NEWS RELEASE

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CONTACT: Stanford University News Service (650) 723-2558

A brief history of satellite navigation

STANFORD -- Getting lost soon may be a problem of the past.

The reason: the growing use of radio signals from satellites for navigation.

With handheld receivers that cost less than $300, users can determine their position anywhere on the globe, provided they are outside and have a clear view of the sky. When combined with a computerized map, such receivers can pinpoint an individual or a vehicle's location on a given street within 30 feet.

More than 60,000 of these receiver sets are sold each month, for myriad purposes. Rental car companies equip luxury cars with satellite receivers and computer maps to help customers navigate. Scientists use the receivers to study the movement of animals in the wild. Ambulance drivers calculate the shortest route to pick up heart attack victims. Geophysicists track the motion of earthquake faults.

This revolution in navigation is the consequence of the development of a military satellite navigation system called the Global Positioning System/NAVSTAR, developed in the 1970s under the direction of Bradford W. Parkinson, now Stanford professor of aeronautics and astronautics, and a U.S. Air Force colonel at the time.

On May 17, Parkinson discussed his experiences in the evolution of satellite navigation, which has spawned a whole new research area at Stanford under his direction. Current research, sponsored by the Federal Aviation Administration, includes contracts and grants exceeding $12 million. Specific research areas include control of small model aircraft and robotic farm tractors. More than 25 graduate students are involved in GPS-related research. Other Stanford faculty members involved are Robert Cannon, the Charles Lee Powell Professor of Aeronautics and Astronautics; Per K. Enge, research professor of aeronautics and astronautics; J. David Powell, professor of aeronautics and astronautics; and Bernard Widrow, professor of electrical engineering.

The story of the system began Oct. 4, 1957, when the Soviets launched Sputnik, the first artificial satellite to orbit the Earth, Parkinson said in his lecture. Two researchers at the Johns Hopkins Applied Physics Laboratory in Baltimore -- William Guier and George Wiefenbach -- figured out a way to determine Sputnik's orbit simply by measuring the Doppler-induced changes in the frequency of the simple radio signal that it transmitted.

Several years later, Parkinson said, another APL scientist, Frank McClure, was seeking a system that would allow Polaris nuclear submarines to keep precise track of their locations. He realized that this could be done by "inverting" the approach of Guier and Wiefenbach. That is, by measuring a radio signal from a satellite whose position is known, a submarine could determine its own position.

McClure persuaded a colleague, Richard Kerschner, to design a system of satellites that would provide navigation information. The system, TRANSIT, began operating in 1964, with five satellites that broadcast two different tones. The use of two tones allowed the system to compensate for variable signal delays that occurred in the ionosphere. (One satellite became oriented upside down, its antenna pointing away from Earth, and due to limitations of its stabilization system could not be re-oriented. But the remaining satellites were adequate.) It took the submarines six to 10 minutes to get a fix, which was accurate to within 25 meters, Parkinson said.

Meanwhile, the Naval Research Laboratory and the Space and Missile Systems Organization of the U.S. Air Force favored different satellite navigation systems.

The naval lab backed the TIMATION program, which used high-precision clocks to provide both accurate position and precise time measurements to ground observers. The time measurements improved the system by allowing more precise determinations of the satellite location and lengthening the time between required position updates. Two TIMATION satellites, each bearing a quartz clock accurate to one part per billion, were orbited: one in 1967 and the other in 1969.

The Space and Missile Systems Organization pushed a program called 621B, which used a signal that employed pseudo-random noise to resist jamming. Unlike the various Navy systems, 621B provided altitude, as well as latitude and longitude. "To the Navy, navigation is essentially a two- dimensional problem, but the Air Force was definitely interested in the third dimension," Parkinson said. The 621B system was tested using aircraft between 1968 and 1971.

"There was a fierce competition, not just between the Navy and the Air Force, but also between Navy and Navy," he said. "The competition was over dollars. And there were also people like me -- who believed in using inertial guidance rather than external navigation systems -- standing around on the sidelines." Inertial guidance systems rely on sensitive accelerometers to keep track of an object's movements.

Each of the systems had some major drawbacks, Parkinson said. TRANSIT fixes could be updated only four to six times a day, and if too many satellites were launched they would begin jamming each other. TIMATION was easy to jam and only two-dimensional. 621B needed continuous signals from a ground station to operate.

In 1972, Parkinson was transferred by the Air Force to the 621B program over his objections, and thus got into satellite navigation through what he terms a "lucky failure."

He soon was called upon to give an extended briefing on the system to the new director of research and engineering for the Department of Defense, Dr. Malcomb Currie. Currie liked the system and wanted to do something new, so he encouraged Parkinson on his many trips to Washington, D.C., to sell the program.

In August 1973, the 621B proposal went before a streamlined Department of Defense decision- making process, called the Defense System Acquisition and Review Council (DSARC), that had been set up by David Packard in 1972. In this process, all the decision-makers were convened in one room and projects voted up or down.

"That was 'Black Thursday.' The DSARC panel said 'no' to the project," Parkinson recounted.

But the rejection turned out to be another "lucky failure." Currie determined that what the panel wanted was a joint project, with all the services participating, and he put Parkinson in charge of pulling such a project together. Parkinson and a small staff met in an empty Pentagon over the Labor Day weekend in 1973, coming up with a system that incorporated the best features of each of the competing systems: the signal structure from 621B, the orbits and orbital prediction method from TRANSIT and the clocks from TIMATION. They called the new system Global Positioning Satellite/NAVSTAR. When the project went before the DSARC panel on Dec. 17, 1973, it was approved.

"A message you might take from this talk is, 'You succeed better if you fail' or 'Failure is an essential catalyst for success,"' Parkinson said.

The first "phase 1 bird" was launched in February 1978, on time and within budget, Parkinson said. When the system was up and running it provided positions accurate to within 10 meters. The signal was specially encoded so that civilian users were only able to obtain locations with an accuracy of about 50 meters. Nevertheless, civilians -- surveyors being among the first -- immediately started finding uses for this new capability, Parkinson said.

Today there are 25 GPS satellites in orbit: Six to 11 are normally in view at any given time at any point on Earth.

The GPS/Navstar development group had predicted that the military would have use for 27,000 GPS receivers and set of goal of making these for less than $10,000 apiece. Today, the number of military receivers is nearly 40,000, a modest number compared to the nearly three- quarter million civilian sets being sold annually.

"Civilian use is clearly dominating military use," Parkinson acknowledged. Originally, there was some controversy about allowing non-military use of the GPS system. But after the downing of the Korean jetliner KAL 007 when it strayed into Soviet territory, President Reagan decided that GPS, which could reduce the likelihood of such navigational errors, would be made freely available to the airlines, shipping industry and other civilian users.

Commercial interest has grown, particularly with the spread of differential GPS, developed by Parkinson's group at Stanford. Differential GPS uses GPS receivers and satellites in conjunction with a ground station, or pseudo-satellite, at a known position, to provide high-precision tracking in specific locations. The Stanford group has been developing differential GPS for use in an automatic landing system for commercial aircraft. Last October, the system was installed on a United Airlines 737 jetliner and flawlessly executed more than 100 blind landings.

"Differential GPS has largely defeated the GPS encoding so I expect that the military will eventually turn it off," Parkinson predicted. The number of civilian users is now so high that he does not think the government will be able to start charging to use the system, "although they may charge to make improvements."

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