Propulsion is unique in being the main delimiter on how far and how fast one can travel in space.

It is the lack of truly economical high-performance propulsion systems that continues to limit and restrict the extent of human endeavors in space.
Our mission

The Grand Vision

- Human colonization and settlement of other planets and star systems
- Exploration to expand understanding of the universe
- Commercial development and utilization of extraterrestrial resources

- Conceive and investigate new, revolutionary propulsion concepts
- Demonstrate critical functions of promising technologies - perform proof-of-concept
- Perform leading-edge development
Organization

LAUNCH APPLICATIONS

SPACE APPLICATIONS

ADVANCED HIGH-ENERGY CONCEPTS

Technology Readiness Level (TRL)
Rocket Components & Processes

Application of Raman Scattering diagnostic procedure

Chemical Injector Technology
Combustion Physics
Advanced Fuels & Propellants

Uni-Element Combustion Chamber
Airbreathing Propulsion

Rocket-Based Combined Cycle (RBCC) Propulsion
- Subscale Ground Tests
- System Modeling & Analysis
- Flight Experiments

Alternative Combined Cycles
- Methanol Ramjet Demonstration
- Liquid Air Cycle Engines (LACE)
Advanced Launch Systems

Laser Propulsion
- Laser Pulsejet Technology
- Lightcraft Flight Experiments - WSMR

Launch Assist Concepts
- Maglifter

Pulse Detonation Engines

RBCC SSTO vehicle with launch assist

One of the original indoor flight tests
Solar Thermal Propulsion

Direct-Gain Engine Research

Ground Technology Demos
- Joint NASA/AF/Industry AITP
- Shooting Star Technology

SOTV Flight Experiment
- Joint AF/Industry/NASA

Shooting Star Flight Experiment Concept

Solar Thermal Test Facility Concentrator
Multipurpose Hydrogen Test Bed (MHTB)
- Thermal & Pressure Control Subsystems
- Liquid Acquisition Devices
- Low-G Fluid Quantity Gaging

Flight Experiments

Advanced Concepts
- Magnetically-Actuated Propellant Control
- Hydrogen Carbon Matrix Storage
Electric Propulsion

Electrodynamic Tethers
- PROSEDS Flight Experiment
- Jovian Probe

Electromagnetic Thrusters
- Pulsed Inductive Thruster (PIT)
- Plasmoid Thrusters

Earth-orbiting electrodynamic tether

NSTAR Ion-propelled spacecraft
Nuclear Propulsion

Simulated Nuclear Tests
- Bimodal reactor system

Nuclear Electric Flight Test
- Saturn Ring Orbiter Mission
- Asteroid Deflection Demonstration

Interstellar Precursor Mission

Human Exploration Studies
- High-Thrust Nuclear Electric
- Nuclear Thermal Engines
Advanced Nuclear Processes

Gas-Core Nuclear Propulsion
Hot Isomeric Transitions

Gas Core Fission Rocket

Isomer-Based Ejector Ramrocket
Magnetized Target Fusion (MTF)
Inertial Electrostatic Confinement (IEC)
Magnetic Confinement
Antimatter Technology

Production
- Low-cost Degrader/Accumulator
- Vacuum Energy Suppression

Storage
- High-Performance Antiproton Trap
- Plasmoid Thrusters

Energy Utilization
- Compressed Target Interaction Exp
- Antimatter Plasma Heating/Thrust
Summary

- Research focused on the most challenging propulsion technologies needed to *Open Up The Frontier*

- Take advantage of resources inside & outside MSFC
  - Collaborations & leveraged programmatic resources
  - Visiting researcher programs

- Emphasize small, relatively inexpensive research activities
  - Subscale investigations of promising technologies
  - Proof-of-concept demos (TRL 3) “set stage” for advanced development

- Goals & future directions
  - Flight demonstration of new, high-performance launch concept(s)
  - Experimentally prove viability of omniplanetary/interstellar propulsion concept(s)
  - Provide technologies to enable *ambitious* robotic exploration of solar system & near-interstellar space - bimodal nuclear, high-thrust electric, and micro-spacecraft propulsion
Technology Readiness Levels (TRL)

- TRL 9: Actual system “flight proven” through successful mission operations
- TRL 8: Actual system completed and "flight qualified" through test and demonstration
- TRL 7: System prototype demonstration in a space environment
- TRL 6: System/subsystem model or prototype demonstrated in relevant environment
- TRL 5: Component and/or breadboard validation in a relevant environment
- TRL 4: Component and/or breadboard validation in a laboratory environment
- TRL 3: Analytical & experimental demonstration of critical function and/or proof-of-concept
- TRL 2: Technology concept and/or application formulated
- TRL 1: Basic principles observed and formulated
A bridge linking concept to advanced development...

Technology Readiness Level (TRL)

- 1: Universities, R&T Orgs
- 2: Emphasis Proof-of-concept
- 3: Emphasis Mission Applications
- 4: Propulsion Research & Technology
- 5: Technology Demonstration & Development
- 6: Aerospace Industry

Relative Involvement

- 0% to 100%

Research

Advanced Development (Technology Development)

Development (Operational System)

Laboratory-scale Experiments

Subsystem Tests

System Tests
Research Goals - Launch

Requirements to reach 270 km orbit

GOALS:
- Lightweight, high-Isp systems
- Integrated propulsion & aerodynamics
- 
  \( V \) reductions via launch assist & offboard boost
Research Goals - Space

Direct omniplanetary missions within 100 AU

GOALS:  
- Specific impulse ($Isp = \frac{T}{w_p}$) of at least $10^5$ secs  
- Vehicle accelerations ($T/W$) greater than $10^{-3}$ g
Space Transportation Research

JPL

- Advanced Propulsion Workshop
  - 10th NASA/JPL/MSFC/AIAA
  - Advanced Space Propulsion Concepts Workshop
  - Held at Bevill Center in Huntsville, AL  April 5-8, 1999

- Advanced Propulsion Concepts Database
  - Now available NASA wide
  - http://sec353.jpl.nasa.gov/apc
  - General information on a wide range at advanced propulsion concepts and applications
Goal: Conduct research into advanced technologies that may enable dramatic high payoff improvements in space transportation

Initiatives:

- Advanced cycles
  - Pulse detonation wave engine
  - Fusion propulsion
  - Fission propulsion
  - Exotic fuels
- Off-board resources
  - Magnetic assist launch
  - Beamed energy
  - MHD
- Breakthrough physics
Space Transportation Research

JPL
- Lorentz Force Accelerator (LFA)
  - Lithium fueled MPD type electric engine
  - 30 kW version delivered to Princeton for testing
  - 500 kW thruster ordered from MAI, delivery on hold due to U.S. sanctions
  - Mods to high power test chamber underway at JPL

- Micro-Ion Engine Research
  - Performance Goals
    - Isp: ~3000 sec
    - Thrust: mN to mN
    - Power: <10 W
  - Will validate data obtained with USC/AFRL hollow anode

- Fusion and Antimatter Research
  - Penn State has made major upgrades to the portable Penning trap
  - Loaded >10^6 H-ions into trap and demonstrated 1/e lifetime of >5 days
Space Transportation Research

GRC
- **Atomic Propellants, Solid Hydrogen**
  - Takes advantage recombination energy of atoms of boron or carbon
  - Atoms trapped in solid hydrogen ice particles suspended in liquid helium
  - May provide very high specific impulse, Isp >750 sec
  - First test with solid hydrogen and 14 deg.K liquid helium in March 99'
  - Test with atomic constituents are still several years away at current funding levels
  - Collaboration with AFRL-Edwards

- **Lox Augmented Nuclear Thermal Rocket (LANTR)**
  - Combines high thrust to weight of chemical rocket with high Isp of Nuclear Thermal Rocket (NTR)
  - Lox is injected into supersonic flow of NTR nozzle
  - Combustion adds thrust at expense of Isp
  - High thrust is needed while vehicles are in planetary gravity well
  - May begin hot fire tests in FY00
Space Transportation Research

JSC

VASIMR System – Plasma Rocket

- Variable Specific Impulse (Isp) and Thrust at maximum power. Offers operational flexibility.
- Electrodeless design with magnetic insulation.
- High power density.
- Propellant is cheap and plentiful; chemical forms (Ammonia, Methane, etc.) may be easy to store and produce in-situ.
- Continuous acceleration (very low artificial g).
- High efficiency Ion Cyclotron Resonance Heating (ICRH), high voltage and low current.
- Hydrogen is aneutronic, and provides the best radiation shield to GCR and SPEs.
Space Transportation Research

LeRC

- Magnetic Nozzle Experiment for Space Fusion Powered Propulsion
  - Development of plasma source and magnetic nozzle apparatus
  - Experiments with magnetic nozzles scaled from fusion-reactor heated flows
  - Los Alamos National Lab is lead in magnetic nozzle theory development
  - Ohio State University has unique GW power level experiment test facility

- Coaxial Helicity Ejection Experiment (CHE)
  - Utilizes Princeton Plasma Physics Laboratory (PPPL) National Spherical Torrs Experiment (NSTX) reactor
  - Ejection of plasma in toroidal reactors occurs naturally during shut down
  - Experiment using CHE operation through a divertor offers potential for extracting plasma power directly