THE STORY OF GPS

By Catherine Alexandrow

Throughout history, people have attempted to develop means of navigation. Even with the best charts and compasses, early explorers often became disoriented the moment they lost sight of land. During the Age of Exploration, focus was put on the potential to navigate by way of the solar system and stars. Observatories were set up in Paris and London for the sole purpose of learning to navigate by celestial bodies. However, even with the ability to accurately judge the positioning of the solar system, the inability to determine accurate time loomed large. The dilemma of determining time led many historical high-ranking officials to offer great rewards to anyone who could develop an accurate means of navigation, and thus solve the problem of longitude.

In fact, in 1714, the British government passed the Longitude Act, which led to the formation of the Board of Longitude. The board offered a large monetary reward for an invention that would solve the problem of determining longitude – which sounds a bit like the makings of an early research and development agency. John Harrison, an inventive London clockmaker, developed a friction-free clock that proved a superior method. His clock required no lubrication and utilized metals that did not expand and contract in response to changes in temperature, a feature that proved quite useful with the varying temperatures at sea. Harrison also did away with the use of a pendulum and developed a spring method that allowed the clock to be portable. Harrison's clock passed a series of tests and on a nine-week Caribbean journey, lost only 5 seconds, equating to 1.25 minutes of longitude. This portable marine clock was, in fact, simply a large watch. Over time, the marine clock was scaled down to fit in a pocket, and even on a person's wrist.

The early days of navigation created a foundation for later efforts to make precise navigation a reality. Fast-forward to 1959 when a joint effort between DARPA and the Johns Hopkins Applied Physics Laboratory began to fine-tune the early explorers' discoveries. TRANSIT, sponsored by the Navy and developed under the leadership of Dr. Richard Kirschner at Johns Hopkins, was the first satellite positioning system. This system was a result of researchers at the Naval Center for Space Technology observing Sputnik 1 and determining that the radio transmission from a satellite in a specific orbit could be used to locate an earthbound receiving station. Initially, these researchers monitored the Doppler shift in the frequency of Sputnik's radio transmissions during its orbit. The TRANSIT system, which used six satellites (three for positioning and three as spares), was based on the finding that the Doppler shift could establish the location of the satellite in relation to the receiver station. The Applied Physics Laboratory designed all of the TRANSIT technology, while RCA was responsible for the construction. On Sept. 17, 1959, the first attempt to launch TRANSIT took place, but the satellite did not make it into orbit. It wasn't until June 16, 1963, that TRANSIT made its first successful launch.

However, even before TRANSIT took up residence in space, Ivan Getting, founding president of the Aerospace Corporation, and other researchers were hard at work developing a new system that would ultimately result in what we know today as the Global Positioning System (GPS). TRANSIT utilized a stable quartz oscillator, which functionally is a drawback for a GPS due to its inability to keep precise time. It wasn't until later, with the Navy's TIMATION program, led by Roger Easton at the Naval Research Laboratory, that the idea of fitting GPS satellites with atomic clocks for precise timekeeping became a reality.

Over the next three decades, the Navy and Air Force continued to work on a variety of navigational systems, but the resulting systems lacked compatibility with one another. In 1973, the Department of Defense (DoD) called for the creation of a joint program office to develop a unified navigation system. The resulting system, named the NAVSTAR Global Positioning System, successfully launched from Cape Canaveral in 1989. Twenty-three more satellites were later launched to complete the configuration.

There are three components necessary for a GPS to work: ground stations that control the system, a configuration of satellites fitted with atomic clocks, and receivers carried by users. With all three of these components in place and operational, it was time for DARPA to focus on improving the receivers soldiers were using. One of the early receivers was the PSN-8 Manpack. Between 1988 and 1993, 1,400 of these units were produced and utilized by military personnel. However, these units proved to be cumbersome and impractical for military use. The units were large and weighed close to 50 pounds. In 1988, in response to a Marine Corps Required Operational Capability, DARPA reemerged in the GPS-development landscape, focused on realizing a battery-operated, hand-held receiver with military P-code capability.

In the early 1980s, Dr. Sherman Karp, a program manager in the Strategic Technology Office (STO), approached Dr. Anthony J. Tether, the director of the STO at the time and now director of DARPA, to develop a revolutionary navigation system that digitized GPS signals for the first time, thereby allowing miniature GPS receivers to be fabricated from very large-scale integration semiconductor chips. When Tether asked just how miniature this new receiver would be, Karp grabbed a pack of Virginia Slims cigarettes off a nearby desk, and the miniature GPS receiver (MGR) program was nicknamed: Virginia Slims. The first MGR model weighed a few pounds. This was in

Tech. Sgt. Andrew Morin brings up position data on the Precision Lightweight GPS Receiver, a global positioning satellite device. He is with the 732nd Expeditionary Logistics Readiness Squadron participating in combat convoy security team missions.

U.S. Air Force photo by Master Sgt. Lance Cheung

comparison to the 10-plus pounds for the PSN-8 and the 35 pounds for the conventional, standard DoD receiver.

During the beginning phases of the MGR program, under the leadership of Karp, five defense contractors competed for a hardware development contract, and of those five, Magnavox Research Labs and Rockwell Collins designs were selected for development. After Karp retired, Neil Dougherty stepped into the leadership position and during his tenure continued to make significant progress in the development of the MGR until leaving DARPA. At that time, Dr. Larry Stotts became the MGR program manager and led the MGR effort to its very successful completion in 1991.

During the development phases, Magnavox's effort became too costly, which allowed Rockwell Collins to remain as the sole contractor for the MGR program. Although Rockwell Collins' ideas were risky, their work paid off when they produced a gallium arsenide hybrid chip that allowed for combined analog and digital functionality and the first "all-digital" GPS receiver. These technological breakthroughs forever changed GPS processing.

Originally, the MGR was projected to cost $5,000 per unit. However, with advancements in technology, specifically the MIMIC chip, the increases in silicon operating speed and much lower cost has rendered gallium arsenide obsolete. The newer miniaturized GPS receivers with full military capability now cost less than $1,000 per unit. In addition, a GPS military receiver card for integration with an inertial measurement unit, a small device that will calculate and output the acceleration and angular rate as the receiver moves over the Earth, costs less than $500.

Due to the current miniaturized systems, Precision Lightweight GPS Receivers (PLGR), or more recently, the Defense Advanced GPS Receiver (DAGR), soldiers no longer have to carry less ammunition, food, or life support equipment in order to carry a P-code GPS receiver. Also, the capabilities of these smaller, lightweight GPS receivers have evolved. The MGR of the GPS-legacy PLGR weighed 2.75 pounds, had a text-only display, a reliability time frame of 2,000 hours, and used eight batteries. In comparison, the advanced DAGR weighs only .94 pounds, has the capability to display full maps, has a reliability time frame of 5,000 hours, and uses only four batteries. These advancements directly translate to enhanced military capabilities, as well as major cost savings. All of the Rockwell Collins military receivers (PLGR, DAGR, the miniature airborne GPS receiver, and the joint direct attack munition, etc.) are lineal descendants of the DARPA MGR chip set.

And it's not only military personnel who have reaped the benefits of miniaturized navigation receivers. It's no mystery that many of DARPA's efforts have resulted in advanced civilian applications. Just remember the next time you get in a car and hear a well-articulated voice that tells you to "Turn right at the next corner" that it was DARPA that helped make that technology a reality.