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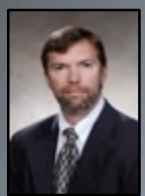
MSFC Engineering Overview

Deputy Engineering Director

Lisa Watson-Morgan, Ph.D.



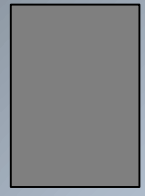
Engineering Management



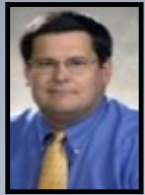
Technical Assistant
Richard Stroud



Technology & Innovation
Assistant
Lybrease Woodard



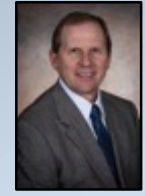
Associate Director
for Technical
Vacant



Director
Larry Leopold



Deputy Director
Lisa Watson-Morgan



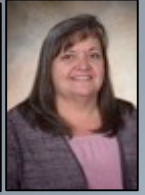
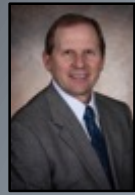
Associate Director for
Operations
Roger Baird, detail



SLS Program Chief
Engineer
Garry Lyles

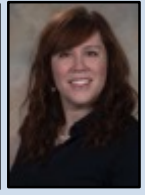
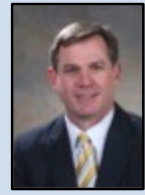


Sr. Lead, Space Trans &
Propulsion
Mike Kynard



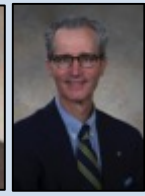
ED10 – Resource Management
Mgr., Roger Baird
Dep. Mgr., Angie Nolen

ED04 – Advanced Concepts
Mgr., Mark Rogers
Dep. Mgr., Rachel McCauley



EE01 – Chief Engineers Office
Chief Eng: Katherine Van Hooser
Dep. Chief Eng., Nelson Parker

EM01 – Materials & Processes Lab
Mgr., Suren Singhal
Dep. Mgr., Scotty Sparks



ES01 – Space Systems Dept.
Mgr. Tia Ferguson
Dep. Mgr., Don Holder, detail

ER01 – Propulsion System Dept.
Mgr. Mary Beth Koelbl
Dep. Mgr., Robert Champion



EV01 – Spacecraft & Vehicle Sys.
Mgr., Charlie Finnegan
Dep. Mgr., Angelia Walker, detail

ET01 – Test Laboratory
Mgr., Ralph Carruth
Dep. Mgr., Vacant



Engineering Disciplines



Advanced Concepts



- Concept Definition, Integration, & Analysis
 - Earth-to-Orbit Transportation
 - In-Space Transportation
 - Habitation & Crew Systems
 - Science & Robotic Exploration
- Architecture Analysis
- Technology Assessments
- Feasibility Studies
- Concept Evaluation

Space Systems



- Instruments & Payloads
- Environmental Control & Life Support Systems
- Electronics
- Software
- Small Mechanical Systems
- Fabrication & Assembly Services

Spacecraft & Vehicle Systems



- Systems Engineering & Integration
- Structural Design and Analysis
- Loads & Dynamics
- Aero-sciences
- Thermal Design, Analysis, & Control
- Modeling & Simulation
- Guidance, Navigation, & Control
- Terrestrial & Space Environments

Propulsion Systems



- Propulsion Engineering
- Liquids & Solids
- Component Design and Development
- Fluid Systems Design & Analysis
- Computational Fluid Mechanics
- In-Space Propulsion
- Nuclear Propulsion

Materials & Processes



- Metallics
- Composites
- Ceramics
- Environmental Effects
- Fracture & Failure Analysis
- NDE & Tribology
- Chemistry
- Materials Control & Informatics
- Advanced Manufacturing

Test Lab



- Propulsion Testing
- Structural Testing
- Thermal Vacuum
- Shock & Vibration
- Acoustic
- Experimental Fluids Test & Development
- Test Support (Piping and Structure Design/Analysis Pressure and Propellants)

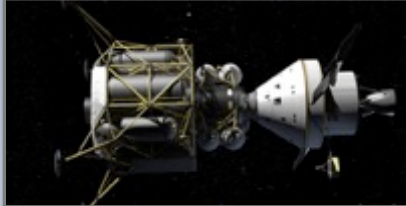
Advanced Concepts

Earth to Orbit Concept Definition & Analysis



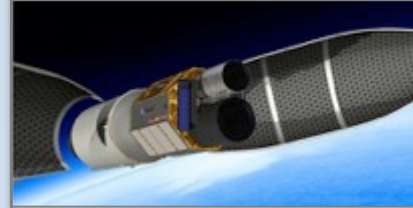
- Earth to Orbit Trajectory Analysis
- Weights & Sizing
- Vehicle Structural Analysis
- System Level Trades

In-Space Systems Analysis



- Architecture Analysis
 - Concept of Operations
 - Mission Analysis
- Technology Assessments
- In Space Element Definition
- Habitation & Crew System

Exploration & Discovery (Analysis, Mission Concept Definition and Spacecraft Concepts)



- Scientific & Robotic Exploration
 - Planetary Science
 - Earth Science
 - Heliophysics
 - Astrophysics
 - Human Exploration Precursors
- Human Exploration
- Technology Demonstrations

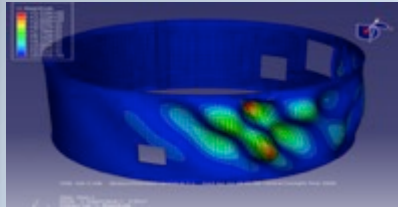
Spacecraft & Vehicle Systems Department

Systems Engineering & Integration



- **Technical Management**
 - Risk and Knowledge Management
 - Perform Metrics and Margin Management
 - Lifecycle Review Planning
 - Certification of Flight Readiness Strategy
 - Trade Study Identification and Tracking
- **System Design and Definition**
 - Integrates and Manages Overall System Design
 - Establishes Design Requirements and Facilitates Compliance
- **Test and Verification**
 - Leads Verification and Validation Planning and Integration
- **Systems Analysis**
 - Leads and Performs System-level Modeling and Analysis
 - Mass Margin Management
 - Ascent Debris Assessment
 - Assistance with Systems Hazard and Failure Evaluations
 - Human Factors Engineering

Structural Design & Analysis



- **Structural Dynamics, Loads & Stress Analysis**
 - Structural analysis
 - Fracture mechanics
 - Vibroacoustic environment definition
 - Integrated coupled loads analysis
- **Structural & Mechanical Design & Modeling**
 - Vehicle component design and integration
 - Pyrotechnic systems analysis
 - Meteoroid debris analysis
- **Composite Structures**
- **Aerosciences**
 - Aerodynamics
 - Acoustic environments
 - Rocket exhaust plume characterization
 - Aerothermodynamics
 - Venting
- **Thermal Design, Analysis & Control**
 - Thermal/fluid analysis
 - Launch vehicle TPS
 - Spacecraft thermal analysis

Flight Mechanics & Analysis



- **Control Systems Design & Analysis**
 - Requirements Definition
 - Development
 - Verification
 - Launch Vehicle & Spacecraft
- **Guidance & Trajectories**
 - Guidance laws
 - Trajectory designs
 - Mission analysis
- **Navigation Systems**
- **Modeling & Simulation**
- **Integrated Systems Health Management and Automation**
 - Architecture definition
 - Algorithm development & modeling
- **Natural environments**
 - Terrestrial
 - Planetary

Propulsion Systems Department

Liquid Propulsion Systems Design & Integration



- Liquid Engine Systems Design and Integration
- Pressurization, Feed and Propellant Systems Design and Integration
- Engine Systems Analysis & Health Management
- Development and integration of pressure-fed chemical propulsion systems for satellites, spacecraft, descent/ascent vehicles, and launch vehicles
- Long-Duration In-Space Cryogenic Propellant Storage and Delivery Systems for chemical and nuclear propulsion stages
- Advanced Propulsion & Power Research & Development including: High Power Electric Propulsion, Nuclear Thermal Propulsion, Space Nuclear Power Systems, and Nuclear Surface Power Systems.

Solid Propulsion Systems



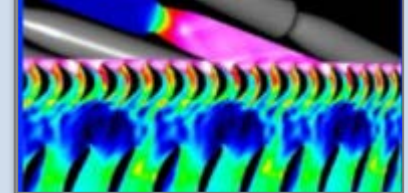
- Solid Boost Propulsion Systems Integration for SLS
- Separation & Maneuvering Solid Propulsion Systems Design and Development
- Solid Propulsion Design and Trade Studies
- Anomaly Resolution/Tiger Team Support
- Flight Readiness Assessments
- Propellant Grain Design
- Ballistics Performance Analysis
- Requirements Analysis/Development/Test Planning
- Propellant/Liner/Inhibitor Formulation and Evaluation
- Propellant and Liner Mix Cast Insight
- Independent access to motor production capacity

Propulsion Component Design & Development



- Turbo-machinery Design, Analysis, Test, Evaluation, Assessment of Turbo-machinery Components and Advanced Development
- Combustion Devices Design, Analysis, Test, Evaluation, Assessment of Combustion Devices Components and Advanced Development
- Valves, Actuators, & Ducts Analysis, Design, Test, Evaluation, and Assessment of Valves, Regulators, Actuators, Lines, Ducts and Advanced Development
- Detail Component and System Design specializing in Propulsion Components and Subsystems
- Thrust Vector Control Systems Analysis, Design, Test, Evaluation, and Assessment of TVC systems

Propulsion Structural, Thermal, & Fluid Analysis



- Structural Dynamics Analysis
- Strength, Fatigue, and Fracture Analysis
- Rotordynamic Analysis
- High speed Vibration Data Analysis
- Vibroacoustic and Shock Analysis
- Internal and Lift-off/Separation Acoustics
- Multiphase Flows
- Combustion Dynamics
- Loads and environment predictions
- Air and Waterflow Testing for Turbines, Pumps, Nozzles, and Feedlines
- Thermal and thermal structural analysis
- Thermal fluid analysis including characterization of environments
- Thermo-chemical analysis and testing
- Infrared thermography

Test Laboratory

Propulsion Test



- Sub-scale injectors & elements, thrusters, gas generators, turbopumps
- Oxygen & Hydrogen cold flow
- Cryostructural
- On-orbit vacuum environment
- Solar thermal propulsion
- Solid motor propellant & materials
- Hot gas material characterization
- Engine Systems (LH2, CH4, RP-1)

Experimental Fluid Dynamics Test



- Air & water flow
- Full flow air blow down for turbopump turbine inlet testing
- Subscale nozzle internal contours & back pressure data via blow down testing
- Pump impeller & inducer sub- & full-scale performance mapping via visual water flow testing
- Subsonic & supersonic vehicle model & nozzle testing at Mach 0.2-5.0
- Air blow down testing of subscale solid motor casing & nozzle designs
- Probe calibration testing

Environmental Test



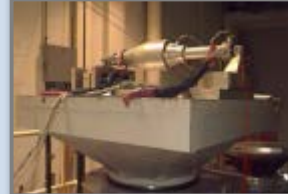
- Thermal vacuum
- Thermal cycle/humidity
- Altitude
- Launch ascent/descent
- Vacuum bake out
- Optical certification bake out
- Arc Jet/Hot Gas
- Development, qualification, acceptance, & research testing of space flight hardware

Structural Strength Test



- Hazardous structural test
- Cryostructural test
- Tensile & compressive loads test
- Combined Environments
- Load environments to simulate launch, on orbit, & landing conditions for development, qualification, acceptance & research testing of space flight hardware

Structural Dynamics Test



- Experimental modal analysis to verify & correlate analytical finite element models of space flight hardware.
- Vibration, acoustic, & pyrotechnic shock testing for space flight hardware development, qualification & acceptance.
- Micro-gravity vibration emission testing

Test Support



- Propellants, Pressurants & Calibration
- Advanced Instrumentation Applications
- Special Test Equipment Design
- Test Planning
- Emerging Technologies
- Data System & Software Development

Materials & Processes Lab

Laboratory Metrics



~ 150 Civil Servants
~ 120 On-site Contractors

18 Facilities

Numerous Agency Unique Capabilities

Materials Science

- Microgravity (μ g) Flight Experiment Development
- Space Life and Physical Sciences /MaterialsLab
- Metals, Glasses, Semiconductors, Bio-materials, Polymers, Ionic Liquids
- μ g Simulation Systems
 - Electrostatic Levitator
 - Furnaces

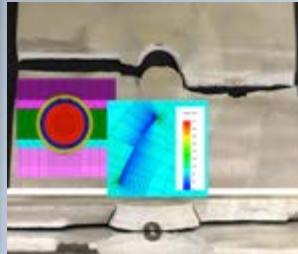
Testing & Environmental Effects



- Mechanical Property Testing
- Hydrogen Testing
- Tribology
- Metrology
- Analytical Chemistry
- Space Environmental Effects Testing
- Debris & Weather Impact Testing
- Flight Experiments



Damage Tolerance



- Damage Tolerance Determinations
- Fracture Control Board
- Fracture Control & Analysis

Non-Destructive Evaluation



- Non-Destructive Evaluation (NDE) Inspections, Process Development & Application

Metallic M&P



- Metallurgical Engineering
- Materials Diagnostics & Failure Analysis
- Metals Process Development
- Corrosion

Metals Manufacturing



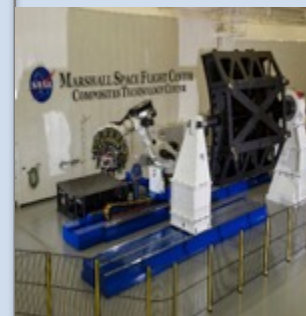
- Solid State Welding
- Large Scale Process Development / Tooling & Manufacturing

Nonmetallic M&P



- Polymers & Composites Test and Application
- Ceramics & Ablatives

Composites Manufacturing



- Fiber Placement Robot
- Additive Mfg
- Digital Mfg Support
- TPS Process Development

Materials Selection, Control, & Engineering Support

- Materials Requirements, MUAs, MIULs
- M&P Controls
- Contamination & Foreign Object Debris Control
- Materials Obsolescence Support



Materials Data Management

- MAPTIS – Agency asset
- Physical Sciences Informatics
- Database Management

Space Systems Department

Systems Engineering & Integration



- Lead Systems Engineers
- Hardware & Software Requirements & Verification
- System Level Trade Studies
- Avionics Systems Integration
- Engineering Discipline Interface
- Systems Engineering Management Plan

Mechanical Design, Analysis & Fabrication



- Strength Analysis
- Structural Dynamics & Loads Analysis
- Vibroacoustics
- Thermal Design & Analysis
- Mechanisms
- Fluid Systems Design & Analysis
- Modeling & Simulation
- Loads & Dynamics
- Mechanical Fabrication & Assembly

Avionics Design



- Instrumentation & Advanced Flight Sensors
- GN&C Hardware
- Imaging & Video Systems
- Embedded Control Systems
- Optics
- Flight & Ground Computers
- Data Systems
- RF Systems
- Communications

Electrical Integration & Fabrication



- Electrical Power Systems
- Electromagnetic Environmental Effects
- EMC Analysis
- Electrical Integration
- Electronic Fabrication & Assembly
- Electronic Packaging Design
- EEE Parts Analysis & Verification

Flight & Ground Software



- Mission-Critical Flight Software
- Propulsion Controllers
- Payload Flight Software
- Software Testing, Costing & Metrics
- Systems Integration Lab (SIL)
- Systems Integration & Test

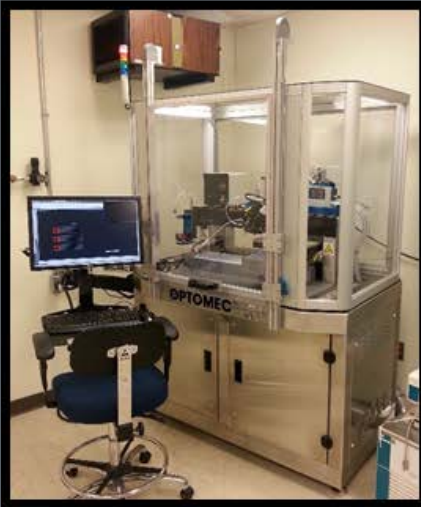
Systems Development, Integration & Test



- Science Payload Hardware Development
- Systems Integration & Test
- Flight Experiment & Payload Operations
- Sub-orbital Flight Tests of "Breadboard" Instruments
- Water and Air Systems Development Testing
- ECLSS Flight Hardware Acceptance & Quality Testing
- Fluid System Design & Analysis (ECLSS)

EEE Parts Packaging- Additive Electronics Laboratory

**Optomec High Precision
3D Aerosol Jet Printer**



Primary Focus: Utilizing 3D additive dispensing, screen printing, and aerosol jet deposition processes to develop nanoelectronics including but not limited to:

- **Solid State Ultracapacitors**
- **Graphene Superconducting Circuitry**
- **Organic Photovoltaics & LEDs**
- **Electroluminescent Devices**
- **Sensors**
- **PCBs**
- **Antennas**
- **3D Flexible Interconnects for Area Array Packaging**
- **Embedded Electronics Packaging**
- **Advanced Electronic Manufacturing**

**HMI 485 High Precision
Screen & Stencil Printer**



**Hengli Custom 8-Zone HT
Sintering Furnace**



**Hengli Custom 4-Zone LT
Sintering Furnace**



**Silverson L5M-A
Laboratory**



**PVA 350 Tabletop
Robotic Dispensing System**



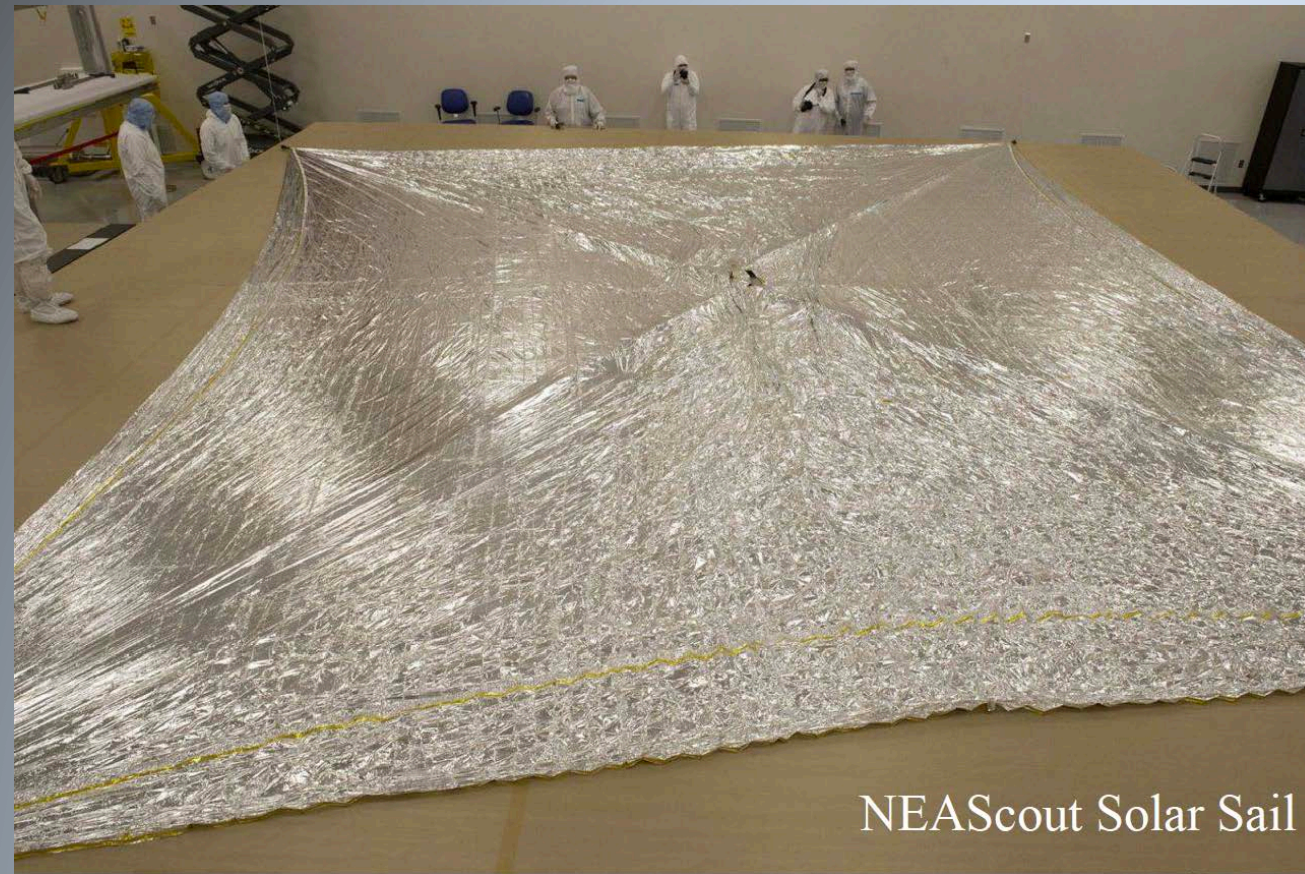
Solar Array Antenna



National Aeronautics and
Space Administration

The Lightweight
Integrated Solar Array
and anTenna (LISA-T)

Near Earth Asteroid Scout Sail



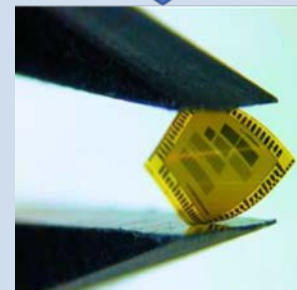
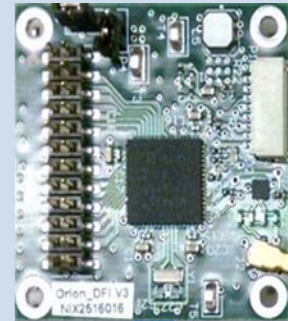
SLS EM-1 Secondary Payload

NASA MSFC Materials & Process Development Flexible Sensing Technology

Background and requirement

ISM Multi Material Fabrication Key Areas:

- **Development of Flexible Sensing Technology:**
 - Development of next-generation flexible sensor platforms and printed sensors for Astronaut Crew Health Monitoring on International Space Station.
 - Development of materials and processes for printed sensors.
 - Evaluation and incorporation of new component technologies (flexible components, wireless communications, etc.)
- **Energy Storage Technology Development:**
 - Develop triboelectric power in order to build a self-contained sensor system.
 - Further maturation of an all-printed supercapacitor.
 - Developing very high energy density supercapacitors for battery replacement with several commercial companies.
 - Developed an Al-air battery with University of Tennessee & ORNL for scalable battery replacement applications.



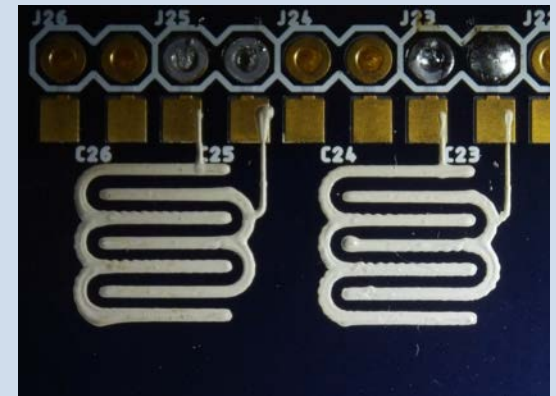
**Flexible
Electronics
Sensors**

NASA MSFC Materials & Process Development Flexible Sensor Development

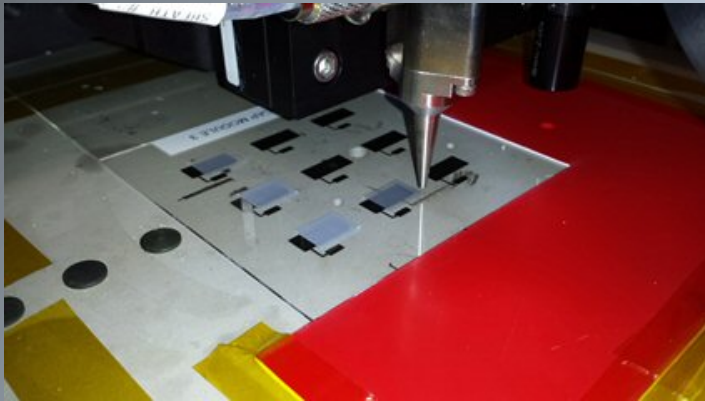
Multi Material Fabrication and Materials Development

Development of Flexible Sensing Technology:

- Development of next-generation wireless flexible sensor platforms and printed sensors for Astronaut Crew Health Monitoring on International Space Station.
- Development of materials and processes for printed sensors.
- Evaluation and incorporation of new component technologies (flexible components, wireless communications, etc.)



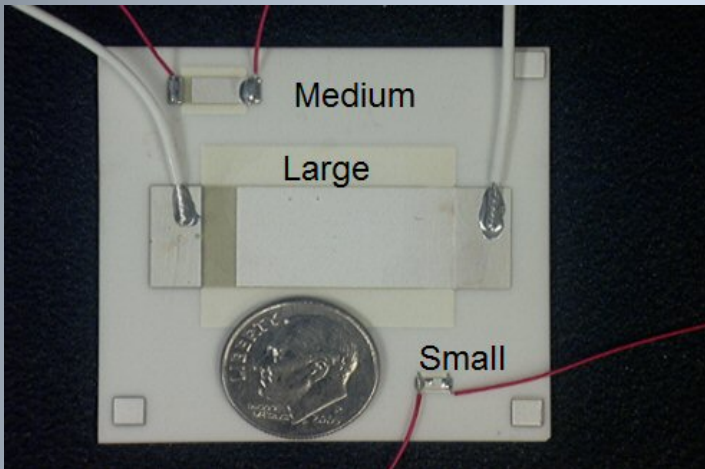
Printing Electronics



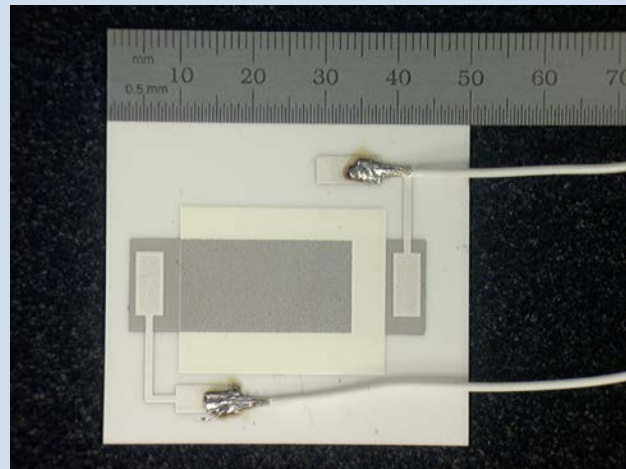
Dielectric ink printing



Wireless humidity sensor



Three different sizes



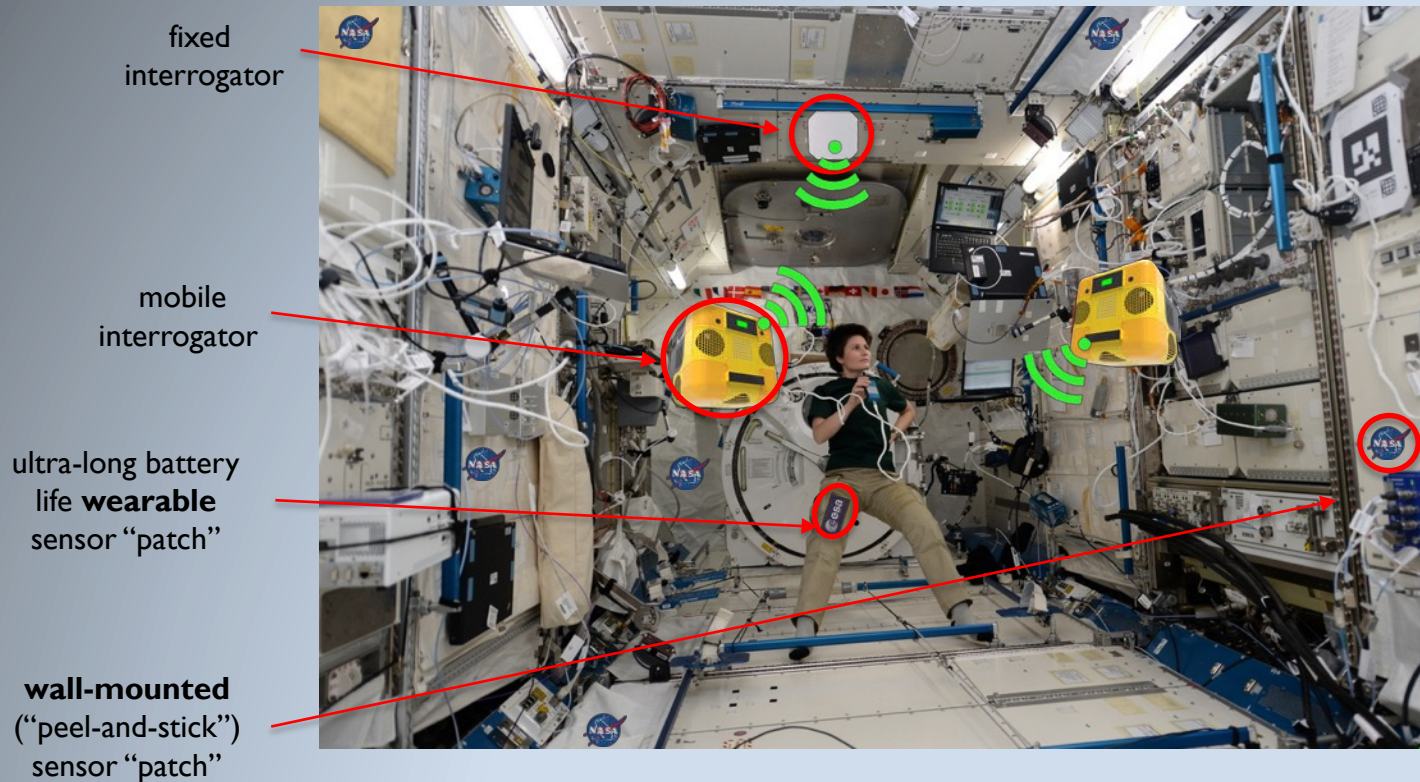
Ultra cap with leads

Ultracapacitors and Humidity Sensors

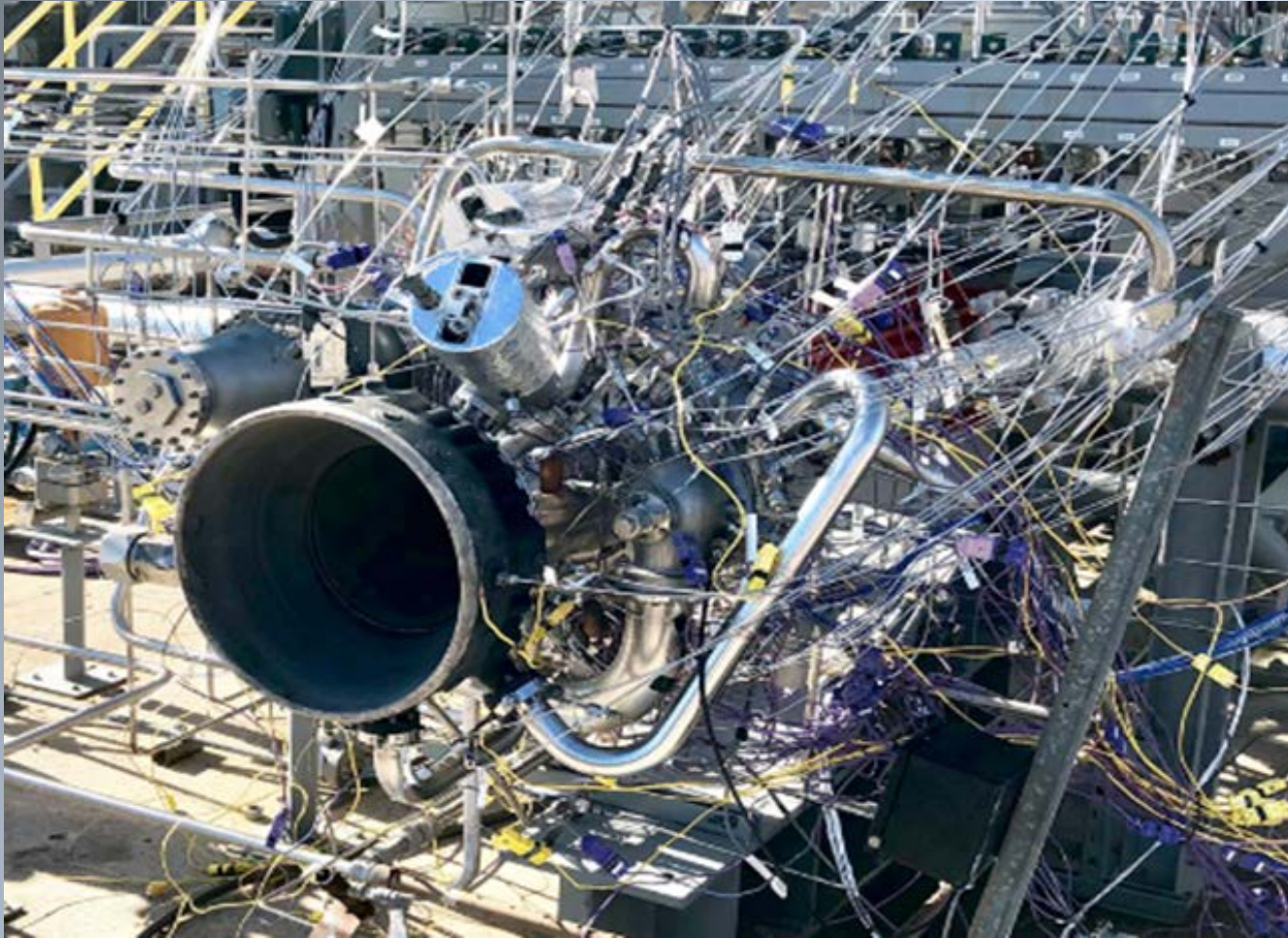
NASA MSFC Materials & Process Development

Flexible Sensor Development

Wearable Wireless Sensors Operational Concept



We are not there yet! Engine Instrumentation March 2019



Engineering the Future

