, thus allowing reduced margins and saving mass.	EDS, Lander	Ares V FY13 Altair FY13	Desirable
ENERGY STORAGE AND POWER SYSTEMS								
Energy Storage Project								

Technology			ETDP Project	Funding Status	Benefits Statement	Connectivity to Architecture Elements	Need Date	Architecture Assessed Criticality
Ref #	Title	Brief Description of Capability Need						
ES-1	Low Cycle Life Rechargeable Battery	Low mass rechargeable battery is required to power the Altair ascent module during ascent from the lunar surface.	Energy Storage Project	Funded	Reduce Altair mass thereby allowing more payload capability. Improve crew safety and reliability by enabling recharging from lunar outpost in emergency.	Lander	Altair FY13	Critical
ES-2	Low Mass, High Reliability PEM Fuel Cell	Low mass, highly reliable fuel cell is required for Altair power generation. Flow-through and non-flow-through options should be examined. Flow-through is more advanced technology and will replace active ancillary components with passive components. Non flow-through can save >50kg on Altair and offers increased reliability by eliminating ancillary components altogether.	Energy Storage Project	Funded	Reduce Altair mass thereby allowing more payload capability. Improve crew safety and reliability by improving power system reliability.	Lander	Altair FY13	Critical
ES-3	Regenerative Fuel Cells for Lunar Surface Energy Storage	Shaded periods on the lunar surface can range up to 15 days or more. If the lunar outpost relies on solar arrays as its primary power source, such shaded time periods will result in a tremendous amount of energy storage to maintain outpost operations during these eclipse periods. State-of-the-art battery systems would be prohibitively massive to meet these energy requirements. Regenerative fuel cells are required.	Energy Storage Project	Funded	Significantly improve energy density storage and generation during lunar night, thereby reducing mass required to be transported to the lunar surface and enabling more productive lunar night operations.	Surface Power, All Surface Systems	Surface Systems FY14	Critical
ES-4	High Energy Density Rechargeable Batteries	Need high-energy-density rechargeable batteries to power both unpressurized and pressurized rovers for crew transport as well as systems to remove surface elements from Altair and emplace them on the lunar surface.	Energy Storage Project	Funded	Enable long-life reliable operations of surface mobility systems	Surface Mobility	Surface Systems FY14	Highly Desirable
ES-5	Suit Power	High energy density, high specific energy batteries are needed that meet the requirements for human rated space applications, especially with respect to safety. Technologies must keep the suit within mass and volume allocations while enabling an 8 hour EVA.	Energy Storage Project	Funded	Reducing power system mass reduces logistics mass transportation requirements. Improve crew EVA safety, comfort ,and productivity.	EVA Systems	EVA Systems FY13	Critical
ES-6	Lunar Surface Flywheel Energy Storage	Develop high speed flywheels with advanced fibers using carbon nanotubes in a quartz glass to generate electrical power during eclipse periods and to power mobility systems.	ETDP is not funding this activity at this time.	Unfunded	Improve energy density storage and during lunar night, thereby reducing mass required to be transported to the lunar surface and enabling more productive lunar night operations.	Surface Power Systems	Surface Systems FY14	Desirable
ES-7	Battery Boost Converter Development	There is significant power still left in a lithium-ion cell as the battery voltage drops off to levels below what can be used. Battery booster development is desired to extract maximum energy and improve efficiency.	ETDP is not funding this activity at this time.	Unfunded	Increasing battery life will reduce the logistics resupply mass required and extend the mission life of mobility systems.	Altair and Surface Systems	Altair FY13, Surface Systems FY14	Highly Desirable
Surface Power Systems Project								
SPS-1	Higher Voltage Electrical Power Distribution	Most conventional spacecraft operate between 28Vdc (satellites) and 120V (International Space Station). Higher voltage power distribution provides lighter weight systems. These systems must accommodate the lunar environment constraints such as the temperature variations and lunar dust. The higher voltage systems need to accommodate a diversity of power sources (PV, fuel cells, batteries) to facilitate the evolution of the lunar outpost. The power system must be highly automated to permit operation for long periods of untended operation. High voltage converters, switches, and cabling is required. AC distribution may be desirable.	Surface Power Systems Project	Funded	Reduce mass of surface power systems, cabling and surface mobility systems through the use of higher voltages.	Surface Power, All Surface Systems	Surface Systems FY14	Highly Desirable

Technology			ETDP Project	Funding Status	Benefits Statement	Connectivity to Architecture Elements	Need Date	Architecture Assessed Criticality
Ref #	Title	Brief Description of Capability Need						
SPS-2	Advanced Power Management and Distribution Systems	Lunar outpost power systems will need lightweight and efficient power management and distribution systems on the surface. Likewise, these PMAD systems must have sufficient lifetime/reliability in the unique lunar surface environment (temperature extremes, radiation, and dust).	Surface Power Systems Project	Funded	Improve reliability and reduce mass of surface power systems.	Surface Power	Surface Systems FY14	Highly Desirable
SPS-3	Modular Power System Components	Potential cost savings could be achieved by use of common electric power system components in Orion, Ares, EDS, Altair and lunar surface systems. Most commercial and military satellites utilize common power components to achieve reduced development time and recurring cost.	ETDP is not funding this activity at this time.	Unfunded	Reduce life cycle costs through modularity and commonality.	All Architecture Elements	Surface Systems FY14	Highly Desirable
SPS-4	Lightweight Cable Technology	The distribution of significant amounts of power on the lunar surface will require power cabling connecting power sources, energy storage devices, and user element loads. A lightweight cable technology is required that would provide mass reduction and ease of deployment, integration and test. Large amounts of cabling may be required to link surface systems, particularly if nuclear systems are deployed. Cabling within elements (i.e. habitats and rovers) will also benefit from lightweight, efficient cabling.	ETDP is not funding this activity at this time.	Unfunded	Significantly reduce mass of cabling, thereby reducing transportation cargo requirements.	Surface Power Systems	Surface Systems FY14	Highly Desirable
SPS-5	Large Lightweight High Strength Solar Arrays	Need large solar arrays that stay deployed during mobility. Also need longer stow and deploy cycle life and high efficiency at lunar-equatorial temperatures.	ETDP is not funding this activity at this time.	Unfunded	Reduced mass and longer life will reduce logistics mass transportation requirements.	Surface Power Systems, Surface Mobility Systems, Habitat	Surface Systems FY14	Highly Desirable
Advanced Fission-Based Power Systems								
FSP-1	Nuclear Fission Power Systems	Abundant amounts of power and energy will be needed for lunar and Mars outposts. For lunar applications, large eclipse periods in non-polar regions (in some cases greater than 15 days) would put a significant burden on chemical energy storage with a PV source. For a lunar polar outpost, solar power with regen fuel cell is likely sufficient. For Mars missions, fission power will be required because of significantly lower solar insulation (36% of lunar) and obscuration of light due to dust storms. Demonstration of a small nuclear reactor as a secondary power supply source for a lunar outpost will provide risk reduction for Mars applications. The last US nuclear power sources were launched in 1965 (SNAP-10A).	Advanced Fission Based Power Systems Project	Funded	Significantly increase availability of power during lunar night. Provide extensibility demonstration for future Mars and solar system exploration.	Nuclear Fission Power Systems	Nuclear Fission Power Systems FY16	Highly Desirable
THERMAL CONTROL SYSTEMS								
Thermal Control Project								
TC-1	Phase Change Material (PCM)	Phase change material planned for use in Orion and other potential applications is immature and requires additional technology development. PCM heat exchangers may also be required for EVA systems, rovers, ISRU systems and other surface systems.	Advanced Thermal Control Project	Funded	Improve heat exchanger specific performance, thereby saving mass	Orion, Lander, Small Pressurized Rover, Habitat, Possibly EVA Systems	Orion FY13 Altair FY13 Surface Systems FY14 EVA Systems FY13	Highly Desirable

Technology			ETDP Project	Funding Status	Benefits Statement	Connectivity to Architecture Elements	Need Date	Architecture Assessed Criticality
Ref #	Title	Brief Description of Capability Need						
TC-2	Heat Rejection Systems for Advanced Thermal Control Systems	Highly reliable, lightweight thermal control, sun shades and heat rejection systems are required for a variety of surface system applications. Improved modeling and simulation techniques for lunar thermal environments are needed.	Advanced Thermal Control Project	Funded	Improve heat rejection system specific performance, thereby saving mass. Improve system reliability and life.	Orion, Lander, Small Pressurized Rover, Habitat, Possibly EVA Systems	Orion FY13 Altair FY13 Surface Systems FY14 EVA Systems FY13	Highly Desirable
TC-3	Evaporative Heat Sink for Advanced Thermal Control Systems	Short duration missions or mission phases that have a hotter thermal environment than nominal or higher heat load than nominal will likely require the use of lightweight, reliable evaporative heat sinks.	Advanced Thermal Control Project	Funded	Improve evaporator heat sink system specific performance, thereby saving mass. Improve system reliability and life.	Lander, Small Pressurized Rover, Habitat (back-up), Possibly EVA Systems	Altair FY13 Surface Systems FY14 EVA Systems FY13	Highly Desirable
TC-4	Heat Exchangers and Coldplates for Thermal Control Systems	Lightweight, highly reliable and robust heat exchangers and coldplates are required for a variety of surface system applications.	Advanced Thermal Control Project	Funded	Improve heat exchanger and coldplate system specific performance, thereby saving mass. Improve system reliability and life.	Lander, Small Pressurized Rover, Habitat, Possibly EVA System	Altair FY13 Surface Systems FY14 EVA Systems FY13	Highly Desirable
TC-5	Long-Duration Advanced Thermal Control System Fluids	Long-duration advanced thermal control system fluids are required for a variety of surface system applications.	Advanced Thermal Control Project	Funded	Improve fluid life, thereby increasing system life and reducing logistics mass transportation requirements.	Lander, Habitat, Small Pressurized Rover	Altair FY13 Surface Systems FY14	Critical
TC-6	Fusible Heat Sink Thermal Management for Small Pressurized Rover	A flexible lightweight thermal management is required for the small pressurized rover. A fusible heat sink could combine thermal management with radiation protection. A closed loop sublimate/evaporate cycle is desired.	Advanced Thermal Control Project	Funded	Reduce logistics mass transportation requirements by closing thermal loop. Improve human safety and integrated system mass through increased radiation protection.	Small Pressurized Rover, Possibly Habitat	Surface Systems FY14	Critical
TC-7	Sublimator-Driven Coldplate Technology	The sublimator driven coldplate is a novel thermal technology development that could benefit the Altair ascent stage.	Advanced Thermal Control Project	Funded	Improve heat exchanger and coldplate system specific performance, thereby saving mass. Improve system reliability and life.	Lander, Small Pressurized Rover, Habitat, Possibly EVA Systems	Altair FY13 Surface Systems FY14 EVA Systems FY13	Highly Desirable
TC-8	Dust Mitigation for Thermal Control Systems	Performance degradation assessments and dust mitigation approaches are needed for radiators and thermal control systems.	Dust Management and Thermal Control Systems Projects	Funded	Increase operational life and performance of thermal control systems. Improved life will reduce mass of logistics resupply required.	All Surface Systems	Surface Systems FY14	Critical
AVIONICS AND SOFTWARE								
Radiation-Hardened Electronics for Space Environments (RHESE) Project								
RHE-1	Radiation Mitigation and Environmental Hardness for Avionics	Need Single Event Effect (SEE) Immune Reconfigurable Field Programmable Gate Arrays (FPGAs) that provide a method for emulating multiple avionic functions within a nonvolatile, reconfigurable gate array that is radiation hardened by design. Need SiGe materials to enable and support externally-distributed, environmentally-exposed electronic units (remote Data Acquisition Units, miniaturized sensor nodes, and remote control electronics for actuators) capable of operations in the natural lunar environments. This technology would enable low-temperature and low-power, mixed signal operations in lunar environments. This technology could greatly reduce cabling mass by locating control electronics on Altair system extremities.	Radiation Hardened Electronics for Space Environments Project (RHESE)	Funded	Improve reliability and life of avionics components, thereby improving crew safety and reducing logistics mass transportation requirements.	All architecture elements except for Ares I and V.	Orion FY13 Altair FY13 Ares V FY13 Surface Systems FY14	Highly Desirable
RHE-2	High Density, Rad-Tolerant Non Volatile Memory Technology	A high density, rad tolerant, non volatile memory technology will be required in multiple systems across Constellation architecture elements to hold code and data.	Radiation Hardened Electronics for Space Environments Project (RHESE)	Funded	Improve reliability and life of avionics components, thereby improving crew safety and reducing logistics mass transportation requirements.	All architecture elements except for Ares I and V.	Orion FY13 Altair FY13 Ares V FY13 Surface Systems FY14	Highly Desirable

Technology			ETDP Project	Funding Status	Benefits Statement	Connectivity to Architecture Elements	Need Date	Architecture Assessed Criticality
Ref #	Title	Brief Description of Capability Need						
RHE-3	Reconfigurable Fault Tolerance Technology	A reconfigurable fault tolerance computing technology is required that meets all fault tolerance requirements (0, 1 or 2 faults) and that can be used in multiple systems across Constellation architecture elements.	Radiation Hardened Electronics for Space Environments Project (RHESE)	Funded	Improve reliability and life of avionics components, thereby improving crew safety and reducing logistics mass transportation requirements.	All architecture elements except for Ares I and V.	Orion FY13 Altair FY13 Surface Systems FY14	Highly Desirable
RHE-4	High Density, Rad-Tolerant Volatile Memory Technology	A high density, high performance, low power, rad tolerant, volatile memory technology will be required in multiple systems across Constellation architecture elements to hold code and data.	Radiation Hardened Electronics for Space Environments Project (RHESE)	Funded	Improve reliability and life of avionics components, thereby improving crew safety and reducing logistics mass transportation requirements.	All architecture elements except for Ares I and V.	Orion FY13 Altair FY13 Ares V FY13 Surface Systems FY14	Highly Desirable
RHE-5	Common Avionics Technology	Common avionics technology at the board and chassis level is desired to allow mass reduction while providing good thermal management, easy maintenance, and sparing that can be used across all architecture elements.	ETDP is not funding this activity at this time.	Unfunded	Reduce mass and cost through commonality and modularity	All architecture elements except for Ares I and V.	Orion FY13 Altair FY13 Ares V FY13 Surface Systems FY14	Desirable
RHE-6	Hardened Displays for Lunar Environments	Low power, light weight displays are desired across all crewed lunar surface elements that will be exposed to the harsh lunar environments.	ETDP is not funding this activity at this time.	Unfunded	Increasing life of displays reduces logistics mass	All Surface Systems	Surface Systems FY14	Desirable
RHE-7	High Temperature Tolerant Electronics	Electronics technology such as silicon carbide is desired to enable electronics to operate at high temperatures and eliminate active cooling. Heat tolerance and passive radiation cooling would reduce the design complexity as well as reducing mass.	ETDP is not funding this activity at this time.	Unfunded	Improve integrated mass of avionics and possible increase life.	All Surface Systems	Surface Systems FY14	Highly Desirable
RHE-8	Modeling of Radiation Effects on Electronics	Accurate modeling of the natural radiation environment and its sporadic and cumulative effects on modern spacecraft avionics and electronics is needed for use in subsystem design and development.	ETDP is not funding this activity at this time.	Unfunded	Reducing design uncertainty can save radiation shielding mass and improve component reliability.	All architecture elements except for Ares I and V.	Orion FY13 Altair FY13 Ares V FY13 Surface Systems FY14	Highly Desirable
Intelligent Software Design								
ISD-1	Software Development Tools	Reliable software development tools are needed to optimize the development of the MOP/MOD software required to support Constellation mission operations.	Intelligent Software Design Project (ISD)	Funded	Improve speed and cost of software development. Improve reliability of software.	Mission Operations	Mission Operations FY14	Desirable
ISD-2	Software Verification and Validation Technologies	The development of tests to mitigate specific classes or types of software defects is needed. Error injection, tracing and analysis technologies are required. Model-based analysis for validation of safety-critical software designs is needed. Advanced validation testing that determines failure boundaries and margins for safety-critical functions is needed. Auto code tools need development for state estimation, data analysis and to streamline the test activity. Verification and validation of autonomy and automation functions implemented in flight computers is required.	Intelligent Software Design Project (ISD)	Funded	Improve speed and cost of software development. Improve reliability of software.	All architecture elements.	Ares I FY09 Ares V FY13 Orion FY13 Altair FY13 Surface Systems FY14	Desirable
ISD-3	Design-Level Software Re-use	Technology is required -for rapid, low-cost development of reliable lunar software systems from reusable design-level models (e.g., UML). Initial focus should be on navigation and communications software components compliant with C3I, then ECLSS.	ETDP is not funding this activity at this time.	Unfunded	Improve speed and cost of human-rated software development.	All architecture elements.	Ares I FY09 Ares V FY13 Orion FY13 Altair FY13 Surface Systems FY14	Desirable
ISD-4	Integrated High Fidelity Analysis Tools	Need advanced integrated high fidelity modeling and analysis tools that combine aspects of structural design, loads, dynamics, thermal and operations kinematics (such as separation, landing, mating or deployment).	ETDP is not funding this activity at this time.	Unfunded	Improve speed and cost of system design.	All architecture elements.	Ares I FY09 Ares V FY13 Orion FY13 Altair FY13 Surface Systems FY14	Desirable

Technology			ETDP Project	Funding Status	Benefits Statement	Connectivity to Architecture Elements	Need Date	Architecture Assessed Criticality
Ref #	Title	Brief Description of Capability Need						
ISD-5	Modeling of Software-Intensive Systems	Tools and techniques are needed that model physical and behavioral aspects of software system design, properties, cause and effects, environment, and interactions in order to enable model-based design and test verification and validation and improve capability to analyze software system characteristics (timing, behavior, performance, fault propagation) to support verification and testability of design.	ETDP is not funding this activity at this time.	Unfunded	Improve reliability of software.	All architecture elements.	Ares I FY09 Ares V FY13 Orion FY13 Altair FY13 Surface Systems FY14	Desirable
ISD-6	Compliance and Model Checkers for Mission-Critical Software	Efficient code analyzers, compliance rule and model checkers for mission-critical software are needed. Due to their complexity, the use of such tools is currently limited to a small number of flight software modules. They need to be extended to the entire flight software.	ETDP is not funding this activity at this time.	Unfunded	Improve reliability of software.	All architecture elements.	Ares I FY09 Ares V FY13 Orion FY13 Altair FY13 Surface Systems FY14	Desirable
Automation for Operations Project								
AFO-1	Automation for Mission Operations	Automation capabilities are needed to enhance mission operations support, thereby reducing manpower requirements while improving overall support capability. These technologies include interactive procedures, scheduling tools and constraint data management.	Automation for Operation Project (A4O)	Funded	Reduce mission operations cost.	Mission Operations	Mission Operations FY14	Desirable
AFO-2	Mission Monitoring Tools	New mission operations monitoring technologies are needed to provide a fully integrated environment for the flight control team. In addition to telemetry data and command processed in the same display environment, the technology should integrate procedures, rules, information searches and other capabilities currently being used by the team from separate and disconnected sources.	Automation for Operation Project (A4O)	Funded	Reduce mission operations cost.	Mission Operations	Mission Operations FY14	Desirable
AFO-3	Training Support Technologies	Training support applications and simulations technologies are needed for both stand-alone part-task trainers and full capability simulations of vehicle systems.	Automation for Operation Project (A4O)	Funded	Reduce mission operations cost.	Mission Operations	Mission Operations FY14	Desirable
AFO-4	CFDP Compatible Tools	Need CFDP compatible tools for file transfers, which is a CCSDS-based implementation of internet file transfer protocols (FTP).	ETDP is not funding this activity at this time.	Unfunded	Reduce mission operations cost.	Mission Operations	Mission Operations FY14	Desirable
AFO-5	Semantic Technologies, Ontology and Registry Development	Utilizing semantic technologies, ontology and registry development technologies will significantly enhance MOP support in the reconfiguration process. As it relates to data mining and knowledge management, the ability to search through the multiple mission operations data files and information to obtain specific operations information would significantly enhance troubleshooting.	ETDP is not funding this activity at this time.	Unfunded	Reduce mission operations cost.	Mission Operations	Mission Operations FY14	Desirable
INTEGRATED SYSTEMS HEALTH MANAGEMENT								
Integrated Systems Health Management Project								
ISHM-1	Solid Rocket Motor Health Management	Abort detection of solid rocket motors is a new capability not provided for on the Shuttle. Techniques to detect abort conditions are needed for SRMs and must be researched to define highly reliable and safe abort detection capabilities. Ground testing of approaches is required. Completion required by Ares I CDR.	Integrated Systems Health Management (ISHM) Project	Funded	Improve human safety through better fault detection and abort capability.	Ares I and V	Ares I FY09 Ares V FY13	Critical
ISHM-2	ISHM Prognostic/Diagnostic Tools	System modeling tools and methods that will allow optimization of sensor selection and placement during the system design stage are needed. Certifiable advanced fault isolation tools and methods are required. System integration tools and methods are needed to integrate multiple subsystem health and status application into a coherent, unified health and status picture for the entire architecture.	Integrated Systems Health Management (ISHM) Project	Funded	Improve human safety through better design tools to enable IVHM systems.	Ares I and V	Ares I FY09 Ares V FY13	Desirable

Technology			ETDP Project	Funding Status	Benefits Statement	Connectivity to Architecture Elements	Need Date	Architecture Assessed Criticality
Ref #	Title	Brief Description of Capability Need						
ISHM-3	Integrated Systems Health Management	For both crewed and dormant configurations, monitoring and management of the health of critical subsystems is required. Reliable, fault-tolerant embedded sensors and algorithms for built-in-tests, fault detection, isolation, warning, and reconfiguration or repair are required. A failure prediction capability is desirable for informed logistics management. Informative crew alerting systems are required.	Integrated Systems Health Management (ISHM) Project	Funded	Improve safety/reliability and reduce repair time for surface elements. Enable health determination and repair during dormant operations	All architecture elements	Ares I FY09 Ares V FY13 Orion FY13 Altair FY13 Surface Systems FY14	Highly Desirable
ISHM-4	On-Board Decision Support Tools	There is a need to link diagnostic and prognostic tools to on-board reconfiguration managers and or intelligent controllers. Technology is needed for on-board decision support and expert-guided troubleshooting for crew and ground controllers.	Integrated Systems Health Management (ISHM) Project	Funded	Improve safety/reliability and reduce repair time for surface elements.	All architecture elements	Ares I FY09 Ares V FY13 Orion FY13 Altair FY13 Surface Systems FY14	Highly Desirable
ISHM-5	EDS State Determination	The Earth Departure Stage (EDS) will rendezvous and transfer the Orion and Altair from Earth orbit to lunar orbit. Operation with the Orion requires the EDS to implement human rating requirements including anytime abort. EDS has many components and composite structures. The state of each of these components must be automatically determined for and evaluated to determine if an abort is required. Techniques to determine the state of these unique systems are needed that work in a reliable integrated fashion with each other and the Orion systems for abort detection and determination. Research is necessary to determine the candidate techniques necessary to perform these functions and the integration techniques necessary for safe and reliable operation. Required by Ares V PDR.	ETDP is not funding this activity at this time.	Unfunded	Improve human safety through better fault detection and abort capability.	EDS	Ares V FY13	Highly Desirable
ISHM-6	Advanced Caution and Warning Systems for Mission Operations	Development is needed for a Mission Control Center model-based fault isolation and root-cause determination tool. It needs to integrate the troubleshooting and root cause determination with procedure planning and execution.	ETDP is not funding this activity at this time.	Unfunded	Reduce mission operations cost improved system reliability	Mission Operations	Mission Operations FY14	Highly Desirable
ISHM-7	Modular DFI/LFI Instrumentation	There is a need for micro-sized data acquisition, processing and storage systems that require minimum integration and operations for networking and wireless for data acquisition needs. Wireless connectivity between the sensor, data acquisition and other vehicle and external systems is required. Data reduction to processed solutions, event triggering and collection, and plug-and-play wireless connectivity are required features. Sending real-time solutions to the rest of the system and ground operations, with raw data only when required, reduces overhead and increases usable information for the end users.	ETDP is not funding this activity at this time.	Unfunded	Improve safety/reliability and reduce repair time for surface elements.	Orion, Lander, Habitat, Small Pressurized Rover	Orion FY13 Altair FY13 Surface Systems FY14	Highly Desirable
GUIDANCE, NAVIGATION, AND CONTROL								
Autonomous Landing and Hazard Avoidance Technology (ALHAT) Project								
ALH-1	Autonomous Landing and Hazard Avoidance Technologies	Need autonomous landing and hazard avoidance systems, including terrain relative navigation, that operate in all lighting conditions, including darkness. Need 100-m accuracy at 3-sigma certainty. Need 0.5 meter hazard recognition and avoidance.	ALHAT Project	Funded	Enable autonomous precision landing near the lunar outpost. Enable operation in all lighting conditions.	Lander	Altair FY13	Critical

Technology			ETDP Project	Funding Status	Benefits Statement	Connectivity to Architecture Elements	Need Date	Architecture Assessed Criticality
Ref #	Title	Brief Description of Capability Need						
ALH-2	Hazard Detection and Avoidance	Prior to being able to identify a specific technology development project, the Altair Project Office (APO) requires engineering assessments of the following strategies in order to trade the cost vs. risk: 1) cargo lander mission to a landing site equipped with navigation aids. Consider a range of landing aids from passive to active. Assume the locations of the landing aids are known. Determine the minimum suite of navigation and sensor equipment necessary for the cargo lander to meet performance requirements. Work with the APO GN&C Lead to develop options for navigation aids. 2) Crew mission to a landing site with polar lighting conditions and no navigation aids placed at the landing site. Utilize the crew's capabilities to maximum extent possible to determine the minimum suite of navigation and sensor equipment necessary to meet performance requirements.	ALHAT Project	Funded	Enable final requirements determination for ALHAT project and supporting navigation aids. Improve reliability and confidence in Altair ability to land autonomously.	Lander	Altair FY13	Critical
Advanced Rendezvous and Docking (AR&D) Sensors Project								
ARD-1	Reliable Automated Rendezvous and Docking Technologies	Need reliable sensors and algorithms that enable AR&D between Orion and ISS, and Orion and Altair. The U.S. does not currently have an off-the-shelf human-rated reliable sensor suite to support rendezvous, proximity operations and docking.	AR&D Sensors Project	Funded	Improve crew safety and mission reliability through reliable AR&D.	Orion, Lander	Orion FY13 Altair FY13	Highly Desirable
ARD-2	Natural Feature Image Recognition	Additional low mass relative navigation capability is needed to supplement the primary Orion VNS, using on-board Orion centerline camera and VPU for processing.	AR&D Sensors Project	Funded	Improve reliability of rendezvous and docking.	Orion, Lander	Orion FY13 Altair FY13	Desirable
ARD-3	Parallel Path to VNS	Need to maintain parallel path of relative navigation sensor development in order to reduce risk associated with VNS.	ETDP is not funding this activity at this time.	Unfunded	Improve reliability of rendezvous and docking. Reduce program development risk.	Orion, Lander	Orion FY13 Altair FY13	Desirable
ARD-4	Lidar Feature Recognition	Need to increase operational flexibility using on-board Lidar system (assuming Lidar is selected for VNS). Need to increase robustness when Orion is unable to view targets or reflectors on target vehicle due to pointing, blockage or other constraints.	ETDP is not funding this activity at this time.	Unfunded	Improve reliability of rendezvous and docking.	Orion, Lander	Orion FY13 Altair FY13	Highly Desirable
ARD-5	Lunar Navigation Technologies	Need capability for rendezvous bearing using optical system with moon in FOV. Need to investigate rendezvous bearing options for lunar missions, such as non-optical lunar orbit navigation using surface features for precise orbit determination.	ETDP is not funding this activity at this time.	Unfunded	Improve reliability of rendezvous and docking in lunar orbit.	Orion, Lander	Orion FY13 Altair FY13	Highly Desirable
Advanced Surface Navigation Sensors Project								
ANS-1	Reliable Surface Navigation Sensors	Need sensors for object detection and collision avoidance for crewed and uncrewed operations (e.g., lidar, radar, stereo-scopic vision systems). Need reliable approach and dock sensors that operate in lunar environment and provide short distance ranging (relative position, high resolution) and orientation data.	Advanced Surface Navigation Sensors Project	Funded	Improve human safety and productivity through automation and reduced EVA requirements.	Surface Mobility, Habitat	Surface Systems FY14	Highly Desirable
ENVIRONMENTAL CONTROL AND LIFE SUPPORT								
Exploration Life Support Project								
ELS-1	CO2 and Moisture Removal System	Need lightweight regenerable system for controlling CO2 and humidity in cabin air.	Exploration Life Support Project (ELS)	Funded	Reduce logistics mass transportation requirements by closing ECLSS loop. Reduce system mass.	Habitat, Small Pressurized Rover, EVA Systems	Surface Systems FY14 EVA Systems FY13	Critical
ELS-2	High Pressure Oxygen Supply	Technologies for the production and delivery of high pressure (up to 3000-3600 psia) oxygen for low volume storage are needed.	Exploration Life Support Project (ELS)	Funded	Reduce logistics mass transportation requirements by closing ECLSS loop. Reduce system mass.	Habitat, Small Pressurized Rover, EVA	Surface Systems FY14 EVA Systems FY13	Highly Desirable

Technology			ETDP Project	Funding Status	Benefits Statement	Connectivity to Architecture Elements	Need Date	Architecture Assessed Criticality
Ref #	Title	Brief Description of Capability Need						
ELS-3	Highly Efficient Partial - Gravity Water Recovery	Technologies are required for the recovery of water from wastewaters that achieve high water recovery (>95%) with low equipment resupply burdens. Need devices that take advantage of partial gravity environments to simplify and enhance the robustness of existing systems that have been flight qualified for 0-g applications.	Exploration Life Support Project (ELS)	Funded	Reduce logistics mass transportation requirements by closing ECLSS loop. Not as critical if water can be recovered from Altair.	Habitat, Small Pressurized Rover	Surface Systems FY14	Highly Desirable
ELS-4	Carbon Dioxide Reduction	Technologies to enable the recovery of oxygen from carbon dioxide are needed.	Exploration Life Support Project (ELS)	Funded	Reduce logistics mass transportation requirements by closing ECLSS loop.	Habitat, Small Pressurized Rover	Surface Systems FY14	Critical
ELS-5	Brine Water Recovery	Technologies are needed for the recovery of water from residual, concentrated wastewater brines produced by primary water recovery systems.	Exploration Life Support Project (ELS)	Funded	Reduce logistics mass transportation requirements by closing ECLSS loop. Not as critical if water can be recovered from Altair.	Habitat, Small Pressurized Rover	Surface Systems FY14	Highly Desirable
ELS-6	Improved CO2 Removal for Loop Closure	Increased robustness, lower power and improved integration with CO2 reduction for CO2 and humidity removal are required.	Exploration Life Support Project (ELS)	Funded	Reduce logistics mass transportation requirements by closing ECLSS loop. Reduce system mass an and power required.	Habitat, Small Pressurized Rover	Surface Systems FY14	Critical
ELS-7	Advanced Biocide	A biocide which is compatible with materials, stable for more than 6 months and does not require removal is desired.	Exploration Life Support Project (ELS)	Funded	Reduce logistics mass transportation requirements by closing ECLSS loop. Increase system life.	Habitat, Small Pressurized Rover	Surface Systems FY14	Highly Desirable
ELS-8	Urine Pretreatment	Improved urine pretreatment methods are required, such as chemical methods that are low-toxicity, non-corrosive and simple to use.	Exploration Life Support Project (ELS)	Funded	Reduce logistics mass transportation requirements by closing ECLSS loop. Increase system life and improve crew safety.	Habitat, Small Pressurized Rover	Surface Systems FY14	Highly Desirable
ELS-9	Urine Receptacle Assembly	A simple, no-power, urine collection and venting device that works for both male and female crew is desired.	ETDP is not funding this activity at this time.	Unfunded	Reduce power requirements and improve crew comfort/productivity.	Habitat, Small Pressurized Rover, Orion, possibly EVA systems.	Orion FY13 Surface Systems FY14 EVA Systems FY13	Desirable
ELS-10	Trace Contaminant Adsorbents	Need development of ammonia sorbent and methods for removal of contaminants previously removed by condensing heat exchangers for use with open loop ARS systems.	Exploration Life Support Project (ELS)	Funded	Reduce logistics mass transportation requirements by closing ECLSS loop. Increase system life and improve crew safety.	Habitat, Small Pressurized Rover	Surface Systems FY14	Highly Desirable
ELS-11	Improved Trace Contaminant Control	Need reduction of expendable sorbents, lower catalytic oxidation temperature, possible photocatalytic filtration of entire air stream to reduce condensate contaminant load and incorporation into integrated CO2 removal/reduction system.	Exploration Life Support Project (ELS)	Funded	Reduce logistics mass transportation requirements by closing ECLSS loop. Increase system life and improve crew safety.	Habitat, Small Pressurized Rover	Surface Systems FY14	Highly Desirable
ELS-12	Advanced Hygiene and Waste Removal Systems	Need efficient, lightweight hygiene and waste removal systems designed to function in lunar partial gravity environment.	Exploration Life Support Project (ELS)	Funded	Reduce logistics mass transportation requirements by closing ECLSS loop. Reduce system mass.	Habitat, Small Pressurized Rover	Surface Systems FY14	Highly Desirable
ELS-13	Waste Stabilization and Dewatering	Need 50% recovery of water from solid waste, with resulting residual waste stabilization. Methods should avoid physical transfer of waste from collection container to processor.	Exploration Life Support Project (ELS)	Funded	Reduce logistics mass transportation requirements by closing ECLSS loop. Not as critical if water can be recovered from Altair.	Habitat, Small Pressurized Rover	Surface Systems FY14	Highly Desirable

Technology			ETDP Project	Funding Status	Benefits Statement	Connectivity to Architecture Elements	Need Date	Architecture Assessed Criticality
Ref #	Title	Brief Description of Capability Need						
ELS-14	Lunar Dust Filtration	Need improved filtration methods for lunar dust. Control below SOA HEPA filtration is desired to protect crew. Filtration to 0.1 micron level is desired.	Exploration Life Support Project (ELS)	Funded	Improve crew health/safety, increase crew functionality, and reduce mechanical maintenance issues through improved approaches for detecting dust.	Habitat, Small Pressurized Rover, Lander	Altair FY13 Surface Systems FY14	Critical
ELS-15	Deployable Post-Fire Cleanup Device	Need small, self-contained cleanup device to remove products of combustion without having to vent cabin.	Exploration Life Support Project (ELS)	Funded	Improve crew health/safety and increase crew functionality.	Habitat, Small Pressurized Rover, Orion, Lander	Orion FY13 Altair FY13 Surface Systems FY14	Highly Desirable
ELS-16	Advanced Clothing/Fabric Cleaning Systems	Need systems to clean and repair clothing and other fabrics on the lunar surface. Consider use of anti-bacterial materials and fabrics to reduce the need for cleaning.	ETDP is not funding this activity at this time	Unfunded	Reducing amount of clothing to be transported can significantly reduce logistics mass transportation requirements	Habitat	Surface Systems FY14	Highly Desirable
Advanced Environmental Monitor and Control Project								
AEMC-1	Particulate Monitor	Technologies are needed to monitor and quantify the amount of airborne particulate matter (on a mass or surface area basis) in cabin atmospheres down to the submicron range.	Advanced Environmental Monitor and Control (AEMC) Project	Funded	Improve crew health and safety, increase crew functionality, and reduce mechanical maintenance issues through improved approaches for detecting particulates.	Habitat, Small Pressurized Rover, Lander	Altair FY13 Surface Systems FY14	Highly Desirable
AEMC-2	Improved Oxygen Monitor	Due to tight O2 control bands, require cabin O2 monitor accurate to +/- 0.05%, with longer calibration or simple calibration after long dormancy.	Advanced Environmental Monitor and Control (AEMC) Project	Funded	Improve crew health and safety and increase crew functionality.	Habitat, Small Pressurized Rover, Orion, Lander	Orion FY13 Altair FY13 Surface Systems FY14	Highly Desirable
AEMC-3	Biocide Monitor	Need a simple, reliable device that can provide rapid and accurate indications of the biocide content of processed or stored water for periodic status monitoring and off-nominal process upset assessments.	ETDP is not funding this activity at this time	Unfunded	Improve crew health and safety and increase crew functionality.	Habitat, Small Pressurized Rover	Surface Systems FY14	Highly Desirable
AEMC-4	Post Fire Cleanup Monitor	Need technologies to determine the safety of cabin atmospheres following hazardous fire events.	Advanced Environmental Monitor and Control (AEMC) Project	Funded	Improve crew health and safety and increase crew functionality.	Habitat, Small Pressurized Rover, Orion, Lander	Orion FY13 Altair FY13 Surface Systems FY14	Highly Desirable
AEMC-5	Microbial Water Quality Monitor	Need simple, reliable devices that can provide accurate and rapid indications of the microbiological content of processed water for periodic status monitoring and off-nominal process upset assessments.	Advanced Environmental Monitor and Control (AEMC) Project	Funded	Improve crew health and safety and increase crew functionality.	Habitat, Small Pressurized Rover, Orion, Lander	Orion FY13 Altair FY13 Surface Systems FY14	Highly Desirable
AEMC-6	Atmosphere Trace Contaminant Monitor	Need technology that allows long-term continuous or periodic monitoring of atmosphere concentrations of targeted trace contaminants with minimal calibration required.	Advanced Environmental Monitor and Control (AEMC) Project	Funded	Improve crew health and safety and increase crew functionality.	Habitat, Small Pressurized Rover, Orion, Lander	Orion FY13 Altair FY13 Surface Systems FY14	Highly Desirable
AEMC-7	Major Constituent Analyzer	Technology that allows long-term continuous monitoring of atmosphere concentrations of oxygen, carbon dioxide and water vapor with minimal calibration required.	Advanced Environmental Monitor and Control (AEMC) Project	Funded	Improve crew health and safety and increase crew functionality.	Habitat, Small Pressurized Rover, Orion, Lander	Orion FY13 Altair FY13 Surface Systems FY14	Highly Desirable
AEMC-8	On-line TOC monitor	Need simple, robust, automated TOC monitor to be used for process control for water processor.	ETDP is funding in out years	Funded	Improve crew health and safety and increase crew functionality.	Habitat, Small Pressurized Rover	Surface Systems FY14	Highly Desirable
Fire Prevention, Detection and Suppression Project								
FPD-1	Reliable Fire Detection	Need device to detect carbon monoxide and other fire indicators that eliminates false positives.	Fire Prevention, Detection and Suppression Project (FPDS)	Funded	Improve crew health and safety and increase crew functionality.	Habitat, Small Pressurized Rover, Orion, Lander	Orion FY13 Altair FY13 Surface Systems FY14	Highly Desirable

Technology			ETDP Project	Funding Status	Benefits Statement	Connectivity to Architecture Elements	Need Date	Architecture Assessed Criticality
Ref #	Title	Brief Description of Capability Need						
FPD-2	Partial Gravity Fire Suppression	Need technology suitable for the suppression of fires in partial-g and elevated oxygen environments.	ETDP is not funding this activity at this time	Unfunded	Improve crew health and safety and increase crew functionality	Habitat, Small Pressurized Rover, Orion, Lander	Orion FY13 Altair FY13 Surface Systems FY14	Highly Desirable
Advanced Waste Treatment Project								
AWT-1	Advanced Waste Treatment Techniques	Examine approaches for recycling, reuse, transport, removal, storage, reduction and disposal of liquid and solid wastes. Ability to convert crew trash and waste into useful consumables such as water and methane fuel is desired. Examine use of bioreactor.	ETDP is not funding this activity at this time.	Unfunded	Reduce logistics mass transportation requirements by producing water, methane, hydrogen and other consumables.	Habitat, Small Pressurized Rover	Surface Systems FY14	Highly Desirable
CREW SUPPORT AND ACCOMMODATIONS								
Extra-Vehicular Activity (EVA) Technology Development Project								
EVA-1	PLSS Packaging	EVA Systems need technology development to better package PLSS components for lunar surface missions. The Shuttle EMU packaging mass is 120% of the component mass and the Constellation target is 20%. PLSS components are expected to be heavier than Apollo components due to longer mission durations. Technology development for packaging must include both component layout to maximize suit center of gravity and the ability to perform lunar maintenance of suit components, as well as the development of materials that can support and provided structural protection for PLSS components. The benefits of this technology investment include decreased maintenance costs and improved crew performance during lunar missions.	EVA Project	Funded	Reducing PLSS mass reduces logistics mass transportation requirements and improves crew EVA comfort and productivity.	EVA Systems	EVA Systems FY13	Critical
EVA-2	Suit Ventilation	Technologies are needed to perform the functions of oxygen circulation, CO2 removal, trace contaminant removal and humidity control with minimal consumables to be replaced.	EVA Project	Funded	Reducing consumables mass reduces logistics mass transportation requirements. Improve crew EVA safety, comfort and productivity.	EVA Systems	EVA Systems FY13	Critical
EVA-3	Suit Oxygen Supply	The oxygen subsystem provides a pressurized oxygen environment for the crew member. The primary components of the oxygen subsystem are an oxygen tank and a regulator. Additional system components could include quick disconnects and flex-hoses. Need oxygen supply technologies that will decrease on-back system mass, reduce pre-breathe time for crew members and enable in-suit decompression sickness treatment. Need a liquid-oxygen based life support system to significantly reduce mass. Need lightweight O2 tanks. Need multi-set point O2 regulator options for pre-breathe protocols and DCS remediation.	EVA Project	Funded	Reducing oxygen system mass reduces logistics mass transportation requirements. Improve crew EVA safety, comfort and productivity.	EVA Systems	EVA Systems FY13	Critical
EVA-4	Suit Thermal Control	The thermal subsystem performs the function of providing temperature control of the astronaut. In the current PLSS schematic, the thermal subsystem consists of a single-phase water loop containing a pump, an evaporative cooling device and the Liquid Cooling and Ventilation Garment (LCVG) that the astronaut wears. Need technologies for suit thermal control that will provide components that meet the longer life requirements for lunar missions or eliminate consumables. They must also decrease the sensitivity of thermal subsystem components to water quality, which will make them more reliable. Lastly, development of the SWME is necessary because it has been already selected as the primary heat rejection technology for the lunar suit.	EVA Project	Funded	Reducing thermal system mass and increasing life reduces logistics mass transportation requirements. Improve crew EVA safety, comfort and productivity.	EVA Systems	EVA Systems FY13	Critical

Technology			ETDP Project	Funding Status	Benefits Statement	Connectivity to Architecture Elements	Need Date	Architecture Assessed Criticality
Ref #	Title	Brief Description of Capability Need						
EVA-5	Suit CAI	The Communications, Avionics and Informatics (CAI) system is responsible for providing communication of several types of data between the suit and the architecture network, avionics hardware to perform numerous functions, and information systems that will provide crew members data to perform their tasks more efficiently and safer. Technology developments will enable the EVA Suit System to meet current C3I requirements and also reduce crew time needed for suit operations.	EVA Project	Funded	Improve crew EVA safety and productivity.	EVA Systems	EVA Systems FY13	Highly Desirable
EVA-6	Suit Pressure Garment	Technology development is needed for suit materials and pressure garment components that will enable long duration lunar missions and be compatible with suit port operations. Need lightweight, durable, protective suit materials Provide damage resistance and tolerance. Provide protection from MMOD, radiation and solar events. Need flexible aerogels or other insulation for exploration of lunar poles and operation during lunar noon. Need materials or coatings or electrostatic charging mechanisms that will prevent dust from sticking to suits and make them easier to clean. Need joint and seal designs that are dust-resistant. Need mobility and comfort approaching shirt sleeve environment. Increased glove dexterity. More flexible and comfortable boots for walking on planetary surfaces.	ETDP is not funding this activity at this time.	Partially Funded	Increasing pressure garment life reduces logistics mass transportation requirements. Improve crew EVA safety, comfort and productivity	EVA Systems	EVA Systems FY13	Critical
EVA-7	Recovery of EVA CO2 and H2O	Need technologies to enable the recovery of carbon dioxide and water from EVA Portable Life Support System (PLSS) equipment.	ETDP is not funding this activity at this time.	Unfunded	Reduce logistics mass transportation requirements by closing PLSS ECLSS loop.	EVA Systems	EVA Systems FY13	Highly Desirable
EVA-8	Lightweight Efficient Suitport/Suitlock/Airlock Technologies	Need minimum gas loss systems that can depress and repress quickly and keep suits in suitlock or suitport for dust mitigation and not require a large amount of power. Need systems that are dust sealing and long life. Need hatches that are common, reduced swing, pressure and non-pressure assisted.	ETDP is not funding this activity at this time.	Unfunded	Improve crew EVA safety and productivity.	EVA Systems, Habitat, Small Pressurized Rover, Possibly Lander	Altair FY13 Surface Systems FY14 EVA Systems FY13	Critical
EVA-9	Rapid-Recharge EVA Suit	Rapid recharge capability enables a shorter duration life support system resulting in mass savings. Rapid recharge allows for unrestricted EVA duration in extreme environments and enhances safety in the case of suit or rover failures. Need efficient, dust proof connectors for rapid recharge and airlock use.	ETDP is not funding this activity at this time.	Unfunded	Improve crew EVA safety and productivity.	EVA Systems, Habitat, Small Pressurized Rover	Surface Systems FY14 EVA Systems FY13	Highly Desirable
IN-SITU RESOURCE UTILIZATION (ISRU)								
In-Situ Resource Utilization (ISRU) Project								
ISRU-1	Excavation and Handling of Regolith for Oxygen Production	Capability is required to provide regolith feedstock for oxygen extraction. Architecture currently baselining production of 1000 kg of O2/yr minimum. Need excavation rates of <150 kg/hr at a depth of up to <12 cm below the surface. Desire operational life of systems of 3 years in temperature range of 123 to -88 C. Need to understand reduced gravity effects and dust abrasion and mitigation approaches. Excavation and regolith transfer concepts need to be developed in conjunction with available human robotic systems platforms.	ISRU Project	Funded	Producing in-situ oxygen could reduce logistics mass transportation requirements and demonstrate technologies for Mars exploration.	ISRU, Power Systems, Habitat	Surface Systems FY14 ISRU FY16	Highly Desirable
ISRU-2	Oxygen and Water Extraction and Production from Regolith	Need capability to produce a minimum of 1000 kg of oxygen and or 1000 kg of water per year. Need to process over two kg/hr of oxygen. Desire operational life of systems of three years in temperature range of 123 to -88 C.	ISRU Project	Funded	Producing in-situ oxygen could reduce logistics mass transportation requirements and demonstrate technologies for Mars exploration	ISRU, Power Systems, Habitat	Surface Systems FY14 ISRU FY16	Highly Desirable

Technology			ETDP Project	Funding Status	Benefits Statement	Connectivity to Architecture Elements	Need Date	Architecture Assessed Criticality
Ref #	Title	Brief Description of Capability Need						
ISRU-3	Excavation and Handling of Regolith for Site Preparation	Need capability to clear landing area of hazards (rocks, pits, etc.), build berms for exhaust plume or radiation shield production, clear pathways and areas for payload delivery and outpost hardware emplacement, excavate for nuclear reactor placement, etc. Need capability to excavate down to three meters in depth and build berms up to three meters in height. Need to provide regolith stabilization or hardening techniques including microwave/solar sintering technologies. Desire operational life of systems of three years in temperature range of 123 to -88 C.	ETDP is not funding this activity at this time.	Unfunded	Enables proper construction of lunar outpost. Minimizing potential hazards improves crew safety and mission success. Demonstrate technologies for Mars exploration.	All Surface Systems	Surface Systems FY14 ISRU FY16	Highly Desirable
ISRU-4	Prospecting for Minerals and Volatiles for ISRU	Efficiency of volatiles (hydrogen, carbon, nitrogen, helium) extraction from regolith is based on regolith feedstock. Need capability to map regolith minerals over area near outpost production plant could increase ISRU productivity.	ETDP is not funding this activity at this time.	Unfunded	Producing in-situ volatiles could reduce logistics mass transportation requirements and demonstrate technologies for Mars exploration.	ISRU, Power Systems, Habitat	Surface Systems FY14 ISRU FY16	Desirable
ISRU-5	Volatile Extraction and Production From Regolith	Need capability to extract large amounts of in-situ volatiles (hydrogen, carbon, nitrogen, helium). Desire operational life of systems of three years in temperature range of 123 to -88 C.	ETDP is not funding this activity at this time.	Unfunded	Producing in-situ volatiles could reduce logistics mass transportation requirements and demonstrate technologies for Mars exploration.	ISRU, Power Systems, Habitat	Surface Systems FY14 ISRU FY16	Desirable
ROBOTICS, OPERATIONS AND SUPPORTABILITY								
Supportability Project								
SUP-1	Minimally Intrusive Detection, Repair, and Self-Repair	Need technologies for detecting damage and providing self-repair and self-healing. A need exists for materials and systems that increase sustainability, provide supportability, enhance robustness as well as improve safety and reliability.	Supportability Project	Funded	Reduces crew risk and chance for mission abort. Decreases logistics mass resupply requirements by increasing system life.	All Surface Systems	Surface Systems FY14	Highly Desirable
SUP-2	Corrosion Detection & Control	Need technologies for the prevention, detection and mitigation of corrosion in spaceport facilities and ground support equipment, including refractory concrete. Need technologies which implement protective barriers as well as controlled release of corrosion inhibitors. Need reactive technologies, such as the integration of corrosion detection into the paint itself, which have significant advantages over current corrosion detection techniques.	Supportability Project	Funded	Reduces life-cycle costs of ground support equipment.	Ground Operations	Ground Operations FY09	
SUP-3	Non-Destructive Evaluation Techniques	Need lightweight portable capability to remotely inspect structures and to inspect subsystems through insulation, shielding or structures. Examine a variety of advanced methods (e.g., Microwave Millimeter Scanning, Positron Annihilation Imaging, Magneto-Optical Imaging, Broadband Dielectric Spectroscopy). Need to verify integrity of critical structures and insulation. Lightweight, low power, portable NDE in-situ inspection tools for damage, leaks, thermal, electrostatic charge, moisture and dust contamination are needed.	ETDP is not funding this activity at this time.	Unfunded	Reduces crew risk and chance for mission abort. Decreases logistics mass resupply requirements by increasing system life.	All Surface Systems	Surface Systems FY14	Highly Desirable
SUP-4	Free-Form Manufacturing Techniques	Ability to manufacture and repair hardware may be critical for lunar sustainability and enabling for long-stays on Mars. Need capability to manufacture a variety of spare parts from extracted ores or transported raw materials using lightweight, lower-power systems (e.g., low-voltage electron beam fabrication methods)	ETDP is not funding this activity at this time.	Unfunded	Reduces crew risk and chance for mission abort. Decreases logistics mass resupply requirements by increasing system life.	All Surface Systems	Surface Systems FY14	Desirable
SUP-5	Advanced Field Repair Techniques	Techniques and lightweight tools are required to repair and replace habitat system structures, mechanisms and electronics on-site with minimal training or expertise. Systems will need to be spared and repaired on the surface. Replacement or repair will occur during brief EVA, or during long robotic caretaking periods.	ETDP is not funding this activity at this time.	Unfunded	Reduces crew risk and chance for mission abort. Decreases logistics mass resupply requirements by increasing system life.	All Surface Systems	Surface Systems FY14	Highly Desirable

Technology			ETDP Project	Funding Status	Benefits Statement	Connectivity to Architecture Elements	Need Date	Architecture Assessed Criticality
Ref #	Title	Brief Description of Capability Need						
SUP-6	Helium consumption reduction technologies	Technology development is desired in the areas of advanced sensors to provide real-time purity analysis, capture and re-purification systems which can reduce total quantity of helium needed to be procured, and alternative purge technologies which can eliminate helium purging in certain systems	ETDP is not funding this activity at this time	Unfunded	Reducing helium consumption will provide a minor reduction in life cycle costs. It could reduce risk if a helium shortage were to actually occur,.	Ground Operations	Ground Operations FY09	Desirable
Human Robotic Systems Project								
HRS-1	Wheel-on-Limb Mobility Systems	System improvements needed for wheel-on-limb mobility systems including light weight, high-speed adaptive suspension using modest power, a variety of tool-use scenarios (e.g., picking up or drilling samples and putting in glove box) and night driving.	Human Robotic Systems Project	Funded	Enable exploration over a variety of terrain and soil, increasing science return and reducing probability of mission failure. Enable off-loading of payloads from tall landers and tool manipulation, increasing design flexibility and reducing EVA requirements.	Habitat, Surface Mobility	Surface Systems FY14	Critical
HRS-2	Wheels for the Lunar Environment	Need lunar wheels with 10,000 km life, 40K to 400K operating temperature, and capable of carrying 100X own weight.	ETDP is not funding this activity at this time	Unfunded	Enable exploration over a variety of temperature extremes, increasing science return and reducing probability of mission failure. Reduce system mass and increase life, thereby reducing logistics mass transportation requirements	Surface Mobility	Surface Systems FY14	Critical
HRS-3	Automated Docking of Rovers	Need capability to have rovers return to Altair or other outpost docking station and automatically dock, providing a reliable recharge cycle. This capability is needed for service when crew are not present on the surface.	Human Robotic Systems Project	Funded	Allowing repeated autonomous recharge cycles reduces EVA requirements and increases science return.	Surface Mobility	Surface Systems FY14	Highly Desirable
HRS-4	Long-Life High-Performance Drivetrain and Suspension Systems	Need mechanisms suitable for long life in lunar regolith/dust environment Need to operate over 10,000 km within a period of 5 years Need mechanisms that can transport heavy loads. Need drive/steering/suspension units that can be easily serviced/replaced.	Human Robotic Systems Project	Funded	Enable exploration over a variety of temperature extremes, increasing science return and reducing probability of mission failure. Reduce system mass and increase life, thereby reducing logistics mass transportation requirements.	Surface Mobility	Surface Systems FY14	Critical
HRS-5	Automated Payload Offloading	Need the ability to deploy a payload from an Altair bay to the surface or to a waiting vehicle. Need the ability to offload payloads from vehicles at the final use-site of the payload.	Human Robotic Systems Project	Funded	Enables offloading of payload without the presence of crew, increasing design flexibility and reducing EVA requirements.	Surface Mobility, Logistics, Science Payloads	Surface Systems FY14	Critical
HRS-6	Environmentally Robust Electrical Docking for Rover	Solar powered and RTG powered rovers are low power systems, with top speeds on the order of 10-30 cm/s. Human mobility will need rates on the order of 1-3 m/s. Recharging enables long life, EVA speed and human-scaled rovers.	Human Robotic Systems Project	Funded	Allowing rapid repeated autonomous recharge cycles reduces EVA requirements and increases science return.	Surface Mobility	Surface Systems FY14	Highly Desirable
HRS-7	Lunar Rover Active Suspension Systems	Apollo crew reported difficulty in maintaining control of the Lunar Roving Vehicle when driving at or above 10 kph. Applying modern, active suspension control systems to the lunar environment would expand range, improve controllability and reduce crew fatigue.	Human Robotic Systems Project	Funded	Enable exploration over a variety of terrain, increasing science return and reducing probability of mission failure. Reduce crew fatigue, thereby improving EVA productivity.	Surface Mobility	Surface Systems FY14	Highly Desirable

Technology			ETDP Project	Funding Status	Benefits Statement	Connectivity to Architecture Elements	Need Date	Architecture Assessed Criticality
Ref #	Title	Brief Description of Capability Need						
HRS-8	Advanced Crew Accommodations for Mounting Suited Subjects	The seated posture of the Apollo Lunar Roving Vehicle was uncomfortable and provided limited viewing. A better interface is needed, with upright and other postures being considered. Connections to rover data systems, suit recharge systems and communication is also needed.	Human Robotic Systems Project	Funded	Reduce crew fatigue, and improve EVA productivity.	Surface Mobility	Surface Systems FY14	Desirable
HRS-9	High-Dexterity Robotic Manipulation Systems	Need systems for remote manipulation from pressurized rover or for teleoperated rover that are lightweight and highly dexterous and can operate in lunar dust environment.	Human Robotic Systems Project	Funded	Improve human safety and science productivity through reduction in EVA requirements. Increase system life, thereby reducing logistics mass resupply requirements.	Habitat, Surface Mobility	Surface Systems FY14	Highly Desirable
HRS-10	Light Weight, Lower Power Element Mating Mechanism	Need to berth or dock module-to-module and module-to-rover. Need high-level of automation, not requiring crew EVA. Need to operate with low power. Needs dust-tolerant seals and to maintain seal integrity over multiple cycles.	ETDP is not funding this activity at this time.	Unfunded	Improve human safety and productivity through automation and reduced EVA requirements. Reduce system mass.	Habitat, Surface Mobility	Surface Systems FY14	Highly Desirable
HRS-11	Common Lightweight Interfaces for Payloads and Surface Elements	Common lightweight interfaces that could be used in many or all payloads are desired. These interfaces would be used for all operations, from ground handling, launch integration, payload handling on the lunar surface, through final emplacement on the surface.	ETDP is not funding this activity at this time.	Unfunded	Reduces mass of structure, allowing increased payload to the surface and/or enabling architecture closure.	Lander, Surface Mobility	Altair FY13 Surface Systems FY14	Desirable
COMMUNICATIONS AND NAVIGATION								
Communications and Navigation Technologies								
CN-1	Lunar Wireless Network	Need system to support 15 simultaneous users with aggregate bandwidth of 60 mbs at extended ranges to at least 5.6 km. Need to support minimum data rates of 16 kbs and maximum data rates of 20 mbs Need to be able to convert conventional IP stacks to SN stacks.	Space Operations Mission Directorate funded Additional information on this funding is not available.	Funded	Improve situational awareness and communications, improving operational efficiency.	Communication Systems, EVA Systems, Surface Mobility Systems	Communication Systems FY14 EVA Systems FY13 Surface Systems FY14	Highly Desirable
CN-2	Lunar Surface Communication Radios	Need user network radios to communicate with the LCT and LCS using the same waveforms and protocols (form factor will differ between rover network radio and astronaut suit radios). Need to be able to support surface needs.	Space Operations Mission Directorate funded Additional information on this funding is not available.	Funded	Improve situational awareness and communications, improving operational efficiency.	Communication Systems, EVA Systems, Surface Mobility Systems	Communication Systems FY14 EVA Systems FY13 Surface Systems FY14	Desirable
CN-3	Delay/Disruption Tolerant Networking	Need delay and disruption tolerant networks to provide a network that can operate in disrupted and intermittently connected networks and the time delays common between the Earth and the lunar surface.	Space Operations Mission Directorate funded Additional information on this funding is not available.	Funded	Improve crew safety and mission reliability. Improve situational awareness and communications, improving operational efficiency.	Communication Systems, EVA Systems, Surface Mobility Systems	Communication Systems FY14 EVA Systems FY13 Surface Systems FY14	Highly Desirable
CN-4	Lightweight Atomic Clock/Ultra Stable Oscillator	Need ion clock with performance of 10E-13 drift per day to support navigation requirements.	Space Operations Mission Directorate funded Additional information on this funding is not available.	Funded	Improve situational awareness and communications, improving operational efficiency.	Communication Systems, EVA Systems, Surface Mobility Systems	Communication Systems FY14 EVA Systems FY13 Surface Systems FY14	Desirable

Technology			ETDP Project	Funding Status	Benefits Statement	Connectivity to Architecture Elements	Need Date	Architecture Assessed Criticality
Ref #	Title	Brief Description of Capability Need						
CN-5	Mobile User Objective Service (MUOS) Radio	Need low-mass space-qualified MUOS radio for dissimilar voice and Emergency Return Mode communications. Need highly integrated, low mass, low power MUOS/UHF sub-system. Need dynamic Doppler compensation for MUOS waveform using no information from Orion. Need ability to transmit non-spread QPSK waveform at UHF from LLO to the DSN.	Space Operations Mission Directorate funded Additional information on this funding is not available.	Funded	Improve situational awareness and communications, improving operational efficiency.	Communication Systems, EVA Systems, Surface Mobility Systems	Communication Systems FY14 EVA Systems FY13 Surface Systems FY14	Desirable
CN-6	High Data Router	Need to provide high data routing of 300 Mbps among the lunar assets, between those assets and Earth. The first is to provide the necessary support for the crew and mission needs and for analysis of critical events. The later is to disseminate discovered information from the lunar surface to the public, to researchers and to mission control.	Space Operations Mission Directorate funded Additional information on this funding is not available.	Funded	Improve situational awareness and communications, improving operational efficiency.	Communication Systems, EVA Systems, Surface Mobility Systems	Communication Systems FY14 EVA Systems FY13 Surface Systems FY14	Desirable
CN-7	Low Lunar Orbit Attitude Control	Attitude maintenance in LLO for long periods of time will require development of new control techniques which may require novel non-linear control methodologies.	ETDP is not funding this activity at this time.	Unfunded	Marginally reduce propellant mass and improve mission reliability.	Orion	Orion FY13	Desirable
CN-8	Integrated Onboard GN&C System	Need automated GN&C hardware and software system to provide crew with mission-preserving on-board operations during loss-of-communications events. Also need automated GN&C for all mission phases, including orbit, landing and RPODU.	ETDP is not funding this activity at this time.	Unfunded	Improve mission reliability.	Orion, Lander	Orion FY13 Altair FY13	Highly Desirable
CN-9	IPsec for Lunar	Managing IPsec keys and security policies for the lunar phase will require technology advancements due to needs beyond those developed for terrestrial and LEO environments.	ETDP is not funding this activity at this time.	Unfunded	Improve data security and communications reliability.	Communication Systems	Communication Systems FY14	Desirable
CN-10	Wireless Spacecraft	Need to increase on-board data flow (e.g., avionics and or crew to off-board data) through reliable RF communication capable of mitigating vehicle internal multipath distortion while reducing overall mass due to spacecraft cabling. Potentially allows lower vehicle mass through highly reduced cabling needs. Allows for spacecraft bus scalability.	ETDP is not funding this activity at this time.	Unfunded	Improve communications reliability and reduce system mass.	Communication Systems, Orion	Orion FY13 Communication Systems FY14	Highly Desirable
CN-11	Mixed Signal Technology	A common mixed signal technology is needed that can provide radiation-tolerant, fault-tolerant operation across all architecture elements.	ETDP is not funding this activity at this time.	Unfunded	Improve situational awareness and communications, improving operational efficiency.	Communication Systems, EVA Systems, Surface Mobility Systems	Communication Systems FY14 EVA Systems FY13 Surface Systems FY14	Desirable
CN-12	Software Defined Radio for Altair S-Band Communications	A low mass, space qualified, multi-functional S-band Radio is desired that supports multiple S-band frequencies and data rates, multiple C3I data formats/waveforms, radiometric functions to provide range/range-rate, and normal and reverse band operations.	ETDP is not funding this activity at this time.	Unfunded	Improve situational awareness and communications, improving operational efficiency.	Communication Systems	Communication Systems FY14	Highly Desirable
CN-13	Surface Over-the-Horizon Communications Technologies	Capability is desired for non-line-of-sight, low-frequency radios that exploit the unique surface signal propagation environment, combined with advanced coded modulation techniques as well as non-powered optical surface relays, to provide safety critical backup surface communications capability for remote surface exploration and when surface assets and orbiting satellites are not in view.	ETDP is not funding this activity at this time.	Unfunded	Improve situational awareness and communications, improving operational efficiency.	Communication Systems	Communication Systems FY14	Desirable
High-Bandwidth Communication Project								
HBC-1	High-Bandwidth, Advanced Optical Communications	Need optical based terminals to enable high bandwidth links to support surface to surface, surface to space and direct to Earth communications. Need to transmit at a gigabit/sec and receive at ten megabits/sec. Need photon counting detectors at 1.5 micron wavelength, two-way ranging with centimeter class precision and clock synchronization.	High-Bandwidth Communication Project	Funded	Significantly increase data transmission capacity for high-definition video and other applications.	Communication Systems	Communication Systems FY14	Desirable