COMMUNICATIONS & INTELLIGENT SYSTEMS DIVISION

NASA GLENN RESEARCH CENTER

Division Overview

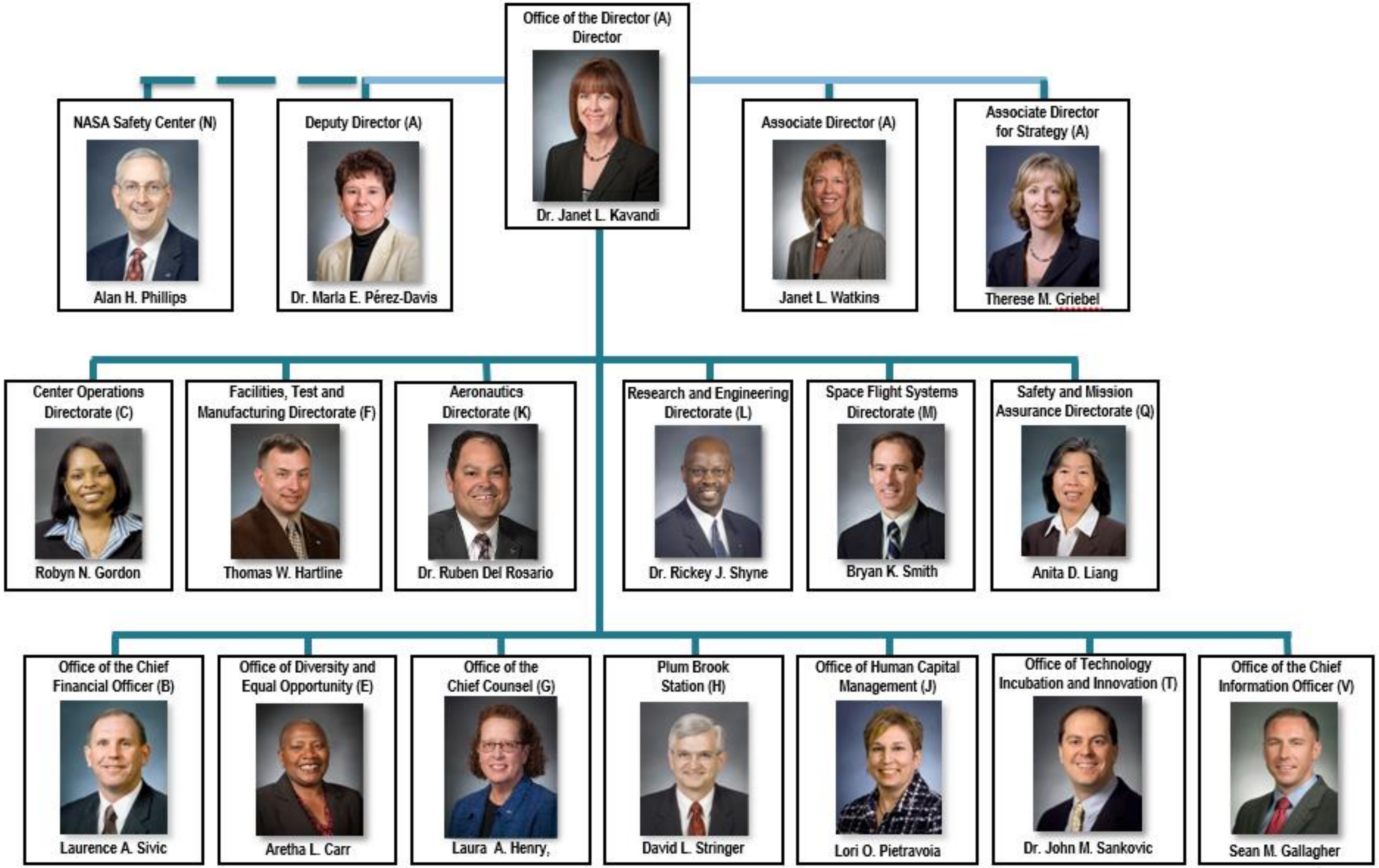
Dawn Emerson

February 14-15, 2017

Presentation to

Kirtland AFRL Space Vehicles Directorate

Glenn Senior Management



Research and Engineering Directorate Leadership Team

Deputy Director of Research and Engineering (L)

Dr. Ajay K. Misra

Director of Research and Engineering (L)

Dr. Rickey J. Shyne

Associate Director of Research and Engineering (L)

Maria Babula

Chief Engineer Office (LA)

Richard T. Manella

Management Support and Integration Office (LB)

Susan Kolibas

Communications and Intelligent Systems Division (LC)

Dawn C. Emerson

Power Division (LE)

Randall B. Furnas

Materials and Structures Division (LM)

James J. Zakrajsek, Acting

Systems Engineering and Architecture Division (LS)

Derrick J. Cheston

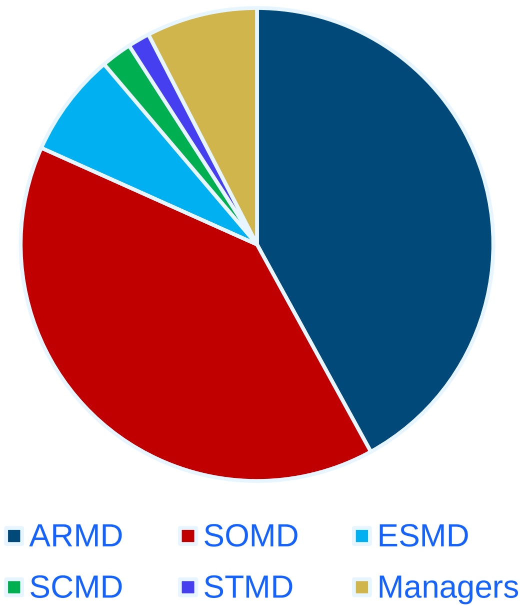
Propulsion Division (LT)

Dr. George R. Schmidt

Communications and Intelligent Systems Division (LC)

Provides expertise, plans, conducts and directs research and engineering in the competency fields of advanced communications and intelligent systems with emphasis on advanced technologies, architecture definition and system development for application in current and future aeronautics and space systems.

LC Support to Mission Directorates



LC Competency Elements:

Space Communications (SpaceComm) & Aeronautical Communications (AeroComm)

Expertise:

- Networks & Architectures
- Information & Signal Processing
- Advanced High Frequency
- Optical Communications

Intelligent Systems – Cross-Cutting Competencies

Expertise:

- Optics and Photonics
- Smart Sensor Systems
- Instrumentation- Electronic
- Controls- Dynamic System Modeling and Controls

Communications and Intelligent Systems Division (LC)

115 FTE
58 WYE

Communications and Intelligent Systems Division (LC)
Chief: Dawn C. Emerson
Deputy Chief: Dr. Félix A. Miranda

Communications ST: Dr. Robert R. Romanofsky

Architectures, Networks and Systems Integration Branch
LCA/Denise Ponchak

Intelligent Control and Autonomy Branch
LCC/Dr. Sanjay Garg

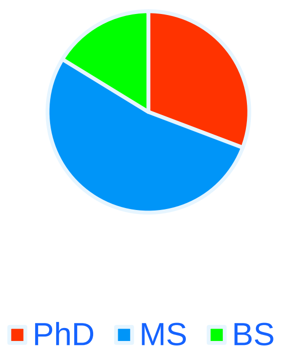
Advanced High Frequency Branch
LCF/Dave Buchanan

Information and Signal Processing Branch
LCI/Gene Fujikawa

Optics and Photonics Branch
LCP/Dr. George Baaklini

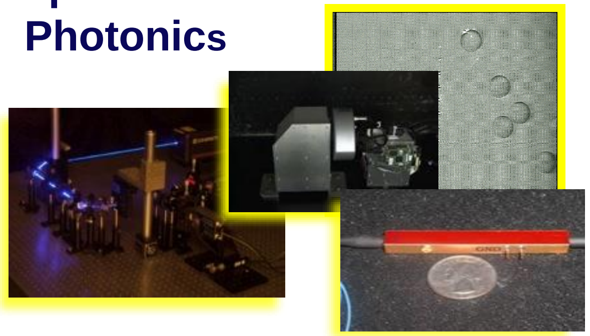
Smart Sensors and Electronics Systems Branch
LCS/Dr. Larry Matus

Education



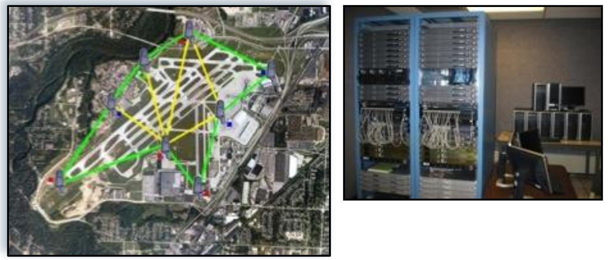
Communications and Intelligent Systems Division (LC)

Optics and Photonics



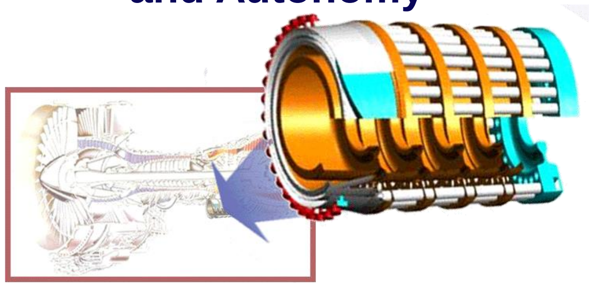
Optical Instrumentation
Optical Communications
Health Monitoring

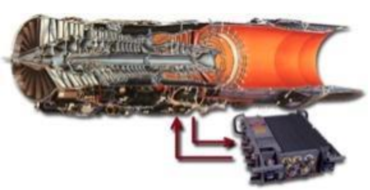
Architectures, Networks and Systems Integration



Communications Architectures
Modeling and Simulation/Tech Demos
Spectrum and Link Analysis

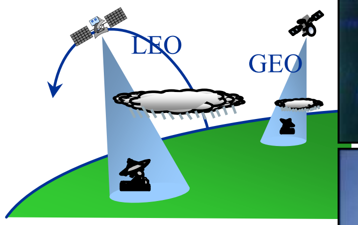
Intelligent Control and Autonomy





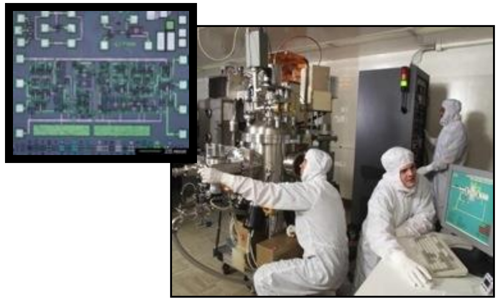
Intelligent Controls
Dynamic Modeling
Health Management

Advanced High Frequency



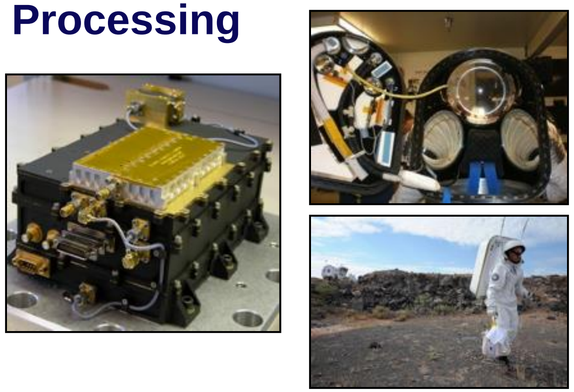
Antennas/Propagation
RF Systems and Components
3-D Electromagnetic Modeling

Smart Sensors and Electronics Systems

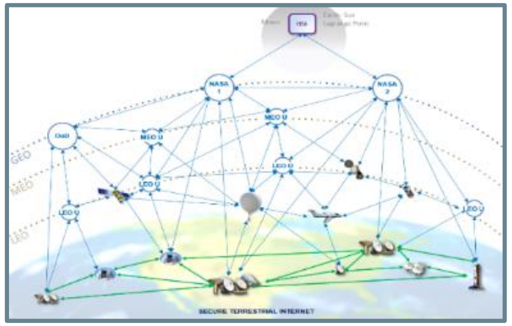


Thin Film Physical Sensors
High Temp/Harsh Environment Focus
Wireless Technologies

Information and Signal Processing

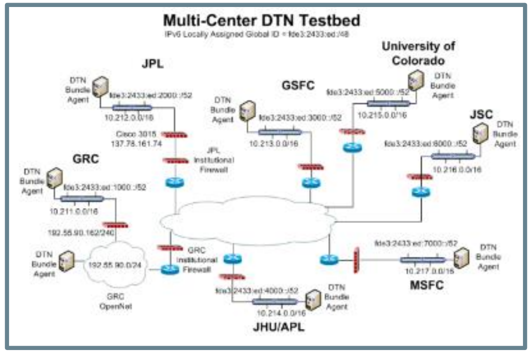


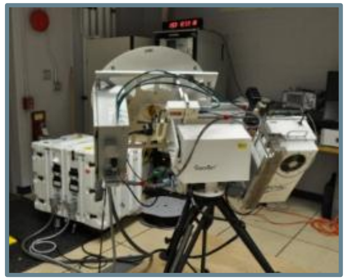
Radio Systems – SDRs, Cognitive
Bandwidth and Power-Efficiency
Waveform Development

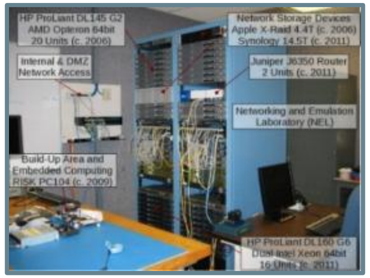


Communications Systems

- Systems engineering of future SCaN Integrated Network Architecture.
- Requirements decomposition, systems definition, development, hardware and software build up, test and delivery of Space Network compatibility test unit including TDRS signal simulator.

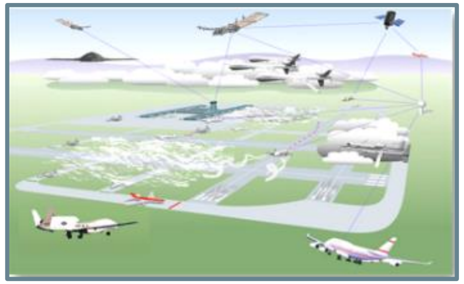






Aeronautical Communications

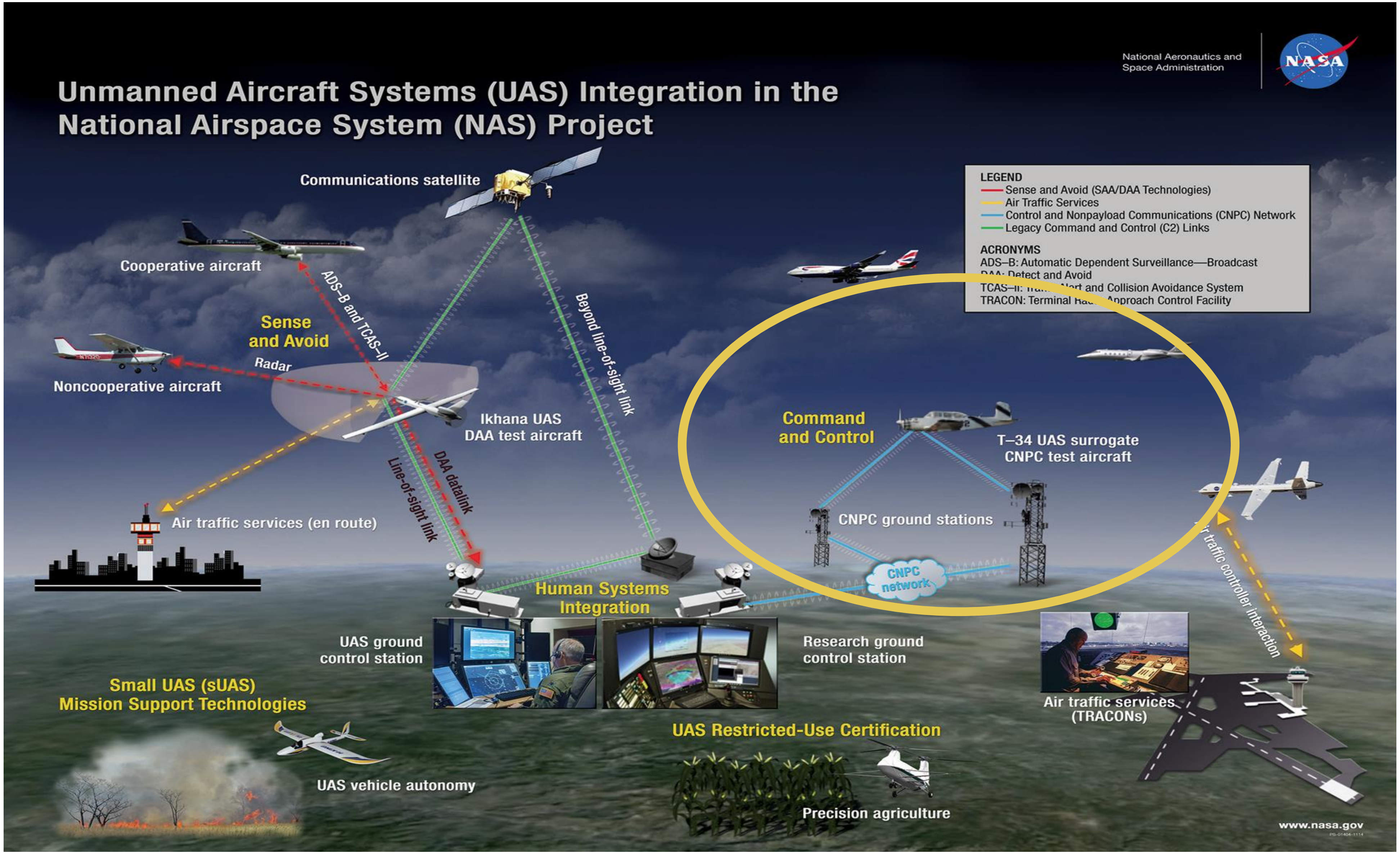
- Includes air-to-air, air-to-ground, and ground-based mobile wireless communications, information networking, navigation and surveillance research, technology development, testing and demonstration, advanced concepts and architectures development, and national and international technology standards development.



Network Research

- Development of network components, design of network layers and networked systems architectures. Emphasis is on secure wireless mobility, protocol characterization and development, requirements definition, and flight software/hardware component assessment. Also includes "virtual" mission operations.

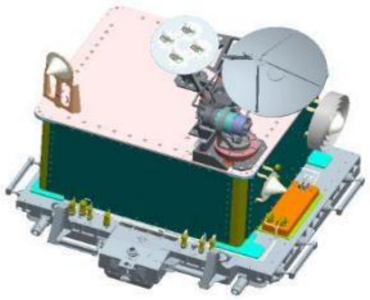
UAS in the NAS



Information and Signal Processing Branch (LCI)

LCI Overview

Conducts research and technology development of information and signal processing methods and approaches of digital communications systems for aerospace applications. Emphasis on software-defined and cognitive radios; open SDR architectures and waveform development; position, navigation and timing methods; spectrum and power efficient techniques; reconfigurable microelectronic devices



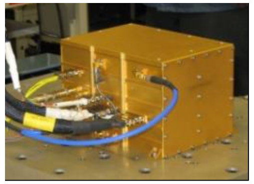
SCaN Testbed

Focus Areas

- Software-Defined and Cognitive Radios
  - Space Telecommunications Radio System (STRS)
  - STRS-compliant Hardware and Software
  - SDR Waveform Development
  - Digital Core for RF/Optical Terminal
- High Speed Signal Processing
  - Computer Modeling and Simulation Tools
  - Wireless and Microelectronic Devices for Communications
- Advanced Exploration Systems
  - Integrated Audio/Microphone Arraying
  - EVA Radio Development
  - Surface Navigation
- SCaN Testbed Flight Radio Experiments and Demonstrations
  - GPS Navigation and Timing
  - Ka-Band, Bandwidth-Efficient, High Rate Waveform
  - S- and Ka-Band IP Networking and Routing
  - Adaptive Modulation and Coding for Cognitive Radio

Facilities/Labs

- Software-Defined and Cognitive Radio Technology Development Laboratory
- Digital Systems and Signal Processing Lab
- EVA Radio and Integrated Audio Lab
- SCaN Testbed on ISS Available for Experimenters



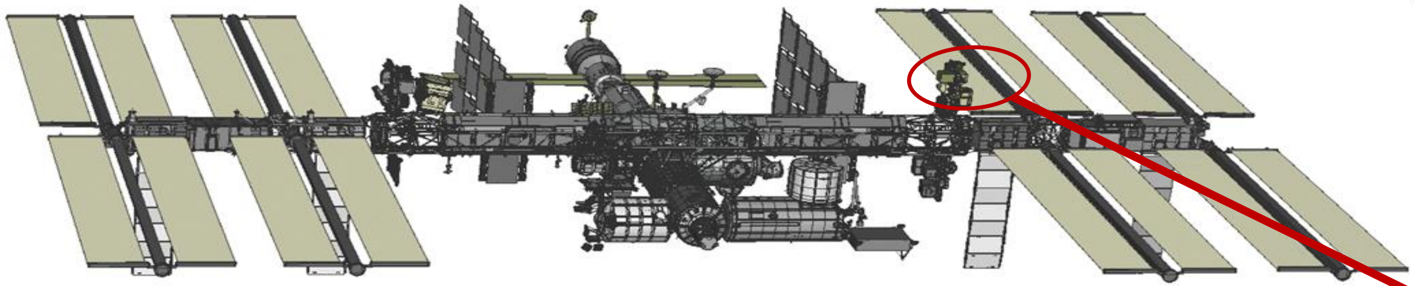
Software Defined Radios

Extra-Vehicular Activity (EVA) Radio

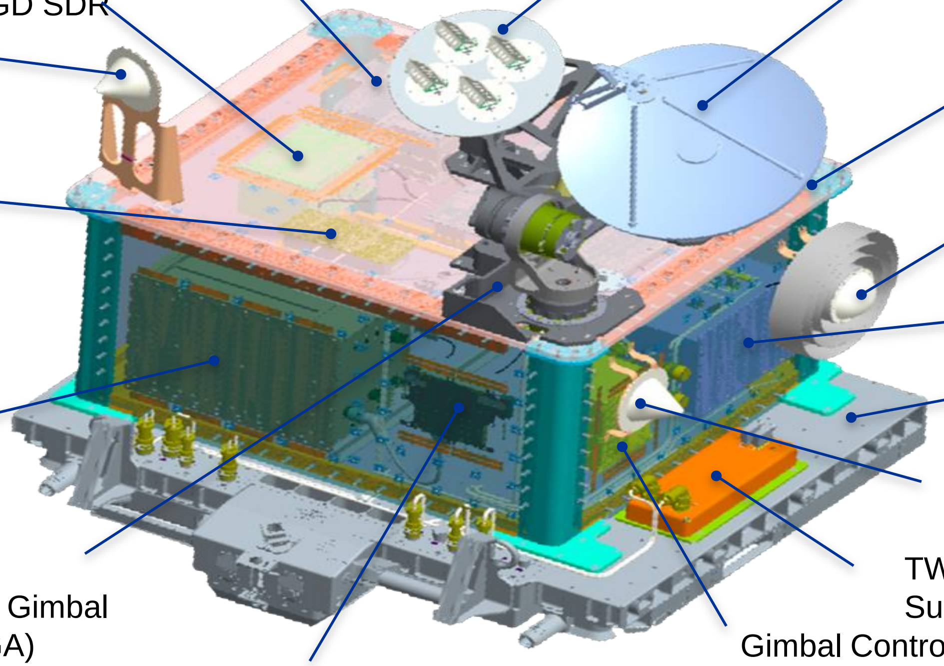
AES/EVA Integrated Audio

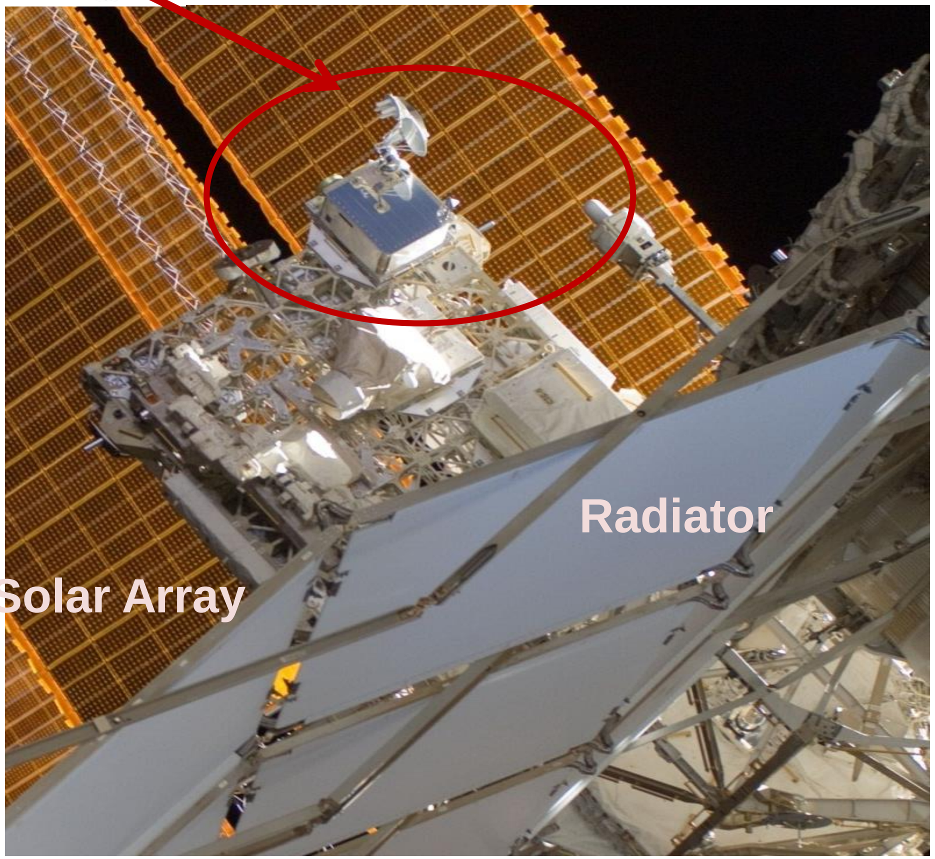
iROC Flexible Digital Core

Space Communication and Navigation Testbed



SCaN Testbed aboard International Space Station



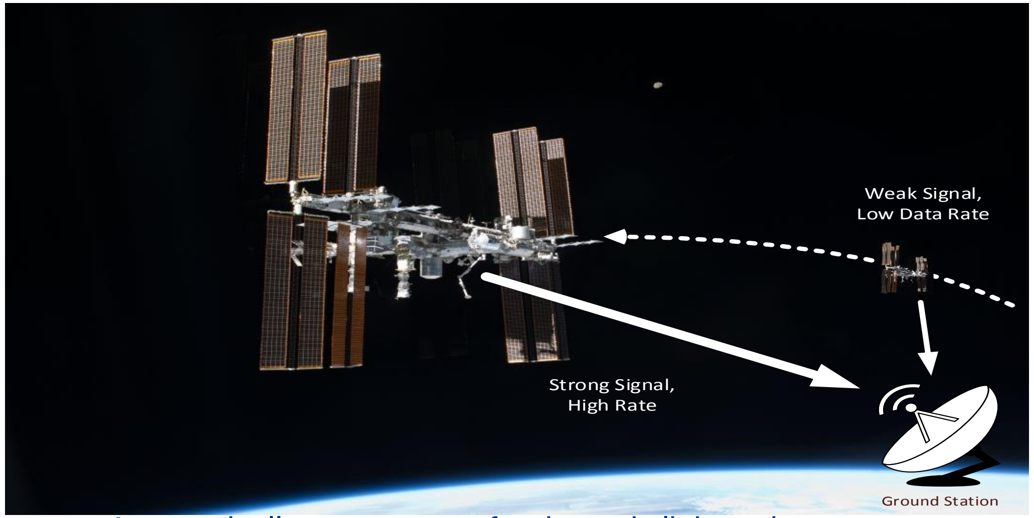


Roadmap to Cognitive Communications

Goal: Develop next generation cognitive technologies for communications to increase mission science return and improve resource efficiencies.

SCaN Test Bed is an early proving ground for experiments in cognitive communications

- Performed experiments in VCM and ACM
- Moving toward cognitive communications
  - Enhanced adaptive capability- More efficient use of spectrum, power and network resource management. Adapt mission operations based on internal and external environments.



Automatically compensate for dynamic link environment

SDR	Variable Coding & Modulation (VCM)	Adaptive Coding & Modulation (ACM)	Cognitive Radio/System
Configurable Properties	Reconfigure system based on predictions	Dynamic reconfiguration based on feedback	Adapting and learning to form intelligent systems: cognitive radios, intelligent networking, user initiated services

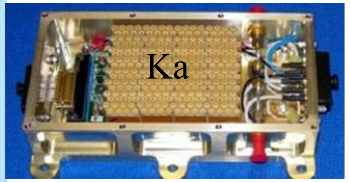
Advanced High Frequency Branch (LCF)

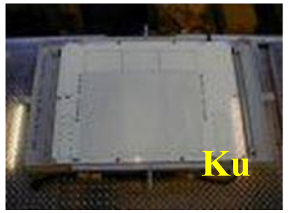
COMMUNICATIONS & INTELLIGENT SYSTEMS DIVISION
NASA GLENN RESEARCH CENTER

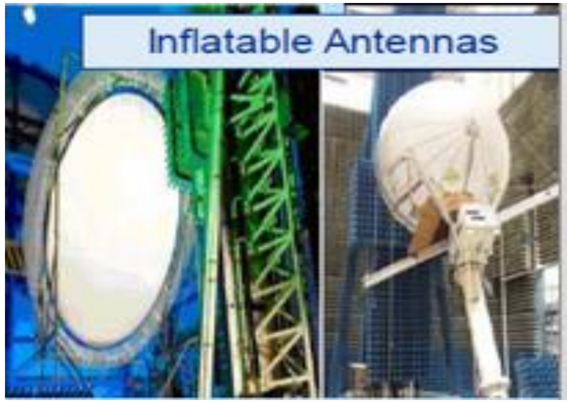
Branch Overview

- Conducts research and technology development, integration, validation, and verification at frequencies extending up to the terahertz region in the areas of semiconductor devices and integrated circuits, antennas, power combiners, frequency and phase agile devices for phased arrays, and radio wave propagation through Earth's atmosphere, in support of NASA space missions and aeronautics applications.
- R&D is conducted in-house and also in collaboration with academia and industry to develop low mass, small size, high power and efficiency traveling-wave tube amplifiers, solid state power amplifiers; novel antenna technologies (e.g., wideband antennas, hybrid antennas (i.e., RF/Optical), ground stations, among others.
- The Branch supports development of advanced technologies such as superconducting quantum interference filter (SQIF) for ultra-sensitive receivers and Ka-band multi-access arrays for NASA's next generation space communications.
- Facilities include planar and cylindrical near-field, far-field and compact antenna ranges, cryogenic microwave and millimeter-wave device and circuit characterization laboratory, high power amplifier characterization laboratory, radio wave propagation laboratory, and clean room facilities.
- Semiconductor device modeling and high frequency circuit simulation, fabrication, and integration facilities are also available.

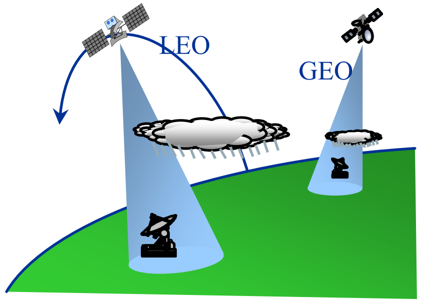
Advanced RF Antenna and Optical Technologies

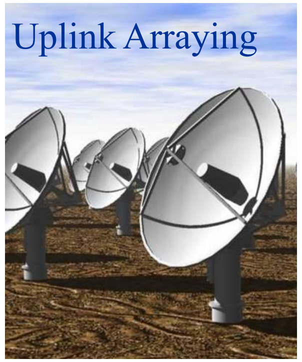




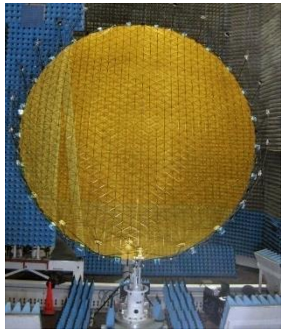


Antennas/Propagation



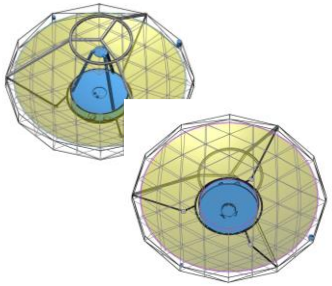


Mesh Antennas

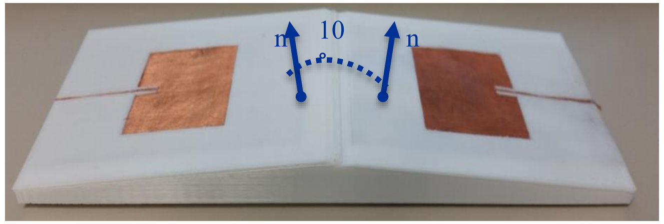


Shape Memory
Polymers Antennas

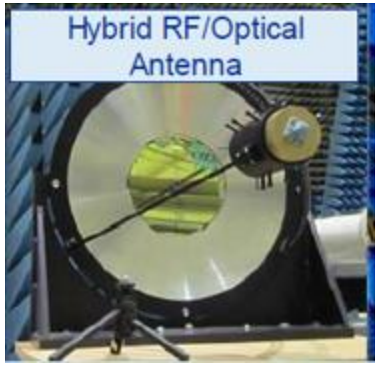
Teletenna Concept



3-D Printed Antennas for Cubesats

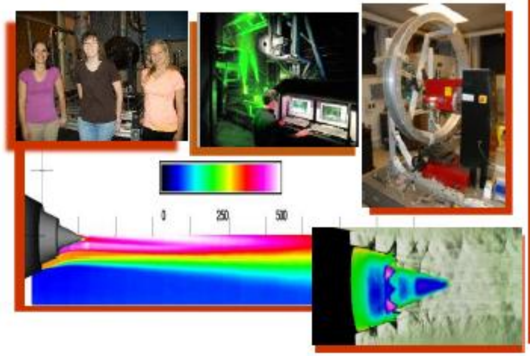


SCaN Testbed
Ground Station



Optics and Photonics Branch (LCP)

Optical Instrumentation



http://www.grc.nasa.gov/WWW/Optinstr/

- Our data and instrumentation help designers understand the fundamental physics of new systems, validate aeronautics computational and life models, and improve space optical communications for human and robotic explorations.
- Our data leads to improved designs, validation and verification of systems performances, increased communications, safety and security and reduced design cycle times for many of the core technologies developed at Glenn and across NASA.

Photonics and Health Monitoring

Flow/Noise Diagnostics
- Particle imaging Velocimetry (PIV)
- Background Oriented Schlieren
- Rayleigh Scattering
- PIV Tomography
- Combustion diagnostics
- Raman Diagnostics (Species, T)
- Plasma generation

Surface Diagnostics
- Temperature Sensitive Paint
- Pressure Sensitive Paint
- Stress Sensitive Film

Engine Icing
- Light Extinction Tomography
- Light Extinction Probes
- Raman Spectroscopy
- Impedance Sensor

Optical Communications

Free Space Communications
- Optical Teletennas
- Beaconless Pointing Systems
- High Data Rate for Deep Space & Near Earth

Secure Quantum Communications
- Quantum Entanglement
- Pulsed photon Pairs
- Quantum Illumination
- Quantum Key Distributions

Mobile and Remote Sensing
- On-Orbit Solar Cell Characterization MISSE 5-8; TACSAT- 4;
- Hyperspectral Imaging
- Mobile Sensing Platforms

Communications
- Communications over power lines
- Communications Interface Boards
- High Data Rate

Health Monitoring
- Microwave Blade Tip Clearance
- Self diagnostic Accelerometer
- Fiber optics sensors
- Morphology dependent resonance
- Phosphor Thermography
- Capacitance & piezo patches sensors
- Wireless and wired techniques

Remote Sensing of Harmful Algal Blooms (HAB) in Lake Erie

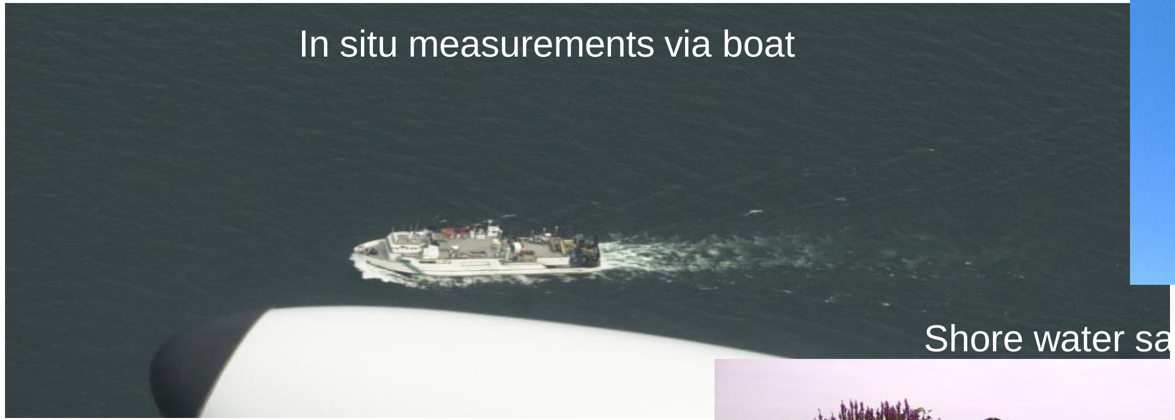
Current status

- Airborne hyperspectral sensing capability for monitoring potentially harmful algal blooms
- 14 flights in 2014, 26 flights in 2015 and 6 flights this year
- Provide HAB data on water intakes in Lake Erie, small lakes and the Ohio river

Research partners also conduct water sampling and ground optical measurements

- NOAA GLERL
- University of Toledo
- Kent State University
- Michigan Tech Research Institute
- Bowling Green State University
- OhioView
- Naval Research Lab

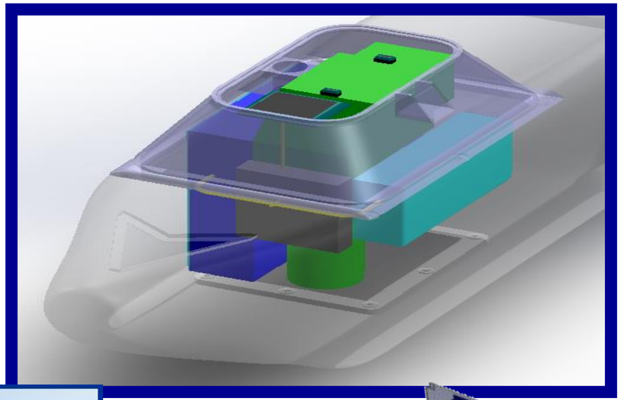
NASA aircraft

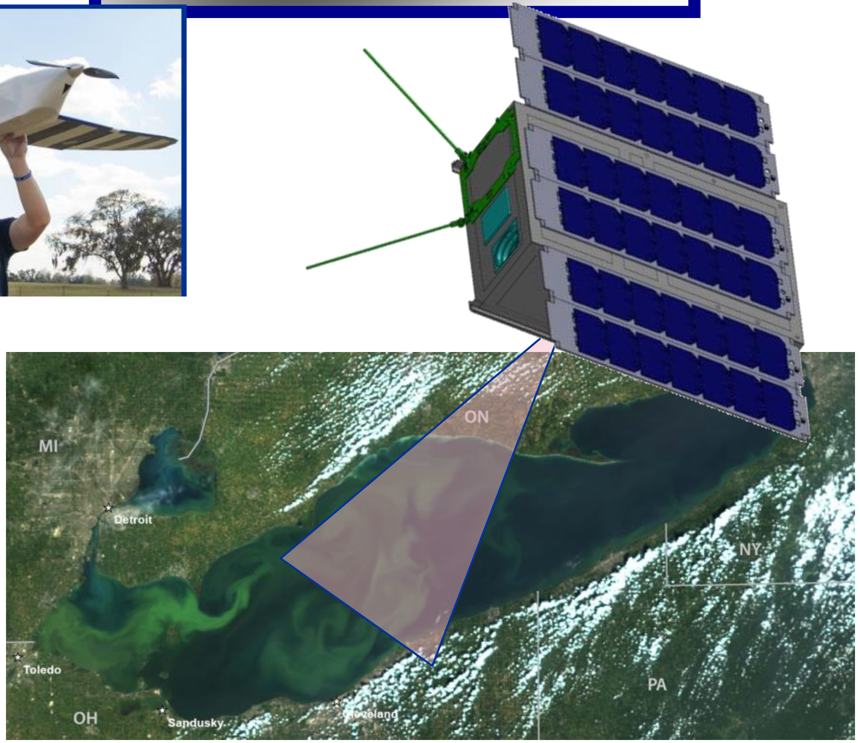


HAB information provided by remote sensing and water sampling can provide for early warning to ensure proper water treatment and shutoff avoidance

Future Directions in HSI HAB Research

- New Platforms:
  - Integrate a hyperspectral imager into an unmanned aerial vehicle (UAV) starting in August 2016
  - Two hyperspectral imagers in development that are appropriate for a cubesat
- New Algorithms
  - Mirror based atmospheric correction
  - Verimax rotated principal component analysis
  - Tuned Cyanobacteria index





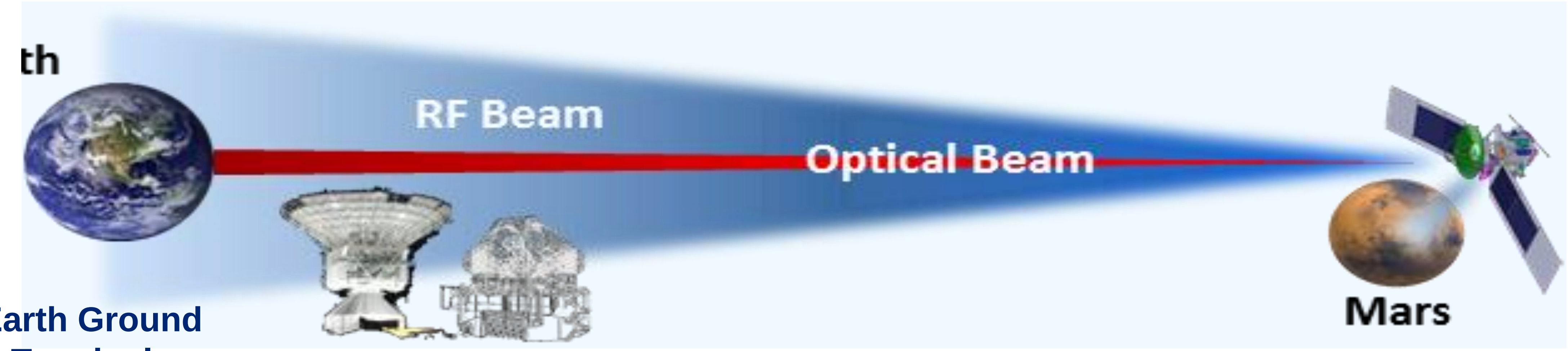
Integrated Radio and Optical Communications (iROC)

iROC Objectives:

- Combine the best features of deep space RF and optical communications elements into an integrated system:
- Increase data throughput while reducing spacecraft mass, power and volume.
- Extensible to, and mitigates risk for missions from near Earth to deep space.
- Prototype and demonstrate performance of key components to increase TRL, leading to an integrated hybrid communications system demonstration.

Key enabling technologies :

- Combined RF/optical Teletenna
- Precision beaconless pointing /navigation through sensor fusion
- RF/optical Software Defined Radio (SDR)
- Networked RF/optical link management (DTN)



Earth Ground Terminals

Combining RF & optical for minimal Size, Weight and Power (SWaP)

Smart Sensors and Electronics Systems Branch (LCS)

Description

Conducts research and development of adaptable instrumentation to enable intelligent measurement systems for ongoing and future aerospace propulsion and space exploration programs. Emphasis is on smart sensors and electronics systems for diagnostic engine health monitoring, controls, safety, security, surveillance, and biomedical applications; often for high temperature/harsh environments.

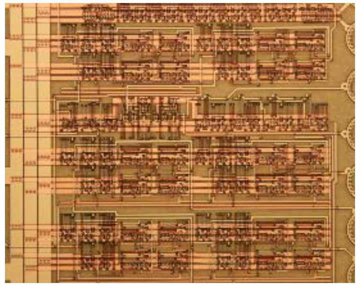
Microsystems Fabrication Facility

Facilities/Labs

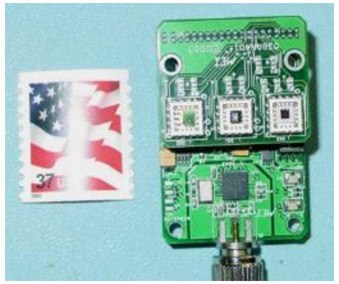
- Microsystems Fabrication Facilities
  - Class 100 Clean Room
  - Class 1000 Clean Room
- Chemical vapor deposition laboratories
- Chemical sensor testing laboratories
- Harsh environment laboratories
  - Nanostructure fabrication and analysis
  - Sensor and electronic device test and evaluation

Focus Areas

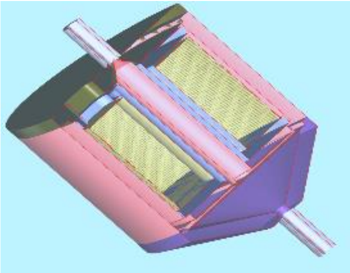
- Silicon Carbide (SiC) - based electronic devices
  - Sensors and electronics for high temp (600°C) use
  - Wireless sensor technologies, integrated circuits, and packaging
- Micro-Electro-Mechanical Systems (MEMS)
  - Pressure, acceleration, fuel actuation, and deep etching
- Chemical gas species sensors
  - Leak detection, emission, fire and environmental, and human health monitoring
- Microfabricated thin-film physical sensors
  - Temperature, strain, heat flux, flow, and radiation measurements
- Harsh environment nanotechnology
  - Nano-based processing using microfabrication techniques
  - Smart memory alloys and ultra low power devices



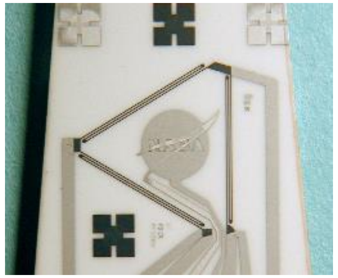
SiC Signal Processing



Chemical Gas Sensors



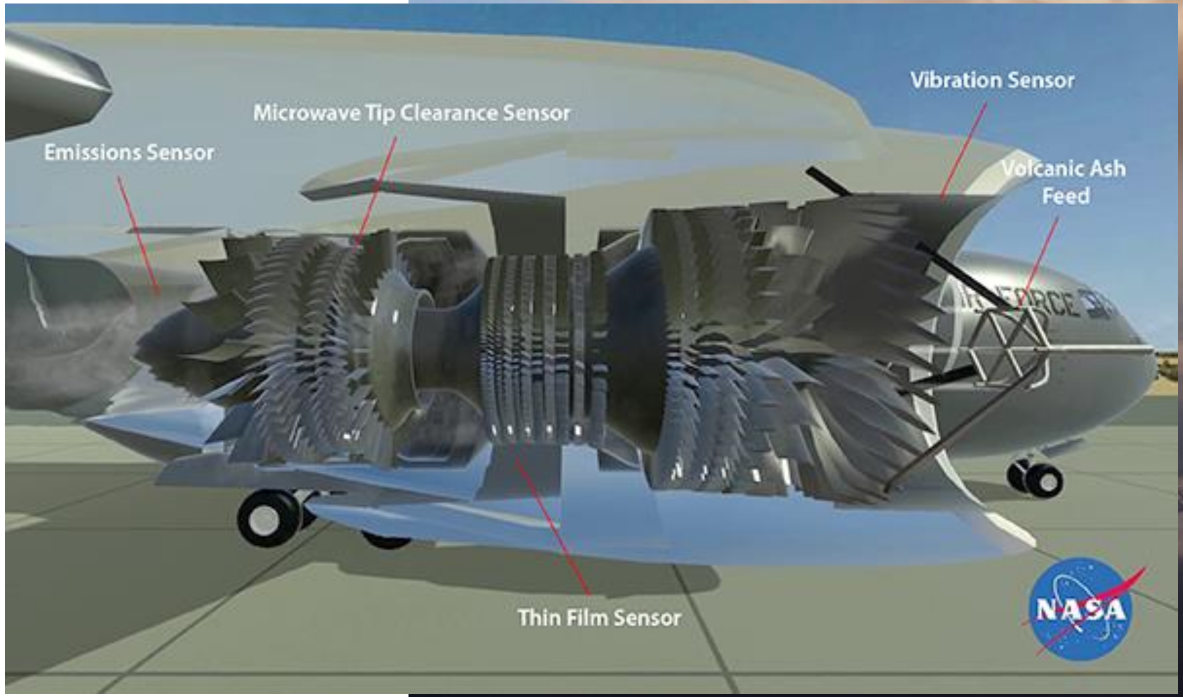
MEMS Fuel Actuation



Thin Film Physical Sensors

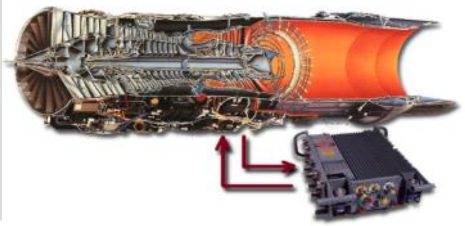
Vehicle Integration Propulsion Research (VIPR)

Goal: Determine capability of advanced detection, diagnostic and prognostic systems to characterize engine performance, and identify fault modalities, during rapid engine degradation caused by the ingestion of volcanic ash



Intelligent Control and Autonomy Branch (LCC)

Propulsion Controls



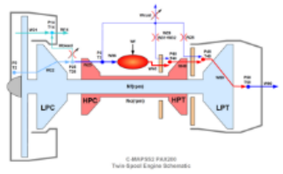
Active Combustion Control
Control of Thermo-acoustic Instability
High Bandwidth Fuel Actuation

Advanced Control Architecture
Distributed Engine Control
Hardware-in-the-loop Test-bed

Intelligent Engine Control
Enhanced Engine Response for Emergency Operations
Robust Engine Control
Model-Based Engine Control
V&V of Advanced Controls

High Speed Propulsion
Aero-Propulso-Servo Elasticity for Supersonic Propulsion System
Mode Transition Management for Air-Breathing Hypersonic Propulsion

Health Management



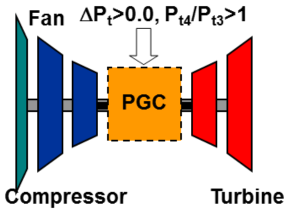
Propulsion & Power Systems
Gas Path Health Management
Sensor Selection
Sensor Data Qualification
Fault Modeling and Diagnostics
Model-Based Engine Simulation for Engine Test, Calibration and Performance Analyses

Current NASA Programs

Aeronautics Research Mission
Advanced Air Vehicle
Airspace Operations and Safety
Transformative Aeronautics Concepts

Human Exploration and Operations Mission
Space Launch System
SCAN
Orion

Advanced Propulsion Concepts



Unsteady Propulsion
Pulse Detonation Engine
Pressure Gain Combustion

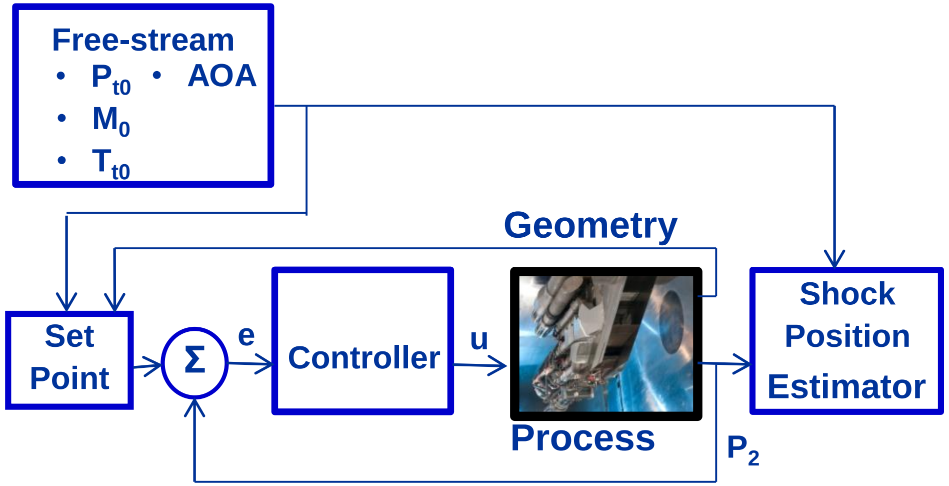
Communications

Integrated Radio and Optical Comm
Spacecraft Attitude Estimation
Spacecraft Structural Dynamics

Software Tools

Engine Modeling & Control
C-MAPSS (Commercial Modula Aero Propulsion System Simulation)
C-MAPSS40k (40,000 lb Thrust Engine)
T-MATS (Tool for Modeling and Analysis of Thermodynamic Systems)
Combustion Instability Simulation

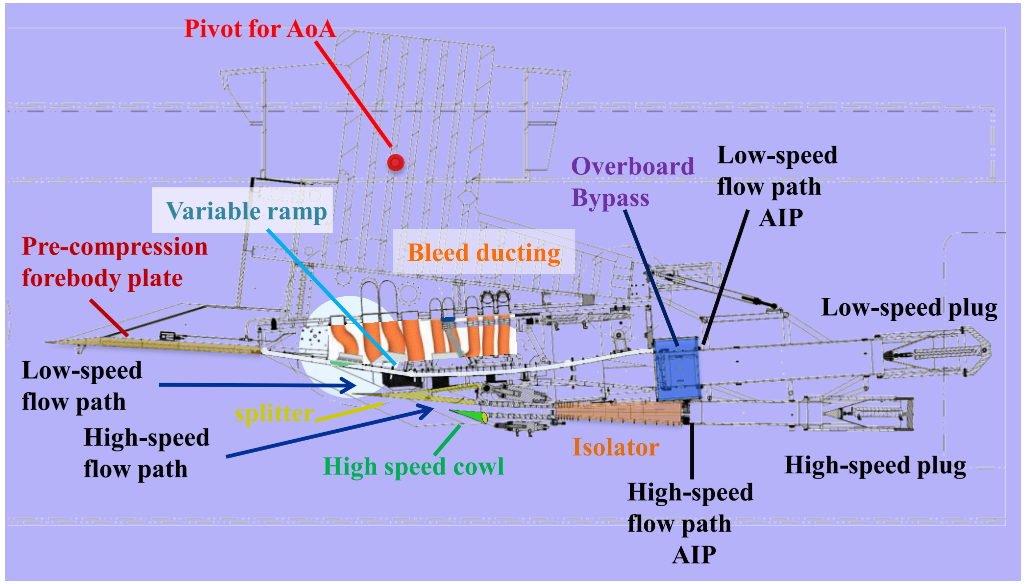
Hypersonic Propulsion System Control



Control for Safe Transition from Low Speed To High Speed Flow Path Demonstrated in 10X10 testing for Mach 2.5 and 3

GRC 10-foot x 10-foot Combined Cycle Engine (CCE) Testbed

- Low to high speed flowpath transition control
- Shock positioning
- Fuel flow



Intelligent Control and Autonomy Branch