CubeSat Developers' Workshop 2007

SRI International

Alternative Communication Strategies for Picosatellites

Presented by

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SRI International

SRI is a world-leading independent R&D organization

SRI Main Facility, Menlo Park, CA

Sarnoff Corporation Main Facility, Princeton, NJ

- Founded by Stanford University in 1946
  - A nonprofit corporation
  - Independent in 1970; changed name from Stanford Research Institute to SRI International in 1977
- Sarnoff Corporation acquired in 1987 (formerly RCA Laboratories)
- 2,000 staff members combined
  - 900 with advanced degrees
  - More than 20 offices worldwide, including Sarnoff India and SRI Taiwan
- Consolidated 2006 revenue: $411 million

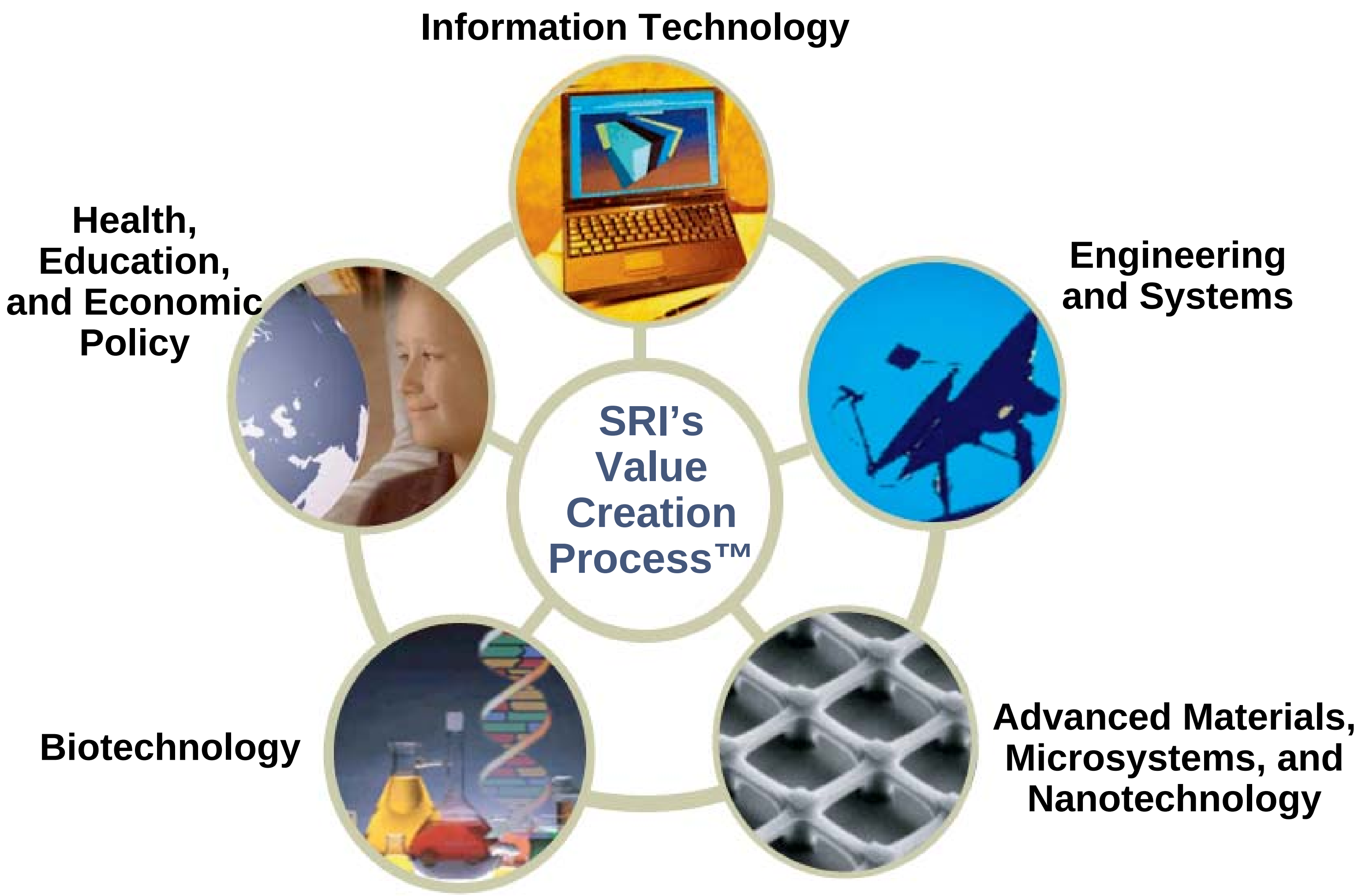
SRI State College, PA

SRI Tokyo, Japan

SRI Washington, DC

SRI Focus Areas

Multidisciplinary teams leverage developments from SRI's core technology and research areas

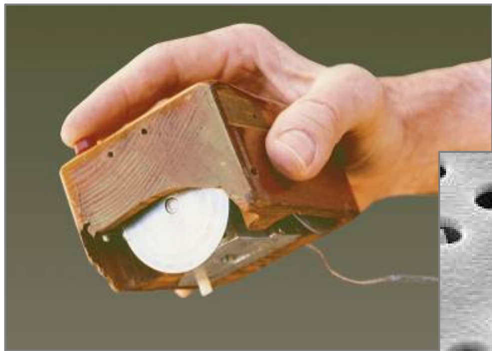


Deep Technical Capabilities

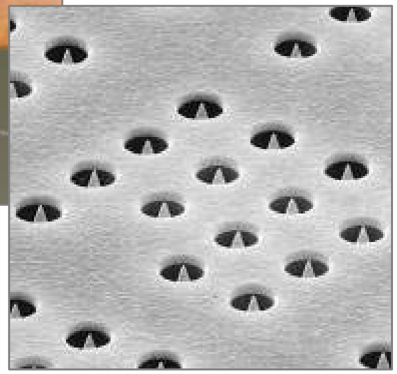
SRI applies interdisciplinary skills to provide solutions to client needs

- Information and computing
- Networks and communication
- Automation and robotics
- Intelligence systems
- Data collection and measurement
- Homeland security
- Automotive
- Energy and environment
- Marine science and technology
- Advanced materials and structures
- Medical devices
- Computational biology
- Biosciences
- Product development
- Education, health, and economic policy
- Complementary capabilities at Sarnoff
- Speech recognition and translation

SRI Technology and Inventions

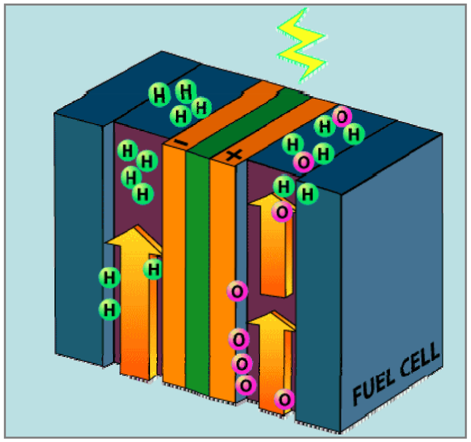


The First Computer Mouse



Micro-volcanoes
for Protein Analysis

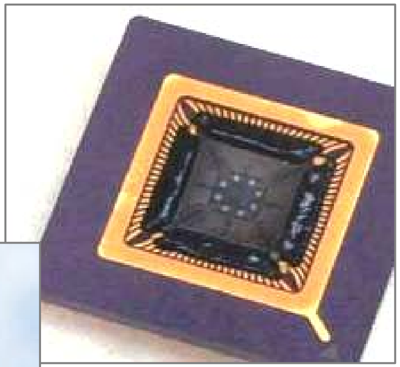
Handheld, Speech-based
Language Translation



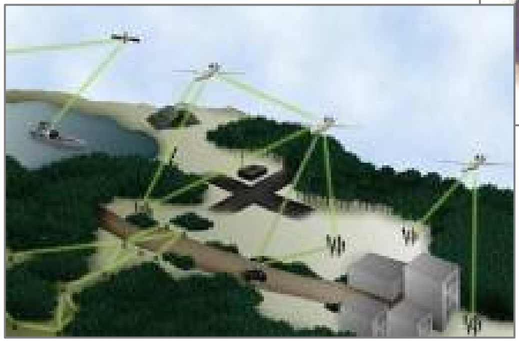
Hydrogen Fuel Cells

High-performance
Polymers

SRI-operated Sondrestrom
Research Facility in Greenland



Molecularly Imprinted
Polymer Gas Sensors



Mobile Ad Hoc Wireless Networks
for First Responders

SRI Space Engineering Systems Laboratory

- Picosatellite Payload Development
- Earth Station
- Life Test System

UHF Earth Station Construction

SRI Big Dish Antennas

- 150-foot dish

  Tracking capability: 1°/s

  Resolution: 0.01°

  Elevation: 3° to 87°

  Frequency: Up to ~1.5 GHz

- 60-foot dish

  Tracking capability:

    4°/s azimuth

    1°/s elevation

  Resolution: 0.04°

  Frequency: Up to ~3 GHz

SRI 150-foot Dish

Picosatellite Communications

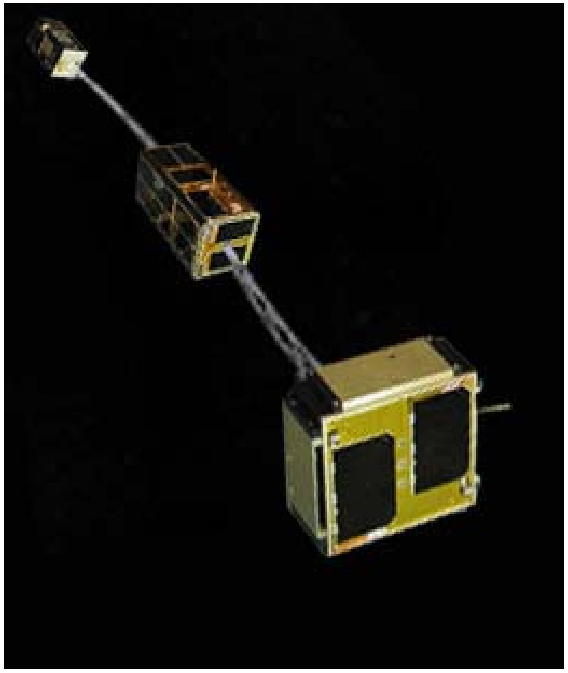
Current CubeSat Communications Paradigm

- Communication frequencies
  - Amateur
  - Dedicated
  - ISM
- Equipment
  - Off-the-shelf components
  - Amateur radios
  - ISM radios
- Earth stations
  - Amateur stations
  - Individual lab stations

ICOM 910H

Lessons Learned from Previous Launches

- Large numbers of small satellites
  - Problems with satellite localization
- Similar frequencies
  - Satellite discrimination issues
- Higher frequencies
  - Require better pointing accuracy
- Spread spectrum radios
  - Latency and handshaking make communication more difficult



MAST Satellite

Future Directions in Picosatellite Communications

- Upgraded Current Capabilities
- Inter-Satellite Communications
- Ground Station Networking
- Software Defined Radio
- Phased Array Antennas

Upgraded Current Capabilities

- Higher Frequencies
  - Potential for greater throughput
  - Better pointing accuracy required
  - Fewer off-the-shelf resources
- Optical Frequencies
  - No FCC license necessary
  - Potentially more data throughput
- Antennas
  - Directional antennas provide more efficient radiation patterns
  - Microstrip antennas require very little space
  - Memory alloy structures for deployable antennas

Inter-Satellite Communications

- Network Standards
  - Allow for possibility of communication between different types of physical links
- Ad Hoc Networking
  - Enables dynamic networking between satellites
- Better Link Margins
  - Lower power communications with better data throughput
- Dedicated Inter-Satellite Frequencies
  - Allows increased security
- Data Forwarding
  - Allows access to real-time data while satellite is not visible
- Dedicated Communication Satellite
  - A larger dedicated communication satellite could allow low power picosatellite communications

Ground Station Networking

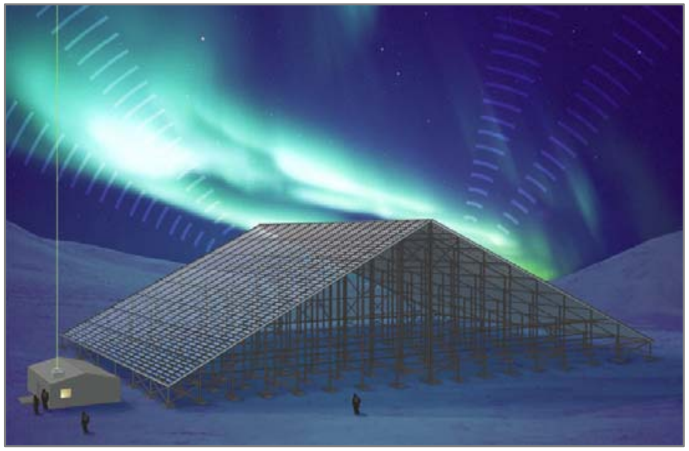
- Advantages
  - Increased operations for ground station operators
  - More data throughput
  - Takes advantage of idle earth stations
  - Allows participation without individual earth stations
- Disadvantages
  - Requires standard equipment
  - Security concerns
  - FCC licenses require transmission only over US
- GENSO

Software Defined Radio

- Advantages
  - Specialized modulation schemes available
  - Enables multiple comm links on one satellite
  - Enables policy-based communication
  - Requires less dedicated hardware
  - Flexibility
- Disadvantages
  - Much longer development time
  - Not necessarily compatible with other ground stations

Phased Array Antennas

- Phased Array Antennas
  - By delaying the feed to each antenna element, constructive and destructive interference result in the ability to “steer a beam” with very fine precision, and little waste radiation in undesired directions
- Advanced Modular Incoherent Scatter Radar (AMISR)
  - NSF-sponsored installation for space weather
  - Collaborative effort, led by SRI
  - 430 to 450 MHz



AMISR Conceptual Drawing

AMISR Installation at Poker Flat, Alaska

Phased Array Antennas

Ground-based

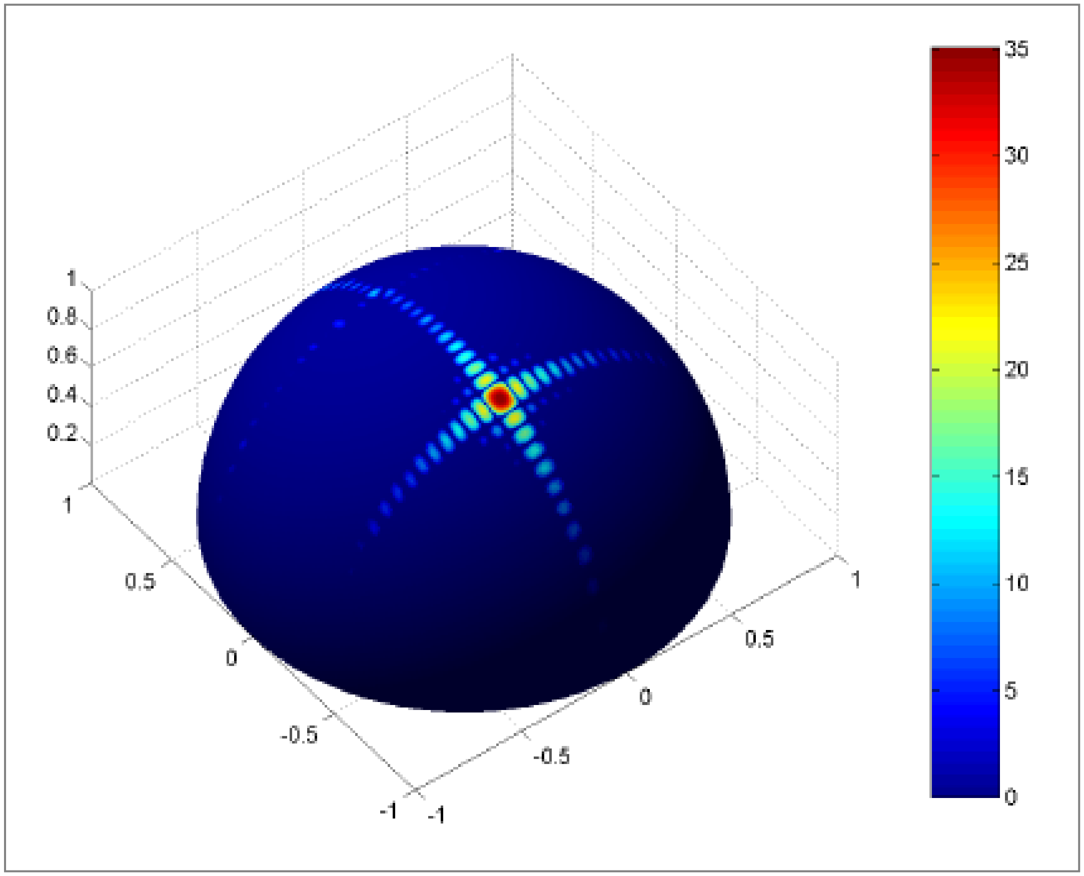
- Beamforming
- Simultaneous tracking of multiple satellites
- Simultaneous tracking at multiple frequencies

AMISR Antenna Elements

Phased Array Antennas

Satellite-based

- Inter-Satellite Links
  - Patch antennas on multiple sides could communicate with several satellites in different locations at once
  - Either attitude determination or stabilization could allow dynamic links
- Satellite-to-Ground Link
  - Attitude and orbit knowledge enable beam pointing, which means less power is required

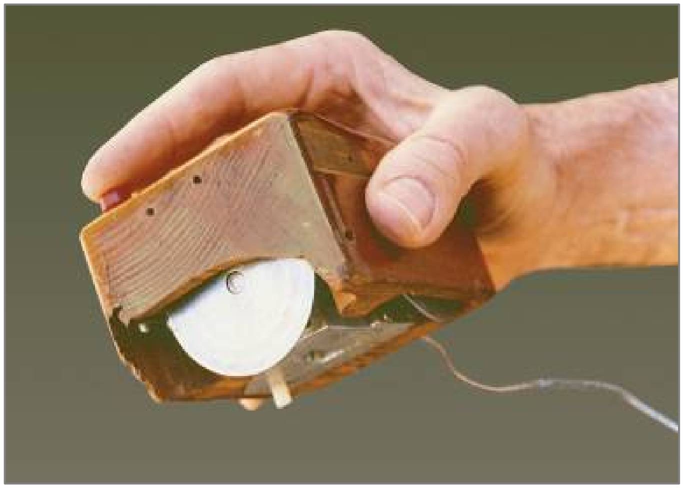


AMISR Radiation Power

Backup Information

Information and Computing

Pioneering next-generation, disruptive technologies



1964–1968: SRI's Doug Engelbart and team invented the computer mouse and demonstrated the foundations of personal computing

Handheld, speech-based language translation

- Speech
  - Recognition and translation
  - Natural language understanding
- Networks and distributed computing
  - Information security
  - Mobile and wireless communications
- Artificial intelligence
  - Intelligent assistance
  - Vision systems
  - Collaborative mobile robots
- System reliability
  - Formal methods for design and analysis
  - IC and complex system verification
- Software systems
  - Intelligent project planning and tracking
  - Decision aids

SRI International®

Networks and Communication

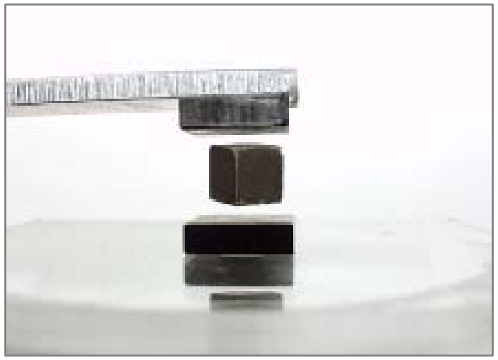
Operationally effective systems for government and commercial clients

Mobile ad hoc wireless networks for first responders

- Network-centric systems
  - Intelligent planning
  - Self-configuring information flows
  - Wireless, mobile, ad hoc networks
  - Modeling and simulation of networks and communications
- Testing and training
  - Instrumentation for military testing and training
  - Live-virtual-constructive training systems
- Intelligent system applications
  - Distributed speech
  - Distributed natural language
  - Distributed robots
- Secure networks

Automation and Robotics

From the world's first reasoning robot to the latest advances



Diamagnetic levitation

- Advanced materials for automation
  - Electroactive polymer "artificial muscle"
  - RF (radio frequency) tags
- Robots
  - Inspection systems
  - Micro robots
  - Collaborative robots
- Robotics
  - Video and image understanding
  - Machine vision systems for document understanding
  - Manufacturing and materials handling
- Transport: diamagnetic levitation
  - Ultra-clean transport
  - Medical laboratory automation

Intelligence Systems

Meeting national defense and other needs from field support to end-to-end, secure information management systems

National intelligence support

- Signal technology
  - National intelligence processing and reporting systems
  - Advanced signal processing and geolocation algorithms
- Intelligence and information systems
  - Computer tools, simulations, and networks in support of information warfare and tactical intelligence systems
  - Simulation suites for intelligence collection systems
- Communications and signal technology
  - Communications system design, development, signal processing, and testbeds
  - Advanced terrestrial and space antenna systems
- Information operations
  - Offensive and defensive

Data Collection and Measurement

State-of-the-art sensing and information processing

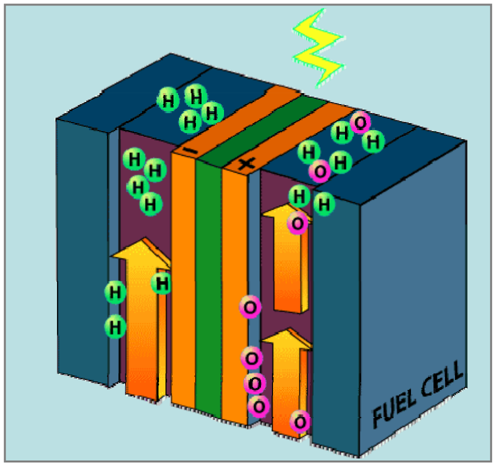
The SRI "Dish" in the hills above Stanford University

SRI-operated Sondrestrom Research Facility in Greenland

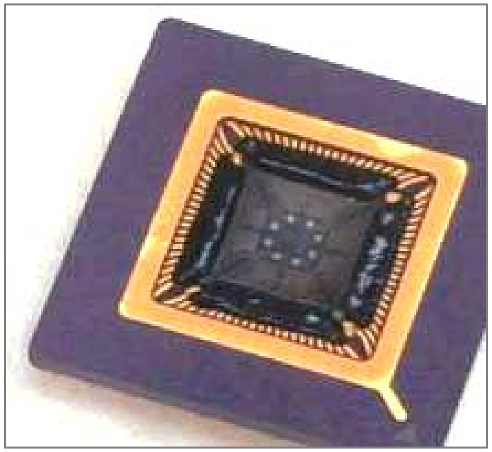
- Radio frequency systems
  - Radio and astronomical measurements
  - Foliage- and ground-penetrating radar
  - Over-the-horizon radar
- Intelligent pattern recognition
  - Radar
  - Multisensor
- Sensors
  - Custom wireless embedded sensors
  - Signal processing
- Environmental impact
  - Analyses
  - Planning and systems design

Energy and Environment

From basic research to pilot tests and commercialization



Hydrogen fuel cells

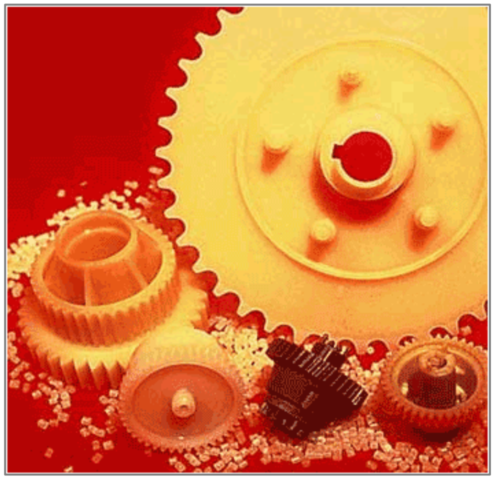


Molecularly imprinted polymer gas sensors

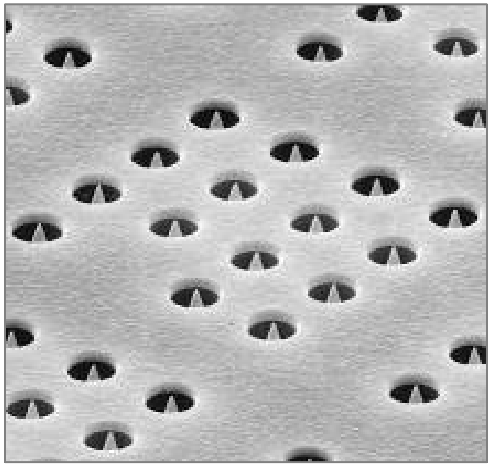
- Energy
  - Long-life batteries
  - Fuel cells
  - Solar cells
  - Hydrogen fuel generation, storage, and distribution
- Environment
  - Waste destruction
  - Potable water production
  - Biodegradable materials
  - Microsensors and systems
  - Noise suppression and vibration control
  - Ultrasensitive hazardous materials detection
  - Handheld biological and chemical sensors

Advanced Materials and Structures

From basic research to pilot tests and commercialization



High-performance polymers



Micro-volcanoes for protein analysis

- Materials
  - Nano materials
  - Polymers
  - Coatings and ceramics
  - High-temperature materials
  - OLEDs (organic light-emitting diodes)
- Processes
  - Catalysis
  - Analytical chemistry
  - Optical technologies
- Microstructures
  - Nano devices and microelectronics
  - MEMS and NEMS
- Structural design
  - Blast containment
  - Structural testing and failure mechanics