Division Overview

Dr. Félix A. Miranda

U. of Queensland – TAMU – AFRL/AFOSR Meeting
Texas A&M University
College Station, TX, 77843-3120

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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 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)

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

PhD • MS • BS

115 FTE
58 WYE
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
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.

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

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

Unmanned Aircraft Systems (UAS) Integration in the National Airspace System (NAS) Project

Legend:
- Sense and Avoid (SAA/DAA Technologies)
- Air Traffic Services
- Command and Control (C2) and Non-Participating Communications (CNP) Network
- Traditional Command and Control (C2) Links

AOP/RRM:
- ADS-B: Automatic Dependent Surveillance—Broadcast
- ACAS: Airborne Collision Avoidance System
- TCAS: Traffic Collision Avoidance System
- TRACON: Terminal Radar Approach Control Facility

Small UAS (sUAS)
Mission Support Technologies

UAS vehicle autonomy

UAS Restricted-Use Certification

Precision agriculture

Research ground control station

UAS ground control station

Human Systems Integration

Communications satellite

Radar

Ikhana UAS DAA test aircraft

Noncooperative aircraft

Cooperative aircraft

Air traffic services (on route)

UAS in the NAS

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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

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

SCaN Testbed aboard International Space Station

S-Band MGA
Ka-Band HGA
RF Subsystem Plate Assembly
L-Band LGA (GPS)
Avionics
ExPA (FRAM)
S-Band LGA
Thermostat Control Assembly
Harris SDR
Harris Up/Dn Converter
Antenna Pointing System Integrated Gimbal Assembly (APS IGA)
Gimbal Control Electronics (GCE)
TWTA Power Supply Unit
Solar Array
Radiator
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.

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

Automatically compensate for dynamic link environment
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.

R&D 100 Award Winning Technologies
Advanced RF Antenna and Optical Technologies

Antennas/Propagation

3-D Printed Antennas for Cubesats

SCaN Testbed Ground Station

Hybrid RF/Optical Antenna

Uplink Arraying

Mesh Antennas

Shape Memory Polymers Antennas

Teletenna Concept

Phased Array Systems

AlphaSat Propagation Terminal in Milan, Italy

Inflatable Antennas

LEO GEO

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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.

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

Photonics and Health Monitoring

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

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
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)

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.

**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

**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

**Microsystems Fabrication Facility**

**SiC Signal Processing**

**Chemical Gas Sensors**

**MEMS Fuel Actuation**

**Thin Film Physical Sensors**
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-Propulsion-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

**Advanced Propulsion Concepts**
- Unsteady Propulsion
  - Pulse Detonation Engine
  - Pressure Gain Combustion

**Communications**
- Integrated Radio and Optical Comm
  - Spacecraft Attitude Estimation
  - Spacecraft Structural Dynamics

**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

**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