

how it works

THE SKYCAM MOBILE CAMERA SYSTEM CAN QUICKLY AND ACCURATELY MOVE ANYWHERE WITHIN A 3-D SPACE.

Flying over the action

By Robert Cravotta, Technical Editor

NOT TO BE CONFUSED with stationary, mounted cameras on top of buildings all over the country to monitor weather and traffic patterns, CF Inflight's Skycam is a robotic camera system that can dynamically view a sports field, arena, or concert stage from nearly anywhere and any angle within a defined

space. The system has been used in football, basketball, and boxing broadcasts, as well as at the X-Games and Olympics, and it won an Emmy award for outstanding engineering achievement of 2002. At less than 30 lbs, the 36-in.-tall Skycam can "fly" at 28 mph from any point in a large, 3-D space to any other point to provide a unique view of a sporting or an entertainment event.

The Skycam system includes a camera assembly, a gyroscopic stabilization and camera-control system, a four-point cable-suspension system, fiber-optic video and data transmission, and a computerized controller that supports one or two operators. The camera assembly comprises a Panasonic AW-E800 camera that uses a $\frac{2}{3}$ -in. IT (Interline Transfer) Type 3 CCD

system with a Fuji graphics-quality lens to deliver approximately 850 lines of resolution across an SDI (serial-digital-interface) output. The camera system also features 2-lux low-light sensitivity and a 65-dB SNR.

The spar is the structure that houses the Skycam's remote components, which ride the suspension-cable system (**Figure 1**). It allows the weight of the control electronics housed above the suspension system to neutrally match the weight of the camera assembly below the suspension system. Balancing the weight of the remote components above and below the suspension system allows the Skycam to use lightweight gyroscopic stabilizing mechanics to achieve more stable movement and a steadier image while moving.

The upper section of the spar houses the stabilization sensors, pan motor, power-distribution system, fiber-optic-communication components, and local processing boards for stabilizing and controlling the camera (see **sidebar** "Real-time control"). The lower section houses the camera, camera yoke, and tilt motor. Balanced at the spar's center of grav-

ity is the reel system that forms the heart of the four-point cable-suspension and control system.

The Skycam's freedom of movement depends on four 0.1-in.-diameter, Kevlar-braided suspension cables, each with a tensile strength of 600 lbs. They connect the spar to four anchor points, such as the light stanchions in a stadium (**Figure 2**). Each suspension cable goes



The spar provides a balanced structural platform for the camera, yoke, tilt motor, stabilization sensors and controller, and the cable-spooling mechanism, also known as the reel.

Figure 1

over a pulley and attaches to a spooling mechanism, known as a reel. The four reels work together to enable the Skycam to fly throughout the space within the four anchor points.

Commanding all of the reels to simultaneously pull in the cable raises the Skycam to a higher altitude. Likewise, commanding all of the reels to simultaneously release the cable lowers the system's altitude. Commanding two of the reels to pull in and the other two reels to let out simultaneously moves the Skycam laterally. A dedicated processor controls each reel. The central control computer instructs and coordinates the actions of the four reels and collects response and safety information through a fiber-optic network.

The Skycam uses single-mode fiber optics that run along each suspension cable to support higher resolution picture quality. This system also increases the data and communication reliability between the Skycam and the central control computer with redundancy by sending signals over all of the fiber-optic lines. Using fiber optics mitigates signal interruptions and avoids the distance and line-of-sight safety constraints that a wireless-

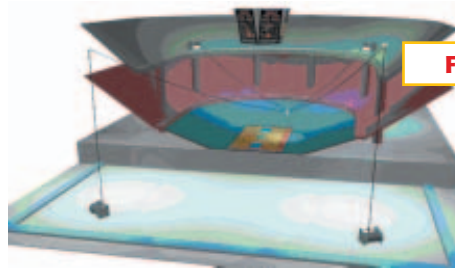


Figure 2

Four 0.1-in.-diameter cables suspend the Skycam between four stable, reinforced anchor points, allowing it to move anywhere inside the 3-D space within the four anchor points and avoid obstructions.

transmission approach could necessitate.

The central control computer, in real time, monitors more than 80 sensor- and performance-based parameters, interprets the operator's joystick commands, tracks the Skycam's position, converts the operator's commands into positional coordinates, and synchronizes the action of each reel so that the Skycam performs the proper motion. The central

control computer supports single- or dual-operator modes to control the Skycam motion and camera. If there are two operators, the second operator can focus on controlling the camera functions, such as pan, tilt, zoom, iris, and focus.

The central control computer allows the operators to focus on capturing the action by performing obstacle avoidance. Before deploying the Skycam, the operator describes any obstacles in the fly space. The operator abstracts the obstacles, such as a scoreboard, a column, goal posts, or fan seating, as primitive shapes and enters them into the Skypath software. The primitive shapes include planes, spheres, cones, boxes, cylinders, and four-point planes called curtains. When the Skycam is moving, the Skypath software prevents the camera and suspension lines from hitting any of the obstacles and, if

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possible, directs the Skycam around the obstacles.

The Skypath software can provide further assistance for the operators beyond obstacle avoidance. The operator can define custom reference points within the flight space to assist navigating and simplify common or repetitive actions. The software does not yet include image recognition and tracking to assist the operator in keeping the camera on the action, but it would not be surprising if such a feature became part of the system in the near future. □

REAL-TIME CONTROL

The Skycam relies on x86 processors to implement local, real-time motor control for each reel; collect positional and safety data; and perform network-based communication with the central control computer. The processors control each reel with a precision of 0.01 in., so that the camera can move around smoothly without bouncing. The central control computer runs the Skypath software over the Windows operating system.

Early versions of the Skycam ran MS-DOS as the operating system for the local control processors. Recently, Skycam developers migrated the operating

system for the local processors to embedded Linux. A key consideration for migrating the original operating system was to obtain support for a distributed network between the local processors and the central control computer.

Linux has its roots as an operating system suited for soft, real-time applications, such as for servers and workstations, that manifested itself as jerky flight motion as the flight speed increased. The jerkiness in movement was due to the nondeterministic variability for the operating system's response time when task switching, especially when moving the Skycam near

its maximum speed.

The developers were able to port their previous Linux operating-system-migration efforts to LynxOS, a hard-real-time, Linux-compatible operating system. The developers removed portions of code that were initially written to avoid the Linux-kernel timing issues and were able to incorporate the priority inheritance protocol as defined by the Posix.1c pthreads standard. These changes and the real-time determinism of the operating system significantly improved the maximum speed that the Skycam could move while maintaining the necessary camera stability.