



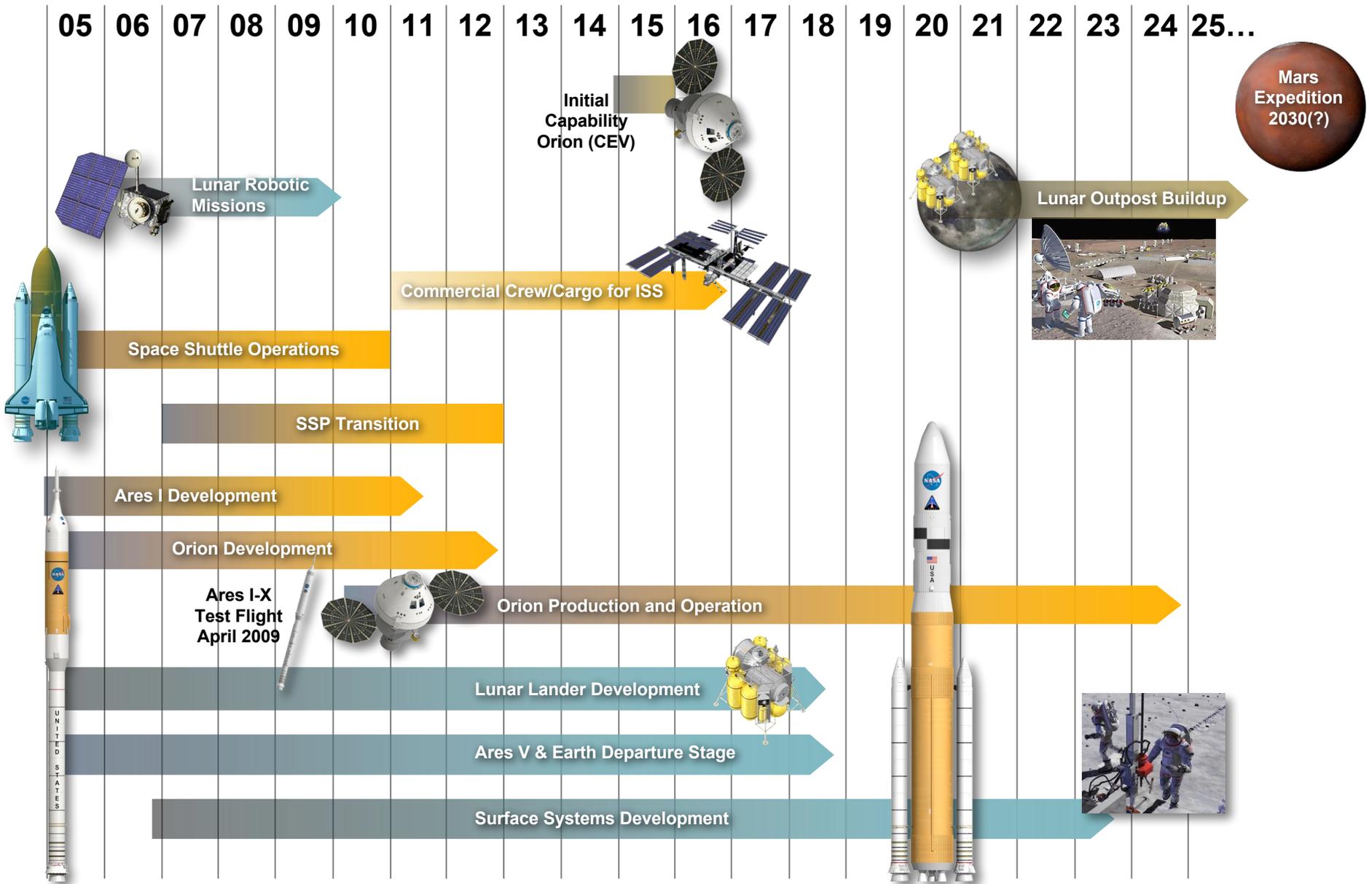
# 3<sup>RD</sup> SPACE EXPLORATION CONFERENCE & EXHIBIT

## Constellation Program's Technology Development Needs

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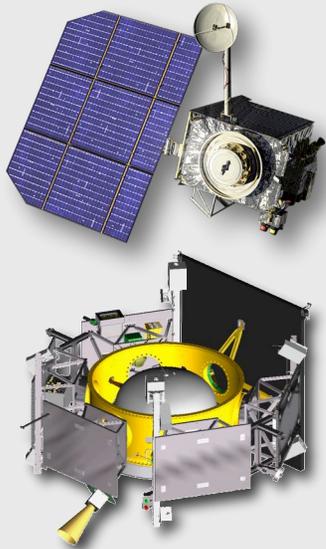
# Exploration Roadmap



# Enabling Exploration

## Advanced Capabilities Division (ACD)

### Lunar Precursor Robotic Program



### Human Program



### Technology Program



## Commercial Crew Cargo Program

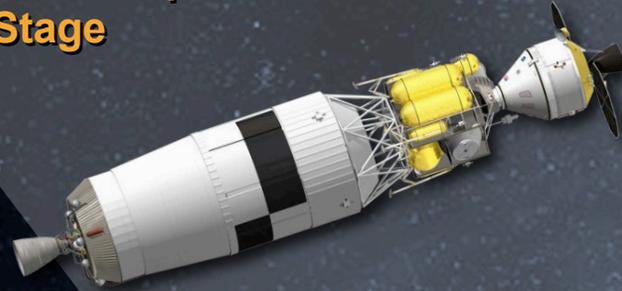


## Constellation Program



# Constellation Program Fleet of Vehicles

Earth Departure Stage



Orion Crew Exploration Vehicle



Ares I Crew Launch Vehicle



Ares V Cargo Launch Vehicle

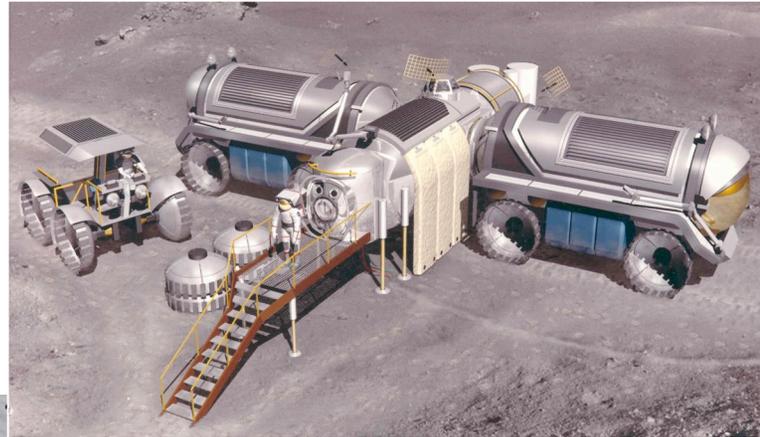


Lunar Lander



1 2 3 4

# Lunar Surface Systems



## **CxP's Technology Development Needs: Determination & Prioritization Methodology**

- ◆ CxP determines and prioritizes its technology development needs to support NASA budget cycle
  - Goal is to ensure ESMD's technology development investments are traceable to requirements or Needs, Goals, and Objectives
  - Requirements driven approach
- ◆ Priorities allow CxP to smartly pursue collaboration opportunities with externalities
- Technology Needs Assessment uses existing Program analyses: risk assessments, requirements achievability assessments, technical performance measures, supportability assessments, breath of applicability, and engineering judgment

## Timeframe/Criticality Groupings

- ◆ Tech Develop Needs grouped by timeframe and criticality
- ◆ Timeframes: Initial Capability (IC), Lunar Transport (LT), Lunar Surface (LS), and Mars Forward (MF)
- ◆ Criticalities: critical, highly desirable (HD), and desirable
- ◆ 12 groups include:

IC – critical	LT – critical	LS – critical	MF- critical
IC – HD	LT – HD	LS – HD	MF – HD
IC – desir	LT – desir	LS – desir	MF – desir

- ◆ Needs prioritize within each of these groups

# Program-Level Prioritization Methodology

- ◆ CxP established a Technology Prioritization Panel (TPP) to integrate all projects' and SIGs' needs into the CxP prioritized list
- ◆ TPP membership consists of senior managers
- ◆ Final TPP results approved at CxP Control Board

# CxP's Technology Needs Summary

Count of ID	Initial Capability			IC TOTAL	Lunar Surface			LS TOTAL	Lunar Transport			LT TOTAL	Mars		Mars TOTAL	Grand Total
	Critical	Highly Desirable	Desirable		Critical	Highly Desirable	Desirable		Critical	Highly Desirable	Desirable		Critical	Highly Desirable		
Submitting Project/SIG																
Project - Ares	5			5					10			10				15
Project - EVA Systems	1			1					7			7				8
Project - Ground Operations		6		6												6
Project - Lunar Lander									11	3	6	20				20
Project - Lunar Surface Systems					32	47	19	98	2	1	1	4				102
Project - Mission Operations		7		7		7		7		7		7				21
Project - Orion	5	4		9					9	4	1	14		1	1	24
SIG - Environments & Constraints					1	5		6		3		3				9
SIG - Ground & Mission Ops						2		2								2
SIG - Integrated Loads, Struct & Mech		3	1	4		9	9	18		3	1	4				26
SIG - Integrated Power Loads					1			1		1		1				2
SIG - Supportability, Oper, Afford						3		3								3
SIG - SW & Avionics Integration Office		3		3	3	3	1	7	2	10		12	3		3	25
SIG - Thermal & ECLSS	1	4		5	3	6	1	10	4	10	2	16				31
SIG- Flight Performance				0				0				0			0	0
<b>Grand Total</b>	<b>12</b>	<b>27</b>	<b>1</b>	<b>40</b>	<b>40</b>	<b>82</b>	<b>30</b>	<b>152</b>	<b>45</b>	<b>42</b>	<b>11</b>	<b>98</b>	<b>3</b>	<b>1</b>	<b>4</b>	<b>294</b>

# Needs Mapped to ESMD's Technology Development Program (ETDP)

- ◆ CxP and ETDP mapped needs to ETDP's development projects
  - Determined which needs are within/out of scope of ETDP
  - Distinguish between Technology Development vs. Research vs. Engineering
  - Limited ETDP budget
  - Scope the work, schedule and budget
- Insufficient ETDP funding to cover all needs

# Critical Lunar Technology Development Collaboration Opportunities

- ◆ Advanced Composite
- ◆ Mass Reduction Technologies
- ◆ Dust: Simulants, Mitigation, Filtration, Clean-up & Dust Tolerant Hardware
- ◆ Cryo Fluids Management
- ◆ Energy Storage & Power
- ◆ Surface Communications
- ◆ Surface Mobility
- ◆ Lunar Surface Habitation

# Plan Forward

- ◆ Pursue tech development collaborations to meet needs
  - Internal to NASA – other NASA Mission Directorates, International Space Station, etc.
  - Externally – Academia, industry, national laboratories, DOD, etc.
  
- ◆ Plan to post CxP's prioritized needs and quad charts to:  
[http://www.nasa.gov/directorates/esmd/home/tech\\_exchange\\_conf.html#participants](http://www.nasa.gov/directorates/esmd/home/tech_exchange_conf.html#participants)

# **CxP's Technology Development Priorities**

# Initial Capability - Top Priorities (Critical with Top 7 HD)

TPP Rank	Criticality	Title	ROO
1	critical	521: Shell Buckling	Ares
2	critical	522: Friction Stir Welding of Spun Formed Dome	Ares
3	critical	391: Robustness Options for Orions Baseline PICA Heat Shield	Orion
4	critical	101: CO2/Humidity removal for open-loop ARS	Thermal/ECLSS SIG (Orion, EVA, Lander)
5	critical	548: Suit Pressure Garment	EVA
6	critical	528: Composite damage tolerance/detection	Ares
7	critical	523: Solid Rocket Motor Health Management	Ares
8	critical	530: Composite joining technology	Ares
9	critical	305: Carrier Structure Sensitivity to Defects	Orion
1	HD	306: SM Main Engine Composite Nozzle	Orion
2	HD	561: Cryogenic Fluid Management	GO
3	HD	566: Corrosion Detection & Control	GO
4	HD	575: Minimally Intrusive Repair, Detection & Self-Repair	GO
5	HD	567: Automation for mission Ops - IC	MO
6	HD	574: Integrated System Health Management (ISHM) - Prognostic	GO
7	HD	304: PICA Bond System Design & Margin	Orion
10	critical	322: Natural Feature Image Recognition (FY08 funded)	Orion
11	critical	324: Parallel Path to VNS (FY08 funded)	Orion
	<b>Key:</b>		
		Part of ETDP Portfolio	
		Not currently funded	
		NESC	

**Highly Desirables  
TPP agreed were  
higher priority than  
criticals below**

# Initial Capability - Highly Desirable

<u>TPP Rank</u>	<u>Title</u>	<u>ROO</u>
8	256: SW&Avionics-Modular DFI/LFI (Instrumentation) for Orion & Ares	ILSM
9	568: Software Development Tools - IC	MO
10	589: Advanced Caution and Warning Systems for CxP Mission Op	MO
11	578: Spacecraft Alignment Systems	GO
12	579: Water Detection & Removal	GO
13	109: Biocide	Thermal/ECLSS SIG
14	590: Semantic Technologies, Ontology and Registry Development	MO
15	204: Software Verification and Validation Technologies	SAVIO
16	202: Mobile User Objective Service (MUOS) Radio	SAVIO
17	257: SW&Avionics - Modular Instrumentation Systems for ILSM	ILSM
18	591: Mission Monitoring Tools - IC	MO
19	592: CFDP Compatible Tools - IC	MO
20	265: Integrated High Fidelity Analysis Tools	ILSM
21	325: Lidar Feature Recognition	Orion
22	110: Urine pretreatment	Thermal/ECLSS SIG
23	203: Wireless Spacecraft	SAVIO
24	125: Fire Detection that eliminates false positives	Thermal/ECLSS SIG
25	593: Training Support Technologies - IC	MO
26	111: Urine receptacle assembly	Thermal/ECLSS SIG
27	301: Pilot in the Loop Vibration Simulation	MO
<b><u>Key:</u></b>		
	Part of ETDP Portfolio	
	Not currently funded	
	NESC	

## Transport - Top Priorities (Critical with top 3 HD)

<u>TPP Rank</u>	<u>Criticality</u>	<u>Title</u>	<u>ROO</u>
1	critical	462: High reliability LOX/LH2 Throttling Engine	Lander
2	critical	463: Cryogenic Fluid Management	Lander
3	critical	524: Large Composite Manufacturing	Ares
4	critical	464: LO2/LCH4 Main Engine & RCS	Lander
5	critical	527: Long-term Cryogenic Storage	Ares
6	critical	538: Composite Primary Structure Technology	Lander
7	critical	387: CEV Parachute Materials	Orion
8	critical	542: Suit Ventilation	EVA
9	critical	526: HTPB Propellant	Ares
10	critical	537: Hazard Detection and Avoidance	Lander
11	critical	124: Phase Change Material	Thermal/ECLSS SIG
12	critical	544: Suit Power	EVA
13	critical	303: Composite Carrier Structure	Orion
14	critical	390: Robust Ablative Heat Shield Architecture	Orion
15	critical	543: PLSS Packaging	EVA
16	critical	525: TVC architecture development to minimize operations (EHA)	Ares
17	critical	601: Airlock /habitat hatches that are dust sealing, long life, common, etc.	LSS
18	critical	541: Radiation Effects Mitigation and Environmental Hardness	Lander
19	critical	302: Alternate Weight Saving Window Materials	Orion
20	critical	545: Suit Oxygen Supply	EVA
21	critical	546: Suit Thermal Control	EVA
22	critical	607: CO2 & Moisture Removal System	Lander
23	critical	531: Liquid Level Measurement	Ares
24	critical	532: Multi-layer Insulation	Ares
25	critical	594: Advancd Airlock/ Suitlock with Dust Filtration	LSS

# Transport - Top Priorities (Critical with top 3 HD) cont'd

<u>TPP Rank</u>	<u>Criticality</u>	<u>Title</u>	<u>ROO</u>
26	critical	529: EDS state determination/abort	Ares
27	critical	465: Low Cycle Life Rechargeable Battery	Lander
28	critical	466: Low mass, high reliability PEM fuel cell	Lander
29	critical	386: Optically Efficient Coating for Backshell TPS	Orion
30	critical	539: Crewed Composite Pressure Vessel Design and Validation	Lander
31	critical	105: Lunar dust filtration	Thermal/ECLSS SIG
32	critical	549: Suit Pressure Garment	EVA
33	critical	610: High Pressure Oxygen	Lander
34	critical	534: Leak Detection	Ares
35	critical	547: Suit CAI	EVA
1	<b>HD</b>	627: Lander dust mitigation	Lander
2	<b>HD</b>	612: Sublimator-driven coldplate	Lander
3	<b>HD</b>	540: High Reliability Power Efficient Actuators	Lander
36	critical	536: Pneumatic actuator system- primarily guided actuator (gas strut)	Ares
37	critical	535: Nozzle sensitivity to pocketing/ ply lifting using HTPB	Ares
38	critical	326: Low Lunar Orbit Attitude Control	Orion
39	critical	123: Heat rejection systems	Thermal/ECLSS SIG
40	critical	383: Integrated Onboard GN&C System	Orion
41	critical	384: High Performance, Non-Toxic Monopropellant for CM RCS	Orion
42	critical	207: Cable-Reduction Technology	SAVIO
43	critical	102: Post-fire cleanup (combustion products) monitor	Thermal/ECLSS SIG
44	critical	205: IPsec for Lunar	SAVIO
45	critical	323: Lunar Navigation Technologies	Orion
	<b>Key:</b>		
		Part of ETDP Portfolio	
		Not currently funded	
		NESC	

HD of higher priority than criticals below

## Transport - Highly Desirable

<u>TPP Rank</u>	<u>Title</u>	<u>ROO</u>
4	272: Friction Stir Weld and Friction Stir Processing Improvements	ILSM SIG
5	602: Automation for mission Ops - LT	MO
6	181: Modular Power System Components	Int. Power Loads SIG
7	107: Deployable post-fire cleanup device	Thermal/ECLSS SIG
8	657: Advanced Caution and Warning Systems for CxP Mission Op	MO
9	262: Composite Tankage for wet storage	ILSM SIG
10	208: High Density, Low Power, Rad-Tolerant Volatile Memory Tech	SAVIO
11	103: Targeted trace contaminant adsorbents	Thermal/ECLSS SIG
12	277: Thermal - Lunar Mission CEV Re-Entry TPS	ILSM SIG
13	419: Mobile User Objective Service (MUOS) Radio	SAVIO
14	603: Software Development Tools - LT	MO
15	394: Coupling of Aerothermal and TPS Material Response Tools	Orion
16	660: Mission Monitoring Tools - LT	MO
17	210: Reconfigurable Fault Tolerance Technology	SAVIO
18	388: Improved Aerothermodynamic Modeling for Database Generation	Orion
19	701: Hydrogen Fuel cell reactant chilling/liquefaction	LSS
20	229: Radiation Charging Analysis Tool (RCAT)	Environments & Constraints SIG
21	604: Semantic Technologies, Ontology and Registry Development	MO

## Transport - Highly Desirable Cont'd

<u>TPP Rank</u>	<u>Title</u>	<u>ROO</u>
22	420: Wireless Spacecraft	SAVIO
23	228: NASCAP Lunar Update	Environments & Constraints SIG
24	209: Mixed Signal Technology	SAVIO
25	389: Flight Spectrometer Development	Orion
26	392: Integrated Aerothermal/TPS Analysis of Arc Jet Testing	Orion
27	227: Lunar Macroscale Plasma Model	Environments & Constraints SIG
28	214: Extend fault diagnostic and prognostic tools	SAVIO
29	106: Improved oxygen monitor	Thermal/ECLSS SIG
30	664: CFDP Compatible Tools - LT	MO
31	475: Biocide development	Thermal/ECLSS SIG
32	108: Particulate monitor	Thermal/ECLSS SIG
33	476: Urine pretreatment	Thermal/ECLSS SIG
34	213: Modeling software-intensive systems	SAVIO
35	211: Multi-Function Structure Technology	SAVIO
36	215: Compliance and Model Checkers for mission-critical software	SAVIO
37	477: Urine receptacle assembly	Thermal/ECLSS SIG
38	478: Fire detection that eliminates false positives	Thermal/ECLSS SIG
39	127: Lightweight and low volume HX and coldplates	Thermal/ECLSS SIG
40	666: Training Support Technologies - LT	MO
41	216: High Data Router -- Roo:SIG - SW & Avionics Integration	SAVIO
42	121: Biocide monitor	Thermal/ECLSS SIG

# Surface - Critical

<u>TPP Rank</u>	<u>Title</u>	<u>ROO</u>
1	611: Dust-Tolerant EVA-Compatible Connectors	LSS
2	606: Lunar Surface Energy Storage - Regenerative Fuel Cells	LSS
3	595: Wheel-on-limb mobility systems (ILSM 251)	LSS
4	623: Dust/Regolith Mitigation Techniques within Habitable Cabin	LSS
5	605: Wheels for the lunar environment	LSS
6	625: Dust Control/ Remove Airborne Dust	LSS
7	639: Water Recovery with Limited Resupply	LSS
8	608: Automatic docking of rovers for service during periods	LSS
9	614: Surface Comm: Lunar Wireless Network	LSS
10	632: Long-Life High-Performance Drivetrain and Suspension System	LSS
11	609: Dust Mitigation of Mechanical Components	LSS
12	619: Integrated Systems Health Management	LSS
13	636: Lunar regolith and dust simulant development, evaluation	LSS
14	640: Evaporative Heat Sink for Advanced Thermal Control Sys	LSS
15	217: Delay/Disruption Tolerant Networking	SAVIO
16	641: Heat Exchangers and Coldplates for Advanced Thermal Control	LSS
17	643: Heat Rejection Systems and Models for Advanced Thermal	LSS
18	644: Carbon Dioxide Reduction	LSS
19	647: Oxygen liquefaction, storage, surface transfer & distribution	LSS
20	648: Automatic payload offload to deploy equipment from lander to surface	LSS

## Surface - Critical Cont'd

<u>TPP Rank</u>	<u>Title</u>	<u>ROO</u>
21	221: High Density, Low Power, Rad-Tolerant Non Volatile Memo	SAVIO
22	642: Long-Duration Advanced Thermal Control System Fluids	LSS
23	645: High Pressure Oxygen Supply	LSS
24	633: Dust degradation effects and mitigation for thermal control sys	LSS
25	286: Lunar Meteoroid Ejecta Environment Model	Environments & Constraints SIG
26	622: Environmentally robust electrical docking for rover com	LSS
27	471: Phase Change Material	Thermal/ECLSS SIG
28	112: Improved CO2 removal for loop closure	Thermal/ECLSS SIG
29	472: Lightweight heat rejection systems	Thermal/ECLSS SIG
30	628: Design-level SW reuse: Nav/Com, ECLSS	LSS
31	624: Heat Sink thermal management for Small Pressurized Rover	LSS
32	629: Certified in-situ repair techniques for habitat pressure	LSS
33	634: Brine Water Recovery	LSS
34	183: Higher Voltage Electrical Power Distribution	Int. Power Loads SIG
35	626: Active Suspension systems to increase speed and reduce	LSS
36	635: Human Radiation/ Toxin Monitoring and Countermeasures	LSS
37	616: Surface Comm: Radios	LSS
38	631: Particulate Monitor	LSS
39	630: Post Fire Cleanup Monitor	LSS
40	219: Atomic Clock	SAVIO

## Surface – Highly Desirable

<u>Priority</u>	<u>ID</u>	<u>Title</u>	<u>ROO</u>
1	731	In-situ water production from Regolith	LSS
2	728	In-Situ production of oxygen from regolith	LSS
3	729	Excavation and material transportation for oxygen production	LSS
4	260	Nano-material coatings for Dust Mitigation	ILSM
5	652	Electrostatic Curtain	LSS
6	662	Two-Phase Advanced Thermal Control System for Lunar Habitats	LSS
7	671	Advanced Crew Accommodations for mounting suited subjects on exterior of pressurized rovers	LSS
8	674	Containment and environmental management for lunar science samples	LSS
9	658	Long-Life, Low-Temperature Electronics and Mechanical Systems	LSS
10	654	Fission Surface Power	LSS
11	661	High Specific-Energy-Density Power Systems	LSS
12	665	Actuators for extreme environments	LSS
13	668	Lunar Surface Energy Storage - High energy density rechargeable batteries	LSS
14	670	Advanced Power Management and Distribution Systems	LSS
15	672	Light weight materials for inflatable structures.	LSS
16	741	Modular Power System Components	LSS
17	676	Advanced Field Repair Techniques	LSS
18	223	RFID	SAVIO

## Surface – Highly Desirable

19	22 2	Upper Ka-band Transmitter and Receivers	SAVIO
20	67 68 3	Autonomous Navigation and Guidance System Technology and Radiation Tolerant External HDTV cameras	LSS
21	68 9	Light Weight, Lower Power Element Mating Mechanism	LSS
22	8	Partial Gravity Fire Suppression	LSS
23	73 21 2	Cold and heat tolerant, low mass power for remotely deployed instrument packages	LSS
24	68 9	Atomic Clock	SAVIO
25	67 5	Deployable Post-Fire Cleanup	LSS
26	67 9	Miniaturized EVA Radio	LSS
27	73 7	Integrated Transponder/Rcvr for Comm/Nav using SDR Tech.	LSS
28	3	Self Cleaning Solar Array	LSS
29	73 18 0	Excavation and material transportation for Outpost preparation and deployment	LSS
30	69 6	Electronics Repair	SOA
31	68 1	Atmosphere Trace Contaminant Monitor	LSS
32	68 3	Reliable Surface Navigation Sensors, including 3D lidar	LSS
33	68 0	Low Power/Rapid Gas Recovery Pump for Airlock/Suitlock	LSS
34	73 6	Resource and site characterization for Outpost and ISRU planning	LSS
35	68 4	Lunar Surface Flywheel Energy Storage	LSS
36	2	Major Constituent Analyzer	LSS

## Surface – Highly Desirable

37	342	Hard and Soft Goods surface coatings	E&C
38	735	Large light wt, high strength Solar Arrays	LSS
39	343	Compressed gas lunar regolith cleaning	E&C
40	344	Automated lunar regolith cleaning systems	E&C
41	699	In-situ methane production	LSS
42	705	Material Flammability Test Methods for Partial Gravity Environments	LSS
43	707	Fire Detection with Low False Positives	LSS
44	703	Surface navigation and communication coverage for exploration science operations	LSS
45	667	Waste Stabilization and Dewatering	LSS
46	649	Simplified, Robust Partial-Gravity Water Processing and Phase Separation	LSS
47	675	Improved Urine Pretreatment Methods	LSS
48	115	Improved trace contaminant control	TE
49	669	Recovery of EVA CO2 and H2O	LSS
50	650	Biocide Water Quality Monitor	LSS
51	656	Polymeric Composite minimum gage thickness for Habitats (pressure shells)	LSS
52	659	Aluminum-Lithium minimum gage thickness for Habitats (pressure shells)	LSS
53	651	On-Line Total Organic Carbon Water Quality Monitor	LSS
54	653	Microbial Water Quality Monitor	LSS

## Surface – Highly Desirable

55	<b>687</b>	<b>Advanced Clothing/Fabric Cleaning Systems</b>	<b>LSS</b>
56	<b>681</b>	<b>Sustainable Food Production, Processing, and Preparation</b>	<b>LSS</b>
57	<b>244</b>	<b>Deployable/Erectable/Rigidizable mechanisms and blankets for protection from lunar dust particle impingement</b>	<b>ILSM</b>
58	<b>187</b>	<b>Structural and Mechanical Replacement Part Fabrication</b>	<b>SOA</b>
59	<b>243</b>	<b>Light-weight mechanisms and secondary structures for inflatable lunar surface habitats</b>	<b>ILSM</b>
60	<b>269</b>	<b>Lightweight, impact-resistant materials and structures for habitable vehicles.</b>	<b>ILSM</b>
61	<b>345</b>	<b>Manual lunar regolith cleaning systems</b>	<b>E&amp;C</b>
62	<b>341</b>	<b>Site Preparation</b>	<b>E&amp;C</b>
63	<b>346</b>	<b>Crew and Equipment Translation Systems</b>	<b>E&amp;C</b>

## Mars - Critical

<u>TPP Rank</u>	<u>Title</u>	<u>ROO</u>
1	218: Delay/Disruption Tolerant Networking	SAVIO
2	226: Optical Communications/Navigation	SAVIO
3	220: Atomic Clock	SAVIO

## Mars – Highly Desirable

<u>TPP Rank</u>	<u>Title</u>	<u>ROO</u>
1	533: x-Ray Pulsar Navigation	Orion