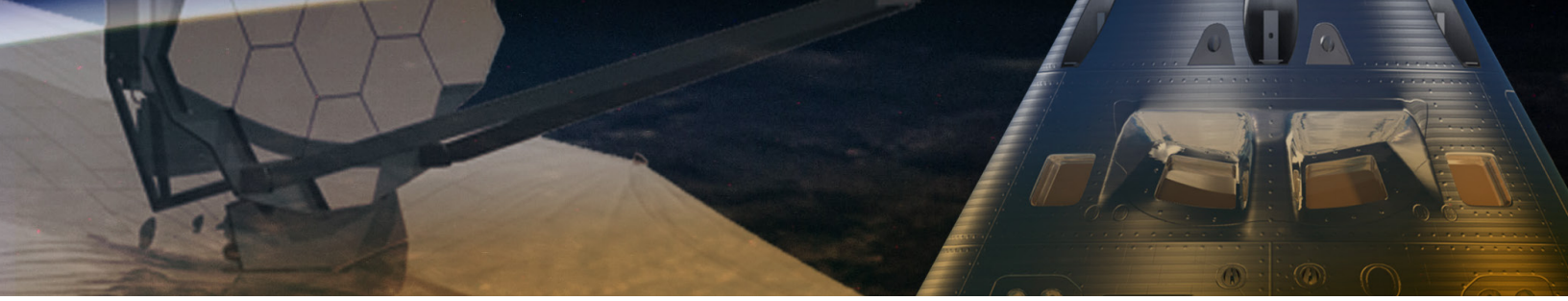
National Aeronautics and Space Administration

2020 NASA Technology Taxonomy

2015 Technology Areas to 2020 Taxonomy Areas Crosswalk

The page intentionally left blank.



CONTENTS

Introduction . . . iii

TX to TA Mapping . . . 1

TX01: Propulsion Systems . . . 3

TX02: Flight Computing and Avionics . . . 7

TX03: Aerospace Power and Energy Storage . . . 11

TX04: Robotic Systems . . . 13

TX05: Communications, Navigation, and Orbital Debris Tracking and Characterization Systems . . . 17

TX06: Human Health, Life Support, and Habitation Systems . . . 21

TX07: Exploration Destination Systems . . . 25

TX08: Sensors and Instruments . . . 27

TX09: Entry, Descent, and Landing . . . 29

TX10: Autonomous Systems . . . 31

TX11: Software, Modeling, Simulation, and Information Processing . . . 33

TX12: Materials, Structures, Mechanical Systems, and Manufacturing . . . 37

TX13: Ground, Test, and Surface Systems . . . 41

TX14: Thermal Management Systems . . . 45

TX15: Flight Vehicle Systems . . . 47

TX16: Air Traffic Management and Range Tracking Systems . . . 49

TX17: Guidance, Navigation, and Control . . . 51

TA to TX Mapping . . . 55

TA1: Launch Propulsion Systems . . . 57

TA2: In-Space Propulsion Systems . . . 59

TA3: Space Power and Energy Storage . . . 61

TA4: Robotics and Autonomous Systems . . . 63

TA5: Communications, Navigation, and Orbital Debris Tracking and Characterization Systems . . . 67

TA6: Human Health, Life Support, and Habitation Systems . . . 71

TA7: Human Exploration Destination Systems . . . 73

TA8: Science Instruments, Observatories, and Sensor Systems . . . 75

TA9: Entry, Descent, and Landing . . . 77

TA10: Nanotechnology . . . 79

TA11: Modeling, Simulation, Information Technology and Processing . . . 81

TA12: Materials, Structures, Mechanical Systems, and Manufacturing . . . 83

TA13: Ground and Launch Systems . . . 85

TA14: Thermal Management Systems . . . 87

TA15: Aeronautics . . . 89

Introduction

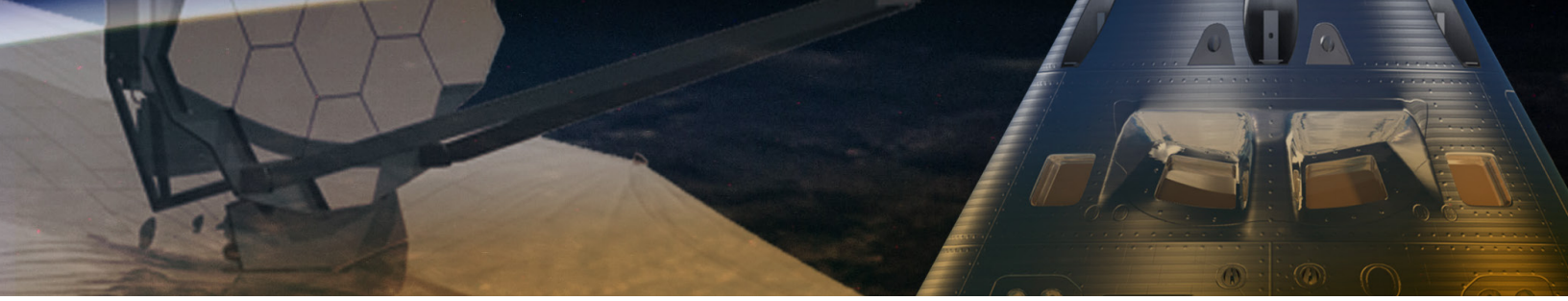
NASA engages in a multitude of technology development activities to enable NASA missions by broadening knowledge of and capabilities in aeronautics, science, and space. To manage and communicate this extensive and diverse technology portfolio, NASA uses a technology taxonomy. This taxonomy identifies, organizes, and communicates the technology areas that NASA advances in order to achieve future space missions and aeronautics activities.

The 2020 NASA Technology Taxonomy is part of an evolution that began with the original roadmaps and Technology Area Breakdown Structure (TABS) drafted in 2010, followed by updates in 2012 and 2015. The 2020 Taxonomy is an update to the 2015 TABS. The taxonomy provides a structure for articulating NASA's technology portfolio, which is key to NASA's ability to manage and communicate its technology development efforts.

The updated 2020 NASA Technology Taxonomy reflects a shift to a structure that aligns technology areas based on technical disciplines. To achieve this shift the revision retains, modifies and introduces new Level 1 and Level 2 technology areas while dissolving others and combining them with existing areas. The 2020 update also includes new technologies relevant to NASA, such as cybersecurity and advancements in artificial intelligence.

To help users of the Taxonomy navigate these changes, this companion document provides a crosswalk between the 2015 Technology Areas (TAs) and the updated 2020 Taxonomy areas (TXs). The first section of this document maps each of the 17 TX areas to its previous TAs in the 2015 TABS. In some cases, the TX is new and therefore not mapped to a TA. The second section of the document reverses the crosswalk, mapping each of the 15 TAs to its new TX in the 2020 Taxonomy. This crosswalk enables readers to identify where technology areas moved to with the update, thereby easing the transition from the 2015 TABS to the 2020 Taxonomy.

Figure 1 shows the breakdown of the structure used in the 2020 Technology Taxonomy.



TX01 Propulsion Systems
- 1.1 Chemical Space Propulsion
- 1.2 Electric Space Propulsion
- 1.3 Aero Propulsion
- 1.4 Advanced Propulsion

TX02 Flight Computing and Avionics
- 2.1 Avionics Component Technologies
- 2.2 Avionics Systems and Subsystems
- 2.3 Avionics Tools, Models, and Analysis

TX03 Aerospace Power and Energy Storage
- 3.1 Power Generation and Energy Conversion
- 3.2 Energy Storage
- 3.3 Power Management and Distribution

TX04 Robotic Systems
- 4.1 Sensing and Perception
- 4.2 Mobility
- 4.3 Manipulation
- 4.4 Human-Robot Interaction
- 4.5 Autonomous Rendezvous and Docking
- 4.6 Robotics Integration

TX05 Communications, Navigation, and Orbital Debris Tracking/Characterization Systems
- 5.1 Optical Communications
- 5.2 Radio Frequency
- 5.3 Internetworking
- 5.4 Network Provided Position, Navigation, and Timing
- 5.5 Revolutionary Communications Technologies
- 5.6 Networking and Ground Based Orbital Debris Tracking and Management
- 5.7 Acoustic Communications

TX06 Human Health, Life Support, and Habitation Systems
- 6.1 Environmental Control and Life Support Systems and Habitation Systems
- 6.2 Extravehicular Activity Systems
- 6.3 Human Health and Performance
- 6.4 Environmental Monitoring, Safety, and Emergency Response
- 6.5 Radiation
- 6.6 Human Systems Integration

TX07 Exploration Destination Systems
- 7.1 In-Situ Resource Utilization
- 7.2 Mission Infrastructure, Sustainability, and Supportability
- 7.3 Mission Operations and Safety

TX08 Sensors and Instruments
- 8.1 Remote Sensing Instruments and Sensors
- 8.2 Observatories
- 8.3 In-Situ Instruments and Sensors

TX09 Entry, Descent, and Landing
- 9.1 Aeroassist and Atmospheric Entry
- 9.2 Descent
- 9.3 Landing
- 9.4 Vehicle Systems

TX10 Autonomous Systems
- 10.1 Situational and Self Awareness
- 10.2 Reasoning and Acting
- 10.3 Collaboration and Interaction
- 10.4 Engineering and Integrity

TX11 Software, Modeling, Simulation, and Information Processing
- 11.1 Software Development, Engineering, and Integrity
- 11.2 Modeling
- 11.3 Simulation
- 11.4 Information Processing
- 11.5 Mission Architecture, Systems Analysis, and Concept Development
- 11.6 Ground Computing

TX12 Materials, Structures, Mechanical Systems, and Manufacturing
- 12.1 Materials
- 12.2 Structures
- 12.3 Mechanical Systems
- 12.4 Manufacturing
- 12.5 Structural Dynamics

TX13 Ground, Test, and Surface Systems
- 13.1 Infrastructure Optimization
- 13.2 Test and Qualification
- 13.3 Assembly, Integration, and Launch
- 13.4 Mission Success Technologies

TX14 Thermal Management Systems
- 14.1 Cryogenic Systems
- 14.2 Thermal Control Components and Systems
- 14.3 Thermal Protection Components and Systems

TX15 Flight Vehicle Systems
- 15.1 Aerosciences
- 15.2 Flight Mechanics

TX16 Air Traffic Management and Range Tracking Systems
- 16.1 Safe All Vehicle Access
- 16.2 Weather/Environment
- 16.3 Traffic Management Concepts
- 16.4 Architectures and Infrastructure
- 16.5 Range Tracking, Surveillance, and Flight Safety Technologies
- 16.6 Integrated Modeling, Simulation, and Testing

TX17 Guidance, Navigation, and Control (GN&C)
- 17.1 Guidance and Targeting Algorithms
- 17.2 Navigation Technologies
- 17.3 Control Technologies
- 17.4 Attitude Estimation Technologies
- 17.5 GNC Systems Engineering Technologies
- 17.6 Technologies for Aircraft Trajectory Generation, Management, and Optimization for Airspace Operations

Figure 1. The second-level breakdown of the structure used in the 2020 Technology Taxonomy.

TX to TA Mapping

Propellant
Supply
Thermal
Management
Magnets
Neutralizer
Cathode
Thrust
Beam
Raw
Power
Conditioned
Power
Ionization
Chamber
Ion
Acceleration
Electrodes
Atoms
Ions
Electrons
Ion
Thruster

TX01 Propulsion Systems

TX01	Propulsion Systems	Original TA in 2015 Technology Area Breakdown Structure	
TX01.1	Chemical Space Propulsion	1.1	Solid Propulsion
		1.2	Liquid Rocket Propulsion
		1.4	Ancillary Propulsion Systems
		2.1	Chemical Propulsion
TX01.1.1	Integrated Systems and Ancillary Technologies	1.1.2	Case Materials
		1.1.3	Nozzle Systems
		1.4.1	Auxiliary Control Systems
		1.4.2	Main Propulsion Systems (Excluding Engines)
		1.4.3	Launch Abort Systems
		1.4.4	Thrust Vector Control Systems
		1.4.5	Health Management and Sensors
		1.4.6	Pyro and Separation Systems
		1.4.7	Fundamental Ancillary Propulsion Technologies
		1.6.3	Pointing Systems
		1.6.4	Telemetry Systems
		1.6.5	Balloon Trajectory Control
		1.6.6	Power Systems
		1.6.7	Mechanical Systems-Launch Systems
		1.6.8	Mechanical Systems-Parachute
		1.6.9	Mechanical Systems-Floatation
		10.3.2	Propulsion Components
TX01.1.2	Earth Storable	1.2.5	Propellants
		1.2.6	Fundamental Liquid Propulsion Technologies
		2.1.1	Liquid Storable
		10.3.1	Propellants
TX01.1.3	Cryogenic	1.2.1	LH2/LOX Based
		1.2.2	RP/LOX Based
		1.2.3	CH4/LOX Based
		1.2.6	Fundamental Liquid Propulsion Technologies
		2.1.2	Liquid Cryogenic

TX01 Propulsion Systems

TX01	Propulsion Systems	Original TA in 2015 Technology Area Breakdown Structure	
TX01.1.4	Solids	1.1.1	Propellants
		1.1.2	Case materials
		1.1.3	Nozzle Systems
		1.1.5	Fundamental Solid Propulsion Technologies
		1.1.6	Integrated Solid Motor Systems
		1.1.7	Liner and Insulation
		2.1.4	Solids
TX01.1.5	Hybrids	2.1.5	Hybrid
		1.1.4	Hybrid Rocket Propulsion Systems
TX01.1.6	Gels	2.1.3	Gels
		10.3.1	Propellants
TX01.1.7	Cold Gas	2.1.6	Cold Gas/Warm Gas
TX01.1.8	Warm Gas	2.1.6	Cold Gas/Warm Gas
TX01.2	Electric Space Propulsion	2.2	Non-Chemical Propulsion
		2.4	Supporting Technologies
TX01.2.1	Integrated Systems and Ancillary Technologies	2.4.1	Engine Health Monitoring and Safety
		2.4.2	Propellant Storage and Transfer
		2.4.3	Materials and Manufacturing Technologies
		2.4.4	Heat Rejection
		2.4.5	Power
TX01.2.2	Electrostatic	1.5.5	Nuclear
		2.2.1	Electric Propulsion
		2.2.3	Electric Sail Propulsion
TX01.2.3	Electromagnetic	2.2.1	Electric Propulsion
TX01.2.4	Electrothermal	2.2.1	Electric Propulsion
TX01.3	Aero Propulsion	1.3	Air Breathing Propulsion Systems
TX01.3.1	Integrated Systems and Ancillary Technologies	1.3.6	Deeply-Cooled Air Cycles
		1.3.7	Air Collection and Enrichment Systems
		1.3.8	Fundamental Air Breathing Propulsion Technologies
TX01.3.2	Turbine Based Combined Cycle	1.3.1	Turbine-Based Combined Cycle
TX01.3.3	Rocket Based Combined Cycle	1.3.2	Rocket-Based Combined Cycle

TX01 Propulsion Systems

TX01	Propulsion Systems	Original TA in 2015 Technology Area Breakdown Structure	
TX01.3.4	Pressure Gain Combustion	1.2.4	Detonation Wave Engines - Closed Cycle
		1.3.3	Detonation Wave Engines - Open Cycle
TX01.3.5	Turbine Based Jet Engines	1.3.4	Turbine-Based Jet Engines
		15.3.1	Achieve Community Goals for Improved Vehicle Efficiency and Environmental Performance in 2025
		15.3.2	Achieve Community Goals for Improved Vertical Lift Vehicle Efficiency and Environmental Performance in 2035
		15.3.3	Achieve Community Goals for Improved Vehicle Efficiency and Environmental Performance Beyond 2035
TX01.3.6	Ramjet/Scramjet	1.3.5	Ramjet and Scramjet Engines
TX01.3.7	Reciprocating Internal Combustion	NEW	
TX01.3.8	All Electric Propulsion	15.4.1	Introduction of Low-Carbon Fuels for Conventional Engines and Exploration of Alternative Propulsion Systems
		15.4.2	Initial Introduction of Alternative Propulsions Systems
TX01.3.9	Hybrid Electric Systems	15.4.1	Introduction of Low-Carbon Fuels for Conventional Engines and Exploration of Alternative Propulsion Systems
		15.4.2	Initial Introduction of Alternative Propulsions Systems
TX01.3.10	Turboelectric Propulsion	15.4.1	Introduction of Low-Carbon Fuels for Conventional Engines and Exploration of Alternative Propulsion Systems
		15.4.2	Initial Introduction of Alternative Propulsions Systems
TX01.3.11	Engine Icing	10.1.3	Coatings
TX01.3.12	Alternative Low Carbon Jet Fuel	15.4.1	Introduction of Low-Carbon Fuels for Conventional Engines and Exploration of Alternative Propulsion Systems
		15.4.2	Initial Introduction of Alternative Propulsions Systems
TX01.4	Advanced Propulsion	1.3	Air Breathing Propulsion Systems
TX01.4.1	Solar Sails	2.2.2	Solar and Drag Sail Propulsion
		10.3.3	In-space Propulsion
TX01.4.2	Electromagnetic Tethers	1.5.3	Space Tether Assist
		2.2.4	Tether Propulsion
		10.3.3	In-space Propulsion
TX01.4.3	Nuclear Thermal Propulsion	1.5.5	Nuclear
		2.2.3	Thermal Propulsion
		10.3.3	In-space Propulsion

TX01 Propulsion Systems

TX01	Propulsion Systems	Original TA in 2015 Technology Area Breakdown Structure	
TX01.4.4	Other Advanced Propulsion Approaches	1.5.1	Ground Launch Assist
		1.5.2	Air Launch and Drop Systems
		1.5.4	Beamed Energy and Energy Addition
		1.5.6	High Energy Density Materials and Propellants
		1.6.1	Super-Pressure Balloon
		1.6.2	Materials
		2.1.7	Micropropulsion
		2.3.1	Beamed Energy Propulsion
		2.3.3	Fusion Propulsion
		2.3.4	High Energy-Density Materials
		2.3.5	Antimatter Propulsion
		2.3.6	Advanced Fission
		2.3.7	Breakthrough Propulsion
		10.3.3	In-Space Propulsion
TX01.X	Other Propulsion Systems	NEW	

TX02 Flight Computing and Avionics

TX02	Flight Computing and Avionics	Original TA in 2015 Technology Area Breakdown Structure	
TX02.1	Avionics Component Technologies	NEW	
TX02.1.1	Radiation Hardened Extreme Environment Components and Implementations	11.1.1	Flight Computing
		12.1.4	Materials for Extreme Environments
TX02.1.2	Electronic Packaging and Implementations	3.3.3	Distribution and Transmission
TX02.1.3	High Performance Processors	11.2.4	Science Modeling
TX02.1.4	High Performance Memories	10.4.2	Nanoelectronics
TX02.1.5	High Performance Field Programmable Gate Arrays	8.1.2	Electronics
		11.1.1	Flight Computing
TX02.1.6	Radiation Hardened ASIC Technologies	8.1.2	Electronics
TX02.1.7	Point-of-Load Power Converters	NEW	
TX02.1.8	Wireless Avionics Technologies	7.2.1	Power Scavenged Wireless Sensor Tag Systems
		13.1.2	Automated Alignment, Coupling, Assembly, and Transportation Systems
		13.1.3	Autonomous Command and Control for Integrated Vehicle and Ground Systems
		14.3.3	TPS Sensors and Measurement Systems
TX02.2	Avionics Systems and Subsystems	NEW	
TX02.2.1	Spacecraft Command and Data Handling Systems (C&DH)	13.1.3	Autonomous Command and Control for Integrated Vehicle and Ground Systems
		13.3.7	Communications, Networking, Timing, and Telemetry

TX02 Flight Computing and Avionics

TX02	Flight Computing and Avionics	Original TA in 2015 Technology Area Breakdown Structure	
TX02.2.1	Spacecraft Command and Data Handling Systems (C&DH)	13.1.3	Autonomous Command and Control for Integrated Vehicle and Ground Systems
		13.3.7	Communications, Networking, Timing, and Telemetry
TX02.2.2	Aircraft Avionics Systems	NEW	
TX02.2.3	Vision and Virtual/ Augmented Reality Avionics	15.1.2	System-Wide Safety, Predictability, and Reliability through Full NextGen Functionality
TX02.2.4	Low Power Embedded Computer Systems	12.1.4	Materials for Extreme Environments
		11.1.1	Flight Computing
TX02.2.5	High Speed Onboard Interconnects and Networks	11.1.1	Flight Computing
TX02.2.6	Data Acquisition Systems	12.2.4	Test Tools and Methods
		13.1.3	Autonomous Command and Control for Integrated Vehicle and Ground Systems
TX02.2.7	Data Reduction Hardware Systems	11.4.1	Science, Engineering, and Mission Data Lifecycle
TX02.2.8	Use of Advanced Commercial-off-the-Shelf (COTS) Technologies	NEW	
TX02.2.9	Hardware Enabling Secure Avionics	NEW	
TX02.3	Avionics Tools, Models, and Analysis	NEW	
TX02.3.1	Electronics Development Tools	11.2.2	Integrated Hardware and Software Modeling
		12.2.4	Test Tools and Methods
TX02.3.2	Space Radiation Analysis and Modeling	11.3.7	Multiscale, Multiphysics, and Multifidelity Simulation
TX02.3.3	Avionics Reliability and Fault-Tolerance Analysis and Modeling	12.2.3	Reliability and Sustainment
		12.3.5	Reliability, Life Assessment, and Health Monitoring

TX02	Flight Computing and Avionics	Original TA in 2015 Technology Area Breakdown Structure	
TX02.3.4	Electromagnetic Environment Effects	NEW	
TX02.X	Other Flight Computing and Avionics	NEW	

The page intentionally left blank.

TX03 Aerospace Power and Energy Storage

TX03	Aerospace Power and Energy Storage	Original TA in 2015 Technology Area Breakdown Structure	
TX03.1	Power Generation and Energy Conservation	3.1	Power Generation
		10.2	Energy Storage, Power Generation, and Power Distribution
TX03.1.1	Photovoltaic	3.1.3	Solar
TX03.1.2	Heat Sources	3.1.4	Radioisotope
TX03.1.3	Static Energy Conversion	NEW	
TX03.1.4	Dynamic Energy Conversion	3.1.1	Energy Harvesting
		3.1.2	Chemical
		3.1.5	Fission
		3.1.6	Fusion
		10.2.2	Power Generation
TX03.1.5	Electrical Machines	NEW	
TX03.1.6	Other Advanced Concepts for Generating/ Converting Power	NEW	
TX03.2	Energy Storage	3.2	Energy Storage
		10.2	Energy Storage, Power Generation, and Power Distribution
TX03.2.1	Electrochemical: Batteries	3.2.1	Batteries
TX03.2.2	Electrochemical: Fuel Cells	3.2.3	Regenerative Fuel Cells
TX03.2.3	Advanced Concepts for Energy Storage	3.2.2	Flywheels
		3.2.4	Capacitors
		10.2.1	Energy Storage
		13.2.4	Alternative Energy Prototypes
TX03.3	Power Management and Distribution	3.3	Power Management and Dsitribution
TX03.3.1	Management and Control	3.3.1	Fault Detection, Isolation, and Recovery
		3.3.2	Management and Control

TX03 Aerospace Power and Energy Storage

TX03	Aerospace Power and Energy Storage	Original TA in 2015 Technology Area Breakdown Structure	
TX03.3.2	Distribution and Transmission	3.3.3	Distribution and Transmission
		3.3.4	Wireless Power Transmission
		10.2.3	Power Distribution
TX03.3.3	Electrical Power Conversion and Regulation	3.3.5	Conversion and Regulation
TX03.3.4	Advanced Electronic Parts	3.3.3	Distribution and Transmission
		3.3.5	Conversion and Regulation
TX03.X	Other Aerospace Power and Energy Storage	NEW	

TX04 Robotic Systems

TX04	Robotic Systems	Original TA in 2015 Technology Area Breakdown Structure	
TX04.1	Sensing and Perception	4.1	Sensing and Perception
TX04.1.1	Sensing for Robotic systems	4.1.1	3D Sensing
		4.1.5	Force and Tactile Sensing
		10.4.1	Sensors and Actuators
TX04.1.2	State Estimation	4.1.2	State Estimation
		4.5.6	Terrain Relative Navigation
TX04.1.3	Onboard Mapping and Data Analysis	4.1.3	Onboard Mapping
		4.1.6	Onboard Science Data Analysis
		4.5.6	Terrain Relative Navigation
TX04.1.4	Object, Event, and Activity Recognition	4.1.4	Object, Event, and Activity Recognition
TX04.2	Mobility	4.2	Mobility
		7.3	Human Mobility Systems
TX04.2.1	Below-Surface Mobility	4.2.2	Below-Surface Mobility
		4.2.8	Mobility Components
		4.3.4	Mobile Manipulation
		7.3.1	EVA Mobility
TX04.2.2	Above-Surface Mobility	4.2.3	Above-Surface Mobility
		4.2.8	Mobility Components
		4.3.4	Mobile Manipulation
		7.3.1	EVA Mobility
		7.3.3	Off-Surface Mobility
TX04.2.3	Small-Body and Microgravity Mobility	4.2.4	Small-Body and Microgravity Mobility
		4.2.8	Mobility Components
		4.3.4	Mobile Manipulation
TX04.2.4	Surface Mobility	4.2.1	Extreme-Terrain Mobility
		4.2.5	Surface Mobility
		4.2.8	Mobility Components
		4.3.4	Mobile Manipulation
		7.3.1	EVA Mobility
		7.3.2	Surface Mobility

TX04 Robotic Systems

TX04	Robotic Systems	Original TA in 2015 Technology Area Breakdown Structure	
TX04.2.5	Robot Navigation and Path Planning	4.2.6	Robot Navigation
		4.5.2	Activity Planning, Scheduling, and Execution
		4.5.6	Terrain Relative Navigation
TX04.2.6	Collaborative Mobility	4.2.7	Collaborative Mobility
		4.2.8	Mobility Components
		4.3.4	Mobile Manipulation
TX04.3	Manipulation	4.3	Manipulation
TX04.3.1	Dexterous Manipulation	4.3.1	Manipulator Components
		4.3.2	Dexterous Manipulation
		4.3.4	Mobile Manipulation
		4.3.5	Collaborative Manipulation
TX04.3.2	Grappling Technologies	4.3.1	Manipulator Components
		4.3.4	Mobile Manipulation
		4.3.5	Collaborative Manipulation
		4.3.7	Grappling
TX04.3.3	Contact Dynamics Modeling	4.3.3	Modeling of Contact Dynamics
		4.7.3	Robot Modeling and Simulation
TX04.3.4	Sample Acquisition and Handling	4.3.6	Sample Acquisition and Handling
TX04.4	Human-Robot Interaction	4.4	Human-System Interaction
TX04.4.1	Multi-Modal and Proximate Interaction	4.4.1	Multi-Modal Interaction
		4.4.3	Proximate Interaction
		4.4.4	Intent Recognition and Reaction
		4.4.6	Common and Standard Human-System Interfaces
		4.4.7	Safety, Trust, and Interfacing of Robotic and Human Proximity Operations
TX04.4.2	Distributed Collaboration and Coordination	4.4.5	Distributed Collaboration and Coordination
TX04.4.3	Remote Interaction	4.4.2	Supervisory Control
		4.4.8	Remote Interaction
TX04.5	Autonomous Rendezvous and Docking	4.6	Autonomous Rendezvous and Docking

TX04 Robotic Systems

TX04	Robotic Systems	Original TA in 2015 Technology Area Breakdown Structure	
TX04.5.1	Relative Navigation Sensors	4.6.1	Relative Navigation Sensors
TX04.5.2	Rendezvous and Docking Algorithms	4.6.2	GN&C Algorithms
TX04.5.3	Rendezvous, Proximity Operations, and Capture (RPOC) Fight and Ground Systems	NEW	
TX04.5.4	Capture Sensors	4.6.1	Relative Navigation Sensors
TX04.5.5	Capture Mechanisms and Fixtures	4.6.3	Docking and Capture Mechanisms and Interfaces
TX04.5.6	Robot Control for Vehicle Capture and Berthing	4.3.7	Grappling
TX04.5.7	Modeling, Simulation, Analysis, and Test of Rendezvous, Proximity Operations, and Capture	NEW	
TX04.6	Robotics Integration	4.7	Systems Engineering
TX04.6.1	Modularity, Commonality, and Interfaces	4.7.1	Modularity, Commonality, and Interfaces
TX04.6.2	Modeling and Simulation for Robots	4.7.3	Robot Modeling and Simulation
TX04.6.3	Robot Software	4.7.4	Robot Software
TX04.X	Other Robotic Systems	NEW	

The page intentionally left blank.

TX05 Communications, Navigation, and Orbital Debris Tracking and Characterization Systems

TX05	Communications, Navigation, and Orbital Debris Tracking and Characterization Systems	Original TA in 2015 Technology Area Breakdown Structure	
TX05.1	Optical Communications	5.1	Optical Communications and Navigation
TX05.1.1	Detector Development	5.1.1	Detector Development
TX05.1.2	Large Apertures	5.1.2	Large Apertures
TX05.1.3	Lasers	5.1.3	Lasers
TX05.1.4	Pointing, Acquisition and Tracking (PAT)	5.1.4	Acquisition and Tracking
TX05.1.5	Atmospheric Mitigation	5.1.5	Atmospheric Mitigation
TX05.1.6	Optimetrics	5.1.6	Optical Tracking
TX05.1.7	Innovative Signal Modulations	NEW	
TX05.2	Radio Frequency	5.2	Radio Frequency Communications
		5.5.1	Radio Systems
TX05.2.1	Spectrum-Efficiency	5.2.1	Spectrum-Efficient Technologies
TX05.2.2	Power-Efficiency	5.2.2	Power-Efficient Technologies
TX05.2.3	Atmospheric Characterization and Mitigation	5.2.3	Propagation
TX05.2.4	Flight and Ground Systems	5.2.4	Flight and Ground Systems
		5.5.2	Ultra Wideband Systems
		13.3.7	Communications, Navigation, Timing, and Telemetry
TX05.2.5	Launch and Re-Entry Communications	5.2.5	Earth Launch and Re-Entry Communications
TX05.2.6	Innovative Antennas	5.2.6	Antennas
TX05.2.7	Innovative RF Technologies	NEW	
TX05.3	Internetworking	5.3	Internetworking
TX05.3.1	Disruption-Tolerant Networking	5.3.1	Disruption-Tolerant Networking

TX05 Communications, Navigation, and Orbital Debris Tracking and Characterization Systems

TX05	Communications, Navigation, and Orbital Debris Tracking and Characterization Systems	Original TA in 2015 Technology Area Breakdown Structure	
TX05.3.2	Adaptive Network Topology	5.3.2	Adaptive Network Topology
TX05.3.3	Information Assurance	5.3.3	Information Assurance
TX05.3.4	Integrated Network Management	5.3.4	Integrated Network Management
TX05.4	Network Provided Position, Navigation, and Timing	5.4	Position, Navigation, and Timing
		5.6	Revolutionary Concepts
TX05.4.1	Timekeeping and Time Distribution	5.4.1	Timekeeping and Time Distribution
TX05.4.2	Revolutionary Position, Navigation, and Timing Technologies	5.6.1	X-Ray Navigation
		5.6.2	X-Ray Communications
		5.6.3	Neutrino-Based Navigation and Tracking
		5.6.4	Quantum Key Distribution
		5.6.5	Quantum Communications
		5.6.6	Superconducting Quantum Interference Filter Microwave Amplifier
		5.6.7	Reconfigurable Large Apertures
TX05.5	Revolutionary Communications Technologies	5.5	Integrated Technologies
TX05.5.1	Cognitive Networking	5.5.3	Cognitive Networks
TX05.5.2	Quantum Communications	5.1.7	Integrated Photonics
TX05.5.3	Hybrid Radio and Optical Technologies	5.5.5	Hybrid Optical Communications and Navigation Sensors
		5.5.6	Radio Frequency and Optical Hybrid Technology
TX05.6	Networking and Ground Based Orbital Debris Tracking and Management	5.7	Orbital Debris Tracking and Characterization
TX05.6.1	Orbital Debris Tracking	5.7.1	Tracking Technologies
TX05.6.2	Orbital Debris Characterization	5.7.2	Characterization Technologies

TX05	Communications, Navigation, and Orbital Debris Tracking and Characterization Systems	Original TA in 2015 Technology Area Breakdown Structure	
TX05.6.3	Orbital Debris Mitigation	NEW	
TX05.6.4	Orbital Debris Monitoring Software Platforms	NEW	
TX05.7	Acoustic Communication	NEW	
TX05.X	Other Communications, Navigation, and Orbital Debris Tracking and Characterization Systems		

The page intentionally left blank.

TX06 Human Health, Life Support, and Habitation Systems

TX06	Human Health, Life Support, and Habitation Systems	Original TA in 2015 Technology Area Breakdown Structure	
TX06.1	Environmental Control & Life Support Systems (ECLSS) and Habitation Systems	6.1	Environmental Control and Life Support Systems and Habitation Systems
TX06.1.1	Atmosphere Revitalization	6.1.1	Air Revitalization
TX06.1.2	Water Recovery and Management	6.1.2	Water Recovery and Management
TX06.1.3	Waste Management	6.1.3	Waste Management
TX06.1.4	Habitation Systems	6.1.4	Habitation
		7.4.1	Integrated Habitat Systems
		7.4.2	Habitat Evolution
		7.4.3	“Smart” Habitats
TX06.1.5	ECLSS Modeling and Simulation Tools	NEW	
TX06.2	Extravehicular Activity Systems	6.2	Extravehicular Activity Systems
TX06.2.1	Pressure Garment	6.2.1	Pressure Garment
TX06.2.2	Portable Life Support System	6.2.2	Portable Life Support System
TX06.2.3	Informatics and Decision Support Systems	6.2.3	Power, Avionics, and Software
TX06.2.4	Decompression Sickness Mitigation	NEW	
TX06.3	Human Health and Performance	6.3	Human Health and Performance
TX06.3.1	Medical Diagnosis and Prognosis	6.3.1	Medical Diagnosis and Prognosis
		10.4.3	Miniature Instruments and Instrument Components
TX06.3.2	Prevention and Countermeasures	6.3.2	Long-Duration Health
		6.3.3	Behavioral Health
TX06.3.3	Behavioral Health and Performance	6.3.3	Behavioral Health

TX06	Human Health, Life Support, and Habitation Systems	Original TA in 2015 Technology Area Breakdown Structure	
TX06.3.4	Contact-less/ Wearable Human Health and Performance Monitoring	NEW	
TX06.3.5	Food Production, Processing, and Preservation	7.2.4	Food Production, Processing, and Preservation
TX06.3.6	Long Duration Health	6.3.2	Long-Duration Health
TX06.3.7	System Transformative Health and Performance Concepts	NEW	
TX06.4	Environmental Monitoring, Safety, and Emergency Response	6.4	Environmental Monitoring, Safety, and Emergency Response
TX06.4.1	Sensors: Air, Water, Microbial, and Acoustic	6.4.1	Sensors: Air, Water, Microbial, and Acoustic
		10.4.1	Sensors and Actuators
TX06.4.2	Fire: Detection, Suppression, and Recovery	6.4.2	Fire: Detection, Suppression, and Recovery
TX06.4.3	Protective Clothing and Breathing	6.4.3	Protective Clothing and Breathing
TX06.4.4	Remediation	6.4.4	Remediation
TX06.5	Radiation	6.5	Radiation
TX06.5.1	Radiation Transport and Risk Modeling	6.5.1	Risk Assessment Modeling
TX06.5.2	Radiation Mitigation and Biological Countermeasures	6.5.2	Radiation Mitigation and Biological Countermeasures
TX06.5.3	Protection Systems	6.5.3	Protection Systems
TX06.5.4	Space Weather Prediction	6.5.4	Space Weather Prediction
TX06.5.5	Monitoring Technology	6.5.5	Monitoring Technology
		10.4.1	Sensors and Actuators

TX06 Human Health, Life Support, and Habitation Systems

TX06	Human Health, Life Support, and Habitation Systems	Original TA in 2015 Technology Area Breakdown Structure	
TX06.6	Human Systems Integration	NEW	
TX06.6.1	Human Factors Engineering	6.3.4	Human Factors
TX06.6.2	Training	7.5.1	Crew Training
TX06.6.3	Habitability and Environment	7.4.1	Integrated Habitat Systems
		7.4.2	Habitat Evolution
		7.4.3	“Smart” Habitats
		7.4.4	Artificial Gravity
TX06.6.4	Operations Effectiveness	7.5.3	Integrated Flight Operations Systems
TX06.6.5	Integrated Systems Safety	7.5.4	Integrated Risk Assessment Tools
TX06.6.6	Maintainability and Supportability	7.2.1	Autonomous Logistics Management
		7.2.2	Maintenance Systems
		7.2.3	Repair Systems
TX06.X	Other Human Health, Life Support, and Habitation Systems	NEW	

The page intentionally left blank.

TX07 Exploration Destination Systems

TX07	Exploration Destination Systems	Original TA in 2015 Technology Area Breakdown Structure	
TX07.1	In-Situ Resource Utilization	7.1	In-Situ Resource Utilization
TX07.1.1	Destination Reconnaissance and Resource Assessment	7.1.1	Destination Reconnaissance, Prospecting, and Mapping
TX07.1.2	Resource Acquisition, Isolation, and Preparation	7.1.2	Resource Acquisition
TX07.1.3	Resource Processing for Production of Mission Consumables	7.1.3	Processing and Production
TX07.1.4	Resource Processing for Production of Manufacturing, Construction, and Energy Storage Feedstock Materials	7.1.4	Manufacturing Products and Infrastructure Emplacement
TX07.2	Mission Infrastructure, Sustainability, and Supportability	7.2	Sustainability and Supportability
		7.6	Crosscutting Systems
TX07.2.1	Logistics Management	7.2.1	Autonomous Logistics Management
TX07.2.2	In-Situ Manufacturing, Maintenance, and Repair	7.2.2	Maintenance Systems
		7.2.3	Repair Systems
TX07.2.3	Surface Construction and Assembly	7.6.2	Construction and Assembly
TX07.2.4	Micro-Gravity Construction and Assembly	7.6.2	Construction and Assembly
TX07.2.5	Particulate Contamination Prevention and Mitigation	7.6.1	Particulate Contamination Prevention and Mitigation

TX07 Exploration Destination Systems

TX07	Exploration Destination Systems	Original TA in 2015 Technology Area Breakdown Structure	
TX07.3	Mission Operations and Safety	7.5	Mission Operations and Safety
TX07.3.1	Mission Planning and Design	NEW	
TX07.3.2	Integrated Flight Operations Systems	7.5.3	Integrated Flight Operations Systems
TX07.3.3	Training	7.5.1	Crew Training
TX07.3.4	Integrated Risk Assessment Tools	7.5.4	Integrated Risk Assessment Tools
TX07.3.5	Planetary Protection	7.5.2	Planetary Protection
		13.2.5	Curatorial Facilities, Planetary Protection, and Clean Rooms
TX07.X	Other Exploration Destination Systems	NEW	

TX08 Sensors and Instruments

TX08	Sensors and Instruments	Original TA in 2015 Technology Area Breakdown Structure	
TX08.1	Remote Sensing Instruments/ Sensors	8.1	Remote Sensing Instruments/Sensors
TX08.1.1	Detectors and Focal Planes	8.1.1	Detectors and Focal Planes
		10.4.3	Miniature Instruments and Instrument Components
TX08.1.2	Electronics	8.1.2	Electronics
		10.4.2	Nanoelectronics
TX08.1.3	Optical Components	8.1.3	Optical Components
TX08.1.4	Microwave, Millimeter-, and Submillimeter-Waves	8.1.4	Microwave, Millimeter-, and Submillimeter-Waves
TX08.1.5	Lasers	8.1.5	Lasers
TX08.1.6	Cryogenic/Thermal	8.1.6	Cryogenic/Thermal
TX08.2	Observatories	8.2	Observatories
TX08.2.1	Mirror Systems	8.2.1	Mirror Systems
TX08.2.2	Structures and Antennas	8.2.2	Structures and Antennas
TX08.2.3	Distributed Aperture	8.2.3	Distributed Aperture
TX08.3	In-Situ Instruments/ Sensor	8.3	In-Situ Instruments/Sensor
TX08.3.1	Field and Particle Detectors	8.3.1	Field and Particle Detectors
		8.3.2	Fields and Waves
TX08.3.2	Atomic and Molecular Species Assessment	NEW	
TX08.3.3	Sample Handling	NEW	
TX08.3.4	Environment Sensors	8.3.3	In-Situ (other)
		10.4.1	Sensors and Actuators
TX08.3.5	Electromagnetic Wave Based Sensors	NEW	
TX08.3.6	Extreme Environments Related to Critical System Health Management		
TX08.X	Other Sensors and Instruments	NEW	

The page intentionally left blank.

TX09 Entry, Descent, and Landing

TX09	Entry, Descent, and Landing	Original TA in 2015 Technology Area Breakdown Structure	
TX09.1	Aeroassist and Atmospheric Entry	9.1	Aeroassist and Atmospheric Entry
TX09.1.1	Thermal Protection Systems	9.1.1	Thermal Protection Systems for Rigid Decelerators
		9.1.2	Thermal Protection Systems for Deployable Decelerators
		10.1.5	Thermal Protection and Control
TX09.1.2	Hypersonic Decelerators	9.1.3	Rigid Hypersonic Decelerators
		9.1.4	Deployable Hypersonic Decelerators
TX09.1.3	Passive Reentry Systems for Smallsats	9.3.5	Small-Body Systems
TX09.2	Descent	9.2	Descent and Targeting
TX09.2.1	Aerodynamic Decelerators	9.2.1	Attached Deployable Decelerators
		9.2.2	Trailing Deployable Decelerators
TX09.2.2	Supersonic Retropropulsion	9.2.3	Supersonic Retropropulsions
TX09.3	Landing	9.3	Landing
TX09.3.1	Touchdown Systems	9.2.8	Autonomous Targeting
		9.3.1	Propulsion and Touchdown Systems
		9.3.2	Egress and Deployment Systems
TX09.3.2	Propulsion Systems for Landing	9.3.1	Propulsion and Touchdown Systems
		9.3.3	Propulsion Systems
TX09.4	Vehicle Systems	9.4	Vehicle Systems
TX09.4.1	Architecture Design and Analysis	9.4.1	Architecture Analysis
TX09.4.2	Separation Systems	9.4.2	Separation Systems
TX09.4.3	System Integration and Analysis for EDL	9.4.3	System Integration and Analysis
TX09.4.4	Atmosphere and Surface Characterization	9.4.4	Atmosphere and Surface Characterization
TX09.4.5	Modeling and Simulation for EDL	9.1.6	Entry Modeling and Simulation
		9.2.5	Descent Modeling and Simulation
		9.3.6	Landing Modeling and Simulation
		9.4.5	Modeling and Simulation

TX09 Entry, Descent, and Landing

TX09	Entry, Descent, and Landing	Original TA in 2015 Technology Area Breakdown Structure	
TX09.4.6	Instrumentation and Health Monitoring for EDL	9.1.5	Instrumentation and Health Monitoring
		9.4.6	Instrumentation and Health Monitoring
TX09.4.7	Guidance, Navigation and Control (GN&C) for EDL	4.5.3	Autonomous Guidance and Control
		9.2.4	GN&C Sensors
		9.2.6	Large Divert Guidance
		9.2.7	Terrain-Relative Sensing and Characterization
		9.3.4	Large Body GN&C
		9.3.5	Small Body Systems
		9.4.7	GN&C Sensors and Systems
TX09.X	Other Entry, Descent, and Landing	NEW	

TX10 Autonomous Systems

TX10	Autonomous Systems	Original TA in 2015 Technology Area Breakdown Structure	
TX10.1	Situational and Self Awareness	4.1	Sensing and Perception
TX10.1.1	Sensing and Perception for Autonomous Systems	4.1	Sensing and Perception
		4.5.5	Adjustable Autonomy
		4.5.8	Automated Data Analysis for Decision Making
TX10.1.2	State Estimation and Monitoring	4.1.2	State Estimation
		4.5.4	Multi-Agent Coordination
		4.5.8	Automated Data Analysis for Decision Making
TX10.1.3	Knowledge and Model Building	4.5.8	Automated Data Analysis for Decision Making
		4.7.3	Robot Modeling and Simulation
TX10.1.4	Hazard Assessment	4.5.8	Automated Data Analysis for Decision Making
		4.7.5	Safety and Trust
TX10.1.5	Event and Trend Identification	4.5.5	Adjustable Autonomy
		4.5.8	Automated Data Analysis for Decision Making
TX10.1.6	Anomaly Detection	4.5.5	Adjustable Autonomy
		4.5.8	Automated Data Analysis for Decision Making
		11.4.8	Cyber Security
TX10.2	Reasoning and Acting	4.5	System-Level Autonomy
TX10.2.1	Mission Planning and Scheduling	4.5.5	Adjustable Autonomy
		4.5.8	Automated Data Analysis for Decision Making
		11.4.5	Advanced Mission Systems
TX10.2.2	Activity and Resourc Planning and Scheduling	4.5.2	Activity Planning, Scheduling, and Execution
		4.5.4	Multi-Agent Coordination
		4.5.8	Automated Data Analysis for Decision Making
		11.4.5	Advanced Mission Systems
TX10.2.3	Motion Planning	4.5.3	Autonomous Guidance and Control
		4.5.7	Path and Motion Planning with Uncertainty
		4.5.8	Automated Data Analysis for Decision Making
TX10.2.4	Execution and Control	4.5.2	Activity Planning, Scheduling, and Execution
		4.5.4	Multi-Agent Coordination
		4.5.5	Adjustable Autonomy
		4.5.8	Automated Data Analysis for Decision Making

TX10	Autonomous Systems	Original TA in 2015 Technology Area Breakdown Structure	
TX10.2.5	Fault Diagnosis and Prognosis	4.5.1	System Health Management
		4.5.8	Automated Data Analysis for Decision Making
TX10.2.6	Fault Response	4.5.1	System Health Management
		4.5.8	Automated Data Analysis for Decision Making
TX10.2.7	Learning and Adapting	4.5.8	Automated Data Analysis for Decision Making
		11.4.5	Advanced Mission Systems
TX10.3	Collaboration and Interaction	4.4	Human System Interaction
TX10.3.1	Joint Knowledge and Understanding	4.4.3	Proximate Interaction
		4.5.4	Multi-Agent Coordination
TX10.3.2	Behavior and Intent Prediction	4.5.4	Multi-Agent Coordination
		4.5.5	Adjustable Autonomy
TX10.3.3	Goal and Task Negotiation	4.5.4	Multi-Agent Coordination
		4.5.5	Adjustable Autonomy
		11.2.3	Human-System Performance Modeling
TX10.3.4	Operational Trust Building	4.4.7	Safety, Trust, and Interfacing of Robotic and Human Proximity Operations
		4.5.4	Multi-Agent Coordination
		4.5.5	Adjustable Autonomy
		4.7.5	Safety and Trust
TX10.4	Engineering and Integrity		
TX10.4.1	Verification and Validation of Autonomous Systems	4.7.2	Verification and Validation of Complex Adaptive Systems
TX10.4.2	Test and Evaluation of Autonomous Systems	NEW	
TX10.4.3	Operational Assurance of Autonomous Systems	NEW	
TX10.4.4	Modeling and Simulation of Autonomous Systems	4.7.3	Robot Modeling and Simulation
TX10.4.5	Architecture and Design of Autonomous Systems	NEW	
TX10.X	Other Autonomous Systems	NEW	

TX11 Software, Modeling, Simulation, and Information Processing

TX11	Software, Modeling, Simulation, and Information Processing	Original TA in 2015 Technology Area Breakdown Structure	
TX11.1	Software Development, Engineering, and Integrity	NEW	
TX11.1.1	Tools and Methodologies for Software Design and Development	11.1.1	Flight Computing
TX11.1.2	Verification and Validation of Software systems	11.3.8	Verification and Validation
TX11.1.3	Test and Evaluation	11.2.1	Software Modeling and Model Checkingt
TX11.1.4	Operational Assurance	NEW	
TX11.1.5	Architecture and Design of Software systems	11.4.7	Human-System Integration
TX11.1.6	Real-time Software	11.1.1	Flight Computing
TX11.1.7	Frameworks, Languages, Tools, and Standards	11.2.5	Frameworks, Languages, Tools, and Standards
TX11.1.8	Software Analysis and Design Tools	11.2.1	Software Modeling and Model Checking
TX11.1.9	Software Cyber Security	11.4.8	Cyber Security
TX11.2	Modeling	11.2	Modeling
TX11.2.1	Software Modeling and Model Checking	11.2.1	Software Modeling and Model Checking
TX11.2.2	Integrated Hardware and Software Modeling	11.2.2	Integrated Hardware and Software Modeling
TX11.2.3	Human-System Performance Modeling	11.2.3	Human-System Performance Modeling
TX11.2.4	Science Modeling	11.2.4	Science Modeling

TX11 Software, Modeling, Simulation, and Information Processing

TX11	Software, Modeling, Simulation, and Information Processing	Original TA in 2015 Technology Area Breakdown Structure	
TX11.3	Simulation	11.3	Simulation
TX11.3.1	Distributed Simulation	11.3.1	Distributed Simulation
TX11.3.2	Integrated System Lifecycle Simulation	11.3.2	Integrated System Lifecycle Simulation
TX11.3.3	Model-Based Systems Engineering (MBSE)	11.3.3	Simulation-Based Systems Engineering
TX11.3.4	Simulation-Based Training and Decision Support Systems	11.3.4	Simulation-Based Training and Decision Support Systems
TX11.3.5	Exascale Simulation	11.3.5	Exascale Simulation
TX11.3.6	Uncertainty Quantification and Nondeterministic Simulation Methods	11.3.6	Uncertainty Quantification and Nondeterministic Simulation Methods
TX11.3.7	Multiscale, Multiphysics, and Multifidelity Simulation	11.3.7	Multiscale, Multiphysics, and Multifidelity Simulation
TX11.4	Information Processing	11.4	Information Processing
TX11.4.1	Science, Engineering, and Mission Data Lifecycle	11.4..1	Science, Engineering, and Mission Data Lifecycle
		11.4.5	Advanced Mission Systems
TX11.4.2	Intelligent Data Understanding	11.4.2	Intelligent Data Understanding
TX11.4.3	Semantic Technologies	11.4.3	Semantic Technologies
TX11.4.4	Collaborative Science and Engineering	11.4.4	Collaborative Science and Engineering
TX11.4.5	Cyber Infrastructure	11.4.6	Cyber Infrastructure
TX11.4.6	Cyber Security	11.4.8	Cyber Security
TX11.4.7	Digital Assistant	NEW	
TX11.4.8	Edge Computing	NEW	

TX11	Software, Modeling, Simulation, and Information Processing	Original TA in 2015 Technology Area Breakdown Structure	
TX11.5	Mission Architecture, Systems Analysis and Concept Development	NEW	
TX11.5.1	Tools and Methodologies for Defining Mission Architectures or Mission Design	11.2.6	Analysis Tools for Mission Design
TX11.5.2	Tools and Methodologies for Performing Systems Analysis	NEW	
TX11.5.3	Tools and Methodologies for Vehicle or Concept Definition Activities	NEW	
TX11.6	Ground Computing	11.1	Computing
TX11.6.1	Exascale Supercomputer	11.1.2	Ground Computing
TX11.6.2	Automated Exascale Software Development Toolset	11.1.2	Ground Computing
TX11.6.3	Exascale Supercomputer File System	11.1.2	Ground Computing
TX11.6.4	Quantum Computer	11.1.2	Ground Computing
TX11.6.5	Public Cloud Supercomputer	11.1.2	Ground Computing
TX11.6.6	Cognitive Computer	11.1.2	Ground Computing
TX11.6.7	High Performance Data Analytics Platform	11.1.2	Ground Computing
TX11.6.8	Cloud Computing	NEW	
TX11.X	Other Software, Modeling, Simulation, and Information Processing	NEW	

The page intentionally left blank.

TX12 Materials, Structures, Mechanical Systems, and Manufacturing

TX12	Materials, Structures, Mechanical Systems, and Manufacturing	Original TA in 2015 Technology Area Breakdown Structure	
TX12.1	Materials	12.1	Materials
		10.1	Engineered Materials and Structures
TX12.1.1	Lightweight Structural Materials	12.1.1	Lightweight Structural Materials
		10.1.1	Lightweight Structures
		10.1.2	Damage-Tolerant Systems
TX12.1.2	Computational Materials	12.1.2	Computationally-Designed Materials
		10.4.2	Nanoelectronics
TX12.1.3	Flexible Material Systems	12.1.3	Flexible Material Systems
		10.4.2	Nanoelectronics
TX12.1.4	Materials for Extreme Environments	12.1.4	Materials for Extreme Environments
TX12.1.5	Coatings	12.1.4	Materials for Extreme Environments
		10.1.3	Coatings
TX12.1.6	Materials for Electrical Power Generation, Energy Storage, Power Distribution and Electrical Machines	12.1.5	Special Materials
TX12.1.7	Special Materials	12.1.5	Special Materials
		10.1.4	Adhesives
TX12.1.8	Smart Materials	NEW	
TX12.2	Structures	12.2	Structures
		10.1	Engineered Materials and Structures
TX12.2.1	Lightweight Concepts	12.2.1	Lightweight Concepts
		10.1.1	Lightweight Structures
TX12.2.2	Design and Certification Methods	12.2.2	Design and Certification Methods
TX12.2.3	Reliability and Sustainment	12.2.3	Reliability and Sustainment
TX12.2.4	Tests, Tools and Methods	12.2.4	Tests, Tools and Methods

TX12 Materials, Structures, Mechanical Systems, and Manufacturing

TX12	Materials, Structures, Mechanical Systems, and Manufacturing	Original TA in 2015 Technology Area Breakdown Structure	
TX12.2.5	Innovative, Multifunctional Concepts	12.2.5	Innovative, Multifunctional Concepts
		10.1.1	Lightweight Structures
TX12.3	Mechanical Systems	12.3	Mechanical Systems
TX12.3.1	Deployables, Docking, and Interfaces	4.6.3	Docking and Capture Mechanisms and Interface
		12.3.1	Deployables, Docking, and Interfaces
		12.3.2	Mechanism Life Extension Systems
TX12.3.2	Electro-Mechanical, Mechanical, and Micromechanisms	12.3.3	Electro-Mechanical, Mechanical, and Micromechanisms
TX12.3.3	Design and Analysis Tools and Methods	12.3.4	Design and Analysis Tools and Methods
TX12.3.4	Reliability, Life Assessment, and Health Monitoring	12.3.5	Reliability, Life Assessment, and Health Monitoring
TX12.3.5	Certification Methods	12.3.6	Certification Methods
TX12.3.6	Mechanical Drive Systems	NEW	
TX12.3.7	Mechanism Life Extension Systems	12.3.2	Mechanism Life Extension Systems
TX12.3.8	Docking and Berthing Mechanisms and Fixtures	4.6.3	Docking and Capture Mechanisms and Interface
		12.3.1	Deployables, Docking, and Interfaces
TX12.4	Manufacturing	12.4	Manufacturing
TX12.4.1	Manufacturing Processes	12.4.1	Manufacturing Processes
TX12.4.2	Intelligent Integrated Manufacturing	12.4.2	Intelligent Integrated Manufacturing and Cyber Physical Systems
TX12.4.3	Electronics and Optics Manufacturing Process	12.4.3	Electronics and Optics Manufacturing Process
		10.4.2	Nanoelectronics
TX12.4.4	Sustainable Manufacturing	12.4.4	Sustainable Manufacturing
TX12.4.5	Nondestructive Evaluation and Sensors	12.4.5	Nondestructive Evaluation and Sensors
		10.4.1	Sensors and Actuators
TX12.4.6	Repurpose Processes	NEW	

TX12 Materials, Structures, Mechanical Systems, and Manufacturing

TX12	Materials, Structures, Mechanical Systems, and Manufacturing	Original TA in 2015 Technology Area Breakdown Structure	
TX12.5	Structural Dynamics	12.2.6	Loads and Environments
TX12.5.1	Loads and Vibration	NEW	
TX12.5.2	Vibroacoustics	NEW	
TX12.5.3	Shock and Impact	NEW	
TX12.5.4	Test, Tools, and Methods	NEW	
TX12.X	Other Manufacturing, Materials, and Structures	NEW	

The page intentionally left blank.

TX13 Ground, Test, and Surface Systems

TX13	Ground, Test, and Surface Systems	Original TA in 2015 Technology Area Breakdown Structure	
TX13.1	Infrastructure Optimization	NEW	
TX13.1.1	Natural and Induced Environment Characterization and Mitigation	13.2.1	Corrosion Prevention, Detection, and Mitigation
		13.2.2	Environmental Remediation and Site Restoration
		13.2.3	Preservation of Natural Ecosystems
		13.3.2	Environment-Hardened Materials and Structures
		13.4.3	Weather Prediction and Mitigation
TX13.1.2	Launch/Test/Ops Site Management	13.1.2	Automated Alignment, Coupling, Assembly, and Transportation Systems
		13.3.5	Prognostics
		13.4.1	Range Tracking, Surveillance, and Flight Safety Technologies
TX13.1.3	Commodity Recovery	13.1.1	On-site Production, Storage, Distribution, and Conservation of Fluids
TX13.1.4	Propellant Production, Storage and Transfer	13.1.1	On-site Production, Storage, Distribution, and Conservation of Fluids
TX13.1.5	Ground and Surface Logistics	13.1.4	Logistics
		13.3.4	Fault Isolation and Diagnostics
TX13.1.6	Test, Operations, and Systems Safety	13.1.2	Automated Alignment, Coupling, Assembly, and Transportation Systems
		13.4.1	Range Tracking, Surveillance, and Flight Safety Technologies
		13.4.4	Robotics and Telerobotics
		13.4.5	Safety Systems
TX13.1.7	Impact/Damage/ Radiation-Resistant Systems	13.3.2	Environment-Hardened Materials and Structures
		13.3.6	Repair, Mitigation, and Recovery Technologies
TX13.2	Test and Qualification	NEW	
TX13.2.1	Mechanical/ Structural Integrity Testing	NEW	
TX13.2.2	Propulsion, Exhaust, and Propellant Management	13.1.1	On-site Production, Storage, Distribution, and Conservation of Fluids
		13.4.4	Robotics and Telerobotics
TX13.2.3	Non-Destructive Inspection, Evaluation, and Root Cause Analysis	13.3.3	On-Site Inspection and Anomaly Detection and Identification
		13.4.4	Robotics and Telerobotics

TX13	Ground, Test, and Surface Systems	Original TA in 2015 Technology Area Breakdown Structure	
TX13.2.4	Verification and Validation of Ground, Test, and Surface Systems	NEW	
TX13.2.5	Flight and Ground Testing Methodologies	13.4.2	Landing and Recovery Systems and Components
		13.4.3	Weather Prediction and Mitigation
TX13.2.6	Advanced Life-Cycle Testing Techniques	13.3.3	Fault Isolation and Diagnostics
		13.3.4	Prognostics
		13.3.8	Decision-Making Tools
TX13.2.7	Test Instruments and Sensors	NEW	
TX13.2.8	Environment Testing	NEW	
TX13.3	Assembly, Integration and Launch	NEW	
TX13.3.1	Offline Element Processing	13.1.2	Automated Alignment, Coupling, Assembly, and Transportation Systems
TX13.3.2	Vehicle and Payload Assembly and Integration	13.1.2	Automated Alignment, Coupling, Assembly, and Transportation Systems
		13.4.4	Robotics and Telerobotics
TX13.3.3	Launch, Recovery and Reutilization	13.3.1	Launch Infrastructure
		13.4.2	Landing and Recovery Systems and Components
TX13.4	Mission Success Technologies	NEW	
TX13.4.1	Mission Planning	13.1.3	Autonomous Command and Control for Integrated Vehicle and Ground Systems
TX13.4.2	Team Preparedness and Training	13.1.3	Autonomous Command and Control for Integrated Vehicle and Ground Systems
TX13.4.3	High-Fidelity Simulation and Visualization	13.1.3	Autonomous Command and Control for Integrated Vehicle and Ground Systems
TX13.4.4	Autonomous, Real-Time Command and Control	13.1.3	Autonomous Command and Control for Integrated Vehicle and Ground Systems
		13.3.8	Decision-Making Tools
TX13.4.5	Operations, Health and Maintenance for Ground and Surface Systems	13.3.3	On-site Inspection and Anomaly Detection and Identification
		13.3.4	Fault Isolation and Diagnostics
		13.3.5	Prognostics
		13.4.4	Robotics and Telerobotics

TX13 Ground, Test, and Surface Systems

TX13	Ground, Test, and Surface Systems	Original TA in 2015 Technology Area Breakdown Structure	
TX13.4.6	Ground Analogs for Space/Surface Systems	NEW	
TX13.X	Other Ground, Test, and Surface Systems	NEW	

The page intentionally left blank.

TX14 Thermal Management Systems

TX14	Thermal Management Systems	Original TA in 2015 Technology Area Breakdown Structure	
TX14.1	Cryogenic Systems	14.1	Cryogenic Systems
TA14.1.1	In-space Propellant Storage and Utilization	14.1.1	Passive Thermal Control
		14.1.2	Active Thermal Control
		14.1.3	Integration and Modeling
TA14.1.2	Launch Vehicle Propellant	14.1.1	Passive Thermal Control
		14.1.2	Active Thermal Control
		14.1.3	Integration and Modeling
TA14.1.3	Thermal conditioning for Sensors, Instruments, and High Efficiency Electronic Motors	14.1.1	Passive Thermal Control
		14.1.2	Active Thermal Control
		14.1.3	Integration and Modeling
TA14.1.4	Ground Testing, and Operations	NEW	
TA14.1.5	Cryogenic Analysis, Safety, and Properties	NEW	
TX14.2	Thermal Control Components and Systems	14.2	Thermal Control Systems
TX14.2.1	Heat Acquisition	14.2.1	Heat Acquisition
TX14.2.2	Heat Transport	14.2.2	Heat Transport
TX14.2.3	Heat Rejection and Storage	14.2.3	Heat Rejection and Energy Storage
		10.1.5	Thermoprotection and Control
TX14.2.4	Insulation and Interfaces	14.2.1	Heat Acquisition
		10.1.5	Thermoprotection and Control
TX14.2.5	Thermal Control Analysis	NEW	
TX14.2.6	Heating Systems	NEW	
TX14.2.7	Verification and Validation of Thermal Management Systems	NEW	
TX14.2.8	Measurement and Control	NEW	

TX14 Thermal Management Systems

TX14	Thermal Management Systems	Original TA in 2015 Technology Area Breakdown Structure	
TX14.3	Thermal Protection Components and Systems	14.3	Thermal Protection Systems
TX14.3.1	Thermal Protection Materials	14.3.1	Ascent/Entry TPS
		10.1.5	Thermoprotection and Control
TX14.3.2	Thermal Protection Systems	14.3.1	Ascent/Entry TPS
		10.1.5	Thermoprotection and Control
TX14.3.3	Thermal Protection Analysis	14.3.2	TPS Modeling and Simulation
TX14.3.4	Thermal Protection System Testing	14.3.2	TPS Modeling and Simulation
TX14.3.5	Thermal Protection System Instrumentation	14.3.3	TPS Sensors and Measurement Systems
TX14.X	Other Thermal Management Systems	NEW	

TX15 Flight Vehicle Systems

TX15	Flight Vehicle Systems	Original TA in 2015 Technology Area Breakdown Structure	
TX15.1	Aerosciences	15	Aeronautics
TX15.1.1	Aerodynamics	15.3.1	Achieve Community Goals for Improved Vehicle Efficiency and Environmental Performance in 2025
		15.3.2	Achieve Community Goals for Improved Vertical Lift Vehicle Efficiency and Environmental Performance in 2035
		15.3.3	Achieve Community Goals for Improved Vehicle Efficiency and Environmental Performance Beyond 2035
TX15.1.2	Aerothermodynamics	15.3.1	Achieve Community Goals for Improved Vehicle Efficiency and Environmental Performance in 2025
		15.3.3	Achieve Community Goals for Improved Vehicle Efficiency and Environmental Performance Beyond 2035
TX15.1.3	Aeroelasticity	15.3.1	Achieve Community Goals for Improved Vehicle Efficiency and Environmental Performance in 2025
		15.3.2	Achieve Community Goals for Improved Vertical Lift Vehicle Efficiency and Environmental Performance in 2035
		15.3.3	Achieve Community Goals for Improved Vehicle Efficiency and Environmental Performance Beyond 2035
TX15.1.4	Aeroacoustics	15.2.1	Supersonic Overland Certification Standard Based on Acceptable Sonic Boom Noise
		15.2.2	Introduction of Affordable, Low-Boom, Low-Noise, and Low-Emission Supersonic Transports
		15.3.1	Achieve Community Goals for Improved Vehicle Efficiency and Environmental Performance in 2025
		15.3.2	Achieve Community Goals for Improved Vertical Lift Vehicle Efficiency and Environmental Performance in 2035
		15.3.3	Achieve Community Goals for Improved Vehicle Efficiency and Environmental Performance Beyond 2035
TX15.1.5	Propulsion Flowpath and Interactions	15.2.2	Introduction of Affordable, Low-Boom, Low-Noise, and Low-Emission Supersonic Transports
TX15.1.6	Advanced Atmospheric Flight Vehicles	15.3.1	Achieve Community Goals for Improved Vehicle Efficiency and Environmental Performance in 2025
		15.3.2	Achieve Community Goals for Improved Vertical Lift Vehicle Efficiency and Environmental Performance in 2035
		15.3.3	Achieve Community Goals for Improved Vehicle Efficiency and Environmental Performance Beyond 2035

TX15 Flight Vehicle Systems

TX15	Flight Vehicle Systems	Original TA in 2015 Technology Area Breakdown Structure	
TX15.1.7	Computational Fluid Dynamics (CFD) Technologies	15.3.1	Achieve Community Goals for Improved Vehicle Efficiency and Environmental Performance in 2025
		15.3.2	Achieve Community Goals for Improved Vertical Lift Vehicle Efficiency and Environmental Performance in 2035
		15.3.3	Achieve Community Goals for Improved Vehicle Efficiency and Environmental Performance Beyond 2035
TX15.1.8	Ground and Flight Test Technologies	15.3.1	Achieve Community Goals for Improved Vehicle Efficiency and Environmental Performance in 2025
		15.3.2	Achieve Community Goals for Improved Vertical Lift Vehicle Efficiency and Environmental Performance in 2035
		15.3.3	Achieve Community Goals for Improved Vehicle Efficiency and Environmental Performance Beyond 2035
TX15.2	Flight Mechanics	NEW	
TX15.2.1	Trajectory Design and Analysis	15.1.1	Improved Efficiency and Hazard Reduction within NextGen Operational Domains
		15.1.2	System-Wide Safety, Predictability, reliability through Full NextGen Functionality
TX15.2.2	Flight Performance and Analysis	15.1.1	Improved Efficiency and Hazard Reduction within NextGen Operational Domains
		15.1.2	System-Wide Safety, Predictability, reliability through Full NextGen Functionality
TX15.2.3	Flight Mechanics Testing and Flight Operations	NEW	
TX15.2.4	Modeling and Simulation for Flight	NEW	
TX15.X	Other Flight Vehicle Systems	NEW	

TX16 Air Traffic Management and Range Tracking Systems

TX16	Air Traffic Management and Range Tracking Systems	Original TA in 2015 Technology Area Breakdown Structure	
TX16.1	Safe All Vehicle Access	15.5.1	Introduction of Advanced Safety Assurance Tools
		15.5.2	An Integrated Safety Assurance System Enabling Continuous System-Wide Safety Monitoring
		15.5.3	Automated Safety Assurance Integrated with Real-Time Operations Enabling a Self-Protecting Aviation System
TX16.2	Weather/ Environment	15.1.1	Improved Efficiency and Hazard Reduction within NextGen Operational Domains
TX16.3	Traffic Management Concepts	15.1.1	Improved Efficiency and Hazard Reduction within NextGen Operational Domains
		15.1.2	System-Wide Safety, Predictability, and Reliability through Full NextGen Functionality
		15.6.2	Ability to Fully Certify and Trust Autonomous Systems for NAS Operations
TX16.4	Architectures and Infrastructure	15.5.3	Automated Safety Assurance Integrated with Real-time Operations Enabling a Self-Protecting Aviation System
		15.6.1	Initial Autonomy Applications
TX16.5	Range Tracking, Surveillance, and Flight Safety Technologies	13.4.1	Range Tracking, Surveillance, and Flight Safety Technologies
TX16.6	Integrated Modeling, Simulation, and Testing	NEW	
TX16.X	Other Air Traffic Management and Range Tracking Systems	NEW	

The page intentionally left blank.

TX17 Guidance, Navigation, and Control (GN&C)

TX17	Guidance, Navigation, and Control (GN&C)	Original TA in 2015 Technology Area Breakdown Structure	
TX17.1	Guidance and Targeting Algorithms	NEW	
TX17.1.1	Guidance Algorithms	4.6.2	Guidance, Navigation, and Control Algorithms
		5.4.5	Auto Precision Formation Flying
		5.4.6	Autonomous Approach and Landing
TX17.1.2	Targeting Algorithms	5.4.5	Auto Precision Formation Flying
		5.4.6	Autonomous Approach and Landing
		9.2.7	Terrain-relative Sensing and Characterization
		9.2.8	Autonomous Targeting
TX17.2	Navigation Technologies	NEW	
TX17.2.1	Onboard Navigation Algorithms	4.5.3	Autonomous Guidance and Control
		4.5.6	Terrain Relative Navigation
		5.4.2	Onboard Auto Navigation and Maneuver
		5.4.5	Auto Precision Formation Flying
		5.4.6	Autonomous Approach and Landing
TX17.2.2	Ground-based Navigation Algorithms	NEW	
TX17.2.3	Navigation Sensors	4.5.3	Autonomous Guidance and Control
		4.5.6	Terrain Relative Navigation
		4.6.1	Relative Navigation Sensors
		5.4.2	Onboard Auto Navigation and Maneuver
		5.4.3	Sensors and Vision Processing Systems
		5.4.4	Relative and Proximity Navigation
		5.4.5	Auto Precision Formation Flying
		5.4.6	Autonomous Approach and Landing
		9.2.7	Terrain-Relative Sensing and Characterization
		9.4.7	GN&C Sensors and Systems
TX17.2.4	Relative Navigation Aids	4.5.6	Terrain Relative Navigation
		5.4.4	Relative and Proximity Navigation
		9.2.7	Terrain-Relative Sensing and Characterization

TX17 Guidance, Navigation, and Control (GN&C)

TX17	Guidance, Navigation, and Control (GN&C)	Original TA in 2015 Technology Area Breakdown Structure	
TX17.2.5	Rendezvous, Proximity Operations, and Capture Sensor Processing and Processors	5.4.2	Onboard Auto Navigation and Maneuver
		5.4.3	Sensors and Vision Processing Systems
TX17.2.6	Rendezvous, Proximity Operations, and Capture Trajectory Design and Orbit Determination	5.4.2	Onboard Auto Navigation and Maneuver
TX17.3	Control Technologies	NEW	
TX17.3.1	Onboard Maneuvering/ Pointing/ Stabilization/Flight Control Algorithms	5.4.2	Onboard Auto Navigation and Maneuver
		5.4.5	Auto Precision Formation Flying
		5.4.6	Autonomous Approach and Landing
TX17.3.2	Dynamics Analysis, Modeling, and Simulation Tools	5.4.5	Auto Precision Formation Flying
		5.4.6	Autonomous Approach and Landing
TX17.3.3	Ground-based Maneuvering/ Pointing/ Stabilization/Flight Control Algorithms	NEW	
TX17.3.4	Control Force/ Torque Actuators	NEW	
TX17.3.5	GN&C actuators for 6DOF Spacecraft Control During Rendezvous, Proximity Operations, and Capture	NEW	
TX17.4	Attitude Estimation Technologies	NEW	
TX17.4.1	Onboard Attitude/ Attitude Rate Estimation Algorithms	5.4.2	Onboard Auto Navigation and Maneuver

TX17	Guidance, Navigation, and Control (GN&C)	Original TA in 2015 Technology Area Breakdown Structure	
TX17.4.2	Ground-Based Attitude Determination/ Reconstruction Algorithm Development	NEW	
TX17.4.3	Attitude Estimation Sensors	5.4.5	Auto Precision Formation Flying
		5.4.6	Autonomous Approach and Landing
		9.4.7	GN&C Sensors and Systems
TX17.5	GN&C Systems Engineering Technologies	NEW	
TX17.5.1	GN&C System Architectures, Requirements and Specifications	NEW	
TX17.5.2	GN&C Fault Management/Fault Tolerance/Autonomy	NEW	
TX17.5.3	GN&C Verification and Validation Tools and Techniques	NEW	
TX17.5.4	GN&C Ground Testbeds/Test Facilities	NEW	
TX17.5.5	Vehicle Flight Dynamics and Mission Design Tools/Techniques	NEW	
TX17.5.6	System Identification	NEW	
TX17.5.7	End-to-End Modeling and Simulation of GN&C systems	NEW	
TX17.5.8	Flying/Handling Qualities	NEW	
TX17.5.9	Onboard and Ground-Based Terrain and Object Simulation, Mapping, and Modeling Software	NEW	

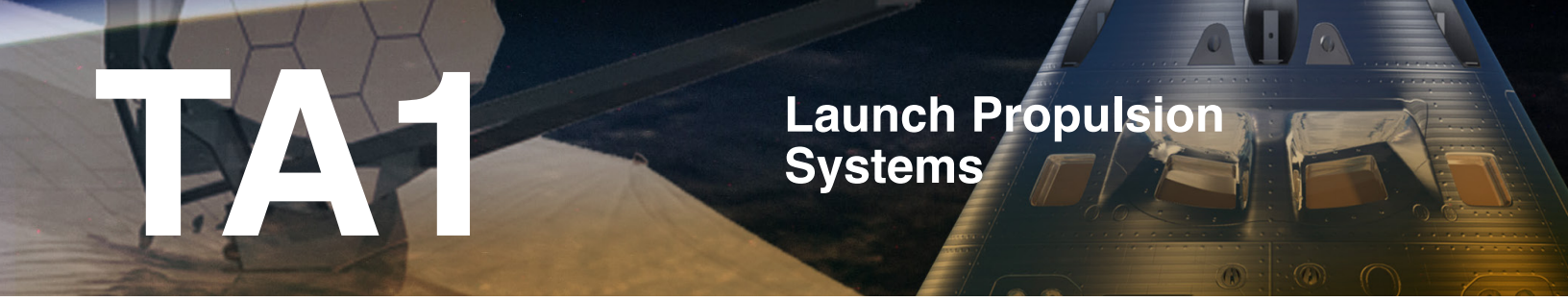
TX17	Guidance, Navigation, and Control (GN&C)	Original TA in 2015 Technology Area Breakdown Structure	
TX17.6	Technologies for Aircraft Trajectory Generation, Management, and Optimization for Airspace Operations	NEW	
TX17.6.1	Strategic Management of Air Vehicles	15.1.1	Improved Efficiency and Hazard Reduction within NextGen Operational Domains
		15.1.2	System-Wide Safety, Predictability, Reliability through Full NextGen Functionality
TX17.6.2	Tactical Management of Air Vehicles	15.1.1	Improved Efficiency and Hazard Reduction within NextGen Operational Domains
		15.1.2	System-Wide Safety, Predictability, Reliability through Full NextGen Functionality
TX17.X	Other Guidance, Navigation, and Control	NEW	

TA to TX Mapping

Propellant
Supply
Thermal
Management
Magnets
Neutralizer
Cathode
Thrust
Beam
Raw
Power
Conditioned
Power
Ionization
Chamber
Ion
Acceleration
Electrodes
Atoms
Ions
Electrons
Ion
Thruster

TA1 Launch Propulsion Systems

TA1 Launch Propulsion Systems		TX Technology Area Breakdown Structure	
TA1.1	Solid Rocket Propulsion Systems	TX01.1	Chemical Propulsion
TA1.1.1	Propellants	TX01.1.4	Solids
TA1.1.2	Case Materials	TX01.1.1	Integrated Systems and Ancillary Technologies
		TX01.1.4	Solids
TA1.1.3	Nozzle Systems	TX01.1.1	Integrated Systems and Ancillary Technologies
		TX01.1.4	Solids
TA1.1.4	Hybrid Rocket Propulsion Systems	TX01.1.4	Solids
		TX01.1.5	Hybrids
TA1.1.5	Fundamental Solid Propulsion Technologies	TX01.1.4	Solids
TA1.1.6	Integrated Solid Motor Systems	TX01.1.4	Solids
TA1.1.7	Liner and Insulation	TX01.1.4	Solids
TA1.2	Liquid Rocket Propulsion Systems	TX01.1	Chemical Propulsion
TA1.2.1	LH2/LOX Based	TX01.1.3	Cryogenic
TA1.2.2	RP/LOX Based	TX01.1.3	Cryogenic
TA1.2.3	CH4/LOX Based	TX01.1.3	Cryogenic
TA1.2.4	Detonation Wave Engines - Closed Cycle	TX01.3.4	Pressure Gain Combustion
TA1.2.5	Propellants	TX01.1.2	Earth Storable
TA1.2.6	Fundamental Liquid Propulsion Technologies	TX01.1.2	Earth Storable
		TX01.1.3	Cryogenic
TA1.3	Air Breathing Propulsion Systems	TX01.3	Aero Systems
TA1.3.1	Turbine-Based Combined Cycle	TX01.3.1	Integrated Systems and Ancillary Technologies
TA1.3.2	Rocket-Based Combined Cycle	TX01.3.2	Turbine-Based Combined Cycle
TA1.3.3	Detonation Wave Engines - Open Cycle	TX01.3.4	Pressure Gain Combustion
TA1.3.4	Turbine-Based Jet Engines	TX01.3.5	Turbine-Based Jet Engines
TA1.3.5	Ramjet and Scramjet Engines	TX01.3.6	Ramjet/Scramjet
TA1.3.6	Deeply-Cooled Air Cycles	TX01.3.1	Integrated Systems and Ancillary Technologies
TA1.3.7	Air Collection and Enrichment Systems	TX01.3.1	Integrated Systems and Ancillary Technologies
TA1.3.8	Fundamental Air Breathing Propulsion Technologies	TX01.3.1	Integrated Systems and Ancillary Technologies



TA1 Launch Propulsion Systems

TA1 Launch Propulsion Systems		TX Technology Area Breakdown Structure	
TA1.4	Ancillary Propulsion Systems	TX01.1	Chemical Propulsion
TA1.4.1	Auxiliary Control Systems	TX01.1.1	Integrated Systems and Ancillary Technologies
TA1.4.2	Main Propulsion Systems (Excluding Engines)	TX01.1.1	Integrated Systems and Ancillary Technologies
TA1.4.3	Launch Abort Systems	TX01.1.1	Integrated Systems and Ancillary Technologies
TA1.4.4	Thrust Vector Control Systems	TX01.1.1	Integrated Systems and Ancillary Technologies
TA1.4.5	Health Management and Sensors	TX01.1.1	Integrated Systems and Ancillary Technologies
TA1.4.6	Pyro and Separation Systems	TX01.1.1	Integrated Systems and Ancillary Technologies
TA1.4.7	Fundamental Ancillary Propulsion Technologies	TX01.1.1	Integrated Systems and Ancillary Technologies
TA1.5	Unvoncentional and Other Propulsion Systems	TX01.4	Advanced Propulsion
TA1.5.1	Ground Launch Assist	TX01.4.4	Other Advanced Propulsion Approaches
TA1.5.2	Air Launch and Drop Systems	TX01.4.4	Other Advanced Propulsion Approaches
TA1.5.3	Space Tether Assist	TX01.4.2	Electromagnetic Tethers
TA1.5.4	Beamed Energy and Energy Addition	TX01.4.4	Other Advanced Propulsion Approaches
TA1.5.5	Nuclear	TX01.2.2	Electrostatic
		TX01.4.3	Nuclear Thermal Propulsion
TA1.5.6	High Energy Density Materials and Propellants	TX01.4.4	Other Advanced Propulsion Approaches
TA1.6	Balloon Launch Systems	TX01.4	Advanced Propulsion
TA1.6.1	Super-Pressure Balloon	TX01.4.4	Other Advanced Propulsion Approaches
TA1.6.2	Materials	TX01.4.4	Other Advanced Propulsion Approaches
TA1.6.3	Pointing Systems	TX01.1.1	Integrated Systems and Ancillary Technologies
TA1.6.4	Telemetry Systems	TX01.1.1	Integrated Systems and Ancillary Technologies
TA1.6.5	Balloon Trajectory Control	TX01.1.1	Integrated Systems and Ancillary Technologies
TA1.6.6	Power Systems	TX01.1.1	Integrated Systems and Ancillary Technologies
TA1.6.7	Mechanical Systems: Launch Systems	TX01.1.1	Integrated Systems and Ancillary Technologies
TA1.6.8	Mechanical Systems: Parachute	TX01.1.1	Integrated Systems and Ancillary Technologies
TA1.6.9	Mechanical Systems: Floatation	TX01.1.1	Integrated Systems and Ancillary Technologies

TA2 In-Space Propulsion Technologies

TA2 In-Space Propulsion Technologies		TX Technology Area Breakdown Structure	
TA2.1	Chemical Propulsion	TX01.1	Chemical Propulsion
TA2.1.1	Liquid Storable	TX01.1.2	Earth Storable
TA2.1.2	Liquid Cryogenic	TX01.1.3	Cryogenic
TA2.1.3	Gels	TX01.1.6	Gels
TA2.1.4	Solids	TX01.1.4	Solids
TA2.1.5	Hybrid	TX01.1.5	Hybrids
TA2.1.6	Cold Gas/Warm Gas	TX01.1.7	Cold Gas
		TX01.1.8	Warm Gas
TA2.1.7	Micropropulsion	TX01.1.4	Solids
TA2.2	Non-Chemical Propulsion	TX1.2	Electric Space Propulsion
TA2.2.1	Electric Propulsion	TX01.2.2	Electrostatic
TA2.2.2	Solar and Drag Sail Propulsion	TX01.4.1	Solar Sails
TA2.2.3	Thermal Propulsion	TX01.4.3	Nuclear Thermal Propulsion
TA2.2.4	Tether Propulsion	TX01.4.2	Electromagnetic Tethers
TA2.3	Advanced (TRL<3) Propulsion Technologies	TX1.4	Advanced Propulsion
TA2.3.1	Beamed Energy Propulsion	TX01.4.4	Other Advanced Propulsion Approaches
TA2.3.2	Electric Sail propulsion	TX01.2.2	Electrostatic
TA2.3.3	Fusion Propulsion	TX01.4.4	Other Advanced Propulsion Approaches
TA2.3.4	High Energy-Density Propulsion	TX01.4.4	Other Advanced Propulsion Approaches
TA2.3.5	Antimatter Propulsion	TX01.4.4	Other Advanced Propulsion Approaches
TA2.3.6	Advanced Fission	TX01.4.4	Other Advanced Propulsion Approaches
TA2.3.7	Breakthrough Propulsion	TX01.4.4	Other Advanced Propulsion Approaches
TA2.4	Supporting Technologies	TX01.2	Electric Space Propulsion
TA2.4.1	Engine Health Monitoring and Safety	TX01.2.1	Integrated Systems and Ancillary Technologies
TA2.4.2	Propellant Storage and Transfer	TX01.2.1	Integrated Systems and Ancillary Technologies
TA2.4.3	Materials and Manufacturing Technologies	TX01.2.1	Integrated Systems and Ancillary Technologies
TA2.4.4	Heat Rejection	TX01.2.1	Integrated Systems and Ancillary Technologies
TA2.4.5	Power	TX01.2.1	Integrated Systems and Ancillary Technologies

The page intentionally left blank.

TA3 Space Power and Energy Storage

TA3 Space Power and Enertgy Storage		TX Technology Area Breakdown Structure	
TA3.1	Power Generation	TX03.1	Power Generation and Conversion
TA3.1.1	Energy Harvesting	TX03.1.4	Dynamic Energy Conversion
TA3.1.2	Chemical	TX03.1.4	Dynamic Energy Conversion
TA3.1.3	Solar	TX03.1.1	Photovoltaic
TA3.1.4	Radioisotope	TX03.1.2	Sources
TA3.1.5	Fission	TX03.1.4	Dynamic Energy Conversion
TA3.1.6	Fusion	TX03.1.4	Dynamic Energy Conversion
TA3.2	Energy Storage	TX03.2	Energy Storage
TA3.2.1	Batteries	TX03.2.1	Electrochemical: Batteries
TA3.2.2	Flywheels	TX03.2.3	Advanced Concepts for Energy Storage
TA3.2.3	Regenerative Fuel Cells	TX03.2.2	Electrochemical: Fuel Cells
TA3.2.4	Capacitors	TX03.2.3	Advanced Concepts for Energy Storage
TA3.3	Power Management and Distribution	TX03.3	Power Management and Distribution
TA3.3.1	Fault Detection, Isolation, and Recovery	TX03.3.1	Management and Control
TA3.3.2	Management and Control	TX03.3.1	Management and Control
TA3.3.3	Distribution and Transmission	TX02.1.2	Electronic Packaging and Implementations
		TX03.3.2	Distribution and Transmission
		TX03.3.4	Advanced Electronic Parts
TA3.3.4	Wireless Power Transmission	TX03.3.2	Distribution and Transmission
TA3.3.5	Conversion and Regulation	TX03.3.3	Electrical Power Conversion and Regulation
		TX03.3.4	Advanced Electronic Parts
TA3.4	Cross-Cutting Technology		
TA3.4.1	Analytical Tools	Not Applicable	
TA3.4.2	Green Energy Impact	Not Applicable	
TA3.4.3	Multi-Functional Structures	Not Applicable	
TA3.4.4	Alternative Fuels	Not Applicable	

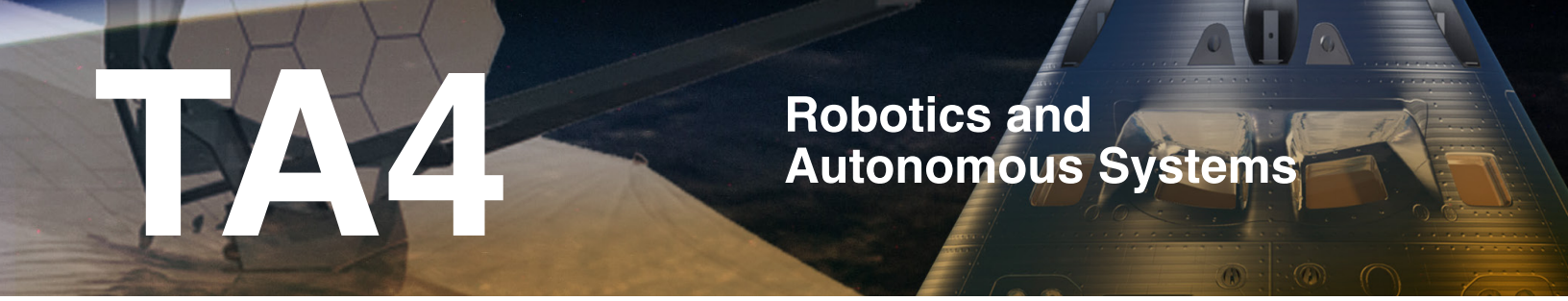
TA3

Space Power and Energy Storage

The page intentionally left blank.

TA4 Robotics and Autonomous Systems

TA4 Robotics and Autonomous Systems		TX Technology Area Breakdown Structure	
TA4.1	Sensing and Perception	TX04.1	Sensing and Perception
		TX10.1.1	Sensing & Perception for Autonomous Systems
TA4.1.1	3D Sensing	TX04.1.1	Sensing for Robotic Systems
TA4.1.2	State Estimation	TX04.1.2	State Estimation
		TX10.1.2	State Estimation and Monitoring
TA4.1.3	Onboard Mapping	TX04.1.3	Onboard Mapping and Data Analysis
TA4.1.4	Object, Event, and Activity Recognition	TX04.1.4	Object, Event, and Activity Recognition
TA4.1.5	Force and Tactile Sensing	TX04.1.1	Sensing for Robotic Systems
TA4.1.6	Onboard Science Data Analysis	TX04.1.3	Onboard Mapping and Data Analysis
TA4.2	Mobility	TX04.2	Mobility
TA4.2.1	Extreme-Terrain Mobility	TX04.2.4	Surface Mobility
TA4.2.2	Below-Surface Mobility	TX04.2.1	Below-Surface Mobility
TA4.2.3	Above-Surface Mobility	TX04.2.2	Above-Surface Mobility
TA4.2.4	Small-Body and Microgravity Mobility	TX04.2.3	Small-Body and Microgravity Mobility
TA4.2.5	Surface Mobility	TX04.2.4	Surface Mobility
TA4.2.6	Robot Navigation	TX04.2.5	Robot Navigation and Path Planning
TA4.2.7	Collaborative Mobility	TX04.2.6	Collaborative Mobility
TA4.2.8	Mobility Components	TX04.2.1	Below-Surface Mobility
		TX04.2.2	Above-Surface Mobility
		TX04.2.3	Small-Body and Microgravity Mobility
		TX04.2.4	Surface Mobility
		TX04.2.6	Collaborative Mobility
TA4.3	Manipulation	TX04.3	Manipulation
TA4.3.1	Manipulator Components	TX04.3.1	Dexterous Manipulation
		TX04.3.2	Grappling Technologies
TA4.3.2	Dexterous Manipulation	TX04.3.1	Dexterous Manipulation
TA4.3.3	Modeling of Contact Dynamics	TX04.3.3	Contact Dynamics Modeling
TA4.3.4	Mobile Manipulation	TX04.2.1	Below-Surface Mobility
		TX04.2.2	Above-Surface Mobility
		TX04.2.3	Small-Body and Microgravity Mobility
		TX04.2.4	Surface Mobility
		TX04.3.1	Dexterous Manipulation
		TX04.3.2	Grappling Technologies

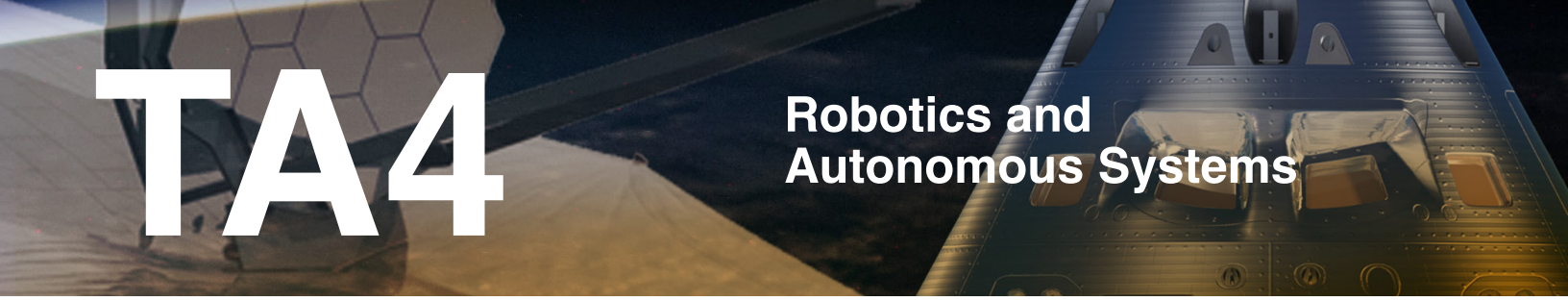


TA4 Robotics and Autonomous Systems

TA4 Robotics and Autonomous Systems		TX Technology Area Breakdown Structure	
TA4.3.5	Collaborative Manipulation	TX04.3.1	Dexterous Manipulation
		TX04.3.2	Grappling Technologies
TA4.3.6	Sample Acquisition and Handling	TX04.3.4	Sample Acquisition and Handling
TA4.3.7	Grappling	TX04.3.2	Grappling Technologies
		TX04.5.6	Robot Control for Vehicle Capture and Berthing
TA4.4	Human-System Interaction	TX04.4	Human-Robot Interaction
TA4.4.1	Multi-Modal Interaction	TX04.4.1	Multi-Modal and Proximate Interaction
TA4.4.2	Supervisory Control	TX04.4.3	Remote Interaction
TA4.4.3	Proximate Interaction	TX04.4.1	Multi-Modal and Proximate Interaction
		TX10.3.1	Joint Knowledge and Understanding
TA4.4.4	Intent Recognition and Reaction	TX04.4.1	Multi-Modal and Proximate Interaction
TA4.4.5	Distributed Collaboration and Coordination	TX04.4.2	Distributed Collaboration and Coordination
TA4.4.6	Common & Standard Human-System Interfaces	TX04.4.1	Multi-Modal and Proximate Interaction
TA4.4.7	Safety, Trust, and Interfacing of Robotic and Human Proximity Operations	TX04.4.1	Multi-Modal and Proximate Interaction
		TX10.3.4	Operational Trust Building
TA4.4.8	Remote Interaction	TX04.4.3	Remote Interaction
TA4.5	System-Level Autonomy	TX10.2	Reason and Acting
TA4.5.1	System Health Management	TX10.2.5	Fault Diagnosis and Prognosis
		TX10.2.6	Fault Response
TA4.5.2	Activity Planning, Scheduling, and Execution	TX04.2.5	Fault Diagnosis and Prognosis
		TX10.2.2	Activity and Resource Planning and Scheduling
		TX10.2.4	Execution and Control
TA4.5.3	Autonomous Guidance and Control	TX09.4.7	Guidance, Navigation and Control (GN&C) for EDL
		TX10.2.3	Motion Planning
		TX17.2.1	Onboard Navigation Algorithms
		TX17.2.3	Navigation Sensors
TA4.5.4	Multi-Agent Coordination	TX10.1.2	State Estimation and Monitoring
		TX10.2.2	Activity and Resource Planning and Scheduling
		TX10.2.4	Execution and Control
		TX10.3.1	Joint Knowledge and Understandin
		TX10.3.2	Behavior and Intent Prediction
		TX10.3.3	Goal and Task Negotiation
		TX10.3.4	Operational Trust Building

TA4 Robotics and Autonomous Systems

TA4 Robotics and Autonomous Systems		TX Technology Area Breakdown Structure	
TA4.5.5	Adjustable Autonomy	TX10.1.1	Sensing and Perception for Autonomous Systems
		TX10.1.5	Event and Trend Identification
		TX10.1.6	Anomaly Detection
		TX10.2.1	Mission Planning and Scheduling
		TX10.2.4	Execution and Control
		TX10.3.2	Behavior and Intent Prediction
		TX10.3.3	Goal and Task Negotiation
		TX10.3.4	Operational Trust Building
TA4.5.6	Terrain Relative Navigation	TX04.1.2	State Estimation
		TX04.1.3	Onboard Mapping and Data Analysis
		TX04.2.5	Robot Navigation and Path Planning
		TX17.2.1	Onboard Navigation Algorithms
		TX17.2.3	Navigation Sensors
		TX17.2.4	Relative Navigation Aids
TA4.5.7	Path and Motion Planning with Uncertainty	TX10.2.3	Motion Planning
TA4.5.8	Automated Data Analysis for Decision Making	TX10.1.1	Sensing and Perception for Autonomous Systems
		TX10.1.2	State Estimation and Monitoring
		TX10.1.3	Knowledge and Model Building
		TX10.1.4	Hazard Assessment
		TX10.1.5	Event and Trend Identification
		TX10.1.6	Anomaly Detection
		TX10.2.1	Mission Planning and Scheduling
		TX10.2.2	Activity and Resource Planning and Scheduling
		TX10.2.3	Motion Planning
		TX10.2.4	Execution and Control
		TX10.2.5	Fault Diagnosis and Prognosis
		TX10.2.6	Fault Response
		TX10.2.7	Learning and Adapting



TA4 Robotics and Autonomous Systems

TA4 Robotics and Autonomous Systems		TX Technology Area Breakdown Structure	
TA4.6	Autonomous Rendezvous and Docking	TX04.5	Autonomous Rendezvous and Docking
TA4.6.1	Relative Navigation Sensors	TX04.5.1	Relative Navigation Sensors
		TX04.5.4	Capture Sensors
		TX17.2.3	Navigation Sensors
TA4.6.2	GN&C Algorithms	TX04.5.2	Rendezvous and Docking Algorithms
		TX17.1.1	Guidance Algorithms
TA4.6.3	Docking and Capture Mechanisms and Interfaces	TX04.5.5	Capture Mechanisms and Fixtures
		TX12.3.1	Deployables, Docking, and Interfaces
		TX12.3.8	Docking and Berthing Mechanisms and Fixtures
TA4.6.4	Mission and System Managers for Autonomy and Automation		
TA4.7	Systems Engineering		
TA4.7.1	Modularity, Commonality, and Interfaces	TX04.6.1	Modularity, Commonality, and Interfaces
TA4.7.2	Verification and Validation of Complex Adaptive Systems	TX10.4.1	Verification and Validation of Autonomous Systems
TA4.7.3	Robot Modeling and Simulation	TX04.3.3	Contact Dynamics Modeling
		TX04.6.2	Modeling and Simulation for Robots
		TX10.1.3	Knowledge and Model Building
		TX10.4.4	Modeling and SImulation of Autonomous Systems
TA4.7.4	Robot Software	TX04.6.3	Robot Software
TA4.7.5	Safety and Trust	TX10.1.4	Hazard Assessment
		TX10.3.4	Operational Trust Building

TA5 Communications, Navigation, and Orbital Debris Tracking and Characterization Systems

TA5 Communications, Navigation, and Orbital Debris Tracking and Characterization Systems		TX Technology Area Breakdown Structure	
TA5.1	Optical Communications and Navigation	TX05.1	Optical Communications
TA5.1.1	Detector Development	TX05.1.1	Detector Development
TA5.1.2	Large Apertures	TX05.1.2	Large Apertures
TA5.1.3	Lasers	TX05.1.3	Lasers
TA5.1.4	Acquisition and Tracking	TX05.1.4	Pointing, Acquisition, and Tracking (PAT)
TA5.1.5	Atmospheric Mitigation	TX05.1.5	Atmospheric Mitigation
TA5.1.6	Optical Tracking	TX05.1.6	Optimetrics
TA5.1.7	Integrated Photonics	TX05.1.7	Quantum Communications
TA5.2	Optical Communications and Navigation	TX05.2	Radio Frequency
		TX05.5.1	Cognitive Networking
TA5.2.1	Spectrum-Efficient Technologies	TX05.2.1	Spectrum-Efficiency
TA5.2.2	Power-Efficient Technologies	TX05.2.2	Power-Efficiency
		TX05.2.4	Flight and Ground Systems
TA5.2.3	Propogation	TX05.2.3	Atmospheric Characterization and Mitigation
TA5.2.4	Flight and Ground Systems	TX05.2.4	Flight and Ground Systems
TA5.2.5	Earth Launch and Re-Entry Communications	TX05.2.5	Launch and Re-Entry Communications
TA5.2.6	Antennas	TX05.2.6	Innovative Antennas
TA5.3	Internetworking	TX05.4	Position, Navigation, and Timing
TA5.3.1	Distruption Tolerant Networking	TX05.3.1	Distruption Tolerant Networking
TA5.3.2	Adaptive Network Topology	TX05.3.2	Adaptive Network Topology
TA5.3.3	Information Assurance	TX05.3.3	Information Assurance
TA5.3.4	Integrated Network Management	TX05.3.4	Integrated Network Management
TA5.4	Position, Navigation, and Timing	TX05.4	Position, Navigation, and Timing
TA5.4.1	Timekeeping and Time Distribution	TX05.4.1	Timekeeping and Time Distribution
TA5.4.2	Onboard Auto Navigation and Maneuver	TX17.2.1	Onboard Navigation Algorithms
		TX17.2.3	Navigation Sensors
		TX17.2.5	Rendezvous, Proximity Operations, and Capture Sensor Processing and Processors
		TX17.2.6	Rendezvous, Proximity Operations, and Capture Trajectory Design and Orbit Determination
		TX17.3.1	Onboard Maneuvering/Pointing/Stabilization/ Flight Control Algorithms
		TX17.4.1	Onboard Attitude/Attitude Rate Estimation Algorithms

TA5 Communications, Navigation, and Orbital Debris Tracking and Characterization Systems

TA5 Communications, Navigation, and Orbital Debris Tracking and Characterization Systems		TX Technology Area Breakdown Structure	
TA5.4.3	Sensors and Vision Processing Systems	TX17.2.3	Navigation Sensors
		TX17.2.5	Rendezvous, Proximity Operations, and Capture Sensor Processing and Processors
TA5.4.4	Relative and Proximity Navigation	TX17.2.3	Navigation Sensors
		TX17.2.4	Relative Navigation Aids
TA5.4.5	Auto Precision Formation Flying	TX17.1.1	Guidance Algorithms
		TX17.1.2	Targeting Algorithms
		TX17.2.1	Onboard Navigation Algorithms
		TX17.2.3	Navigation Sensors
		TX17.3.1	Onboard Maneuvering/Pointing/Stabilization/ Flight Control Algorithms
		TX17.3.2	Dynamics Analysis, Modeling, and Simulation Tools
		TX17.4.3	Attitude Estimation Sensors
TA5.4.6	Autonomous Approach and Landing	TX17.1.1	Guidance Algorithms
		TX17.1.2	Targeting Algorithms
		TX17.2.1	Onboard Navigation Algorithms
		TX17.2.3	Navigation Sensors
		TX17.3.1	Onboard Maneuvering/Pointing/Stabilization/ Flight Control Algorithms
		TX17.3.2	Dynamics Analysis, Modeling, and Simulation Tools
		TX17.4.3	Attitude Estimation Sensors
TA5.5	Integrated Technologies	TX05.5	Revolutionary Communications Technologies
TA5.5.1	Radio Systems	TX05.2	Radio Frequency
TA5.5.2	Ultra Wideband	TX05.2.4	Flight and Ground Systems
TA5.5.3	Cognitive Networks	TX05.5.1	Cognitive Networking
TA5.5.4	Science from the Communications System		
TA5.5.5	Hybrid Optical Communications and Navigation Sensors	TX05.5.3	Hybrid Radio and Optical Technologies
TA5.5.6	Radio Frequency and Optical Hybrid Technology	TX05.5.3	Hybrid Radio and Optical Technologies

TA5 Communications, Navigation, and Orbital Debris Tracking and Characterization Systems

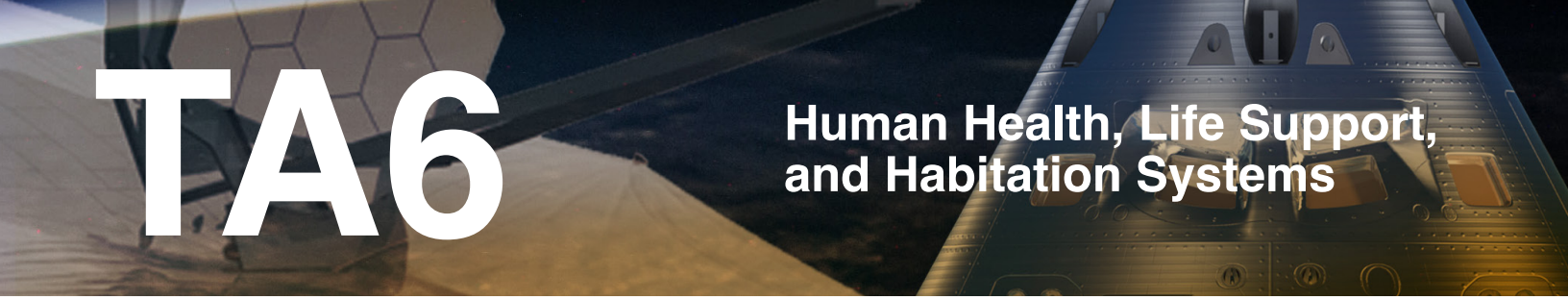
TA5 Communications, Navigation, and Orbital Debris Tracking and Characterization Systems		TX Technology Area Breakdown Structure	
TA5.6	Revolutionary Concepts	TX05.4	Network Provided Position, Navigation, and Timing
TA5.6.1	X-Ray Navigation	TX05.4.2	Revolutionary Position, Navigation, and Timing Technologies
TA5.6.2	X-Ray Communications	TX05.4.2	Revolutionary Position, Navigation, and Timing Technologies
TA5.6.3	Neutrino-Based Navigation and Tracking	TX05.4.2	Revolutionary Position, Navigation, and Timing Technologies
TA5.6.4	Quantum Key Distribution	TX05.4.2	Revolutionary Position, Navigation, and Timing Technologies
TA5.6.5	Quantum Communications	TX05.4.2	Revolutionary Position, Navigation, and Timing Technologies
TA5.6.6	Superconducting Quantum Interference Filter Microwave Amplifier	TX05.4.2	Revolutionary Position, Navigation, and Timing Technologies
TA5.7	Orbital Debris Tracking and Characterization	TX05.6	Networking and Ground-Based Orbital Debris Tracking and Mitigation
TA5.7.1	Tracking Technologies	TX05.6.1	Orbital Debris Tracking
TA5.7.2	Characterization Technologies	TX05.6.2	Orbital Debris Characterization

TA5 Communications, Navigation, and Orbital Debris Tracking and Characterization Systems

The page intentionally left blank.

TA6 Human Health, Life Support, and Habitation Systems

TA6 Human Health, Life Support, and Habitation Systems		TX Technology Area Breakdown Structure	
TA6.1	Environmental Control and Life Support Systems and Habitation Systems	TX06.1	Environmental Control and Life Support Systems and Habitation Systems
TA6.1.1	Air Revitalization	TX06.1.1	Atmosphere Revitalization
TA6.1.2	Water Recovery and Management	TX06.1.2	Water Recovery and Management
TA6.1.3	Waste Management	TX06.1.3	Waste Management
TA6.1.4	Habitation	TX06.1.4	Habitation Systems
TA6.2	Extravehicular Activity Systems	TX06.2	Extravehicular Activity Systems
TA6.2.1	Pressure Garment	TX06.2.1	Pressure Garment
TA6.2.2	Portable Life Support System	TX06.2.2	Portable Life Support System
TA6.2.3	Power, Avionics, and Software	TX06.2.3	Informatics and Decision Support Systems
TA6.3	Human Health and Performance	TX06.3	Human Health and Performance
TA6.3.1	Medical Diagnosis and Prognosis	TX06.3.1	Medical Diagnosis and Prognosis
TA6.3.2	Long-Duration Health	TX06.3.2	Prevention and Countermeasures
		TX06.3.6	Long-Duration Health
TA6.3.3	Behavioral Health	TX06.3.2	Prevention and Countermeasures
		TX06.3.3	Behavioral Health and Performance
TA6.3.4	Human Factors	TX06.6.1	Human Factors Engineering
TA6.4	Environmental Monitoring, Safety, and Emergency Response	TX06.4	Environmental Monitoring, Safety, and Emergency Response
TA6.4.1	Sensors: Air, Water, Microbial, and Acoustic	TX06.4.1	Sensors: Air, Water, Microbial, and Acoustic
TA6.4.2	Fire: Detection, Suppression, and Recovery	TX06.4.2	Fire: Detection, Suppression, and Recovery
TA6.4.3	Protective Clothing and Breathing	TX06.4.3	Protective Clothing and Breathing
TA6.4.4	Remediation	TX06.4.4	Remediation
TA6.5	Radiation	TX06.5	Radiation
TA6.5.1	Risk Assessment Modeling	TX06.5.1	Radiation Transport and Risk Modeling
TA6.5.2	Radiation Mitigationm and Biological Countermeasures	TX06.5.2	Radiation Mitigation and Biological Countermeasures
TA6.5.3	Protection Systems	TX06.5.3	Protection Systems
TA6.5.4	Space Waether Prediction	TX06.5.4	Space Weather Prediction
TA6.5.5	Monitoring Technology	TX06.5.5	Monitoring Technology



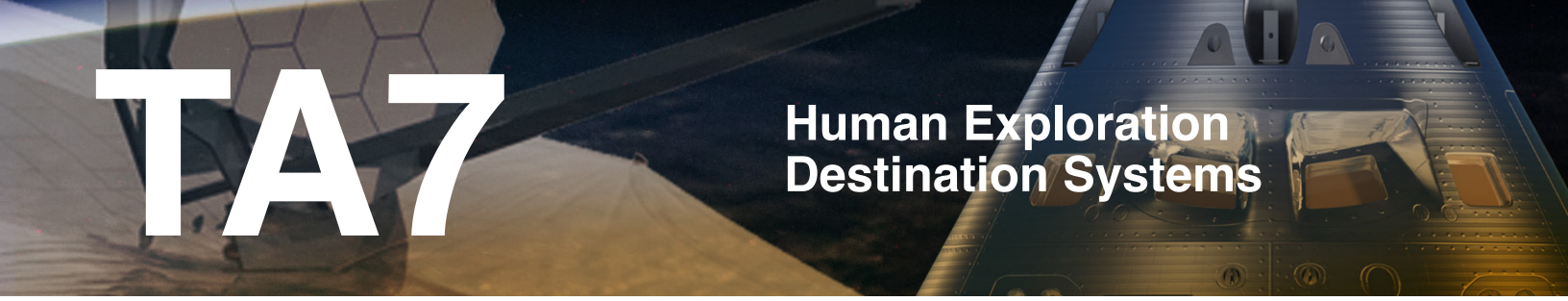
TA6

Human Health, Life Support, and Habitation Systems

The page intentionally left blank.

TA7 Human Exploration Destination Systems

TA7 Human Exploration Destination Systems		TX Technology Area Breakdown Structure	
TA7.1	In-Situ Resource Utilization	TX07.1	In-Situ Resource Utilization
TA7.1.1	Destination Reconnaissance, Prospecting, and Mapping	TX07.1.1	Destination Reconaissance and Resource Assessment
TA7.1.2	Resource Acquisition	TX07.1.2	Resource Acquisition, Isolation, and Preparation
TA7.1.3	Processing and Production	TX07.1.3	Resource Processing for Production of Mission Consumables
TA7.1.4	Manufacturing Products and Infrastructure Emplacement	TX07.1.4	Resource Processing for Production of Manufacturing, Construction, and Energy Storage Feedstock Materials
TA7.2	Sustainability and Supportability	TX07.2	Mission Infrastructure, Sustainability, and Supportability
TA7.2.1	Autonomous Logistics Management	TX02.1.8	Wireless Avionics Technologies
		TX06.6.6	Maintainability and Supportability
		TX07.2.1	Logistics Management
TA7.2.2	Maintenance Systems	TX06.6.6	Maintainability and Supportability
		TX07.2.2	In-Situ Manufacturing, Maintenance, and Repair
TA7.2.3	Repair Systems	TX06.6.6	Maintainability and Supportability
		TX07.2.2	In-Situ Manufacturing, Maintenance, and Repair
TA7.2.4	Food Production, Processing, and Preservation	TX06.3.5	Food Production, Processing, and Preservation
TA7.3	Human Mobility Systems	TX04.2	Mobility
TA7.3.1	EVA Mobility	TX04.2.1	Below-Surface Mobility
		TX04.2.2	Above-Surface Mobility
		TX04.2.4	Surface Mobility
TA7.3.2	Surface Mobility	TX04.2.4	Surface Mobility
TA7.3.3	Off-Surface Mobility	TX04.2.2	Above-Surface Mobility
TA7.4	Habitat Systems	TX06.1.4	Habitation Systems
TA7.4.1	Integrated Habitate Systems	TX06.1.4	Habitation Systems
		TX06.6.3	Habitability and Environment
TA7.4.2	Habitate Evolution	TX06.1.4	Habitation Systems
		TX06.6.3	Habitability and Environment
TA7.4.3	“Smart” Habitats	TX06.1.4	Habitation Systems
		TX06.6.3	Habitability and Environment
TA7.4.4	Artificial Gravity	TX06.3.2	Long-Duration Health
		TX06.6.3	Habitability and Environment



TA7 Human Exploration Destination Systems

TA7 Human Exploration Destination Systems		TX Technology Area Breakdown Structure	
TA7.5	Mission Operations and Safety	TX07.3	Mission Operations and Safety
TA7.5.1	Crew Training	TX06.6.2	Training
		TX07.3.3	Crew Training
TA7.5.2	Planetary Protection	TX07.3.5	Planetary Protection
TA7.5.3	Integrated Flight Operations Systems	TX06.4.4	Operations Effectiveness
		TX07.3.2	Integrated Flight Operations Systems
TA7.5.4	Integrated Risk Assessment Tools	TX06.6.5	Integrated Systems Safety
		TX07.3.4	Integrated Risk Assessment Tools
TA7.6	Cross-Cutting Systems	TX07.2	Mission Infrastructure, Sustainability, and Supportability
TA7.6.1	Particulate Contamination Prevention and Mitigation	TX07.2.5	Particulate Contamination Prevention and Mitigation
TA7.6.2	Construction and Assembly	TX07.2.3	Surface Construction and Assembly
		TX07.2.4	Micro-Gravity Construction and Assembly

TA8 Science Instruments, Observatories, and Sensor Systems

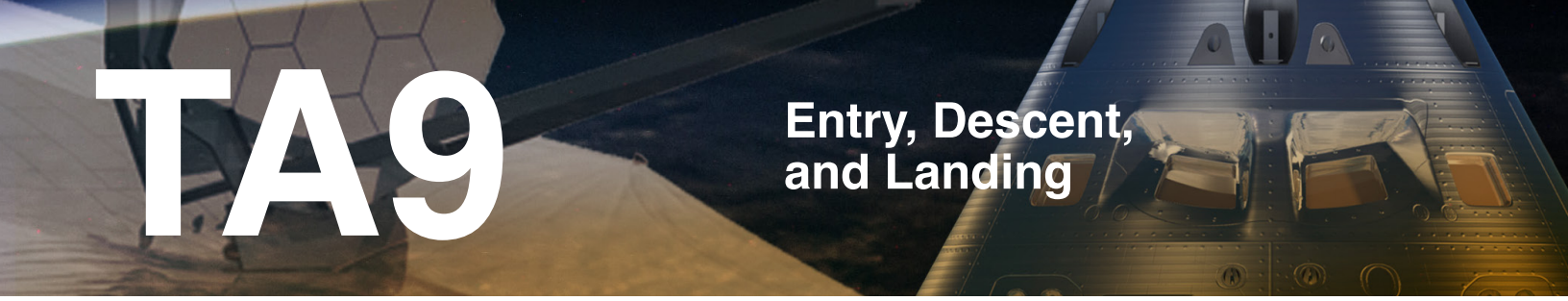
TA8 Science Instruments, Observatories, and Sensor Systems		TX Technology Area Breakdown Structure	
TA8.1	Remote Sensing Instruments/Sensors	TX08.1	Remote Sensing Instruments/Sensors
TA8.1.1	Detectors and Focal Planes	TX08.1.1	Detectors and Focal Planes
TA8.1.2	Electronics	TX02.1.5	High Performance Field Programmable Gate Arrays
		TX02.1.6	Radiation Hardened ASIC Technologies
		TX08.1.2	Electronics
TA8.1.3	Optical Components	TX08.1.3	Optical Components
TA8.1.4	Microwave, Millimeter-, and Submillimeter-Waves	TX08.1.4	Microwave, Millimeter-, and Submillimeter-Waves
TA8.1.5	Lasers	TX08.1.5	Lasers
TA8.1.6	Cryogenic/Thermal	TX08.1.6	Cryogenic/Thermal
TA8.2	Observatories	TX08.2	Observatories
TA8.2.1	Mirror Systems	TX08.2.1	Mirror Systems
TA8.2.2	Structures and Antennas	TX08.2.2	Structures and Antennas
TA8.2.3	Distributed Aperture	TX08.2.3	Distributed Aperture
TA8.3	In-Situ Instruments/Sensor	TX08.3	In-Situ Instruments/Sensor
TA8.3.1	Field and Particle Detectors	TX08.3.1	Field and Particle Detectors
TA8.3.2	Fields and Waves	TX08.3.1	Field and Particle Detectors
TA8.3.3	In-Situ (Other)	TX08.3.4	Environment Sensors

TA8

Science Instruments, Observatories, and Sensor Systems

TA9 Entry, Descent, and Landing

TA9 Entry, Descent, and Landing Systems		TX Technology Area Breakdown Structure	
TA9.1	Aeroassist and Atmospheric Entry	TX09.1	Aeroassist and Atmospheric Entry
TA9.1.1	Thermal Protection Systems for Rigid Decelerators	TX09.1.1	Thermal Protection Systems
TA9.1.2	Thermal Protection Systems for Deployable Decelerators	TX09.1.1	Thermal Protection Systems
TA9.1.3	Rigid Hypersonic Decelerators	TX09.1.2	Hypersonic Decelerators
TA9.1.4	Deployable Hypersonic Decelerators	TX09.1.2	Hypersonic Decelerators
TA9.1.5	Instrumentation and Health Monitoring	TX09.4.6	Instrumentation and Health Monitoring for EDL
TA9.1.6	Entry Modeling and Simulation	TX09.4.5	Modeling and Simulation for EDL
TA9.2	Descent and Targeting	TX09.2	Descent
TA9.2.1	Attached Deployable Decelerators	TX09.2.1	Aerodynamic Decelerators
TA9.2.2	Trailing Deployable Decelerators	TX09.2.1	Aerodynamic Decelerators
TA9.2.3	Supersonic Retropropulsion	TX09.2.2	Supersonic Retropropulsion
TA9.2.4	GN&C Sensors	TX09.4.7	Guidance, Navigation and Control (GN&C) for EDL
TA9.2.5	Descent Modeling and Simulation	TX09.4.5	Modeling and Simulation for EDL
TA9.2.6	Large Divert Guidance	TX09.4.7	Guidance, Navigation and Control (GN&C) for EDL
TA9.2.7	Terrain-Relative Sensing and Characterization	TX09.4.7	Guidance, Navigation and Control (GN&C) for EDL
		TX17.1.2	Targeting Algorithms
		TX17.2.3	Navigation Sensors
		TX17.2.4	Relative Navigation Aids
TA9.2.8	Autonomous Targeting	TX09.3.1	Touchdown Systems
		TX17.1.2	Targeting Algorithms
TA9.3	Landing	TX09.3	Landing
TA9.3.1	Propulsion and Touchdown Systems	TX09.3.1	Touchdown Systems
		TX09.3.2	Propulsion Systems for Landing
TA9.3.2	Egress and Deployment Systems	TX09.3.1	Touchdown Systems
TA9.3.3	Propulsion Systems	TX09.3.2	Propulsion Systems for Landing
TA9.3.4	Large Body GN&C	TX09.4.7	Guidance, Navigation and Control (GN&C) for EDL
TA9.3.5	Small Body Systems	TX09.1.3	Passive Reentry Systems for SmallSats
		TX09.4.7	Guidance, Navigation and Control (GN&C) for EDL
TA9.3.6	Landing Modeling and Simulation	TX09.4.5	Modeling and Simulation for EDL

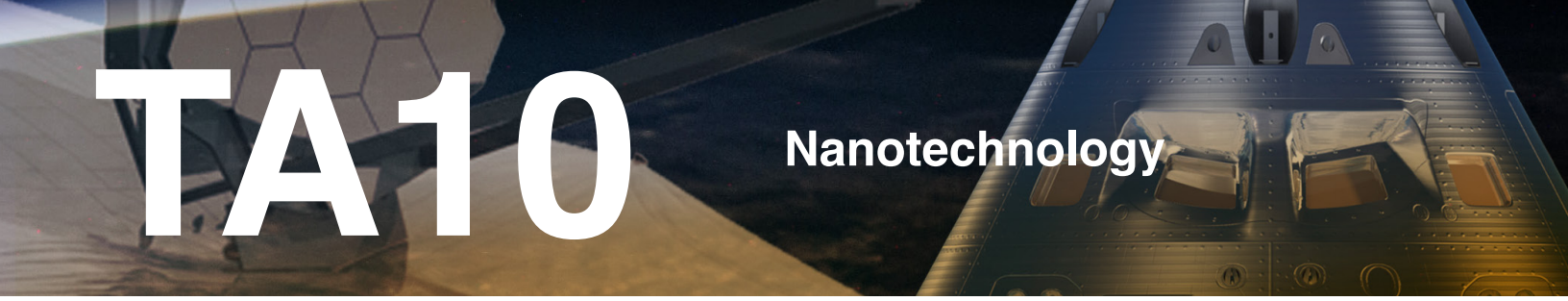


TA9 Entry, Descent, and Landing

TA9 Entry, Descent, and Landing Systems		TX Technology Area Breakdown Structure	
TA9.4	Vehicle Systems	TX09.4	Vehicle Systems
TA9.4.1	Architecture Analysis	TX09.4.1	Architecture Design and Analysis
TA9.4.2	Separation Systems	TX09.4.2	Separation Systems
TA9.4.3	System Integration and Analysis	TX09.4.3	System Integration and Analysis for EDL
TA9.4.4	Atmosphere and Surface Characterization	TX09.4.4	Atmosphere and Surface Characterization
TA9.4.5	Modeling and Simulation	TX09.4.5	Modeling and Simulation for EDL
TA9.4.6	Instrumentation and Health Monitoring	TX09.4.6	Instrumentation and Health Monitoring for EDL
TA9.4.7	GN&C Sensors and Systems	TX09.4.7	Guidance, Navigation and Control (GN&C) for EDL
		TX17.2.3	Navigation Sensors
		TX17.4.3	Attitude Estimation Sensors

TA10 Nanotechnology

TA10 Nanotechnology		TX Technology Area Breakdown Structure	
TA10.1	Engineered Materials and Structures	TX12.1	Materials
		TX12.2	Structures
TA10.1.1	Lightweight Structures	TX12.1.1	Lightweight Structural Materials
		TX12.2.1	Lightweight Concepts
		TX12.2.5	Innovative, Multifunctional Concepts
TA10.1.2	Damage-Tolerant Systems	TX12.1.1	Lightweight Structural Materials
TA10.1.3	Coatings	TX1.3.11	Engine Icing
		TX12.1.5	Coatings
TA10.1.4	Adhesives	TX12.1.7	Special Materials
TA10.1.5	Thermal Protection and Control	TX14.2.3	Heat Rejection and Storage
		TX14.2.4	Insulation and Interfaces
		TX14.3.1	Thermal Protection Materials
		TX14.3.2	Thermal Protection Systems
		TX09.1.1	Thermal Protection Systems
TA10.2	Energy Storage, Power Generation, and Power Distribution	TX03.1	Power Generation and Energy Conversion
		TX03.2	Energy Storage
TA10.2.1	Energy Storage	TX03.2.3	Advanced Concepts for Energy Storage
TA10.2.2	Power Generation	TX03.1.4	Dynamic Energy Conversion
TA10.2.3	Power Distribution	TX03.3.2	Distribution and Transmission
TA10.3	Propulsion	TX01.1	Chemical Space Propulsion
TA10.3.1	Propellants	TX01.1.2	Earth Storable
		TX01.1.4	Solids
		TX01.1.6	Gels
TA10.3.2	Propulsion Components	TX01.1.1	Integrated Systems and Ancillary Technologies
TA10.3.3	In-Space Propulsion	TX01.4.1	Solar Sails
		TX01.4.2	Electromagnetic Tethers
		TX01.4.3	Nuclear Thermal Propulsion
		TX01.4.4	Other Advanced Propulsion Approaches
TA10.4	Sensors, Electronics, and Devices		
TA10.4.1	Sensors and Actuators	TX04.1.1	Sensing for Robotic Systems
		TX06.4.1	Sensors: Air, Water, Microbial, and Acoustic
		TX06.5.5	Monitoring Technology
		TX08.3.4	Environment Sensors
		TX12.4.5	Non-destructive Evaluation and Sensors



TA10 Nanotechnology

TA10 Nanotechnology		TX Technology Area Breakdown Structure	
TA10.4.2	Nanoelectronics	TX02.1.4	High Performance Memories
		TX08.1.2	Electronics
		TX12.1.2	Computational Materials
		TX12.1.3	Flexible Material Systems
		TX12.4.3	Electronics and Optics Manufacturing Process
TA10.4.3	Miniature Instruments and Instrument Components	TX06.3.1	Medical Diagnosis and Prognosis
		TX08.1.1	Detectors and Focal Planes

TA11 Modeling, Simulation, Information Technology and Processing

TA11 Modeling, Simulation, Information Technology and Processing		TX Technology Area Breakdown Structure	
TA11.1	Computing	TX11.6	Ground Computing
TA11.1.1	Flight Computing	TX02.1.1	Radiation Hardened Extreme Environment Components and Implementations
		TX02.1.5	High Performance Field Programmable Gate Arrays
		TX02.2.4	Low Power Embedded Computer Systems
		TX02.2.5	High Speed Onboard Interconnects and Networks
		TX11.1.1	Tools and Methodologies for Software Design and Development
		TX11.1.6	Real-time Software
TA11.1.2	Ground Computing	TX11.6.1	Exascale Supercomputer
		TX11.6.2	Automated Exascale Software Development Toolset
		TX11.6.3	Exascale Supercomputer File System
		TX11.6.4	Quantum Computer
		TX11.6.5	Public Cloud Supercomputer
		TX11.6.6	Cognitive Computer
		TX11.6.7	High Performance Data Analytics Platform
TA11.2	Modeling	TX11.2	Modeling
TA11.2.1	Software Modeling and Model Checking	TX11.1.3	Test and Evaluation
		TX11.1.8	Software Analysis and Design Tools
		TX11.2.1	Software Modeling and Model Checking
TA11.2.2	Integrated Hardware and Software Modeling	TX11.2.2	Integrated Hardware and Software Modeling
TA11.2.3	Human-System Performance Modeling	TX10.3.3	Goal and Task Negotiation
		TX11.2.3	Human-System Performance Modeling
TA11.2.4	Science Modeling	TX02.1.3	High Performance Processors
		TX11.2.4	Science Modeling
TA11.2.5	Frameworks, Languages, Tools, and Standards	TX11.1.7	Frameworks, Languages, Tools, and Standards
TA11.2.6	Analysis Tools for Mission Design	TX11.5.1	Tools and Methodologies for Defining Mission Architectures or Mission Design
TA11.3	Simulation	TX11.3	Simulation
TA11.3.1	Distributed Simulation	TX11.3.1	Distributed Simulation
TA11.3.2	Integrated System Lifecycle Simulation	TX11.3.2	Integrated System Lifecycle Simulation
TA11.3.3	Simulation-Based Systems Engineering	TX11.3.3	Model-Based Systems Engineering (MBSE)

TA11 Modeling, Simulation, Information Technology and Processing

TA11 Modeling, Simulation, Information Technology and Processing		TX Technology Area Breakdown Structure	
TA11.3.4	Simulation-Based Training and Decision Support Systems	TX11.3.4	Simulation-Based Training and Decision Support Systems
TA11.3.5	Exascale Simulation	TX11.3.5	Exascale Simulation
TA11.3.6	Uncertainty Quantification and Nondeterministic Simulation Methods	TX11.3.6	Uncertainty Quantification and Nondeterministic Simulation Methods
TA11.3.7	Multiscale, Multiphysics, and Multifidelity Simulation	TX02.3.2	Space Radiation Analysis and Modeling
		TX11.3.7	Multiscale, Multiphysics, and Multifidelity Simulation
TA11.3.8	Verification and Validation	TX11.1.2	Verification and Validation of Software Systems
TA11.4	Information Processing	TX11.4	Information Processing
TA11.4.1	Science, Engineering, and Mission Data Lifecycle	TX02.2.7	Data Reduction Hardware Systems
		TX11.4.1	Science, Engineering, and Mission Data Lifecycle
TA11.4.2	Intelligent Data Understanding	TX11.4.2	Intelligent Data Understanding
TA11.4.3	Semantic Technologies	TX11.4.3	Semantic Technologies
TA11.4.4	Collaborative Science and Engineering	TX11.4.4	Collaborative Science and Engineering
TA11.4.5	Advanced Mission Systems	TX10.2.1	Mission Planning and Scheduling
		TX10.2.2	Activity and Resource Planning and Scheduling
		TX10.2.7	Learning and Adapting
		TX11.4.1	Science, Engineering, and Mission Data Lifecycle
TA11.4.6	Cyber Infrastructure	TX11.4.5	Cyber Infrastructure
TA11.4.7	Human-System Integration	TX11.1.5	Architecture and Design of Software Systems
TA11.4.8	Cyber Security	TX10.1.6	Real-time Software
		TX11.1.9	Software Cyber Security
		TX11.4.6	Cyber Security

TA12 Materials, Structures, Mechanical Systems and Manufacturing

TA12 Materials, Structures, Mechanical Systems and Manufacturing		TX Technology Area Breakdown Structure	
TA12.1	Materials	TX12.1	Materials
TA12.1.1	Lightweight Structural Materials	TX12.1.1	Lightweight Structural Materials
		TX12.2.1	Lightweight Concepts
TA12.1.2	Computationally-Designed Materials	TX12.1.2	Computational Material
TA12.1.3	Flexible Material Systems	TX12.1.3	Flexible Material Systems
TA12.1.4	Materials for Extreme Environments	TX02.2.4	Low Power Embedded Computer Systems
		TX12.1.4	Materials for Extreme Environments
		TX12.1.5	Coatings
TA12.1.5	Special Materials	TX12.1.6	Materials for Electrical Power Generation, Energy Storage, Power Distribution and Electrical Machines
		TX12.1.7	Special Materials
TA12.2	Structures	TX12.2	Structures
TA12.2.1	Lightweight Concepts	TX12.2.1	Lightweight Concepts
TA12.2.2	Design and Certification Methods	TX12.2.2	Design and Certification Methods
TA12.2.3	Reliability and Sustainment	TX12.2.3	Reliability and Sustainment
TA12.2.4	Test Tools and Methods	TX02.2.6	Data Acquisition Systems
		TX02.3.1	Electronics Development Tools
		TX12.2.4	Tests, Tools and Methods
TA12.2.5	Innovative, Multifunctional Concepts	TX12.2.5	Innovative, Multifunctional Concepts
TA12.2.5	Loads and Environments		
TA12.3	Mechanical Systems	TX12.3	Mechanical Systems
TA12.3.1	Deployables, Docking, and Interfaces	TX12.3.1	Deployables, Docking, and Interfaces
TA12.3.2	Mechanism Life Extension Systems	TX12.3.1	Deployables, Docking, and Interfaces
		TX12.3.7	Mechanism Life Extension Systems
TA12.3.3	Electro-Mechanical, Mechanical, and Micromechanisms	TX12.3.2	Electro-Mechanical, Mechanical, and Micromechanisms
TA12.3.4	Design and Analysis Tools and Methods	TX12.3.3	Design and Analysis Tools and Methods
TA12.3.5	Reliability, Life Assessment, and Health Monitoring	TX12.3.4	Reliability, Life Assessment, and Health Monitoring
TA12.3.6	Certification Methods	TX12.3.5	Certification Methods

TA12 Materials, Structures, Mechanical Systems and Manufacturing

TA12 Materials, Structures, Mechanical Systems and Manufacturing		TX Technology Area Breakdown Structure	
TA12.4	Manufacturing	TX12.4	Manufacturing
TA12.4.1	Manufacturing Processes	TX12.4.1	Manufacturing Processes
TA12.4.2	Intelligent Integrated Manufacturing and Cyber Physical Systems	TX12.4.2	Intelligent Integrated Manufacturing
TA12.4.3	Electronics and Optics Manufacturing Process	TX12.4.3	Electronics and Optics Manufacturing Process
TA12.4.4	Sustainable Manufacturing	TX12.4.4	Sustainable Manufacturing
TA12.4.5	Non-destructive Evaluation and Sensors	TX12.4.5	Non-destructive Evaluation and Sensors

TA13 Ground and Launch Systems

TA13 Ground and Launch Systems		TX Technology Area Breakdown Structure	
TA13.1	Operational Life-Cycle		
TA13.1.1	On-Site Production, Storage, Distribution, and Conservation of Fluids	TX13.1.3	Commodity Recovery
		TX13.1.4	Propellant Production, Storage and Transfer
		TX13.2.2	Propulsion, Exhaust, and Propellant Management
TA13.1.2	Automated Alignment, Coupling, Assembly, and Transportation Systems	TX02.1.8	Wireless Avionics Technologies
		TX13.1.2	Launch/Test/Ops Site Management
		TX13.1.6	Test, Operations, and Systems Safety
		TX13.3.1	Offline Element Processing
		TX13.3.2	Vehicle and Payload Assembly and Integration
TA13.1.3	Autonomous Command and Control for Integrated Vehicle and Ground Systems	TX02.1.8	Wireless Avionics Technologies
		TX02.2.1	Spacecraft Command and Data Handling Systems (C&DH)
		TX02.2.6	Data Acquisition Systems
		TX13.4.1	Mission Planning
		TX13.4.2	Team Preparedness and Training
		TX13.4.3	High-Fidelity Simulation and Visualization
		TX13.4.4	Autonomous, Real-Time Command and Control
TA13.1.4	Logistics	TX13.1.5	Ground and Surface Logistics
TA13.2	Environmental Protection and Green Technologies		
TA13.2.1	Corrosion Prevention, Detection, and Mitigation	TX13.1.1	Natural and Induced Environment Characterization and Mitigation
TA13.2.2	Environmental Remediation and Site Restoration	TX13.1.1	Natural and Induced Environment Characterization and Mitigation
TA13.2.3	Preservation of Natural Ecosystems	TX13.1.1	Natural and Induced Environment Characterization and Mitigation
TA13.2.4	Alternate Energy Prototypes	TX03.2.3	Advanced Concepts for Energy Storage
TA13.2.5	Curatorial Facilities, Planetary Protection, and Clean Rooms	TX07.3.5	Planetary Protection
TA13.3	Reliability and Maintainability		
TA13.3.1	Launch Infrastructure	TX13.3.3	Launch, Recovery and Reutilization
TA13.3.2	Environment-Hardened Materials and Structures	TX13.1.1	Natural and Induced Environment Characterization and Mitigation
		TX13.1.7	Impact/Damage/Radiation-Resistant Systems

TA13 Ground and Launch Systems

TA13 Ground and Launch Systems		TX Technology Area Breakdown Structure	
TA13.3.3	On-Site Inspection and Anomaly Detection and Identification	TX13.2.3	Non-Destructive Inspection, Evaluation, and Root Cause Analysis
		TX13.2.6	Advanced Life-Cycle Testing Techniques
		TX13.4.5	Operations, Health, and Maintenance for Ground and Surface Systems
TA13.3.4	Fault Isolation and Diagnostics	TX13.1.5	Ground and Surface Logistics
		TX13.2.3	Non-Destructive Inspection, Evaluation, and Root Cause Analysis
		TX13.2.6	Advanced Life-Cycle Testing Techniques
		TX13.4.5	Operations, Health, and Maintenance for Ground and Surface Systems
TA13.3.5	Prognostics	TX13.1.2	Launch/Test/Ops Site Management
		TX13.4.5	Operations, Health, and Maintenance for Ground and Surface Systems
TA13.3.6	Repair, Mitigation, and Recovery Technologies	TX13.1.7	Impact/Damage/Radiation-Resistant Systems
TA13.3.7	Communications, Networking, Timing, and Telemetry	TX02.2.1	Spacecraft Command and Data Handling Systems (C&DH)
		TX05.2.4	Flight and Ground Systems
TA13.3.8	Decision-Making Tools	TX13.2.6	Advanced Life-Cycle Testing Techniques
		TX13.4.4	Autonomous, Real-Time Command and Control
TA13.4	Mission Success		
TA13.4.1	Range Tracking, Surveillance, and Flight Safety Technologies	TX13.1.2	Launch/Test/Ops Site Management
		TX13.1.6	Test, Operations, and Systems Safety
		TX16.5	Range Tracking, Surveillance, and Flight Safety Technologies
TA13.4.2	Landing and Recovery Systems and Components	TX13.2.5	Flight and Ground Testing Methodologies
		TX13.3.3	Launch, Recovery and Reutilization
TA13.4.3	Weather Prediction and Mitigation	TX13.1.1	Natural and Induced Environment Characterization and Mitigation
		TX13.2.5	Flight and Ground Testing Methodologies
TA13.4.4	Robotics and Telerobotics	TX13.1.6	Test, Operations, and Systems Safety
		TX13.2.2	Propulsion, Exhaust, and Propellant Management
		TX13.2.3	Non-Destructive Inspection, Evaluation, and Root Cause Analysis
		TX13.3.2	Vehicle and Payload Assembly and Integration
		TX13.4.5	Operations, Health and Maintenance for Ground and Surface Systems
TA13.4.5	Safety Systems	TX13.1.6	Test, Operations, and Systems Safety

TA14 Thermal Management Systems

TA14 Thermal Management Systems		TX Technology Area Breakdown Structure	
TA14.1	Cryogenic Systems	TX14.1	Cryogenic Systems
TA14.1.1	Passive Thermal Control	TX14.1.1	In-space Propellant Storage and Utilization
		TX14.1.2	Launch Vehicle Propellant
		TX14.1.3	Thermal conditioning for Sensors, Instruments, and High Efficiency Electronic Motors
TA14.1.2	Active Thermal Control	TX14.1.1	In-space Propellant Storage and Utilization
		TX14.1.2	Launch Vehicle Propellant
		TX14.1.3	Thermal conditioning for Sensors, Instruments, and High Efficiency Electronic Motors
TA14.1.3	Integration and Modeling	TX14.1.1	In-space Propellant Storage and Utilization
		TX14.1.2	Launch Vehicle Propellant
		TX14.1.3	Thermal conditioning for Sensors, Instruments, and High Efficiency Electronic Motors
TA14.2	Thermal Control Systems	TX14.2	Thermal Control Systems
TA14.2.1	Heat Acquisition	TX14.2.1	Heat Acquisition
		TX14.2.4	Insulation and Interfaces
TA14.2.2	Heat Transport	TX14.2.2	Heat Transport
TA14.2.3	Heat Rejection and Energy Storage	TX14.2.3	Heat Rejection and Storage
TA14.3	Thermal Protection Systems	TX14.3	Thermal Protection Systems
TA14.3.1	Ascent/Entry TPS	TX14.3.1	Thermal Protection Materials
		TX14.3.2	Thermal Protection Systems
		TX14.3.3	Thermal Protection Analysis
		TX14.3.4	Thermal Protection System Testing
TA14.3.2	TPS Modeling and Simulation	TX14.3.3	Thermal Protection Analysis
		TX14.3.4	Thermal Protection System Testing
TA14.3.3	TPS Sensors and Measurement Systems	TX14.3.5	Thermal Protection System Instrumentation

TA14 Thermal Management Systems

The page intentionally left blank.

TA15 Aeronautics

TA15 Aeronautics		TX Technology Area Breakdown Structure	
TA15.1	Safe, Efficient, Growth in Global Aviation	TX15	Flight Vehicle Systems
TA15.1.1	Improved Efficiency and Hazard Reduction within NextGen Operational Domains	TX15.2.1	Trajectory Design and Analysis
		TX15.2.2	Flight Performance and Analysis
		TX16.2	Weather/Environment
		TX16.3	Traffic Management Concepts
		TX17.6.1	Strategic Management of Air Vehicles
		TX17.6.2	Tactical Management of Air Vehicles
TA15.1.2	System-Wide Safety, Predictability, and Reliability through Full NextGen Functionality	TX02.2.3	Vision and Virtual/Augmented Reality Avionics
		TX15.2.1	Trajectory Design and Analysis
		TX15.2.2	Flight Performance and Analysis
		TX16.3	Traffic Management Concepts
		TX17.6.1	Strategic Management of Air Vehicles
		TX17.6.2	Tactical Management of Air Vehicles
TA15.2	Innovation in Commercial Supersonic Aircraft		
TA15.2.1	Supersonic Overland Certification Standard Based on Acceptable Sonic Boom Noise	TX15.1.4	Aeroacoustics
TA15.2.2	Introduction of Affordable, Low-Boom, Low-Noise, and Low-Emission Supersonic Transports	TX15.1.4	Aeroacoustics
		TX15.1.5	Propulsion Flowpath and Interactions
		TX15.1.6	Advanced Atmospheric Flight Vehicles
		TX15.6	Vehicle Concepts
TA15.3	Ultra-Efficient Commercial Vehicles		
TA15.3.1	Achieve Community Goals for Improved Vehicle Efficiency and Environmental Performance in 2025	TX01.3.5	Turbine Based Jet Engines
		TX15.1.1	Aerodynamics
		TX15.1.2	Aerothermodynamics
		TX15.1.3	Aeroelasticity
		TX15.1.4	Aeroacoustics
		TX15.1.6	Advanced Atmospheric Flight Vehicles
		TX15.1.7	Computational Fluid Dynamics (CFD) Technologies
		TX15.1.8	Ground and Flight Test Technologies

TA15 Aeronautics		TX Technology Area Breakdown Structure	
TA15.3.2	Achieve Community Goals for Improved Vertical Lift Vehicle Efficiency and Environmental Performance in 2035	TX01.3.5	Turbine Based Jet Engines
		TX15.1.1	Aerodynamics
		TX15.1.2	Aerothermodynamics
		TX15.1.3	Aeroelasticity
		TX15.1.4	Aeroacoustics
		TX15.1.6	Advanced Atmospheric Flight Vehicles
		TX15.1.7	Computational Fluid Dynamics (CFD) Technologies
		TX15.1.8	Ground and Flight Test Technologies
TA15.3.3	Achieve Community Goals for Improved Vehicle Efficiency and Environmental Performance Beyond 2035	TX01.3.5	Turbine Based Jet Engines
		TX15.1.1	Aerodynamics
		TX15.1.2	Aerothermodynamics
		TX15.1.3	Aeroelasticity
		TX15.1.4	Aeroacoustics
		TX15.1.6	Advanced Atmospheric Flight Vehicles
		TX15.1.7	Computational Fluid Dynamics (CFD) Technologies
		TX15.1.8	Ground and Flight Test Technologies
TA15.4	Transition to Low-Carbon Propulsion	TX01.3	Air Breathing Propulsion Systems
TA15.4.1	Introduction of Low-Carbon Fuels for Conventional Engines and Exploration of Alternative Propulsion Systems	TX01.3.8	All Electric Propulsion
		TX01.3.9	Hybrid Electric Systems
		TX01.3.10	Turboelectric Propulsion
		TX01.3.12	Alternative Low Carbon Jet Fuel
TA15.4.2	Initial Introduction of Alternative Propulsion Systems	TX01.3.8	All Electric Propulsion
		TX01.3.9	Hybrid Electric Systems
		TX01.3.10	Turboelectric Propulsion
		TX01.3.12	Alternative Low Carbon Jet Fuel
TA15.5	Real-Time System-Wide Safety Assurance	TX16.1	Safe All Vehicle Access
TA15.5.1	Introduction of Advanced Safety Assurance Tools	TX16.1	Safe All Vehicle Access
TA15.5.2	An Integrated Safety Assurance System Enabling Continuous System-Wide Safety Monitoring	TX16.1	Safe All Vehicle Access
TA15.5.3	Automated Safety Assurance Integrated with Real-Time Operations Enabling a Self-Protecting Aviation System	TX16.1	Safe All Vehicle Access
		TX16.4	Architectures and Infrastructure
TA15.6	Enable Assured Machine Autonomy for Aviation		
TA15.6.1	Initial Autonomy Applications	TX16.4	Architectures and Infrastructure
TA15.6.2	Ability to Fully Certify and Trust Autonomous Systems for NAS Operations	TX16.3	Traffic Management Concepts