

TA01 • LAUNCH PROPULSION SYSTEMS

- SOLID ROCKET PROPULSION SYSTEMS**
- Propellants
 - Case Materials
 - Nozzle Systems
 - Hybrid Rocket Propulsion Systems
 - Fundamental Solid Propulsion Technologies
- LIQUID ROCKET PROPULSION SYSTEMS**
- LH₂/LOX Based
 - RP/LOX Based
 - CH₄/LOX Based
 - Detonation Wave Engines (Closed Cycle)
 - Propellants
 - Fundamental Liquid Propulsion Technologies
- AIR BREATHING PROPULSION SYSTEMS**
- TBCC
 - RBCC
 - Detonation Wave Engines (Open Cycle)
 - Turbine Based Jet Engines (Flyback Boosters)
 - Ramjet/Scramjet Engines (Accelerators)
 - Deeply-cooled Air Cycles
 - Air Collection & Enrichment System
 - Fundamental Air Breathing Propulsion Technologies
- ANCILLARY PROPULSION SYSTEMS**
- Auxiliary Control Systems
 - Main Propulsion Systems (Excluding Engines)
 - Launch Abort Systems
 - Thrust Vector Control Systems
 - Health Management & Sensors
 - Pyro & Separation Systems
 - Fundamental Ancillary Propulsion Technologies
- UNCONVENTIONAL / OTHER PROPULSION SYSTEMS**
- Ground Launch Assist
 - Air Launch / Drop Systems
 - Space Tether Assist
 - Beamed Energy / Energy Addition
 - Nuclear
 - High Energy Density Materials/Propellants

TA02 • IN-SPACE PROPULSION TECHNOLOGIES

- CHEMICAL PROPULSION**
- Liquid Storable
 - Liquid Cryogenic
 - Gels
 - Solid
 - Hybrid
 - Cold Gas/Warm Gas
 - Micro-propulsion
- NON-CHEMICAL PROPULSION**
- Electric Propulsion
 - Solar Sail Propulsion
 - Thermal Propulsion
 - Tether Propulsion
- ADVANCED (TRL <3) PROPULSION TECHNOLOGIES**
- Beamed Energy Propulsion
 - Electric Sail Propulsion
 - Fusion Propulsion
 - High Energy Density Materials
 - Antimatter Propulsion
 - Advanced Fission
 - Breakthrough Propulsion
- SUPPORTING TECHNOLOGIES**
- Propellant Storage & Transfer

TA03 • SPACE POWER & ENERGY STORAGE

- POWER GENERATION**
- Energy Harvesting
 - Chemical (Fuel Cells, Heat Engines)
 - Solar (Photo-Voltaic & Thermal)
 - Radioisotope
 - Fission
 - Fusion
- ENERGY STORAGE**
- Batteries
 - Flywheels
 - Regenerative Fuel Cells
- POWER MANAGEMENT & DISTRIBUTION**
- FDIR
 - Management & Control
 - Distribution & Transmission
 - Wireless Power Transmission
 - Conversion & Regulation
- CROSS CUTTING TECHNOLOGY**
- Analytical Tools
 - Green Energy Impact
 - Multi-functional Structures
 - Alternative Fuels

TA04 • ROBOTICS, TELE-ROBOTICS & AUTONOMOUS SYSTEMS

- SENSING & PERCEPTION**
- 3-D Perception
 - Relative Position & Velocity Estimation
 - Terrain Mapping, Classification & Characterization
 - Natural & Man-made Object Recognition
 - Sensor Fusion for Sampling & Manipulation
 - Onboard Science Data Analysis
- MOBILITY**
- Extreme Terrain Mobility
 - Below-Surface Mobility
 - Above-Surface Mobility
 - Small Body/Microgravity Mobility
- MANIPULATION**
- Robot Arms
 - Dexterous Manipulators
 - Modeling of Contact Dynamics
 - Mobile Manipulation
 - Collaborative Manipulation
 - Robotic Drilling & Sample Processing
- HUMAN-SYSTEMS INTEGRATION**
- Multi-Modal Human-Systems Interaction
 - Supervisory Control
 - Robot-to-Suit Interfaces
 - Intent Recognition & Reaction
 - Distributed Collaboration
 - Common Human-Systems Interfaces
 - Safety, Trust, & Interfacing of Robotic/Human Proximity Operations
- AUTONOMY**
- Vehicle Systems Management & FDIR
 - Dynamic Planning & Sequencing Tools
 - Autonomous Guidance & Control
 - Multi-Agent Coordination
 - Adjustable Autonomy
 - Terrain Relative Navigation
 - Path & Motion Planning with Uncertainty
- AUTON. RENDEZVOUS & DOCKING**
- Relative Navigation Sensors (long-, mid-, near-range)
 - Guidance Algorithms
 - Docking & Capture Mechanisms/Interfaces
 - Mission/System Managers for Autonomy/Automation
- RTA SYSTEMS ENGINEERING**
- Modularity/Commonality
 - Verification & Validation of Complex Adaptive Systems
 - Onboard Computing

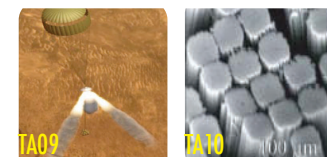
- INTERNETWORKING**
- Disruptive Tolerant Networking
 - Adaptive Network Topology
 - Information Assurance
 - Integrated Network Management
- POSITION, NAVIGATION, AND TIMING**
- Timekeeping & Time Distribution
 - Onboard Auto Navigation & Maneuver
 - Sensors & Vision Processing Systems
 - Relative & Proximity Navigation
 - Auto Precision Formation Flying
 - Auto Approach & Landing
- INTEGRATED TECHNOLOGIES**
- Radio Systems
 - Ultra Wideband
 - Cognitive Networks
 - Science from the Comm. System
 - Hybrid Optical Comm. & Nav. Sensors
 - RF/Optical Hybrid Technology
- REVOLUTIONARY CONCEPTS**
- X-Ray Navigation
 - X-Ray Communications
 - Neutrino-Based Navigation & Tracking
 - Quantum Key Distribution
 - Quantum Communications
 - SQIF Microwave Amplifier
 - Reconfigurable Large Apertures Using Nanosat Constellations

- ENVIRONMENTAL CONTROL & LIFE SUPPORT SYSTEMS & HABITATION SYS.**
- Air Revitalization
 - Water Recovery & Management
 - Waste Management
 - Habitation
- EXTRAVEHICULAR ACTIVITY SYSTEMS**
- Pressure Garment
 - Portable Life Support System
 - Power, Avionics & Software
- HUMAN HEALTH & PERFORMANCE**
- Medical Diagnosis / Prognosis
 - Long-Duration Health
 - Behavioral Health
 - Human Factors
- ENVIRONMENTAL MONITORING, SAFETY & EMERGENCY RESPONSE**
- Sensors: Air, Water, Microbial, etc.
 - Fire: Detection, Suppression, Recovery
 - Protective Clothing / Breathing
 - Remediation
- RADIATION**
- Risk Assessment Modeling
 - Radiation Mitigation
 - Protection Systems
 - Radiation prediction
 - Monitoring Technology

- OPTICAL COMM. & NAVIGATION**
- Detector Development
 - Large Apertures
 - Lasers
 - Acquisition & Tracking
 - Atmospheric Mitigation
- RADIO FREQUENCY COMMUNICATIONS**
- Spectrum Efficient Technologies
 - Power Efficient Technologies
 - Propagation
 - Flight & Ground Systems
 - Earth Launch & Reentry Comm.
 - Antennas

- TA05 • COMMUNICATION & NAVIGATION**

- TA06 • HUMAN HEALTH, LIFE SUPPORT & HABITATION SYSTEMS**



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 - Radiation Mitigation
 - Protection Systems
 - Radiation prediction
 - Monitoring Technology

- TA07 • HUMAN EXPLORATION DESTINATION SYSTEMS**

- TA08 • SCIENCE INSTRUMENTS, OBSERVATORIES & SENSOR SYSTEMS**

- REMOTE SENSING INSTRUMENTS / SENSORS**
- Detectors & Focal Planes
 - Electronics
 - Optical Components
 - Microwave / Radio
 - Lasers
 - Cryogenic / Thermal
- OBSERVATORIES**
- Mirror Systems
 - Structures & Antennas
 - Distributed Aperture
- IN-SITU INSTRUMENTS / SENSOR**
- Particles: Charged & Neutral
 - Fields & Waves
 - In-Situ

TA07 • HUMAN EXPLORATION DESTINATION SYSTEMS

- IN-SITU RESOURCE UTILIZATION**
- Destination Reconnaissance, Prospecting, & Mapping
 - Resource Acquisition
 - Consumables Production
 - Manufacturing Products & Infrastructure Emplacement
- SUSTAINABILITY & SUPPORTABILITY**
- Autonomous Logistics Management
 - Maintenance Systems
 - Repair Systems
 - Food Production, Processing, & Preservation
- “ADVANCED” HUMAN MOBILITY SYSTEMS**
- EVA Mobility
 - Surface Mobility
 - Off-Surface Mobility
- “ADVANCED” HABITAT SYSTEMS**
- Integrated Habitat Systems
 - Habitat Evolution
 - “Smart” Habitats
 - Artificial Gravity
- MISSION OPERATIONS & SAFETY**
- Crew Training
 - Planetary Safety
 - Integrated Flight Operations Systems
 - Integrated Risk Assessment Tools
- CROSS-CUTTING SYSTEMS**
- Construction & Assembly
 - Particulate Contamination Prevention & Mitigation

- TA09 • ENTRY, DESCENT & LANDING SYSTEMS**

- AEROASSIST & ATMOSPHERIC ENTRY**
- Rigid Thermal Protection Systems
 - Flexible Thermal Protection Systems
 - Rigid Hypersonic Decelerators
 - Deployable Hypersonic Decelerators
- DESCENT**
- Attached Deployable Decelerators
 - Trailing Deployable Decelerators
 - Supersonic Retropropulsion
- LANDING**
- Touchdown Systems
 - Egress & Deployment Systems
 - Propulsion Systems
 - Small Body Systems
- VEHICLE SYSTEMS TECHNOLOGY**
- Separation Systems
 - System Integration and Analyses
 - Atmosphere & surface characterization
 - Modeling and Simulation
 - Instrumentation and Health Monitoring
 - GN&C Sensors and Systems

- TA10 • NANOTECHNOLOGY**

- ENGINEERED MATERIALS & STRUCTURES**
- Lightweight Structures
 - Damage Tolerant Systems
 - Coatings
 - Adhesives
 - Thermal Protection & Control
- ENERGY GENERATION & STORAGE**
- Energy Storage
 - Energy Generation
- PROPULSION**
- Propellants
 - Propulsion Components
 - In-Space Propulsion
- SENSORS, ELECTRONICS & DEVICES**
- Sensors & Actuators
 - Nanoelectronics
 - Miniature Instruments

- TA11 • MODELING, SIMULATION, INFORMATION TECHNOLOGY & PROCESSING**

- COMPUTING**
- Flight Computing
 - Ground Computing
- MODELING**
- Software Modeling & Model-Checking
 - Integrated Hardware & Software Modeling
 - Human-System Performance Modeling
 - Science Modeling
 - Frameworks, Languages, Tools & Standards
- SIMULATION**
- Distributed Simulation
 - Integrated System Lifecycle Simulation
 - Simulation-Based Systems Engineering
 - Simulation-Based Training & Decision Support Systems
- INFORMATION PROCESSING**
- Science, Engineering & Mission Data Lifecycle
 - Intelligent Data Understanding
 - Semantic Technologies
 - Collaborative Science & Engineering
 - Advanced Mission Systems

- TA12 • MATERIALS, STRUCTURES, MECHANICAL SYSTEMS & MANUFACTURING**

- MATERIALS**
- Lightweight Structure
 - Computational Design
 - Flexible Material Systems
 - Environment
 - Special Materials
- STRUCTURES**
- Lightweight Concepts
 - Design & Certification Methods
 - Reliability & Sustainment
 - Test Tools & Methods
 - Innovative, Multifunctional Concepts
- MECHANICAL SYSTEMS**
- Deployables, Docking and Interfaces
 - Mechanism Life Extension Systems
 - Electro-mechanical, Mechanical & Micromechanisms
 - Design & Analysis Tools and Methods
 - Reliability / Life Assessment / Health Monitoring
 - Certification Methods
- MANUFACTURING**
- Manufacturing Processes
 - Intelligent Integrated Manufacturing and Cyber Physical Systems
 - Electronics & Optics Manufacturing Process
 - Sustainable Manufacturing
- CROSS-CUTTING**
- Nondestructive Evaluation
 - Model-Based Certification & Sustainment Methods
 - Loads and Environments

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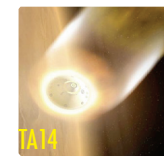
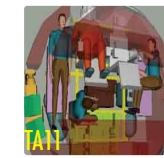
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- CROSS-CUTTING**
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 - Model-Based Certification & Sustainment Methods
 - Loads and Environments

- TA13 • GROUND & LAUNCH SYSTEMS PROCESSING**

- TECHNOLOGIES TO OPTIMIZE THE OPERATIONAL LIFE-CYCLE**
- Storage, Distribution & Conservation of Fluids
 - Automated Alignment, Coupling, & Assembly Systems
 - Autonomous Command & Control for Ground and Integrated Vehicle / Ground Systems
- ENVIRONMENTAL AND GREEN TECHNOLOGIES**
- Corrosion Prevention, Detection, & Mitigation
 - Environmental Remediation & Site Restoration
 - Preservation of Natural Ecosystems
 - Alternate Energy Prototypes
- TECHNOLOGIES TO INCREASE RELIABILITY AND MISSION AVAILABILITY**
- Advanced Launch Technologies
 - Environment-Hardened Materials and Structures
 - Inspection, Anomaly Detection & Identification
 - Fault Isolation and Diagnostics
 - Prognostics Technologies
 - Repair, Mitigation, and Recovery Technologies
 - Communications, Networking, Timing & Telemetry
- TECHNOLOGIES TO IMPROVE MISSION SAFETY/MISSION RISK**
- Range Tracking, Surveillance & Flight Safety Technologies
 - Landing & Recovery Systems & Components
 - Weather Prediction and Mitigation
 - Robotics / Telerobotics
 - Safety Systems

- TA14 • THERMAL MANAGEMENT SYSTEMS**

- CRYOGENIC SYSTEMS**
- Passive Thermal Control
 - Active Thermal Control
 - Integration & Modeling
- THERMAL CONTROL SYSTEMS**
- Heat Acquisition
 - Heat Transfer
 - Heat Rejection & Energy Storage
- THERMAL PROTECTION SYSTEMS**
- Entry / Ascent TPS
 - Plume Shielding (Convective & Radiative)
 - Sensor Systems & Measurement Technologies



Space Technology Roadmaps **STR • TABS**
TECHNOLOGY AREA BREAKDOWN STRUCTURE