"Servant Leadership"

How does NASA Serve the Interests of Humankind in Aerospace Exploration and the Role STEM Plays in it?

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Society of Hispanics and Professional Engineers
Region 6
Regional Leadership Development Conference 2013 at the University of Dayton

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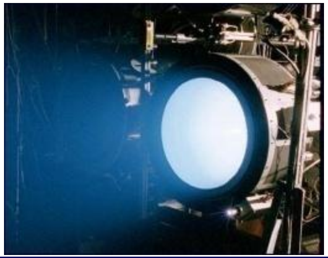
NASA's Vision & Mission

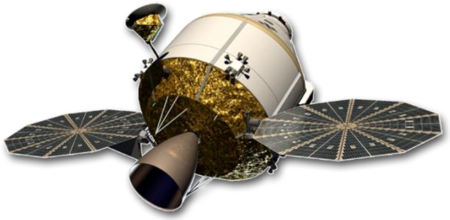
NASA's Vision:

To reach for new heights and reveal the unknown, so that what we do and learn will benefit all humankind

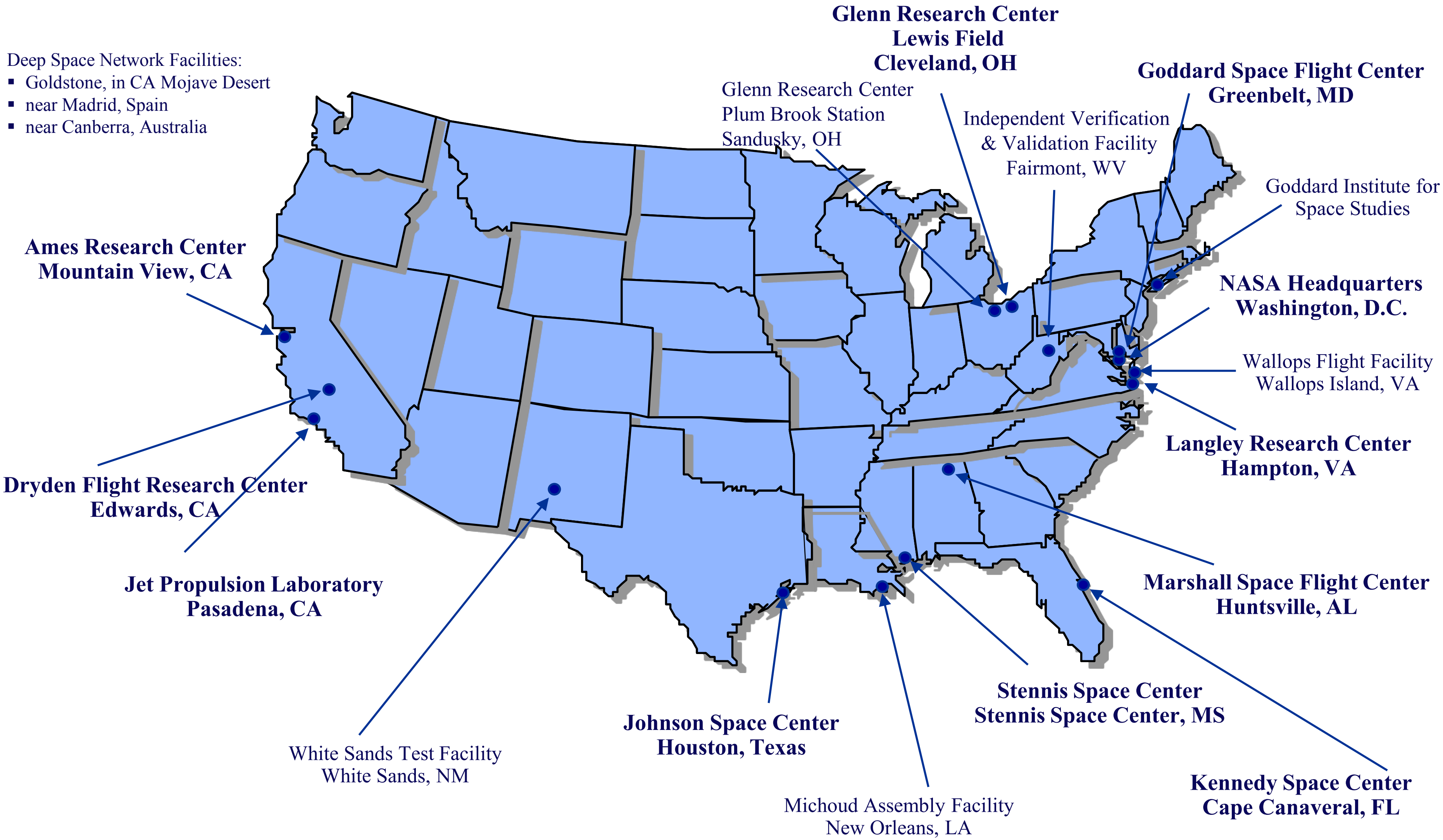
NASA's Mission:

Drive advances in science, technology, and exploration to enhance knowledge, education, innovation, economic vitality, and stewardship of the Earth.





NASA Centers and Installations



A Little About Glenn

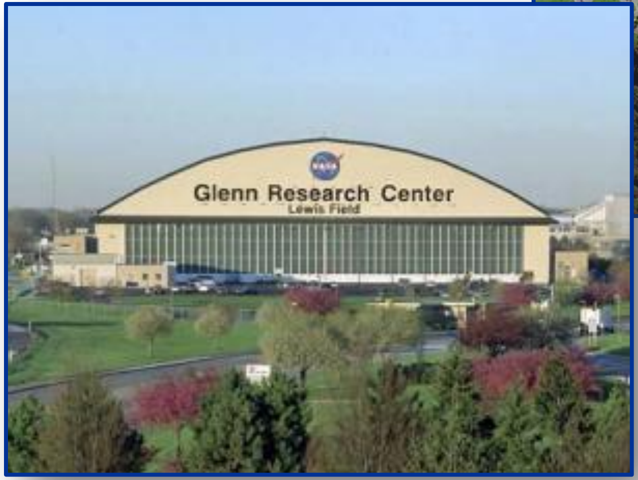
<u>Glenn's Mission</u>: We drive research, technology, and systems to advance aviation, enable exploration of the universe, and improve life on Earth.

- Over the past 70+ years, our scientists and engineers have made major technology contributions that have expanded horizons and opened frontiers for both aviation and space exploration.

- These innovations have enabled U. S. industry to assume a leadership position in the world aerospace marketplace and have contributed to the nation's safety and security.

Lewis Field (Cleveland)

- 350 acres
- 1626 civil servants and 1595 contractors



Plum Brook Station Test Site (Sandusky)

- 6500 acres
- 11 civil servants and 113 contractors

Glenn Research Center Goals

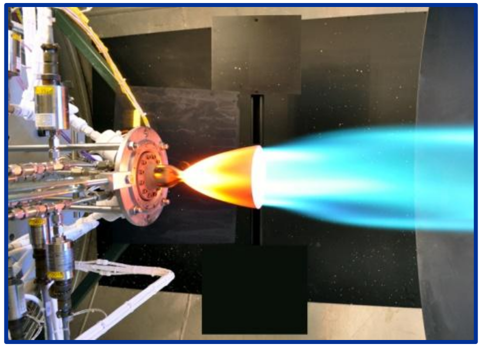
NASA Glenn Strategic Action Plan

- Provide world class R&T, revolutionizing aeronautics and space exploration
- Advance space missions and aeronautics by leveraging our core competencies to deliver concept-through-flight systems
- Deliver program and project management excellence that results in successful missions for our customers and challenging, long-term assignments for continued achievements
- Provide excellent institutional capability to enable NASA mission success
- Be an integral part of the Ohio community and the Nation

Glenn Research Center engineers and scientists work on a variety of exciting projects and programs driving innovation, and tech transfer every day!!

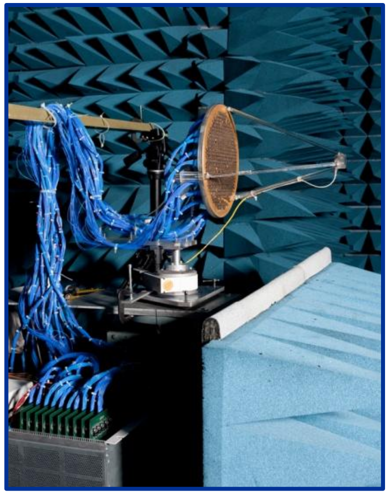
Glenn Core Competencies

Air-Breathing Propulsion



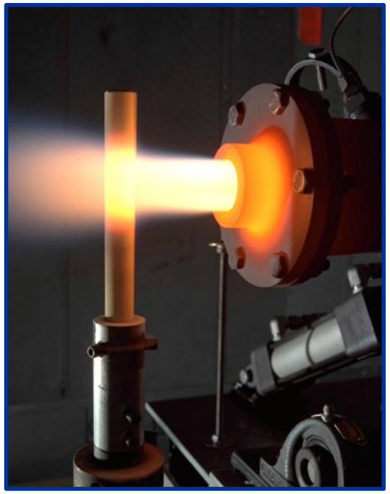
In-Space Propulsion and Cryogenic Fluids Management

Physical Sciences and Biomedical Technologies in Space



Communications Technology and Development

Power, Energy Storage and Conversion



Materials and Structures for Extreme Environments

Examples of Innovations

Space Communications

SCaN Communications Test Bed: These systems will allow researchers to conduct a suite of experiments over the next several years, enabling the advancement of a new generation of space communications.

NASA SCaN Testbed FINAL.mp4

Materials Research

Aerogels: An example of some of the materials and structure research at GRC is in the Aerogels development. Aerogels are the lightest solid materials known to man, and are created by removing moisture from a gel while maintaining the gel structure.

Aeronautics Research

Glenn develops advanced technologies such as ultra-low-emission combustors, chevron nozzles, and aspirated fans to improve the performance of and reduce the emissions and noise from aircraft engines. These accomplishments enabled the development of the GE90 jet engine, the world's most powerful aircraft engine, which powers Boeing's newest intercontinental aircraft, the Boeing 777.

Power and Propulsion

Flywheels: To be used for energy storage and conversion in space and on earth, an extra complexity in spacecraft is the use of momentum wheels to provide attitude control and stability. The addition or removal of energy from one such flywheel applies torque to the corresponding axis of the spacecraft, causing it to react by rotating. Keeping the flywheel rotating at a constant velocity stabilizes that axis of the spacecraft.

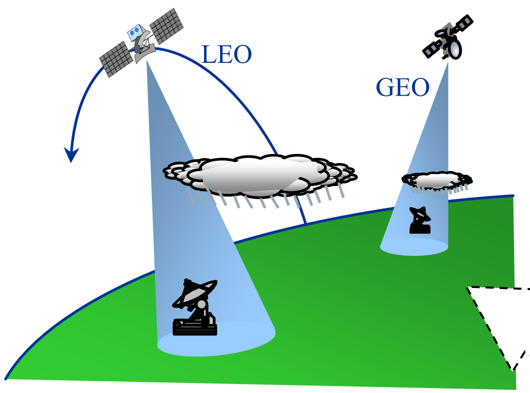
In Space Propulsion: The Service Module ESA Requirements and Formulations Team is also addressing the impact of changes to NASA's exploration architecture including the definition of new MPCV design reference missions (DRMs) and the integration with the Space Launch System (SLS).

Antenna and Optical Systems Branch (RHA)

Overview

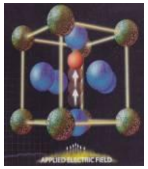
Competencies

- Antenna Systems
- Microwave Systems
- RF (Ka-, V-,W-band) & Optical Propagation
- RF/Optical Communications
- Cryo-Electronics
- Nano-antennas and Nano-electronics



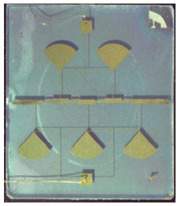
- **Ka-Band Atmospheric Calibration**
- **RF and Optical Propagation Research**

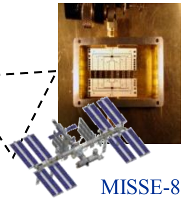
Material → Phase Shifter → Reflectarray



$Ba_xSr_{1-x}TiO_3$ Crystal

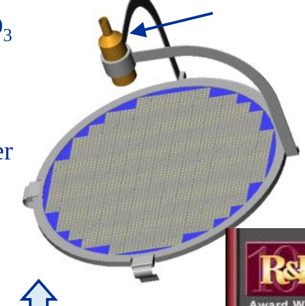
Thin Film Phase Shifter





MISSE-8

Transmit or Receive Feed

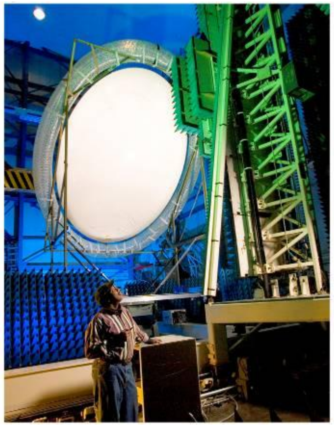


616 Element Reflectarray (12 in. diameter)

(2010 R&D100 Award Winner)

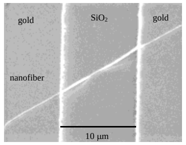
Advanced Phased Arrays

Products



Large Aperture Inflatable/Deployable Antennas

- **Polymer Membranes**
- **Shape Memory Alloys**
- **Mesh Antennas**

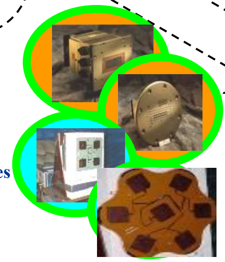


nanoFETS

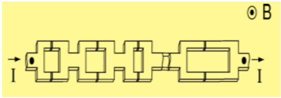
(2010 R&D100 Award Winner)

Phased Arrays

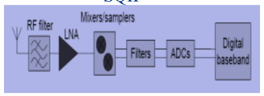
- **Bit Error Compensation Techniques**
- **Alternative Sub-Systems Designs**
- **Optimal Modulation Schemes**



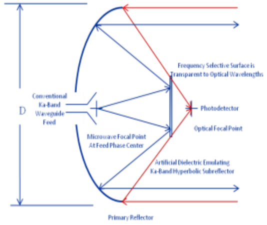
Game Changing Technologies



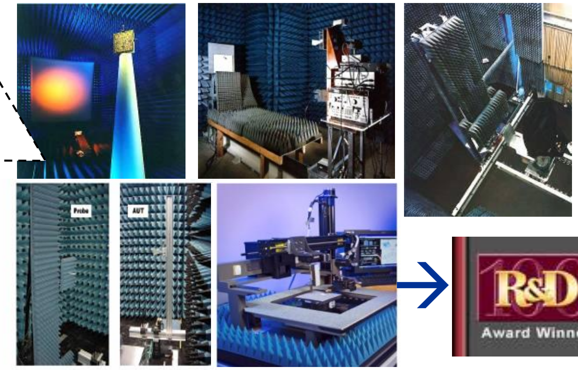
SQIF



Tunable Receivers



RF/Optical Shared Aperture Antennas



Antenna Characterization Facilities

- **Compact Range**
- **Near Field Range**
- **Far Field Range**
- **Cylindrical Near Field Range**
- **Near Field Probe Station Scanner***

***(2007 R&D100 Award Winner)**

Ferroelectric Reflectarray Antenna– The Road From Idea to Deployment

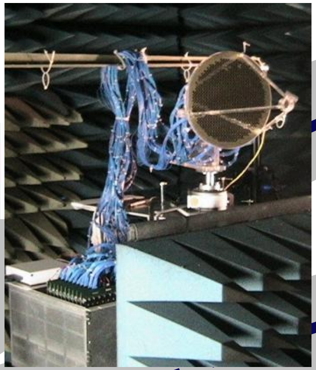
MISSE-8 Space Exp.; STS-134 May 16, 2011

Modified 615 Element Scanning Ferroelectric Reflectarray: 2005-2009

Prototype antenna with practical low-power controller assembled and installed in NASA GRC far-field range for testing. Low-cost, high-efficiency alternative to conventional phased arrays

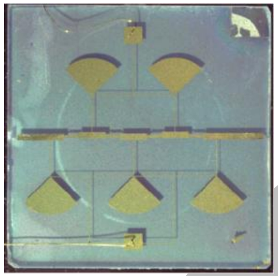
R&D 100 Award Winner

2010



Cellular Reflectarray: 2010

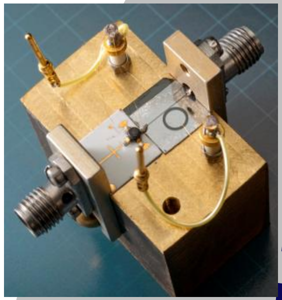
Derivative attracts attention for commercial next generation DirecTV, etc. applications



Thin film ferroelectric phase shifter on Magnesium Oxide

Practical Phase Shifters : 2003-2004

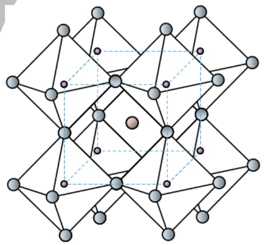
Novel phased array concept based on quasi-optical feed and low-loss ferroelectric phase shifters refined. 50 wafers of $Ba_{0.5}Sr_{0.5}TiO_3$ on lanthanum aluminate processed to yield over 1000 ferroelectric K-band phase shifters. Radiation tests show devices inherently rad hard in addition to other advantages over GaAs



First Ku-Band tunable Oscillator based on thin ferroelectric films

Fundamental Research: 2000-2003

Agile microwave circuits are developed [using room temperature Barium Strontium Titanate ($Ba_{0.5}Sr_{0.5}TiO_3$)], including oscillators, filters, antenna elements, etc., that rival or even outperform their semiconductor counterparts at frequencies up to Ka-band

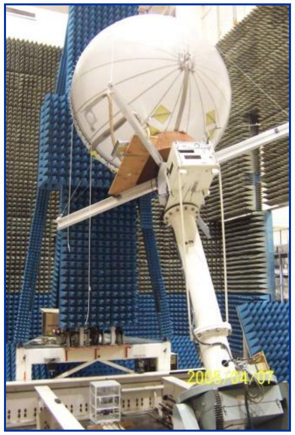


Parent crystal: Strontium Titanate

Seedling Idea: 1995-1999

Basic experiments with strontium titanate at cryogenic temperatures suggest loss tangent of ferroelectric films may be manageable for microwave applications

Beach Ball Antenna – The Road From Idea to Deployment



Prototype Inflatable Radome Antenna System at GRC

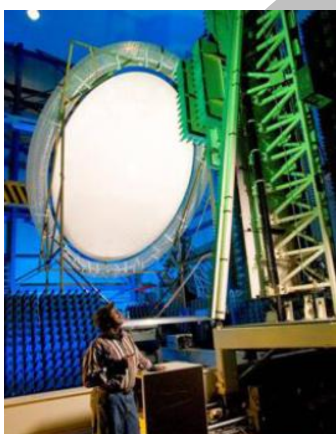
In The Field: 2009-2010

Popular Science's – Invention of the Year 2007, listed as one of the "Inc. 500: The Hottest Products" of 2009. GATR continues to field units which enable high-bandwidth Internet, phone and data access for deployments and projects in Afghanistan, South Africa, South America, Haiti, Korea, as well as assisting hurricane disaster recovery here on our own soil.

2011 2011 2010

First Practical System: 2008

Through the help of NASA Glenn, the SCAN project, a reimbursable Space Act Agreement, material refinements through Air Force Research Laboratory (AFRL) and the Space and Missile Defense Command (SMDC), GATR Technologies markets World's first FCC certified inflatable antenna



4m x 6m parabolic membrane reflector derived from solar concentrator in GRC near-field

Fundamental Research: 2004-2007

Designed and fabricated a 4x6m off-axis inflatable thin film antenna with a rigidized support torus. Characterized the antenna in the NASA GRC Near Field Range at X-band and Ka-band. Antenna exhibited excellent performance at X-band. Ka-band surface errors are understood.

0.3 meter prototype Membrane reflector

Seedling Idea: 2004

Circa 2004 need for large aperture deployable antenna identified for JIMO and Mars Areostationary relay platform. Antenna technology adapted from 1998 Phase II SBIR solar concentrator project.

Beach Ball Antenna – The Road From Idea to Deployment

Inflatable Radome Antenna System

❖ 2010 R&D100 Award for the GATR Inflatable Satellite Communication System

❖ Federal Laboratory Consortium 2011 Award Winner for Excellence in Technology Transfer

❖ 2011 Finalist NorTech Innovation Award

❖ 2013 Space Technology Hall of Fame

- Developed by **GATR Technologies Inc.**, Huntsville, Ala., and further tested and refined through a partnership with **NASA's Glenn Research Center**, The GATR Inflatable Satellite Communication System is the first FCC-certified inflatable antenna for ground-based applications.

- The GATR Antenna System (or GATR) is a deployable inflatable satellite communication terminal serving the military, public safety and broadcast sectors. GATR's unique inflatable design enables deployment of 1.8 and 2.4 meter terminals in as few as two airline checkable cases (weighing less than 100 lbs. each), simplifying transportation and set-up, and making it ideal for first-in deployments, remote applications and contingency scenarios.

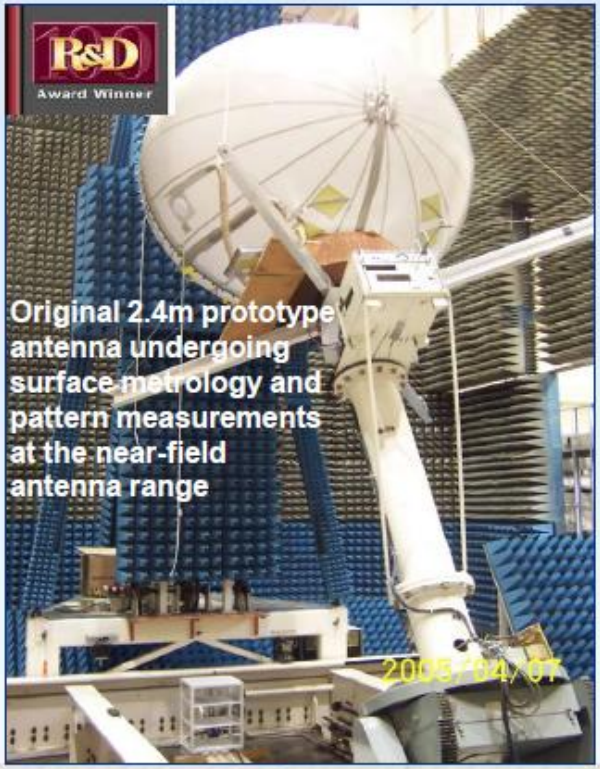
- Users are able to quickly establish a satellite link and transmit and receive secure and non-secure data, voice, and video. The patented design combines the transmission power advantages of a large aperture / high-bandwidth antenna with the low weight and portability of a much smaller antenna.

GATR Antenna System

(l-r): Robert R. Romanofsky, NASA Glenn Research Center and Kevin M. Lambert, QinetiQ North America

Paul Gierow, GATR Technologies Inc.

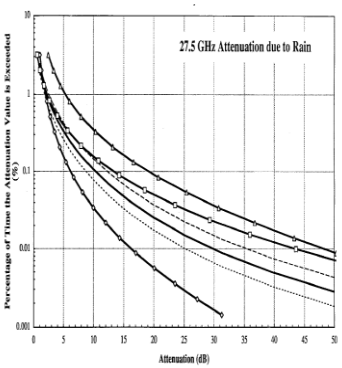
Inflatable Radome Antenna System



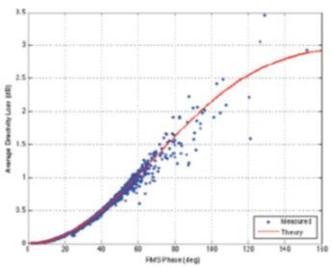
RF Propagation – The Road From Idea to Deployment

mm-wave Propagation Studies: 2012-Future

GRC undertakes expansion of mm-wave frontier via propagation activities in the Q/V/W bands



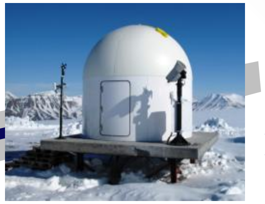
ACTS Propagation Data instrumental in development of ITU-R attenuation models



Phase measurements implemented in array loss predictions

Q-band Radiometer

Uplink Array/ Rain Fade Compensation



Svalbard (NEN)

Guam (SN)

White Sands, NM (SN)

Goldstone, CA (DSN)

Evolution of GRC Propagation Terminals

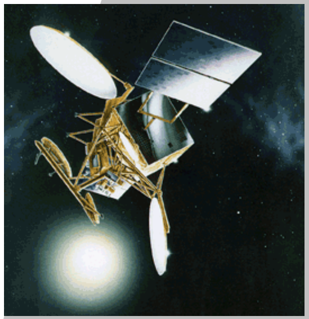
Real-Time Compensation: 2012-2016

SCaN funded effort to integrate real-time compensation techniques into NASA network operations

ACTS Propagation Terminal

Atmospheric Phase Studies: 2004 – Present

Characterization of atmospheric phase noise is studied to identify suitable sites for Uplink Arraying Solution to large aperture 70-m class antenna issues with Deep Space Network. GRC, in collaboration with JPL and GSFC, leads the characterization of atmospheric-induced phase fluctuations for future ground-based arraying architecture



ACTS Satellite

Atmospheric Attenuation Studies: 1993 – 2002

Propagation studies were undertaken by NASA to determine the effects of atmospheric components (e.g., gaseous absorption, clouds, rain, etc.) on the performance of space communication links operating in the Ka-band. Sites throughout the Continental US and Puerto Rico were characterized.

How can this innovations and effort makes a difference?

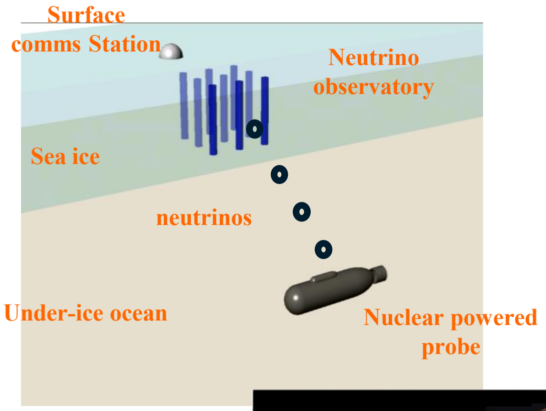
Communication and Navigation Signaling using Neutrino Particles

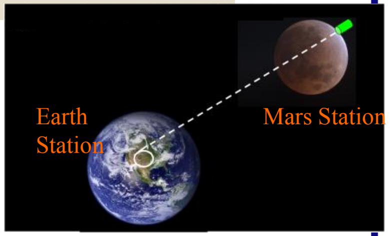
Obed Sands, James Downey (NASA GRC)—Kevin McFarland (University of Rochester) – Deborah Harris (Fermi National Accelerator Laboratory) – Dan Stancil, Brian Hughes (North Carolina State University)

Neutrinos move at speeds near the speed of light, are low-mass and have no electric charge.

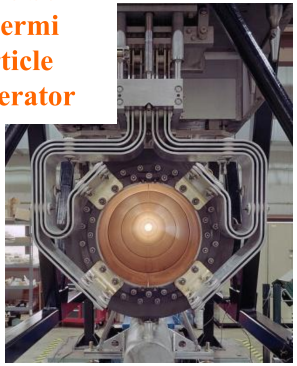
Neutrino beams pass through normal matter nearly unchanged

- •Neutrino beams could enables communication, time dissemination and ranging with buried or submerged spacecrafts on distant planets
- •Neutrino beams could eliminate the need for communications relay spacecraft
- •Demonstrated communication with neutrino beam using Fermi particle accelerator
- •Repeatedly transmitted message “NEUTRINO” from Fermi accelerator using a neutrino beam through Neutrino at Main Inject (NuMI) horn to Main Injector ExpeRiment for v-A (MINERvA) detector.
- • Neutrino beam passed through 240m of dolomite rock

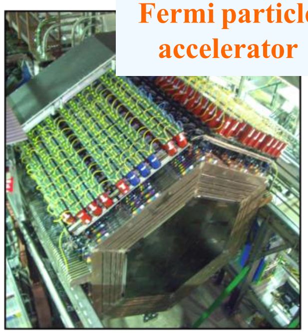




Horn that provides neutrino beam at Fermi particle accelerator



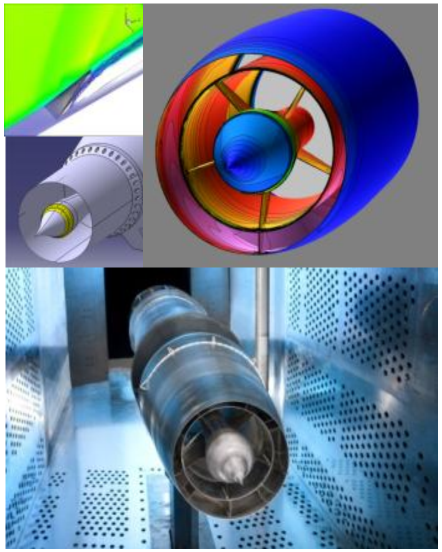
MINERvA detector at Fermi particle accelerator



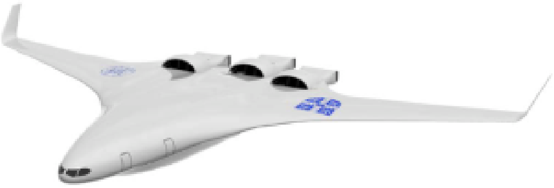
Neutrino communications named as one of top 10 physics breakthroughs for 2012

Aeronautics Research

Fundamental Aeronautics

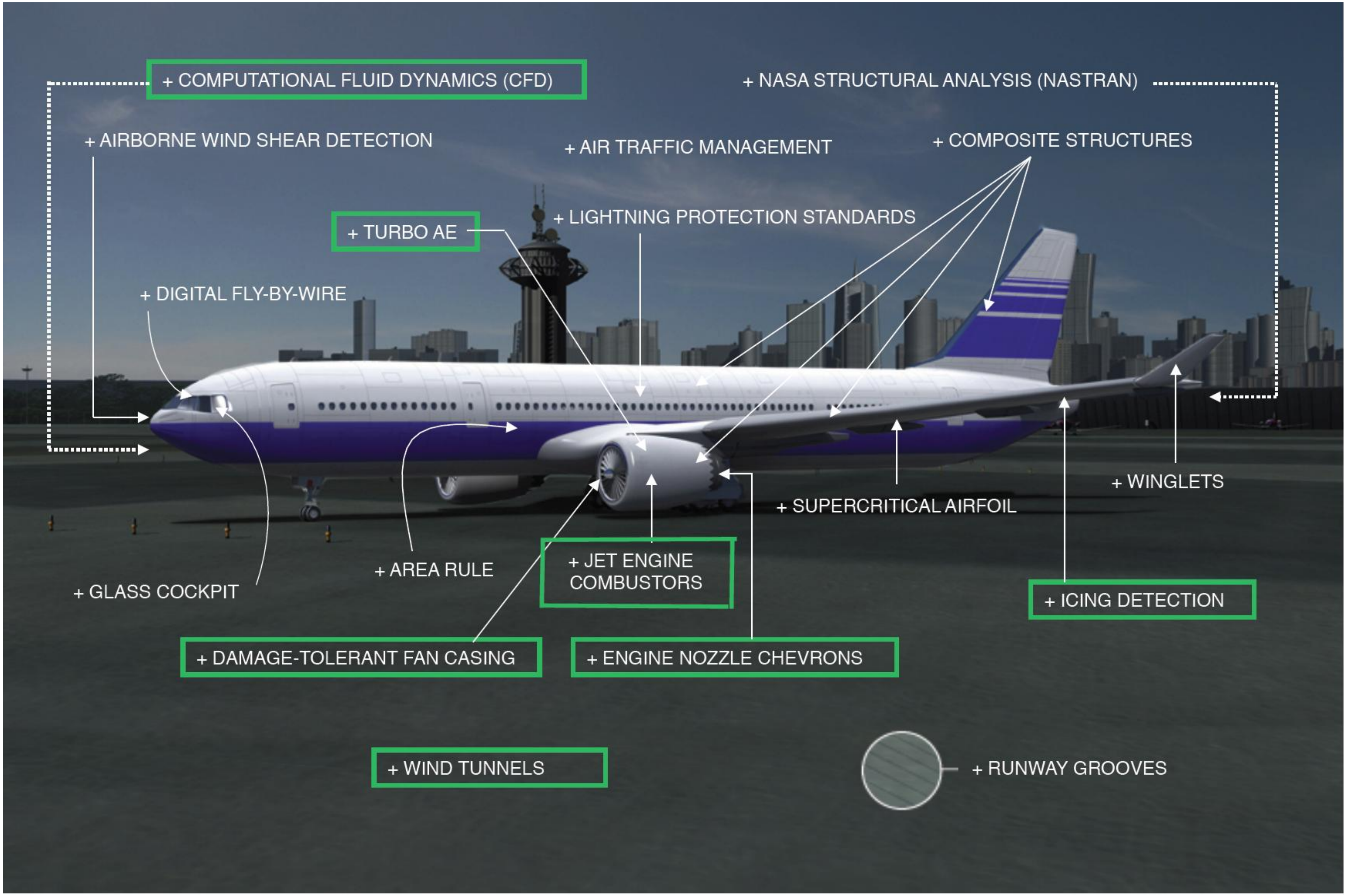


Integrated Systems Research



Aeronautics Test Program

Aeronautics Contributions

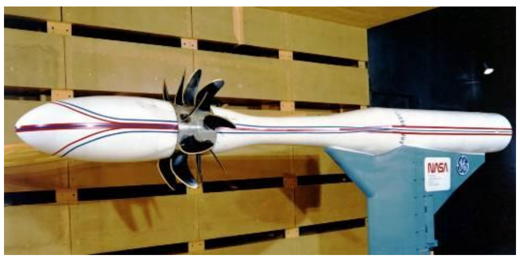


Examples of Innovations

Reducing the Environmental Impact of Aviation

Advance Airframes

Open Rotor Propulsor



Geared Turbofan

Enabling technologies

- Novel architectures for increased lift over drag
- Lightweight structures
- Laminar flow to reduce drag
- Low NOx fuel flexible combustors
- Open rotors
- Ultra-high bypass turbofans
- Hybrid-Electric Propulsion
- Novel architectures for shielding airframe noise
- Distributed Propulsion

Environment Benefit/Goals

- **Fuel burn savings:**
  70% fuel burn reduction (ref B737/CFM56)
- **Emissions reduction:**
  75% less NOX (ref CAEP 6)
- **Noise reduction:**
  1/10 the nuisance noise around airports

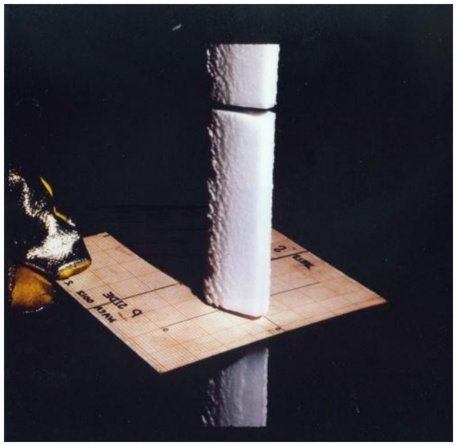
Maintaining or Increasing Aviation Safety

Provides fundamental research of already existing safety challenges and on new and emerging challenges created by the transition to NextGen -- significant increases in air traffic, introduction of new vehicle concepts, continued operation of legacy vehicles, increased reliance on automation, and increased operating complexity.

Airframe Icing Research at Icing Research Tunnel

Rime Ice

(occurs at temperatures below -10°F; white and opaque; liquid drops freeze on impact)

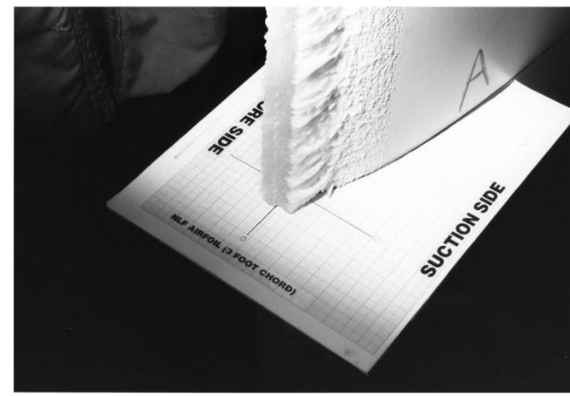


Glaze Ice

(occurs at temperatures near 32°F and high liquid water contents; clear everywhere; liquid drops do not freeze on impact)

Mixed Ice

(ice accretion exhibits glaze ice around stagnation line and rime ice away from it; clear near the stagnation line, white and opaque away from it)



Icing Research Tunnel Research

- Fundamental studies of icing physics to improve computational models
  - Safer aircraft designs
  - Basis for aircraft certification
- Used to reduce flight hours for ice detection instrumentation and ice protection systems development and certification

Scalloped Ice

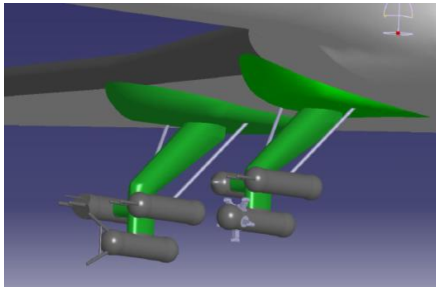
(3-D and complex ice accretion shape exhibited with highly swept wing configurations)

Aviation Safety- Engine Icing

Program

A growing aviation safety issue is flight near certain types of storm clouds that can cause ice to build up inside the core of jet engines and cause temporary shutdowns. NASA has established a project that will develop knowledge, tools and approaches that will enable the reduction of turbofan engine interruptions, failures, and damage due to flight in these high ice-crystal content storm clouds.

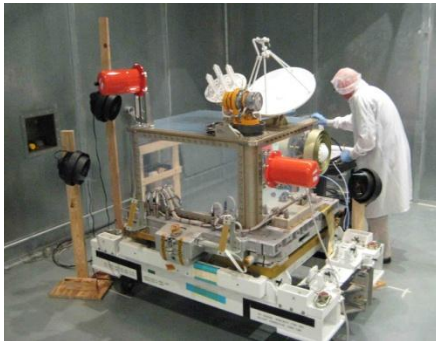
Artist rendition of the engine icing accumulation and shedding.



Proposed aircraft instrumentation configuration for weather data gathering of icing environment at high altitudes.

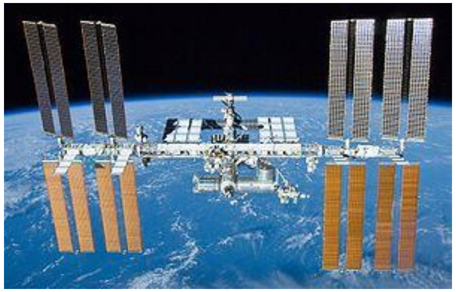
NASA GRC Propulsion System Laboratory to be modified to run engine icing conditions.

Glenn Current Flight Projects



SCaN Testbed

Validating key technologies in communications, networking and navigation with reconfigurable Software Defined Radios



International Space Station (ISS)

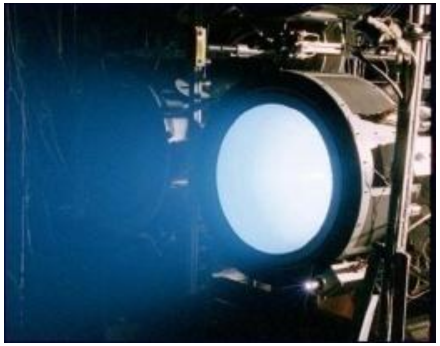
Microgravity Space Experiments: fluid physics, combustion science, and materials experiments

Sustaining engineering for the ISS Electrical Power System

Radioisotope Power Systems (RPS)

Agency Level Program Office assigned to GRC

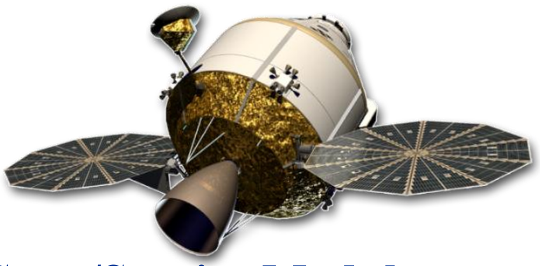
Advanced Stirling Radioisotope Generator (ASRG) flight system development



In-Space Propulsion

Solar Electric Propulsion

Cryogenic Propellant Storage and Transfer



Crew/Service Module

Co-lead with JSC the management of the design, development, verification and certification Crew & Service Module for the Orion Multi-Purpose Crew Vehicle

Launch Systems

Support MSFC Space Launch System

Lead payload shroud element

Space Environmental Test Project

Delivering One-of-a-kind environmental testing capability at ONE location: The Space Power Facility

The World's Largest Environmental Simulation Chamber Contains:

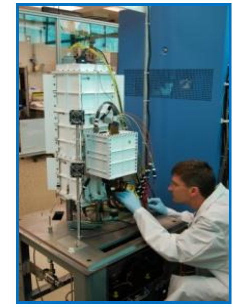
- **Reverberant Acoustic Test Facility (RATF): the most powerful reverberant acoustic chamber in the world**
  - ✓ Capable of reaching an overall sound pressure level of 163 dB
  - ✓ Can accommodate 32' wide by 60' high test article
- **Largest space simulation vacuum chamber in the world**
  - ✓ 800,000 ft3 volume, 100 foot diameter, 122 feet high
  - ✓ Features 40 x 40 ft. cryogenic cold wall, and 7 MW power for solar simulation
  - ✓ Electromagnetic Environmental Effects (E3) Reverberant-mode EMI/EMC test capability
- **Highest capacity Mechanical Vibration Facility (MVF) in the world**
  - ✓ 18' diameter test table, expandable to 32'
  - ✓ Test article mass up to 75,000 lbs
  - ✓ Actuators will be used to perform vibration testing in 3 axes expandable to 6DOF

Science

Radioisotope Power Systems (RPS) Program

Advanced Stirling Converter

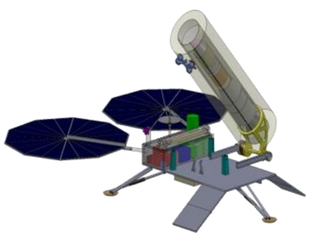
GRC is leading the RPS Program to develop advanced, higher efficiency power systems for NASA missions and spacecraft



Advanced Stirling Radioisotope Generator (ASRG)

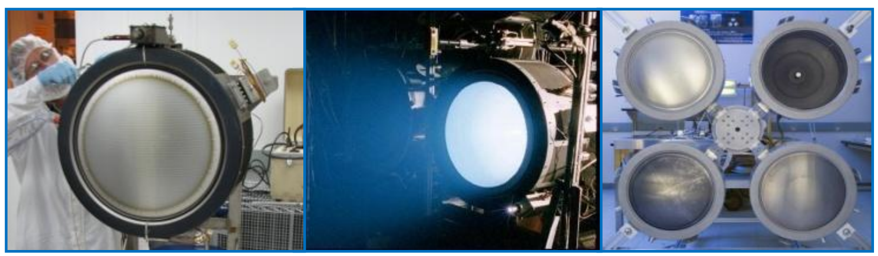
Engineering Unit has accumulated over 14,000 hours of operation

In-Space Propulsion Project (ISP)



GRC is running a competitive study on the development of the Mars Ascent Vehicle for the future Mars Sample Return mission

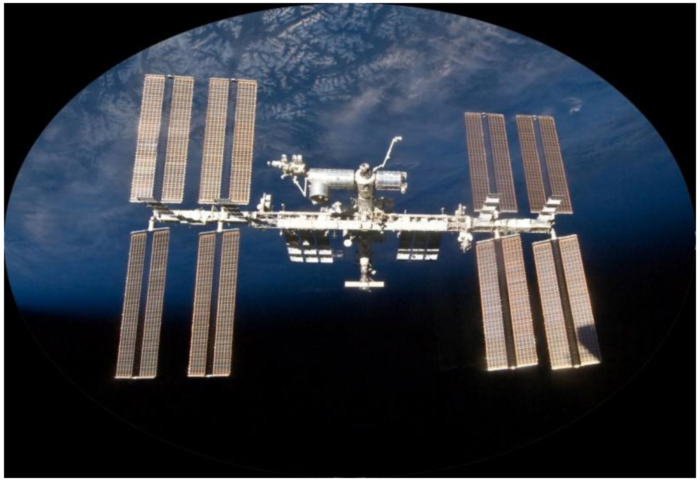
NASA Evolutionary Xenon Thruster (NEXT)



Prototype Model NEXT ion thruster in Performance Acceptance Testing. This test not only verified thruster performance per requirements but also verified manufacturing processes by industry partner Aerojet

Multiple NEXT ion thruster testing demonstrated system level operations with negligible interactions

Fluids and Combustion Facility (FCF)



Combustion Integrated Rack (CIR)
Deployed to ISS on November 14, 2008

Fluids Integrated Rack (FIR)
Deployed to ISS on August 28, 2009

- CIR rack is used to conduct fundamental microgravity research in combustion science
- FIR rack is used to conduct fundamental microgravity research in fluid physics
- These racks are 2 of the 4 science racks in the U.S. Lab of the International Space Station

GRC Exercise Countermeasures Project

Glenn Exercise Countermeasures Lab

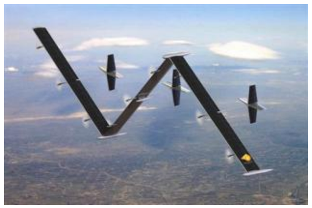
Glenn Harness on International Space Station

- **Glenn's Exercise Countermeasures Lab is used to develop effective and reliable low-gravity exercise hardware requirements and validate candidate technologies for long duration crew health**
  - **In collaboration with the Cleveland Clinic**
- **A new, more comfortable, exercise harness has been designed by the Glenn-led team for use on the International Space Station**
  - **More comfortable harnessing allows crew members to exercise at higher loading resulting in improved health benefits during treadmill running**

Strategic Partnership Development: Reimbursable Business Pursuit

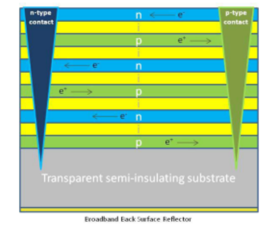
- NASA Glenn (GRC) is actively pursuing the development of strategic partnerships with industry, academia, and other government agencies/laboratories.
- A prime objective of the strategic partnership building is to provide basis for GRC to aggressively pursue/capture non-NASA business opportunities which utilize Center's competencies (people, facilities, intellectual property) and compliment NASA business which Center executes.
- Areas of emphasis for non NASA business pursuit:
  - Advanced Energy
  - Aerospace Medicine (Bioscience/Bioengineering)
  - Homeland Security/Defense
  - Non NASA Space Non NASA Aviation

Strategic Partnership Development: Reimbursable Business Pursuit -- Examples



DARPA Vulture Program
(5 year endurance UAV)

Testing for DARPA of innovative power systems to enable highly mobile and responsive spacecraft



Flywheel module designs for terrestrial applications

Open rotor testing in GRC 9 x 15 Low Speed Wind Tunnel (General Electric Aviation)

AFRL VAATE Turbine Engine Program

NASA Glenn Visitor Center Relocated to the Great Lakes Science Center

We're now where the people are!

- 330,000 visitors / yr (5X previous, onsite location)
- 950 school groups / yr (4X previous)
- 75,000 students / yr (7X previous)

Some Final Thoughts on Innovation and Leadership

- Try to break patterns to get to new ideas
- Adopt a "revolutionary, game changing" mind set
- Don't be afraid to fail

"How do you spur innovation in government? Be willing to fail. How do your make government willing to fail? Make failure cheap."

Maura O'Neil, The U.S. Agency for International Development's chief innovation officer

Government Executive Magazine, October 2012

It has been a pleasure to be here…

thank you for inviting me…

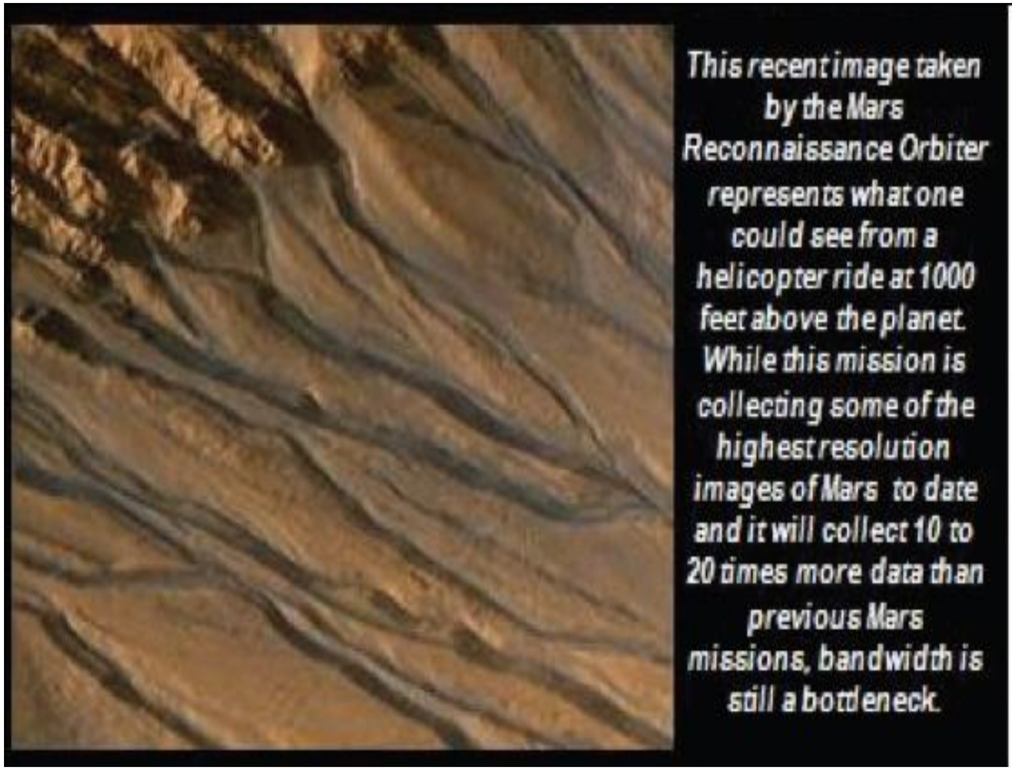
and now let's talk…

Back up Slides

Communications – Lifeline to Missions[1]

- Deep Space Missions are constrained by limited data rates.

- For example, the full potential of MRO cannot be realized with the constraint of 6 Mbps data rate, with the following Implications:
    - 7.5 hrs to empty onboard recorder
    - 1.5 hrs to transfer a single High Resolution Image



Advanced Microwave or Optical Communication data links at 100Mbps will be able to empty the recorder in 26 min and transfer a High Resolution image every 5 mins!!

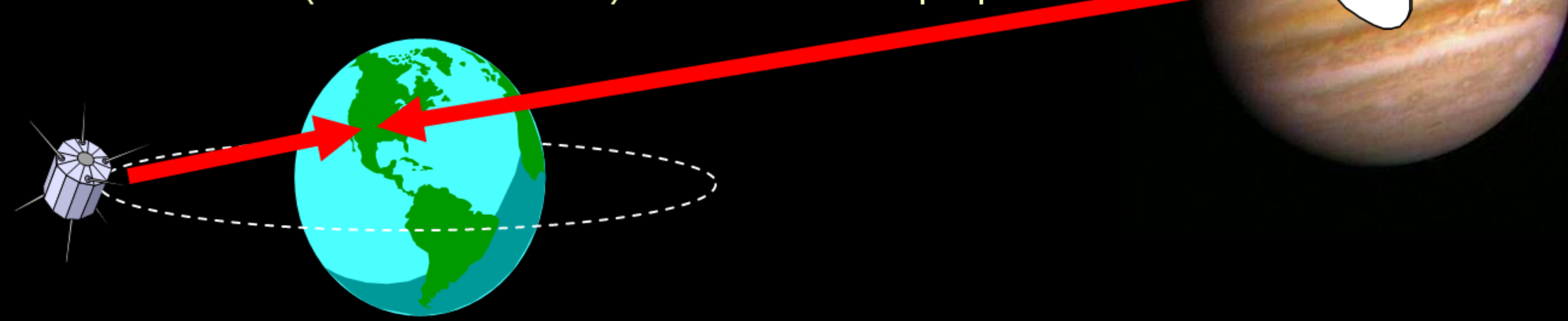
[1]NASA OCT Communications and Navigation System Technology Area Strategic Roadmap

Why are Deep Space Communications Difficult?

Communications performance decreases as the square of the distance.

Jupiter is nearly 1 *billion* km away, while a GEO Earth communications satellite is only about 40 *thousand* km away

– It's about 87 dB (~1/2 billion times) harder from deep space!



A person with a loud voice and good hearing, standing in front of NASA headquarters in Washington, can talk with a friend a block away.

Deep space communications would be like trying to talk with the same friend in Boston!

Relative Difficulty

Place	Distance	Difficulty
Geo	4×10^4 km	Baseline
Moon	4×10^5 km	100
Mars	3×10^8 km	5.6×10^7
Jupiter	8×10^8 km	4.0×10^8
Pluto	5×10^9 km	1.6×10^{10}