Flexible Electronics Development
Supported by NASA

Eric Baumann
Flexible Electronics Sector Manager
NASA’s Vision

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

Some basic questions:
• What is out there in space?
• How do we get there?
• What will we find?
• What can we learn there, or learn just by trying to get there, that will make life better here on Earth?
Requirements for Space Operations

Space operations are often more constraining than terrestrial activities

- Low mass & volume
- Structural load environments
  - Ground transportation
  - Launch
  - Landing
- Natural Environments
  - Thermal
  - Microgravity
  - Radiation
  - Vacuum
- Off gassing and toxicity concerns
- Equipment calibration / stability
- Lifetime / Storage
Space Technology Roadmaps*

TA01  Launch Propulsion Systems
TA02  In-Space Propulsion Systems
TA03  Space Power and Energy Storage
TA04  Robotics, Tele-Robotics and Autonomous Systems
TA05  Communication and Navigation Systems
TA06  Human Health, Life Support and Habitation Systems
TA07  Human Exploration Destination Systems
TA08  Science Instruments, Observatories and Sensor Systems
TA09  Entry, Descent and Landing
TA10  Nanotechnology
TA11  Modeling, Simulation, Information Technology and Processing
TA12  Materials, Structures, Mechanical Systems and Manufacturing
TA13  Ground and Launch Systems Processing
TA14  Thermal Management Systems

* See the National Aeronautics Research and Development Plan for Aeronautics R&D challenges and goals
Flexible solar arrays
- Solar electric vehicles (400kW)
- Conforming to habitats and mobile platforms

Electronics systems with reduced mass and volume
- Power processing units
- Sensors / sensor systems
- Space suits
- Controllers
- Cameras
- Radios
- Data storage
- Antennas
- Displays
Flexible Electronics Needs (cont.)

- Compact, low power, radiation dosimeter and monitoring sensors
- Sensors and instruments sensitive to
  Electromagnetic radiation including photons
  Charged, neutral and dust particles
  DC and AC electromagnetic fields
  Gravity waves
  Acoustic and seismic energy
  Chemical, mineralogical, organic, and in-situ biological samples
  Pressure, temperature, winds
  Other physical phenomenology required by science

Monkey Head Nebula
Flexible Electronics Needs (cont.)

- Smart wiring systems
  - Reduce mass
  - Decrease volume
  - Detect wire damage
  - Self heal insulation
  - Sense connectivity issues
  - Reconfigure power and data to maintain connectivity in response to changing mission conditions
  - Increase reliability
  - Sustainable over long periods

- Electronic systems operating above 500°C to eliminate
  - Active cooling systems
  - Heat pipes
  - Heat sinks
  - Mass
  - Volume
Flexible Electronics Biomedical Needs

• Biomedical sensors
  Easily donned/doffed and comfortable to wear
  Minimally-invasive to the eye and skin
  Noninvasive to the brain
  Microfluidics to deliver samples to sensors
  Attentional state monitoring
  Biomarkers
  Nutrient absorption
  Wireless data communication vs. quick disconnect
  Subcranial, interocular, and spinal fluid pressure

• Surface sensors
  Pulse/Ox    Blood pressure    Dry electrodes
  Temperature Sweat    Electromyography (EMG)
  GSR        Plantar pressure
Flexible Electronics at NASA GRC

- **Aerogels**
  - Flexible, porous, lightweight, high surface area, good thermal insulator
  - Low density = low dielectric properties (1.008 at 0.008g/cm³)
  - Potential dielectric for capacitors, flexible capacitors, super-capacitors
  - Substrate material in sheet form

- **Antennas**
  - Patch antenna on polyimide aerogel
  - Wide bandwidth antennas
  - Conformal antennas

![Image of aerogel and antennas](image-url)
Flexible Electronics at NASA GRC

- Inkjet-printed two-dimensional 2-bit 4 x 4 phased-array antenna
- Multilayer interconnection scheme used to fabricate the subsystem
- 64 carbon nanotube thin-film transistors form the phase shifter
- Switching controlled by mainframe computer
- 5-GHz RF signal at four steering angles were experimentally demonstrated
- Maximum steering angle: elevation ($\theta$) of 34°, azimuth ($\phi$) of -26.5°
Flexible Electronics at NASA JPL

- Eliminate structure, spacecraft on a substrate
- Printable Spacecraft
  A two dimensional “sheet” that contains all of the functional subsystems of a typical spacecraft - science measurement through data downlink.
- Task elements
  Design, build and demonstrate an end to end spacecraft platform
  Define a scientific reference mission to evaluate the programmatic benefits of infusing printed spacecraft.
  Develop roadmaps for multiple applications and focused mission infusion.
  Test printed electronics coupons in space environments and evaluate compatibility
- Program objectives are to investigate technology that might be achievable in a ten year horizon
- Eliminate structure, spacecraft on a substrate
Glenn Analytical Capabilities

Advanced analytical capabilities available to NASA researchers as well as academia, industry and other government agencies

• Analytical Chemistry
  Atomic Absorption
  Spectrophotometry
• Electron Optics
  Scanning electron microscopes
  Transmission electron microscopes
  Electron microprobe
  Focused ion beam / scanning electron microscope
• X-ray diffraction
  Crystallographic characteristics of metals, ceramics, and polymer specimens

• Metallography laboratory
  Sample preparation (metals, ceramics, and matrix composites thereof)
  Interference layering
  Plasma etching surface preparation
• Optical Microscopes
  MEF3 Reichert metallographs
  Nikon Optiphot binocular microscopes
  Olympus and Wild stereo macrosopes
Glenn Sensors and Electronics Capabilities

- Micro-ElectroMechanical Systems (MEMS)
- Microfabricated thin film sensors
  - Temperature
  - Heat flux
- Chemical species sensors
- Nanotechnology
  - Sensing systems
  - Wireless and embedded communications
  - Large area flexible electronic displays
  - Active matrix light-emitting diode (LED) displays
  - Antennas and Radio
  - Frequency identification (RFID) devices
  - Smart keys and smart cards
NASA Glenn Applicable Expertise

- Power management and distribution
- Nano technology
- Energy conversion and storage
  - Solid-state lithium battery
- Advanced control algorithms
- Thin film solar arrays
- Shape memory alloys (actuators)
- Materials development and assessment
- Systems integration
- Problem solving from a different view point
- Aerospace applications
Flexible Electronics Technology Development

• The commercial electronics industry is leading development in most areas of electronics for NASA applications
• NASA is focused on improving technology and partnering with industry to secure electronics capability for a wide range of aerospace missions
The NASA Glenn Research Center is interested in identifying opportunities to partner with the private sector and academia to advance flexible electronics technology for the NASA mission and, beyond aerospace, to help the spur economic growth in the community.
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