Inertial sensors can be used for short-term dead-reckoning of position. Imaging sensors can be used for sensing the local 3-D landscape, including buildings, vegetation, and other obstructions. This local sensing is very important for collision avoidance, landmark identification, and surveillance.

Prof. Khalil Najafi is investigating the design and fabrication of new MEMS inertial sensors (e.g., accelerometers or gyroscopes) which mimic biological hairs. These sensors feature tall, 3-D structures for increased sensitivity, as well as the use of arrays with local signal processing for increased sensitivity, dynamic range/multiplicity of function, and redundancy/robustness.

Miniaturized electromagnetic echolocation is being implemented for navigation, surveillance, and obstacle detection. The revolutionary approach in this technology, being developed by Prof. Kamal Sarabandi, Dr. Jack East, and Dr. Leland Pierce, is to enable an operational low-cost, low-power, lightweight Y-band radar with beam-steering capability. Advancements being made in scanning, filtering, modulation, and antennas will enable a system needing only 200mWatts of peak power, in a volume less than 50cm³, with a weight of 5 grams.

Prof. Euisik Yoon is investigating the design of sensors that can sense self-motion via optical flow in hybrid analog/digital hardware on-chip. One sensor enables the sensing of rotational motion, while another provides for linear motion.

Prof. Kamal Sarabandi is researching energy-efficient receiver architectures incorporating an RF MEMS filter-bank frontend to increase battery lifetime. Because channel selection is achieved at the front end, a fully digital demodulator can be used.

The proposed transceiver architecture utilizes high-Q, low-loss mechanical signal processors wherever possible to implement not only frequency filtering, but also mixing, T/R switching, phase-shifting, and frequency generation. The specific mixer-filter device is being developed by Prof. Clark Nguyen at Berkeley. The inputs are coupled to a free-free beam filter structure via torsional phase-shifting beams in order to affect a quadrature (image-reject) mixer-filter function that can potentially eliminate the need for an RF image-reject filter in the architecture.

Prof. Amir Mortazawi is exploring the use of BST switchable bandpass filters to enable efficient, low power integrated reconfigurable transceivers. These BST switchable filters rely on the electrostrictive effect in BST material which recently has been observed.

The key communications research goal is to allow the platform to communicate over or eavesdrop on any communications channel in the frequency range from 100MHz to 5GHz, allowing the platform to communicate over or listen to virtually any proprietary military, or civilian wireless standard (e.g., NTTR, FTR, GSM, CDMA, WiFi). The research to accomplish this is a targeted combination of MEMS/BST filtering, modulation, demodulation, and antenna technology that will be used to build the radio.

A 24GHz beam steering link provides very high-bandwidth, robust communication to a mobile base-station or flying robot. The high bandwidth allows very large amounts of information to be quickly relayed. Beam steering not only allows more effective use of the transmit energy, but also provides resilience to jamming and eavesdropping. A novel fully-digital beam steering technology is being developed for this by Prof. Michael Flynn. This digital approach is more adaptable, more accurate and more power efficient than conventional MEMS-based techniques.

Prof. David Wentzloff is researching energy-efficient receiver architectures incorporating an RF MEMS filter-bank frontend to increase battery lifetime. Because channel selection is achieved at the front end, a fully digital demodulator can be used.

Using biomimetic technologies, Prof. Kamal Sarabandi is building a sensor and communication platform with a volume of 0.1cm³, weight of 1 gram, lifetime of 76 hours, and communication range of up to 100m. The volume and weight represent a 100-fold improvement over current capability. The separate radio repeaters can network among themselves and with the sensing platform as needed.

Prof. Ken Wise is researching the design and fabrication of a fast high-sampling rate digital approach called a micro gas chromatograph. These devices are targeted to sense the presence of chemical agents with ppb detection levels operating at 10mW and occupying less than 5cm, with detection speeds of less than 10 seconds.

Liquid-based biomimetic hair-like structures can be microfabricated using a novel technology developed by Prof. Khalil Najafi. Combining electrostatic transduction with microhydralic amplification enables low-power, high-force/high-deflection sensing/actuation. Air flow sensing at extremely-low-flow levels (sub-10cm/s) is possible, while an array of micro-hydraulic cells with high force sensitivity can be used for tactile imaging.

Prof. Yogesh Gianchandani is researching ways to make small, low-power, yet highly-sensitive nuclear radiation detectors. These detectors are inherently capable of wireless signaling, and can be deployed as single units or in distributed networks.

While radar is useful for imaging in the dark and otherwise obscured scenarios an alternative method to use infrared imaging. Prof. Mina Rais-Zadeh is developing a sensing technology with the promise of providing a solution with much lower power based on coupled phonon-electron-phonon interactions.
COMBAT Center Faculty

Kamal Sarabandi, Center Director
Developing miniaturized reconfigurable antennas, mm-wave radar.

David Blaauw, Processing Team Leader
Developing ultra-small and low-power micro gas chromatograph for airborne chemical concentration sensing.

Khalil Najafi, Center Deputy Director, Navigation Team Leader
Developing HAIR technology for sensing and actuation.

Leland Pierce, Center Coordinator
Developing simulation code for radar to explore navigation issues.

Joseph Giachino, Technology Transition Leader
Working to transfer new technology to government research labs and industry.

Michael P. Flynn, Communication Team Leader
Developing 24GHz modulator for phased-array applications.

Ken D. Wise, Sensors Team Leader
Developing micro gas chromatograph for airborne chemical concentration sensing.

Dennis Sylvester, Processing Team Leader
Developing low-power, high-speed computing technology.

David Blaauw, Processing Team Leader
Developing low-power, high-speed computing and memory technology.

Jack East, Sensors Team Leader
Developing mm-wave devices and fabrication technology for mm-wave radar.

Stephen R. Forrest, Power Generation Team Leader
Developing flexible solar cells for power generation on the wings.

Yogesh B. Gianchandani, Sensors Team Leader
Developing ultra-small and low-power radiation sensor.

Amir Mortazawi, Communications Team Leader
Developing a low-power filter bank at 2.4GHz for communications applications.

Clark T.-C. Nguyen, Communications Team, University of California at Berkeley
Developing a low-power filter bank at 400MHz for communications applications.

Mina Rais-Zadeh, Sensors Team Leader
Developing low-power infrared imaging sensor.

David D. Wentzloff, Communications Team Leader
Developing all-digital demodulator at 400MHz for communications applications.

Euisik Yoon, Navigation Team Leader
Developing an optical-flow imaging sensor.

Jeramy Zimmerman, Power Generation Team Leader
Developing a high-efficiency, flexible solar panel for the wings.

Research Overview
Power Generation Subsystem

The system employs flexible lightweight, high-efficiency, reconfigurable solar panels as well as a battery, a supercapacitor and power conditioning circuitry. Along with the battery, a supercapacitor is used for storing power and also for providing peak current.

Processing Subsystem

A key element of unmanned vehicle navigation and data acquisition is ultra-high performance data processing capabilities. To allow integration of such processing capabilities in a small air or ground vehicle with today’s or near future power technologies, one or two orders of magnitude of power reduction must be obtained over current data processing technologies. This work is being researched by Prof. Dennis Sylvester and David Blaauw.

The energy per operation of a small processing element with supply voltage scaling down to 250mV demonstrates as much as 20 times energy efficiency improvement over traditional operation at full voltage. If we can successfully operate at 100mV, energy efficiency will improve by over two orders of magnitude, showing the potential of ultra-low voltage operation. To achieve such low operating voltages, we will need to maintain high transistor utilization – this can be handled by aggressive pipelining and parallelism.

About the Center

The Center’s vision is to create new approaches and incorporate bio-mimetic methods for low-cost, low-power, durable, fault-tolerant, miniaturized, packaged electronic systems for intelligent sensors, transceivers, and navigational aids, aimed at boosting military situational awareness in urban environments. To achieve this, the Center is making advances in fundamental research and technology, and demonstrating the feasibility of the research through sensor testbeds, while also transitioning resulting technology to the Army.

A flying bat is used as an integrating vision for the microsensor platform, which includes many bio-mimetic and bio-inspired research approaches. For example, just as a bat must hunt for food for its energy, our system is powered through solar energy scavenging, as well as through the energy stored on-board. While bats communicate and sense using ultrasound, our vision for the robotic testbed is designed around electromagnetic solutions. We are employing optical, IR, and mm-wave radar vision sensors for communication. Our sensing solutions emulate many of the bat’s sensors, including: high-resolution stereo vision, uncooled IR imaging, mm-wave radar (a bio-mimetic analog of a bat’s echolocation sense), a small gas chromatograph for smelling and chemical detection, a nuclear radiation sensor, inertial navigation, vibration, and temperature sensors, power usage monitoring, passive audio, and GPS. Finally, our platform is incorporating bio-inspired highly-parallel, low-power electronics with reconfigurable architectures, which enables sensor processing as well as actuator control and planning capabilities, resulting in truly autonomous behavior.

Kamal Sarabandi, Center Director
University of Michigan
Electrical and Computer Engineering - EECS Dept.
1301 Beal Ave, Room 3228, Ann Arbor, Michigan 48109-2122
(734) 764-0500 • saraband@umich.edu

www.michigancmes.org