National Aeronautics and Space Administration

TA 13: Ground and Launch Systems

2015 NASA Technology Roadmaps

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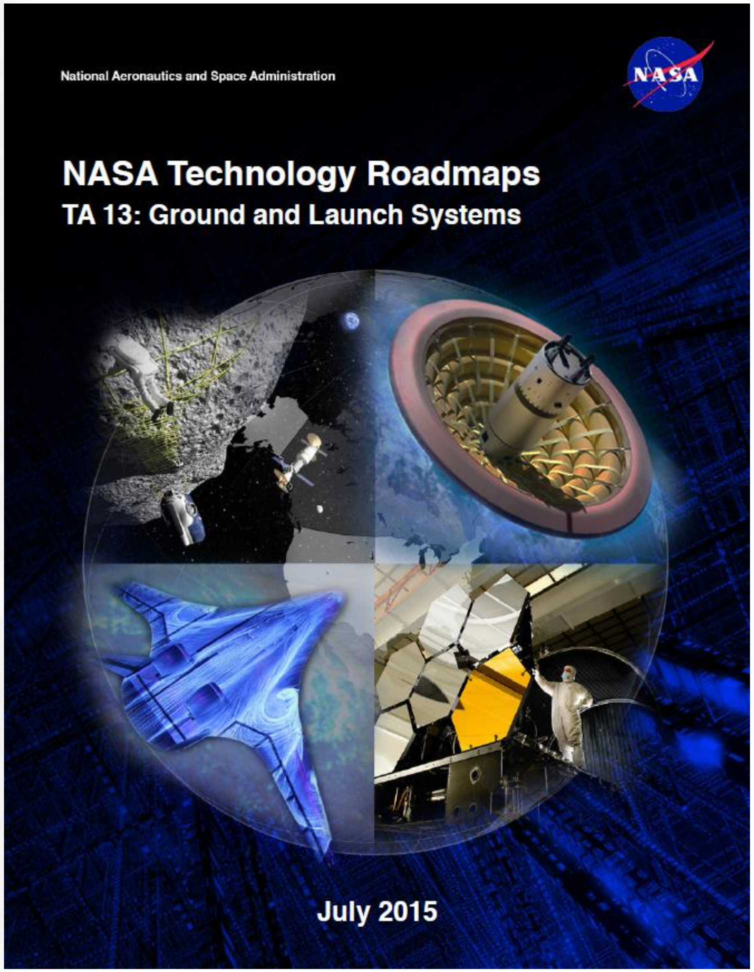
TA 13: Ground and Launch Systems



- Ground operations and maintenance are significant contributing factors to life cycle costs and the high rate of success associated with NASA's missions. Developments in this area can reduce life cycle costs and enable new and more frequent exploration missions. Prime areas are automation, conservation, and situational awareness tools.
  - 4 level 2's
  - 132 technology candidates
    - 17 enabling
    - 115 enhancing

TA 13 Ground and Launch Systems

13.1 Operational Life-Cycle

13.1.1
On-Site Production, Storage, Distribution, and Conservation of Fluids

13.1.2
Automated Alignment, Coupling, Assembly, and Transportation Systems

13.1.3
Autonomous Command and Control for Integrated Vehicle and Ground Systems

13.1.4
Logistics

13.2 Environmental Protection and Green Technologies

13.2.1
Corrosion Prevention, Detection, and Mitigation

13.2.2
Environmental Remediation and Site Restoration

13.2.3
Preservation of Natural Ecosystems

13.2.4
Alternate Energy Prototypes

13.2.5
Curatorial Facilities, Planetary Protection, and Clean Rooms

13.3 Reliability and Maintainability

13.3.1
Launch Infrastructure

13.3.2
Environment-Hardened Materials and Structures

13.3.3
On-Site Inspection and Anomaly Detection and Identification

13.3.4
Fault Isolation and Diagnostics

13.3.5
Prognostics

13.3.6
Repair, Mitigation, and Recovery Technologies

13.3.7
Communications, Networking, Timing, and Telemetry

13.3.8
Decision-Making Tools

13.4 Mission Success

13.4.1
Range Tracking, Surveillance, and Flight Safety Technologies

13.4.2
Landing and Recovery Systems and Components

13.4.3
Weather Prediction and Mitigation

13.4.4
Robotics and Telerobotics

13.4.5
Safety Systems

TA 13 Ground and Launch Systems

13.1	13.2	13.3	13.4
Operational Life-Cycle	Environmental Protection and Green Technologies	Reliability and Maintainability	Mission Success
13.1.1 On-Site Production, Storage, Distribution, and Conservation of Fluids	13.2.1 Corrosion Prevention, Detection, and Mitigation	13.3.1 Launch Infrastructure	13.4.1 Range Tracking, Surveillance, and Flight Safety Technologies
13.1.2 Automated Alignment, Coupling, Assembly, and Transportation Systems	13.2.2 Environmental Remediation and Site Restoration	13.3.2 Environment-Hardened Materials and Structures	13.4.2 Landing and Recovery Systems and Components
13.1.3 Autonomous Command and Control for Integrated Vehicle and Ground Systems	13.2.3 Preservation of Natural Ecosystems	13.3.3 On-Site Inspection and Anomaly Detection and Identification	13.4.3 Weather Prediction and Mitigation
13.1.4 Logistics	13.2.4 Alternate Energy Prototypes	13.3.4 Fault Isolation and Diagnostics	13.4.4 Robotics and Telerobotics
	13.2.5 Curatorial Facilities, Planetary Protection, and Clean Rooms	13.3.5 Prognostics	13.4.5 Safety Systems
		13.3.6 Repair, Mitigation, and Recovery Technologies	
		13.3.7 Communications, Networking, Timing, and Telemetry	
		13.3.8 Decision-Making Tools	

New Content

New Content for TA 13

13.1 Operational Life-Cycle

13.1.4 Logistics

13.2 Environmental Protection and Green Technologies

13.2.5 Curatorial Facilities, Planetary Protection, and Clean Rooms

13.3 Reliability and Maintainability

13.3.8 Decision-Making Tools

Area for NRC Review: 13.1.4 Logistics

National Aeronautics and Space Administration

- Multi-year Program logistics support typically has large warehouses of spare parts with fill rates based on determinations of mean time between failures (MTBF) and vendor lead times for order placing
- There is much reliance on the knowledge base of individual buyers and vendors
- Responses to supply-chain disruptions are largely tactical down to the lower-tier suppliers as issues arise
- Objectives: reduce logistics footprint, ensure timely availability, ensure supply chain resilience, and ensure integrity of component pedigrees

Area for NRC Review: 13.1.4 Logistics (cont'd)

National Aeronautics and Space Administration

- Digital Product Lifecycle Management
  - Digital representations of systems, subsystems, and components in their dynamic, operational environments and their associated engineering and manufacturing processes to reduce order fill times, reduce new component certification times, reduce waste, and reduce costs
- Supply Chain Economic Resilience Modeling
  - Forecast supplier health through integration of multi-parameter models (e.g. Government/other orders, local/regional/national/world economic conditions, natural disasters) and take early mitigation actions
- Additive Manufacturing as Replacement for Original Equipment Manufacturer (OEM) Parts
  - Reduced logistics footprint through local, on-demand manufacturing

Area for NRC Review: 13.1.4 Logistics (cont'd)

National Aeronautics and Space Administration

- Light Fidelity Data Transmission and Identification
  - Order of magnitude increased capabilities over Rf parts locator (e.g. higher bandwidth allows for health monitoring, more secure, more frequent inventory updates)
- Counterfeit Part Countermeasures
  - Reduces paper-intensive data pack maintenance through other means to ensure zero incursions into supply chain and parts are genuine (e.g. unique nano-scale reflective "tag" on surface of part or inside part that can be read using hand-held device)

13.1.4 Logistics Benefit Evaluation

National Aeronautics and Space Administration

Benefits: The major benefits in logistics technologies are reduced logistics costs, reduced mission risk, and overall more efficient ground processing.

0	1	3	9
Unlikely to make significant improvement	Minor improvement	Major improvement	Game-changing, transformational capability

13.1.4 Logistics Alignment Evaluation

Alignment to NASA Need: This area has 5 tech candidates with 0 enabling and 5 enhancing DRMs

Alignment to Non-NASA Aerospace Technology Goals: This area has 5 tech candidates with enhancing applicability. Applicable to any multi-year program with tiered supply chain.

Alignment to Non-Aerospace National Goals: This area has 5 tech candidates with enhancing applicability. Applicable to any multi-year program with tiered supply chain.

- Alignment with NASA Needs

0	1	3	9
Not directly applicable	Impact one mission in one mission area	Impact multiple missions in one mission area	Impact multiple missions in multiple mission areas

- Alignment with non-NASA Aerospace Technology Goals

0	1	3	9
Little or no impact	Impact limited to niche roles	Impact a large subset of activities	Broad impact

- Alignment with non-Aerospace National Goals

0	1	3	9
Little or no impact outside aerospace	Impact limited to niche roles outside aerospace	Useful to specific community outside aerospace	Widely used outside aerospace community

13.1.4 Logistics
Technical Risk and Challenge Evaluation

National Aeronautics and Space Administration

Challenges: Integration and commonality across projects and programs, certification of components manufactured using emerging techniques, and unique and untamperable identification tags.

- Technical Risk and Reasonableness

1	3	3	9	1
Very low, feasible to complete development	Low, cost/timeframe not to exceed past efforts	Moderate/high, cost/timeframe to exceed past efforts	Moderate/high, cost/timeframe not to exceed past efforts	Extremely high

- Sequencing and Timing

-9	-3	-1	1
Extremely complex, highly dependent on multiple other projects	Roughly sketched out, no clear identified users	Clear plan, obvious need, no specifically identified users	Clear plan, obvious need, joint funding likely

- Time and Effort to Achieve Goals

-9	-3	-1	0
National endeavor, >5 years, substantial facilities/organization	Major project, >5 years and substantial new facilities	Moderate effort, <5 years, moderately sized teams	Minimal effort, few years, small team

Area for NRC Review: 13.2.5 Curatorial Facilities, Planetary Protection, and Clean Rooms

National Aeronautics and Space Administration

- Exploration flight hardware has some presence of biological contamination prior to its launch
  - This occurs despite best efforts to perform sterilization at the component level using methods like vapor phase hydrogen peroxide and isopropyl alcohol; and at the entire spacecraft level using dry heat microbial reduction.
- No current capabilities for 100% containment for sample return transportation and analyses
- Objectives: eliminate biological contamination on spacecraft, more sensitive and faster sample results, less personnel required in clean rooms, 100% containment of returned samples

Area for NRC Review: 13.2.5 Curatorial Facilities, Planetary Protection, and Clean Rooms (cont'd)

National Aeronautics and Space Administration

- Molecular-based Analyses of Biological Contamination
  - Move beyond culture-based assessments and achieve increased sensitivity and faster sample results for spaceflight hardware either prior to launch or after return from space
- Next-Generation Ground or In-Flight Sterilization
  - Provide non-destructive penetrating and surface treatments that are more effective and less complex than current methods (e.g., hard radiation, gas-phase chemicals, cold plasma, electron-beam irradiation, ion desorption or ablation, and chemical and abrasive cleaning)
- Scaled-Up Ethylene Oxide Chamber for Full Spacecraft Sterilization
  - Provide more effective results as compared to Dry Heat Microbial Reduction (DHMR) and reduced costs due to fewer required heat-resistive components
- Extraterrestrial Sample-Return Containment
  - Provide 100% isolation and containment facility capabilities, practices, and procedures for handling extraterrestrial samples returned from space

Area for NRC Review: 13.2.5 Curatorial Facilities, Planetary Protection, and Clean Rooms (cont'd)

- Robotic Assistants to Assemble and Inspect Spacecraft
  - Reduce the number of personnel required to enter clean rooms by 50%
- Organically Clean Robotics for Processing Extraterrestrial Samples
  - Reduce the number of personnel required to enter clean rooms by 50%
- Portable Cleanrooms
  - Utilize wherever a payload resides, including vendor facilities, integration areas, and post-flight facilities to reduce launch and landing site costs associated with brick and mortar cleanroom capabilities by 50%
- Portable Gravity Offload Systems
  - Move beyond custom solutions to support dynamic testing of space surface system structures in lunar, Martian, or other microgravity environment to reduce multi-program development costs

13.2.5 Curatorial Facilities, Planetary Protection and Clean Rooms Benefits Evaluation

National Aeronautics and Space Administration

Benefits: Reducing NASA program costs through reduced ground operations crew size, schedules, and less heat-resistant flight hardware components; the savings could be used for new and more frequent exploration missions. Also, increased likelihood of mission success.

0	1	3	9
Unlikely to make significant improvement	Minor improvement	Major improvement	Game-changing, transformational capability

13.2.5 Curatorial Facilities, Planetary Protection and Clean Rooms
Alignment Evaluation

National Aeronautics and Space Administration

NASA

Alignment to NASA Need: This area has 8 tech candidates with 47 enabling and 1 enhancing DRMs

Alignment to Non-NASA Aerospace Technology Goals: This area has 8 tech candidates with enhancing applicability. Applicable to some aspects of future commercial space surface operations efforts such as sample returns.

Alignment to Non-Aerospace National Goals: This area has 8 tech candidates with enhancing applicability. Applicable to programs requiring extremely high biological cleanliness.

- Alignment with NASA Needs

0	1	3	9
Not directly applicable	Impact one mission in one mission area	Impact multiple missions in one mission area	Impact multiple missions in multiple mission areas

- Alignment with non-NASA Aerospace Technology Goals

0	1	3	9
Little or no impact	Impact limited to niche roles	Impact a large subset of activities	Broad impact

- Alignment with non-Aerospace National Goals

0	1	3	9
Little or no impact outside aerospace	Impact limited to niche roles outside aerospace	Useful to specific community outside aerospace	Widely used outside aerospace community

13.2.5 Curatorial Facilities, Planetary Protection and Clean Rooms Technical Risk and Challenge Evaluation

National Aeronautics and Space Administration

Challenges: Impacts to facilities, equipment, and training; mitigating the associated ground personnel hazards; developing and integrating a complete solution meeting biosafety level (BSL)-4 requirements; ensure system materials are compatible.

- Technical Risk and Reasonableness

1	3	3	9	1
Very low, feasible to complete development	Low, cost/timeframe not to exceed past efforts	Moderate/high, cost/timeframe to exceed past efforts	Moderate/high, cost/timeframe not to exceed past efforts	Extremely high

- Sequencing and Timing

-9	-3	-1	1
Extremely complex, highly dependent on multiple other projects	Roughly sketched out, no clear identified users	Clear plan, obvious need, no specifically identified users	Clear plan, obvious need, joint funding likely

- Time and Effort to Achieve Goals

-9	-3	-1	0
National endeavor, >5 years, substantial facilities/organization	Major project, >5 years and substantial new facilities	Moderate effort, <5 years, moderately sized teams	Minimal effort, few years, small team

Area for NRC Review: 13.3.8 Decision-Making Tools

- Launch team on-console must manually synthesize data from multiple sources to make time critical decisions
- Ground crew in the field follow written procedures and use reference documents for detailed information and troubleshooting
- Objectives: reduce ground operations times, reduce safety mishaps and close calls, reduce mission risk

Area for NRC Review: 13.3.8 Decision-Making Tools (cont'd)

National Aeronautics and Space Administration

- Intelligent Procedures for Launch Operations Sequencing and System Troubleshooting
  - Provide intelligent procedures to advise the launch control team during launch operations including propellant loading, constraints management, trend analyses of pressures and temperatures, mission management team polling, late-in-the-launch-countdown/time-critical actions such as access arm retraction, cryogenic systems hold-times, and launch commit criteria.
- Advanced Ground Crew Work Instructions and Procedure Overlays
  - Wearable technology allowing ground crew procedures and instructions to be visually and aurally overlaid onto the actual work as it is being performed. Procedures monitor user actions and provide directions, or certify that the process has been performed correctly.

13.3.8 Decision-Making Tools Benefit Evaluation

National Aeronautics and Space Administration

Benefits: Reduce ground operations times, reduce ground safety mishaps and close calls, and reduce mission risk.

0	1	3	9
Unlikely to make significant improvement	Minor improvement	Major improvement	Game-changing, transformational capability

13.3.8 Decision-Making Tools Alignment Evaluation

Alignment to NASA Need: This area has 2 tech candidates with 0 enabling and 2 enhancing DRMs

Alignment to Non-NASA Aerospace Technology Goals: This area has 2 tech candidates with enhancing applicability. Applicable to any aerospace program with ground crews in the field and console operators.

Alignment to Non-Aerospace National Goals: This area has 2 tech candidates with enhancing applicability. Applicable to any program with ground crews in the field and console operators.

- Alignment with NASA Needs

0	1	3	9
Not directly applicable	Impact one mission in one mission area	Impact multiple missions in one mission area	Impact multiple missions in multiple mission areas

- Alignment with non-NASA Aerospace Technology Goals

0	1	3	9
Little or no impact	Impact limited to niche roles	Impact a large subset of activities	Broad impact

- Alignment with non-Aerospace National Goals

0	1	3	9
Little or no impact outside aerospace	Impact limited to niche roles outside aerospace	Useful to specific community outside aerospace	Widely used outside aerospace community

13.3.8 Decision-Making Tools
Technical Risk and Challenge Evaluation

National Aeronautics and Space Administration

Challenges: Ensure accuracy of advice provided; ensure effective visual and aural overlaid procedures, instructions, and reference material; and ensure effective correlation of successful work task completion

- Technical Risk and Reasonableness

1	3	3	9	1
Very low, feasible to complete development	Low, cost/timeframe not to exceed past efforts	Moderate/high, cost/timeframe to exceed past efforts	Moderate/high, cost/timeframe not to exceed past efforts	Extremely high

- Sequencing and Timing

-9	-3	-1	1
Extremely complex, highly dependent on multiple other projects	Roughly sketched out, no clear identified users	Clear plan, obvious need, no specifically identified users	Clear plan, obvious need, joint funding likely

- Time and Effort to Achieve Goals

-9	-3	-1	0
National endeavor, >5 years, substantial facilities/organization	Major project, >5 years and substantial new facilities	Moderate effort, <5 years, moderately sized teams	Minimal effort, few years, small team

Backup

NRC Evaluation Criteria: Benefits

National Aeronautics and Space Administration

Benefits: Would the technology provide game-changing, transformational capabilities in the timeframe of the study? What other enhancements to existing capabilities could result from development of this technology?

Criteria	Score
The technology is unlikely to result in a significant improvement in performance or reduction in life cycle cost of missions during the next 20 years	0
The technology is likely to result in (a) a minor improvement in mission performance (e.g., less than a 10 percent reduction in system launch mass); (b) a minor improvement in mission life cycle cost; or (c) less than an order of magnitude increase in data or reliability of missions during the next 20 years.	1
The technology is likely to result in (a) a major improvement in mission performance (e.g., a 10 percent to 30 percent reduction in mass); or (b) a minor improvement in mission life cycle cost or an order of magnitude increase in data or reliability of missions during the next 20 years.	3
The technology is likely to provide game-changing, transformational capabilities that would enable important new projects or missions that are not currently feasible during the next 20 years	9

NRC Evaluation Criteria: Alignment

National Aeronautics and Space Administration

Alignment with NASA Needs: How does NASA research in this technology improve NASA's ability to meet its long-term needs? For example, which mission areas and which missions listed in the relevant roadmap would directly benefit from development of this technology, and what would be the nature of that impact? What other planned or potential missions would benefit?

Criteria	Score
Technology is not directly applicable to NASA	0
Technology will impact one mission in one of NASA's mission areas.	1
Technology will impact multiple missions in one of NASA's mission areas	3
Technology will impact multiple missions in multiple NASA mission areas	9

NRC Evaluation Criteria: Alignment

National Aeronautics and Space Administration

Alignment with Non-NASA Aerospace Technology Needs: How does NASA research in this technology improve NASA's ability to address non-NASA aerospace technology needs?

Criteria	Score
Little or no impact on aerospace activities outside of NASA's specific needs.	0
Impact will be limited to niche roles.	1
Will impact a large subset of aerospace activities outside of NASA's specific needs (e.g., commercial spacecraft).	3
Will have a broad impact across the entire aerospace community.	9

NRC Evaluation Criteria: Alignment

National Aeronautics and Space Administration

Alignment with Non-Aerospace National Goals: How well does NASA research in this technology improve NASA's ability to address national goals from broader national perspective (e.g., energy, transportation, health, environmental stewardship, or infrastructure)?

Criteria	Score
Little or no impact outside the aerospace industry .	0
Impact will be limited to niche roles.	1
Will be useful to a specific community outside aerospace (e.g., medicine).	3
Will be widely used outside the aerospace community (e.g., energy generation or storage).	9

NRC Evaluation Criteria: Technical Risk and Challenge

National Aeronautics and Space Administration

Technical Risk and Reasonableness: What is the overall nature of the technical risk and/or the reasonableness that this technology development can succeed in the timeframe envisioned? Is the level of risk sufficiently low that industry could be expected to complete development of this technology without a dedicated NASA research effort, or is it already available for commercial or military applications? Regarding the expected level of effort and timeframe for technology development: (a) are they believable given the complexity of the technology and the technical challenges to be overcome; and (b) are they reasonable given the envisioned benefit vis-a-vis possible alternate technologies?

Criteria	Score
The technical risk associated with development of this technology is very low, such that it is feasible for industry or a specific NASA mission office to complete development (without additional NASA technology funding if a mission need arises).	1
The technical risk associated with development of this technology is low, and the likely cost to NASA and the timeframe to complete technology development are not expected to substantially exceed those of past efforts to develop comparable technologies	3
The technical risk associated with development of this technology is moderate to high, which is a good fit to NASA's level of risk tolerance for technology development, but the likely cost to NASA and the timeframe to complete technology development are expected to substantially exceed those of past efforts to develop comparable technologies	3
The technical risk associated with development of this technology is moderate to high, which is a good fit to NASA's level of risk tolerance for technology development, and the likely cost to NASA and the timeframe to complete technology development are not expected to substantially exceed those of past efforts to develop comparable technologies.	9
The technical risk associated with development of this technology is extremely high, such that it is unreasonable to expect any operational benefits over the next 20 years without unforeseen revolutionary breakthroughs and/or an extraordinary level of effort.	1

NRC Evaluation Criteria: Technical Risk and Challenge

National Aeronautics and Space Administration

NASA

Sequencing and Timing: Is the proposed timing of the development of this technology appropriate relative to when it will be needed? What other new technologies are needed to enable the development of this technology, have they been completed, and how complex are the interactions between this technology and other new technologies under development? What other new technologies does this technology enable? Is there a good plan for proceeding with technology development? Is the technology development effort well connected with prospective users?

Criteria	Score
This is an extremely complex technology and/or is highly dependent on multiple other projects with interfaces that are not well thought out or understood	-9
The development of this technology is just roughly sketched out and there are no clearly identified users (i.e., missions).	-3
There is a clear plan for advancing this technology. While there is an obvious need, there are no specifically identified users.	-1
There is a clear plan for advancing this technology, there is an obvious need, and joint funding by a user seems likely.	1

NRC Evaluation Criteria: Technical Risk and Challenge

National Aeronautics and Space Administration

Time and Effort to Achieve Goals: How much time and what overall effort are required to achieve the goals for this technology?

Criteria	Score
National endeavor: Likely to require more than 5 years and substantial new facilities, organizations, and workforce capabilities to achieve; similar to or larger in scope than the Shuttle, Manhattan Project, or Apollo Program.	-9
Major project: Likely to require more than 5 years and substantial new facilities to achieve; similar in scope to development of the Apollo heat shield or the Orion environmental systems.	-3
Moderate effort: Can be achieved in less than 5 years with a moderately sized (less than 50people) team (e.g., Mars Pathfinder's airbag system).	-1
Minimal effort: Can be achieved in a few years by a very small (less than 10 people) team (e.g., graduate student/faculty university project).	0