previous *NASA Tech Briefs* articles. Active-pixel integrated-circuit image sensors that can be programmed in real time to effect foveal artificial vision on demand are one such example. What is new in SyFT is a synergistic combination of recent advances in foveal imaging, computing, and related fields, along with a generalization of the basic foveal-vision concept to admit a synthetic fovea that is not restricted to one contiguous region of an image.

The figure depicts a mesh-connected SyFT architecture as applied to a focal-plane mosaic of homogeneous or heterogeneous image sensors. The architecture provides a networked array of reprogrammable controllers for autonomous low-level control with on-the-fly processing of image data from individual image sensors. Each image sensor in the mosaic focal plane is mapped to one of the controllers so that taken together the reprogrammable controllers constitute a conceptual (though not necessarily a geometric) image-processing plane corresponding to the mosaic focal plane. The controllers can be made versatile enough to control and to process pixel data from both charged-coupled-device (CCD) and complementary metal oxide/semiconductor (CMOS) image sensors in the mosaic focal plane. The image sensors can also have multiple pixel data outputs where each output has dedicated processing circuitry in its associated controller to achieve high throughput with real-time processing for feature detection and processing.

Each controller includes a routing processor to implement the network protocol and define the network topology for real-time transfer of raw pixel data and processed results between controllers. The network protocol and the capability to implement it are essential to realization of the capability for synthetic foveal imaging across the entire mosaic focal plane. The processing and networking capabilities of the controllers will enable real-time access to data from multiple image sensors, with application-level control of one or more ROI(s) within the mosaic focal plane array for sharing of detected data features among controllers. These capabilities will effectively facilitate the equivalent of rewiring and reconfiguration with different sensors in the mosaic, with scalability to different mosaic sizes dictated by application requirements. Consequently, the mosaic focal plane is treated as an integrated ensemble of synthetic foveal regions that can traverse the entire mosaic for autonomous intelligent feature detection and tracking capability. Unlike the current state-of-the-art in image sensors, "SyFTing" enables intelligent viewing through vast amounts of image data by treating a mosaic focal plane of sensors as an integrated ensemble rather than a collection of isolated sensors.

Airborne Antenna System for Minimum-Cycle-Slip GPS Reception

## The antenna is kept pointing upward as the airplane banks.

Goddard Space Flight Center, Greenbelt, Maryland

A system that includes a Global Positioning System (GPS) antenna and associated apparatus for keeping the antenna aimed upward has been developed for use aboard a remote-sensing-survey airplane. The purpose served by the system is to enable minimum-cycle-slip reception of GPS signals used in precise computation of the trajectory of the airplane, without having to restrict the airplane to maneuvers that increase the flight time needed to perform a survey.

"Cycle slip" signifies loss of continuous track of the phase of a signal. Minimum-cycle-slip reception is desirable because maintaining constant track of the phase of the carrier signal from each available GPS satellite is necessary for surveying to centimeter or subcentimeter precision. Even a loss of signal for as short a time as a nanosecond can cause cycle slip. Cycle slips degrade the quality and precision of survey data acquired during a flight.

The two principal causes of cycle slip
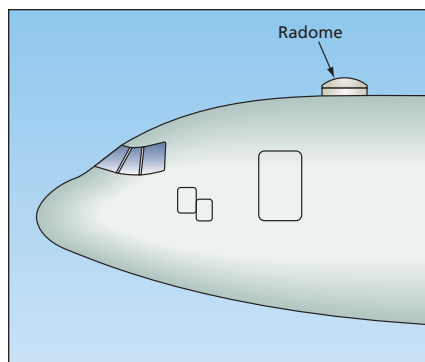
The **Radome Atop the Fuselage** of the NOAA hurricane-hunting airplane houses the present minimum-cycle-slip GPS antenna system.

are weakness of signals and multipath propagation. Heretofore, it has been standard practice to mount a GPS antenna rigidly on top of an airplane, and the radiation pattern of the antenna is typically hemispherical, so that all GPS satellites above the horizon are viewed by the antenna during level flight. When the airplane must be banked for a turn or other maneuver, the reception hemisphere becomes correspondingly tilted; hence, the antenna no longer views satellites that may still be above the Earth horizon but are now below the equatorial plane of the tilted reception hemisphere. Moreover, part of the reception hemisphere (typically, on the inside of a turn) becomes pointed toward ground, with a consequent increase in received noise and, therefore, degradation of GPS measurements.

To minimize the likelihood of loss of signal and cycle slip, bank angles of remote-sensing survey airplanes have generally been limited to 10° or less, resulting in skidding or slipping uncoordinated turns. An airplane must be banked in order to make a coordinated turn. For small-radius, short-time coordinated turns, it is necessary to employ banks as steep as 45°, and turns involving such banks are considered normal maneuvers. These steep banks are highly desirable for minimizing flight

times and for confining airplanes as closely as possible to areas to be surveyed.

The idea underlying the design is that if the antenna can be kept properly aimed, then the incidence of cycle slips caused by loss or weakness of signals can be minimized. The system includes an articulating GPS antenna and associated electronic circuitry mounted under a radome atop an airplane. The electronic circuitry includes a microprocessor-based interface-circuit-and-data-translation module. The system receives data on the current attitude of the airplane from the

inertial navigation system of the airplane. The microprocessor decodes the attitude data and uses them to compute commands for the GPS-antenna-articulating mechanism to tilt the antenna, relative to the airplane, in opposition to the roll or bank of the airplane to keep the antenna pointed toward the zenith.

The system was tested aboard the hurricane-hunting airplane of the National Oceanic and Atmospheric Administration (NOAA) [see figure] during an 11-hour flight to observe the landfall of Hurricane Bret in late summer of 1999. No bank-

angle restrictions were imposed during the flight. Post-flight analysis of the GPS trajectory data revealed that no cycle slip had occurred.

Improved Starting Materials for Back-Illuminated Imagers
Thin, highly doped layers are no longer degraded by high-temperature annealing.

NASA's Jet Propulsion Laboratory, Pasadena, California

An improved type of starting materials for the fabrication of silicon-based imaging integrated circuits that include back-illuminated photodetectors has been conceived, and a process for making these starting materials is undergoing development. These materials are intended to enable reductions in dark currents and increases in quantum efficiencies, relative to those of comparable imagers made from prior silicon-on-insulator (SOI) starting materials.

Some background information is prerequisite to a meaningful description of the improved starting materials and process. A prior SOI starting material, depicted in the upper part the figure, includes:

- A device layer on the front side, typically between 2 and 20 μm thick, made of p-doped silicon (that is, silicon lightly doped with an electron acceptor, which is typically boron);
- A buried oxide (BOX) layer (that is, a buried layer of oxidized silicon) between 0.2 and 0.5 μm thick; and
- A silicon handle layer (also known as a handle wafer) on the back side, between about 600 and 650 μm thick.

After fabrication of the imager circuitry in and on the device layer, the handle wafer is etched away, the BOX layer acting as an etch stop. In subsequent operation of the imager, light enters from the back, through the BOX layer. The advantages of back illumination over front illumination have been discussed in prior *NASA Tech Briefs* articles.

For reasons too complex to discuss within the space available for this arti-

cle, one modification that is necessary for reducing dark current and increasing quantum efficiency is the incorporation of a thin, heavily doped (e.g., p^{++}-doped with boron) silicon layer between the lightly doped device layer and the BOX layer. In prior research, an attempt to incorporate a thin, heavily doped layer by implanting boron at the BOX/device-silicon interface before

bonding the BOX layer to the handle wafer did not yield the desired doping profile: The bonding process unavoidably included a high-temperature anneal that caused the implanted boron to diffuse away from the interface, thereby causing an undesired decrease in the doping concentration at the interface and an undesired increase in the doping concentration in the device layer.
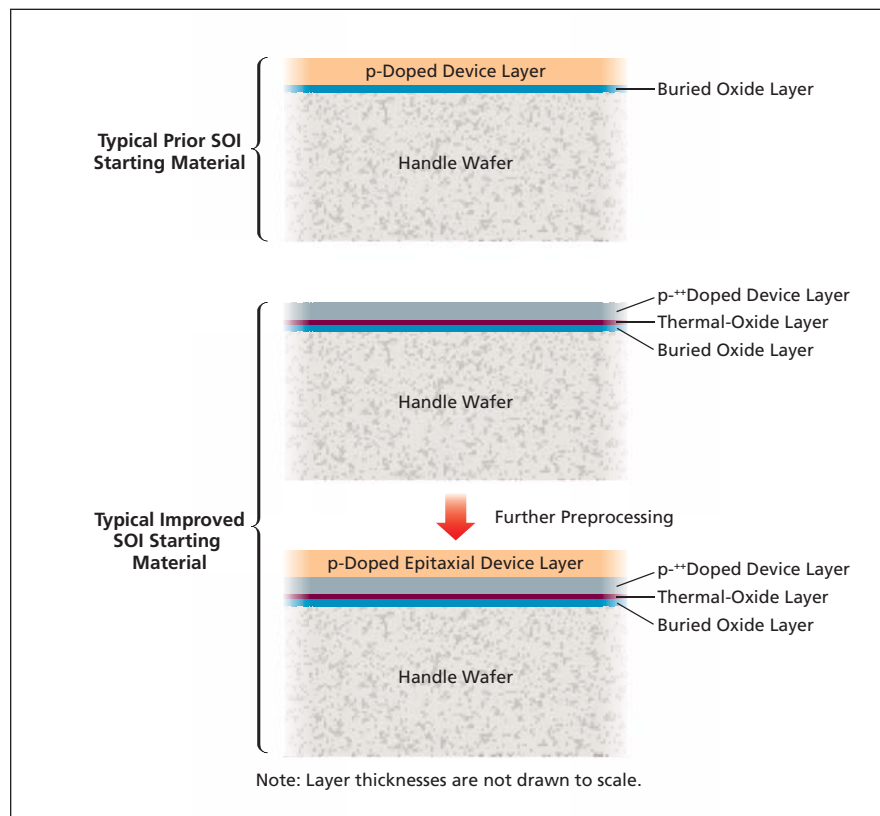
An **SOI Starting Material** of the present improved type differs from a typical prior SOI starting material in several respects.