The Future Brought to You by NASA

America is beginning an exciting new chapter in space exploration. To enable the future, NASA has developed a set of roadmaps to define the key new technologies required for our human and robotic explorers to safely venture into deep space, to better understand how our own solar system evolved, and to unravel the mysteries of our universe.

The map you see here is a graphical representation of the NASA Space Technology Roadmaps, serving as a portal to the various technologies that NASA is developing. Let this technology portal serve as a starting point for your adventures beyond the bounds of Earth...

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- **TA01** Launch Propulsion Systems
- **TA02** In-Space Propulsion Technologies
- **TA03** Space Power & Energy Storage
- **TA04** Robotics, Tele-Robotics & Autonomous Systems
- **TA05** Communication & Navigation
- **TA06** Human Health, Life Support & Habitation Systems
- **TA07** Human Exploration Destination Systems
- **TA08** Science Instruments, Observatories & Sensor Systems
- **TA09** Entry, Descent & Landing Systems
- **TA10** Nanotechnology
- **TA11** Modeling, Simulation, Information Technology & Processing
- **TA12** Materials, Structures, Mechanical Systems & Manufacturing
- **TA13** Ground & Launch Systems Processing
- **TA14** Thermal Management Systems

turn over for details

TA01 Launch Propulsion Systems

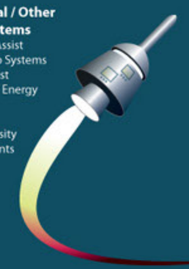
Solid Rocket Propulsion Systems
- Propellants
- Case Materials
- Nozzle Systems
- Hybrid Rocket Propulsion Systems
- Fundamental Solid Propulsion Technologies

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

Ancillar y 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

Autonomous Rendezvous and Docking
- Relative Navigation Sensors (long-, mid-, near-range)
- Guidance Algorithms
- Docking & Capture Mechanisms/Interfaces

RTA Systems Engineering
- Modularity/Commonality
- Verification & Validation of Complex Adaptive Systems
- Onboard Computing

TA05 Communication & Navigation

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

Internetworking
- Disruptive Tolerant Networking
- Adaptive Network Topology
- Information Assurance
- Integrated Network Management

Position, Navigation, and Timing
- Timekeeping and 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 Constellation

TA06 Human Health, Life Support & Habitation Systems

Environmental Control & Life Supp ort Systems & Habitation Sys.
- Air Revitalization
- Water Recovery & Management
- Waste Management
- Habitation

Extra vehicular Activity Systems
- Pressure Garment
- Portable Life Support System
- Power, Avionics and Software

Human Health & Performance
- Medical Diagnosis / Prognosis
- Long-Duration Health
- Behavioral Health & Performance
- Human Factors & Performance

Environmental Monitoring, Safety & Emergency Response
- Sensors: Air, Water, Microbial, etc.
- Fire: Detection, Suppression
- Protective Clothing / Breathing
- Remediation

Radiation
- Risk Assessment Modeling
- Radiation Mitigation
- Protection Systems
- Radiation Prediction
- Monitoring Technology

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, and 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
- Dust Prevention & Mitigation
- Particulate Contamination Prevention & Mitigation

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

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 & Analyses
- Atmosphere & Surface Characterization
- Modeling and Simulation
- Instrumentation and Health Monitoring
- GN&C Sensors and Systems

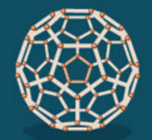
TA10 Nanotechnology

Engineered Materials & Structures
- Lightweight Structures
- Damage Tolerant Systems
- Coatings
- Adhesives
- Thermal Protection & Control

Energy Genera tion & 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 & Engineering 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 & Sensors
- 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

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