ENABLING CONCEPTS & TECHNOLOGIES PROGRAM

Code R Budget Superbowl

June 20, 2002

ENABLING CONCEPTS & TECHNOLOGIES
Program Objectives

NASA Mission

- To understand and protect our home planet
- To explore the universe and search for life
- To inspire the next generation of explorers

Aerospace Technology Enterprise Strategic Goal

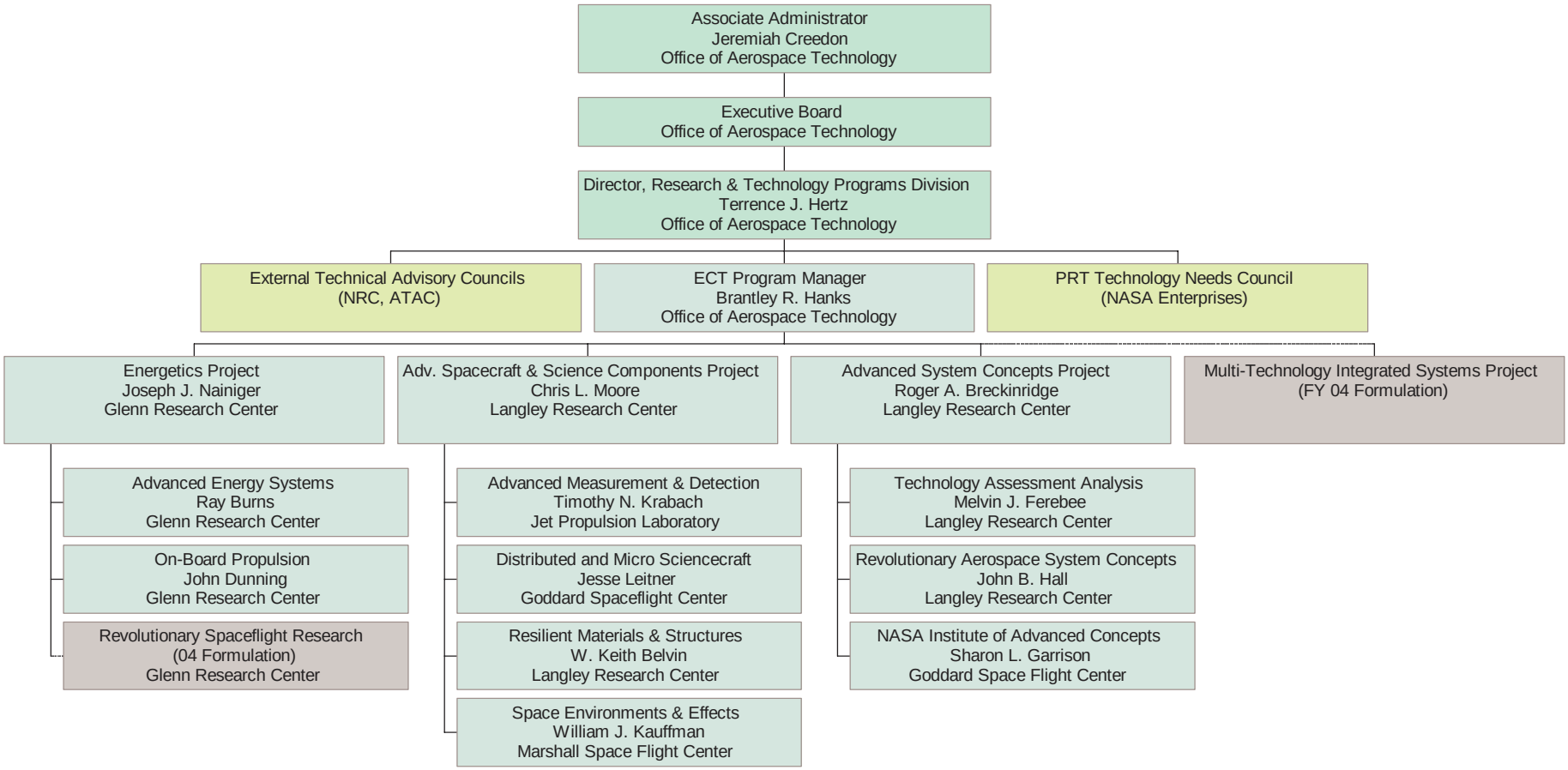
GOAL 3: Pioneer Revolutionary Technology

Develop revolutionary technologies and technology solutions to enable fundamentally new aerospace systems capabilities and missions.

Enabling Concepts and Technologies Program

- Explore revolutionary aerospace system concepts to enable the grand challenges and strategic visions of the NASA Enterprises, and to expand the possibilities for future NASA missions.
- Develop advanced technology for sensing and spacecraft systems to enable bold new missions of exploration, and to provide increased scientific return at lower cost.
- Develop advanced energetics technology to provide low-cost power and propulsion for enhanced mission capabilities, and to enable missions beyond current horizons.

ENABLING CONCEPTS & TECHNOLOGIES PROGRAM ORGANIZATION



ENABLING CONCEPTS & TECHNOLOGIES PROGRAM
PROJECT OBJECTIVES

- **Advanced Systems Concepts Project**
  - Conceptual studies and analysis of revolutionary aerospace system concepts that have the potential to leap well past current plans, or to enable new visions for NASA's strategic plans.

- **Energetics Project**
  - Development of advanced power and propulsion technologies to enable lower-cost missions with increased capability, and to extend mission reach.

- **Advanced Spacecraft & Science Components Project**
  - Development of advanced spacecraft components and subsystems to provide increased scientific return from future missions at lower cost.

- **Space Base NRAs**
  - The ECT Program uses broadly announced peer-reviewed NASA Research Announcements (NRAs) to fill gaps in program content, to capture innovative ideas from external organizations, to leverage high-payoff emerging technologies, and to complement NASA capabilities in critical areas.

ADVANCED SYSTEMS CONCEPTS PROJECT

Project Elements

- *Technology Assessment Analysis (LaRC)*
  - Identifies high-payoff technology areas to guide ECT Program investment decisions, and provides metrics for evaluating the progress of technologies under development.

- *Revolutionary Aerospace Systems Concepts (LaRC)*
  - Internally competed solicitations for advanced concept studies, selected by NASA Headquarters multi-Enterprise technology team.

- *NASA Institute of Advanced Concepts (GSFC)*
  - Externally competed solicitations for paradigm-breaking ideas, managed by University Space Research Association

Final Accomplishments

- Implementation of a systems analysis process for quantifying the relative benefits of candidate technologies in the ECT Program portfolio to guide investment decisions.
- Advanced system concepts that enable at least 5 new mission scenarios for the NASA Enterprises.

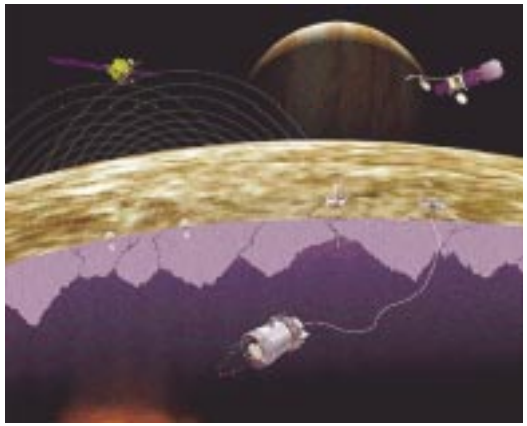
Planned FY02 Accomplishments

- Develop a systematic process for the ECT Program to identify high-payoff technologies and assess their benefits in representative mission applications.
- Perform conceptual studies of far-term mission architectures for the Enterprises through RASC and NIAC solicitations.

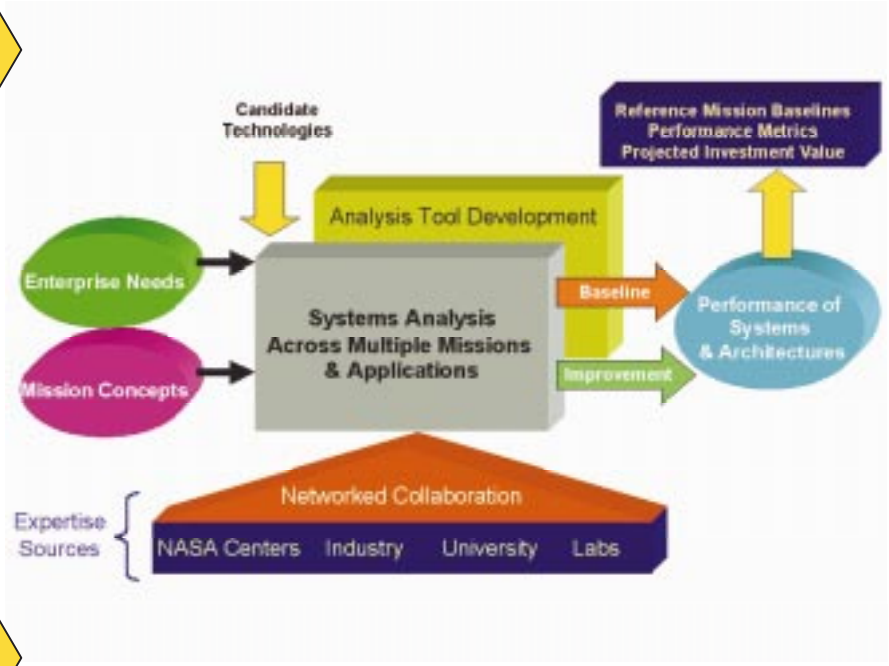
MAJOR PRODUCTS
Advanced System Concepts

NASA Institute of Advanced Concepts (NIAC):
Revolutionary ideas to enable new far-term visions for the NASA Enterprises

Revolutionary Aerospace System Concepts (RASC):
Conceptual studies of innovative mission scenarios to identify high-payoff technology areas



Technology Assessment Analysis:
Guides technology investments and establishes metrics for evaluating program progress



ADVANCED SYSTEM CONCEPTS PROJECT
GPRA METRICS

FY03 Metrics

- None

Proposed FY04 Metrics

- Implement a systems analysis process to assess the system-level benefits of technologies in the ECT Program portfolio, and complete pilot technology assessments on 3 representative mission classes selected by the Enterprises.

ADVANCED SYSTEM CONCEPTS PROJECT RESOURCES

- **FY03 Resources**

	ARC	DFRC	GRC	LaRC	MSFC	Other Centers	OGA	Univ	Industry
Funding $M				11.500		5.000			
FTEs				29		1			

- **FY04 Resources**

	ARC	DFRC	GRC	LaRC	MSFC	Other Centers	OGA	Univ	Industry
Funding $M				11.900		5.200			
FTEs				29		1			

- **5-Year Budget Runout**

	FY02	FY03	FY04	FY05	FY06	FY07
Funding $M	13.000	16.500	17.100	17.600	17.700	17.500

ENERGETICS PROJECT

Project Elements

- *Advanced Energy Systems (GRC)*
  - Advanced photovoltaic solar cells and arrays,advanced radioisotope power systems, lithium battery, flywheel, and regenerative fuel cell energy storage systems, advanced cooling technology for power, power system materials and environmental interactions, and advanced power management and distribution technologies.

- *On-Board Propulsion (GRC)*
  - Advanced electric propulsion systems (ion, Hall, pulse plasma thrusters, magnetoplasmadynamic thrusters, and pulsed inductive thrusters), advanced chemical propulsion systems (monoprops and biprops), and electric and chemical microthrusters.

Final Accomplishments

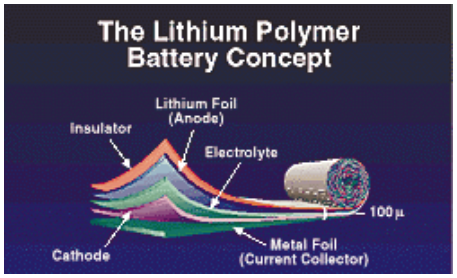
- Develop advanced power technologies to enable a 40-60% reduction in power system mass
- Develop advanced propulsion system concepts to enable 30% reduction in trip time for planetary missions

Planned FY02 Accomplishments

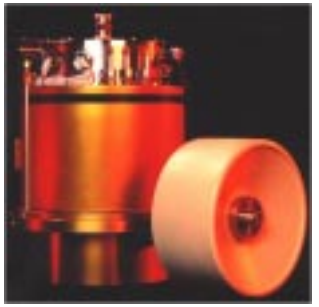
- Demonstrate feasibility of 300 W/m^2 solar array using thin film Fresnel lens concentrators
- Demonstrate high thrust 50 kW Hall thruster
- Demonstrate 2x improvement in Xenon throughput for NSTAR ion thruster
- Demonstrate 1 MW pulsed gaseous MPD thruster
- Demonstrate magnetic bearings for high speed flywheels
- Develop design concept for MEMS Stirling cooler

MAJOR TECHNOLOGY PRODUCTS
Energetics

Advanced photovoltaics



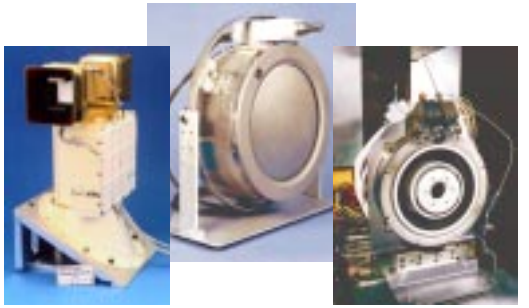
Batteries & fuel cells



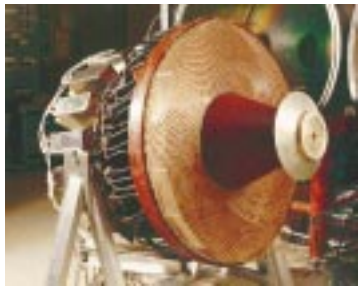
Flywheel energy storage

Stirling converters

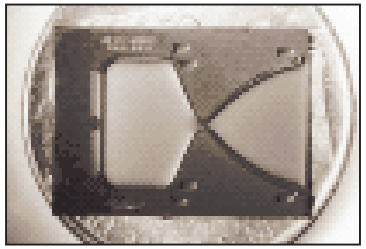
Power management
& distribution



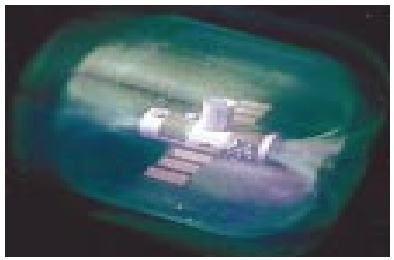
Efficient electric thrusters



High power electric
thrusters



Small chemical thrusters



Revolutionary propulsion
system concepts

ENERGETICS PROJECT
GPRA METRICS

- **FY03 Metrics**
  - Validate ion optics for a 2X increase in life relative to Deep Space 1
  - Complete Hall thruster life and operating point correlations
  - Complete Hall thruster modeling
  - Demonstrate feasibility of high efficiency (i.e., greater than 30 percent) multi-bandgap solar cell on silicon substrate
  - Demonstrate single axis integrated momentum and power control with flywheels
  - Demonstrate 100 percent thrust augmentation of high area ratio nozzle
  - Complete laboratory characterization of solid hydrogen behavior in liquid helium

- **Proposed FY04 Metrics**
  - Demonstrate feasibility of quantum dot solar cells
  - Demonstrate feasibility of > 20% efficiency multi-bandgap thin film solar cell on polyimide substrate
  - Demonstrate solid polymer electrolyte lithium battery with 3x improvement in specific energy
  - Demonstrate feasibility of passive unitized regenerative fuel cell storage system
  - Demonstrate high temperature power converter operating at 200 ^{o}C
  - Demonstrate MEMS Stirling cooler for power electronics
  - Demonstrate feed system for ion thrusters that is 1/10 the weight of current systems
  - Demonstrate lightweight 8 cm ion engine for small spacecraft
  - Demonstrate 10kW throttleable ion engine with specific impulse > 4000 sec
  - Demonstrate lightweight high efficiency power processor for ion thrusters
  - Demonstrate multi-engine operation for electric thrusters

ENERGETICS PROJECT RESOURCES

- **FY03 Resources**

	ARC	DFRC	GRC	LaRC	MSFC	Other Centers	OGA	Univ	Industry
Funding $M			16.520						
FTEs			133						

- **FY04 Resources**

	ARC	DFRC	GRC	LaRC	MSFC	Other Centers	OGA	Univ	Industry
Funding $M			14.720						
FTEs			134						

- **5-Year Budget Runout**

	FY02	FY03	FY04	FY05	FY06	FY07
Funding $M	20.328	16.520	14.720	9.830	5.800	2.000

ADVANCED SPACECRAFT & SCIENCE COMPONENTS PROJECT

Project Elements

- *Advanced Measurement & Detection (JPL)*
  - Miniaturized sensors, advanced active instruments, and nanoscale devices to enable a wide array of in situ and remote sensing capabilities.

- *Distributed & Microspacecraft (GSFC)*
  - Technologies to enable revolutionary science collection capabilities through the coordination of multiple spacecraft, and to enable very small, low-cost spacecraft.

- *Resilient Materials & Structures (LaRC)*
  - Space durable materials, multifunctional and adaptive structures, and large deployable and inflatable structures to reduce spacecraft mass and launch volume, and to improve spacecraft performance and reliability in extreme environments.

- *Space Environments & Effects (MSFC)*
  - Improved models of space environments, analytical tools for predicting the effects of space environments on spacecraft systems, and design guidelines for mitigating these effects.

Final Accomplishments

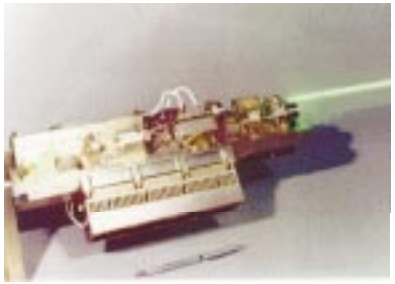
- Demonstrate tunable laser transmitter systems with > 15% efficiency for active sensing
- Develop component technologies for integrated focal plane assemblies to enable at least 5 new measurement capabilities
- Develop microavionics and multifunctional structures to enable a 3x reduction in spacecraft mass and launch volume
- Demonstrate concepts for enabling in-space assembly of 50-meter class structures and apertures from deployable elements.
- Develop space environment models and analytical tools to enable a 15% reduction in spacecraft design margins

ADVANCED SPACECRAFT & SCIENCE COMPONENTS PROJECT

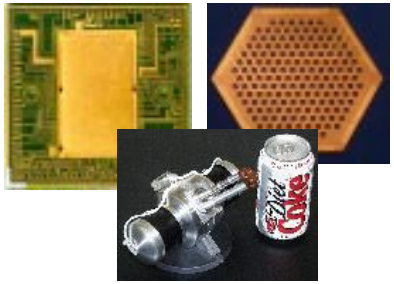
Planned FY02 Accomplishments

- Initiate joint Code R/ Code Y program to reduce risk of future lidar systems for active sensing
- Develop prototype uncooled thermopile detectors for Mars Reconnaissance Orbiter atmospheric sounder
- Develop prototype MEMS micro-shutter array for NGST spectrometer
- Demonstrate operation of monolithic multiplier circuits at 400 GHz for sub-millimeter instruments
- Demonstrate proof-of-concept Helium sorption cryocooler
- Demonstrate deployment of full-scale membrane synthetic aperture radar antenna
- Develop carbon nanotube-doped polymer film to mitigate spacecraft charging
- Characterize structural dynamics of 10 m solar sail model in vacuum
- Demonstrate proof-of-concept dual reflector membrane mirror telescope
- Award Space Environments and Effects NRA contracts for development of improved environment models and predictive tools.

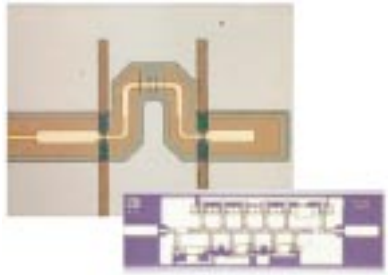
MAJOR TECHNOLOGY PRODUCTS
Advanced Spacecraft & Science Components



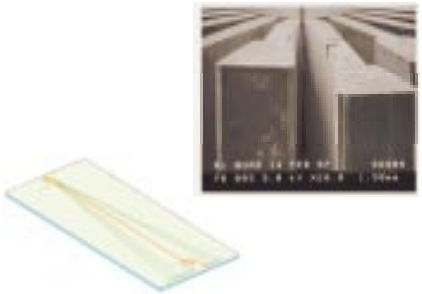
High efficiency, tunable laser transmitters for active sensing



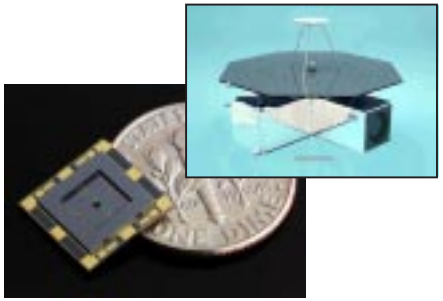
High efficiency detectors (IR, visible, UV, X-ray) and cryocoolers for focal plane assemblies



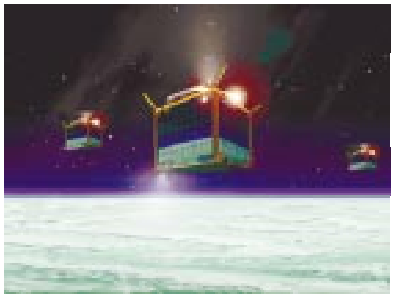
Submillimeter sources, amplifiers, and detectors



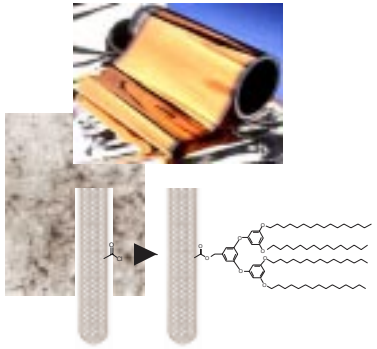
In situ chemical sensors



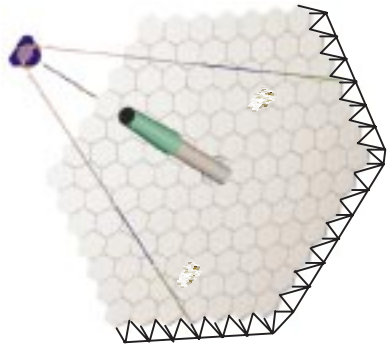
Microavionics and multifunctional structures to reduce spacecraft mass and launch volume



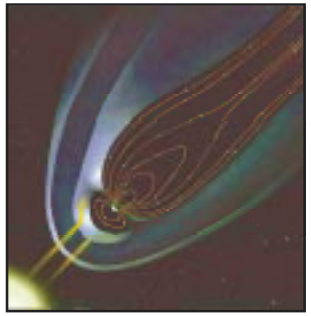
Formation control sensors and algorithms for distributed spacecraft systems



Space-durable materials



Concepts for large ultra-lightweight structures and apertures



Space environment models and analytical tools for predicting environmental effects on spacecraft systems

ADVANCED SPACECRAFT & SCIENCE COMPONENTS
FY03 GPRA METRICS

Advanced Measurement & Detection

- Demonstrate high-efficiency, tunable, narrow-line 2 micron laser transmitter
- Demonstrate a fully conductively cooled laser transmitter
- Characterize 2 micron detector and receiver components
- Perform advanced quantum mechanical modeling and spectroscopy of laser systems
- Demonstrate molecular-level sensors for environmental health monitoring
- Demonstrate photonic/electronic hybrid power devices compatible with flexible substrates
- Demonstrate terahertz amplifiers with gain above 500 gigahertz
- Demonstrate superconducting terahertz receivers
- Demonstrate 20 channel radio frequency single electron transistor multiplexor
- Demonstrate a prototype 256x256 Gallium Nitride Schottky photodiode array
- Demonstrate a prototype 512x512 prototype MicroElectroMechanical Systems (MEMS) microshutter array
- Demonstrate a prototype liquid Helium 4° Kelvin miniature sorption cooler
- Demonstrate a prototype continuous Adiabatic Demagnetization Refrigerator at less than 0.1 degree Kelvin

Distributed & Microspacecraft

- Develop algorithms for attitude determination for spacecraft formations using Global Positioning System (GPS)
- Develop algorithms for attitude control of spacecraft formations using GPS
- Develop relative equations of motion for spacecraft formations at L2 libration point
- Demonstrate integrated micropropulsion subsystem with control electronics
- Demonstrate three-axis inertial measurement unit using microgyros
- Demonstrate alpha voltaic power microgenerator
- Demonstrate integrated microinductors for miniature voltage converter
- Demonstrate sun sensor on chip for microspacecraft navigation
- Demonstrate micro electromechanical system microvalve
- Demonstrate 200 watt-hours per kilogram multifunctional battery / spacecraft structural panel

ADVANCED SPACECRAFT & SCIENCE COMPONENTS
FY03 GPRA METRICS

Resilient Materials & Structures

- Identify viable new concepts for in-space assembly of large space systems
- Demonstrate a prototype membrane waveguide antenna for remote sensing
- Demonstrate the deployment and ultraviolet-rigidization of inflatable boom for solar sails in a laboratory environment
- Demonstrate the deployment of a space boom using shape-memory-composite materials
- Establish proof of concept for a printable electronic circuit on multifunctional membranes

Space Environments & Effects

- Deliver meteoroid environmental model for inner solar system, Venus, and Mars
- Deliver revised NASA / Air Force Spacecraft Charging Analyzer Program (NASCAP-2K, Version 2.0)
- Develop Electronic Properties of Materials Database for use by spacecraft charging models and materials engineers
- Deliver Magneto-tail Charged Particle model for materials degradation studies
- Deliver Low Earth Orbit Spacecraft Charging Guidelines
- Deliver initial state of the art materials knowledge base (SAM-K, Version 1.0)

ADVANCED SPACECRAFT & SCIENCE COMPONENTS PROPOSED FY04 GPRA METRICS

Advanced Measurement & Detection

- Develop compact packaging concept for 2 micron laser transmitter
- Demonstrate proof-of-concept detector array for terahertz imaging
- Demonstrate focal plane array integrated with miniature cryocooler
- Demonstrate flexible transmit/receive modules integrated with membrane SAR antenna
- Develop carbon nanotube arrays for cathode emitters and electrophloresis

Resilient Materials & Structures

- Demonstrate deployment, rigidization, and assembly of inflatable truss elements
- Demonstrate shape and dynamics control of membrane aperture with integral actuators
- Demonstrate proof-of-concept health monitoring system for membrane structures using printable sensors
- Demonstrate deployment of dual reflector membrane mirror telescope

Distributed & Microspacecraft

- Demonstrate laser range sensor for precision formation flying
- Demonstrate precision actuators for relative control of spacecraft in formation
- Develop microspacecraft testbed that incorporates micro navigation subsystem, micro thrusters, and multifunctional structure.

Space Environments & Effects

- Meteoroid / orbital debris database from hypervelocity impact tests and flight data
- Model of low energy charged particle environment
- Integrated software package modeling plumes from electric thrusters

ADVANCED SPACECRAFT & SCIENCE COMPONENTS PROJECT RESOURCES

AT

- **FY03 Resources**

	ARC	DFRC	GRC	LaRC	MSFC	Other Centers	OGA	Univ	Industry
Funding $M				5.100	1.550	13.235			
FTEs				47	4	60			

- **FY04 Resources**

	ARC	DFRC	GRC	LaRC	MSFC	Other Centers	OGA	Univ	Industry
Funding $M				6.100	1.500	13.826			
FTEs				47	4	60			

- **5-Year Budget Runout**

	FY02	FY03	FY04	FY05	FY06	FY07
Funding $M	19.490	19.885	21.426	7.600	0	0

SPACE BASE NRAs
RESOURCES

- **FY03 Resources**

	ARC	DFRC	GRC	LaRC	MSFC	Other Centers	OGA	Univ	Industry
Funding $M	3.700		9.600	6.400	1.100	19.200			
FTEs									

- **FY04 Resources**

	ARC	DFRC	GRC	LaRC	MSFC	Other Centers	OGA	Univ	Industry
Funding $M	1.075		10.144	10.000		18.781			
FTEs									

- **5-Year Budget Runout**

	FY02	FY03	FY04	FY05	FY06	FY07
Funding $M	40.000	40.000	40.000	40.000	40.000	40.000

ENABLING CONCEPTS & TECHNOLOGIES PROGRAM
5 YEAR BUDGET RUNOUT

Project	FY02	FY03	FY04	FY05	FY06	FY07
Enabling Concepts & Technologies Program	92.818	92.905	93.246	93.565	93.789	93.650
Advanced System Concepts	13.000	16.500	17.100	17.600	17.700	17.500
Technology Assessment Analysis		3.500	3.900	4.400	4.400	4.400
Revolutionary Aerospace System Concepts	8.000	8.000	8.000	8.000	8.000	8.000
NASA Institute of Advanced Concepts	5.000	5.000	5.200	5.200	5.300	5.100
Energetics	20.328	16.520	14.720	9.830	5.800	2.000
Advanced Energy Systems	8.000	8.000	8.000	5.000	3.000	1.500
On-Board Propulsion	12.328	8.520	6.720	4.830	2.800	0.500
Revolutionary Spaceflight Research				5.000	10.000	13.900
Advanced Spacecraft & Science Components	19.490	19.885	21.426	7.600		
Advanced Measurement & Detection	12.990	12.335	12.826	2.000		
Distributed & Micro-Sciencecraft		2.000	2.100	1.000		
Resilient Materials & Structures	5.000	4.000	5.000	3.600		
Space Environments & Effects	1.500	1.550	1.500	1.000		
Multi-Technology Integrated Systems				13.535	20.289	20.250
Space Base NRAs	40.000	40.000	40.000	40.000	40.000	40.000

ENABLING CONCEPTS & TECHNOLOGIES PROGRAM ISSUES

- $12M lien for joint Code R/Code Y Laser Risk Reduction Program severely impacts Advanced Measurement and Detection Project if no new funding is provided to ECT:
  - Terminate development of advanced focal planes, cryocoolers, in situ sensors, and microspacecraft components at JPL and GSFC.

- Potential transfer of management responsibility for NASA Institute of Advanced Concepts (NIAC) to Office of Chief Technologist disrupts Advanced System Concepts project.