Waikiki Beach provided the background as ION launched its new Pacific PNT conference April 23–25 in Honolulu, Hawaii.

More than 200 attendees registered to participate in 100+ technical presentations as well as a day of tutorials on April 22, which took place in the Marriott Waikiki Beach Resort & Spa. The general theme of the event was “East Meets West in the Global Cooperative Development of Positioning, Navigation and Timing Technology.”

Paper topics ranged from earthquake and tsunami monitoring and prediction to “collaborative navigation” among unmanned vehicles, aircraft, and vessels.


Betz organized much of his discussion around 12 signal characteristics — such elements as spreading codes, data modulation, and multiplexing — that he said describe the essential aspects of a satnav signal, “from the original signals transmitted by GPS satellites to the most innovative concepts being conceived today.”

A particular emphasis in the paper was the role played by Project 621B, a seminal A novel presentation by Dr. John Betz, The MITRE Corporation, “Signal Structures for Satellite-Based Navigation: Past, Present, and Future,” traced the development of legacy and modernizing GNSS systems. Betz organized much of his discussion around 12 signal characteristics — such elements as spreading codes, data modulation, and multiplexing — that he said describe the essential aspects of a satnav signal, “from the original signals transmitted by GPS satellites to the most innovative concepts being conceived today.”

A particular emphasis in the paper was the role played by Project 621B, a seminal groundbreaking program. This program was instrumental in advancing the technology that underpins modern navigation systems.

continued on page 3
I would like to congratulate the organizers of the ION’s first biennial Pacific PNT 2013 meeting, which was held April 22-25, 2013 at the Waikiki Beach Marriott in Honolulu, Hawaii. The conference was attended by over 200 people, 43% of whom represented Pacific Rim nations. Thank you to Dr. Mikel Miller (General Chair), and Dr. Frank van Graas and Dr. Jade Morton (Program Co-Chairs) for the dynamic and informative technical program.

This past quarter, the ION’s Military Division, in cooperation with the ION Executive Committee, made the difficult decision to cancel this year’s Joint Navigation Conference (JNC) originally scheduled for June 10-13, 2013 in Orlando, FL. This decision was not made lightly, but due to the DOD’s recent policies detailing actions to be taken to prepare for drastic budget cuts, the curtailment of travel, federal sequestration, and possible furloughs for federal employees, it was no longer possible for the ION to ensure that the JNC would be able to maintain the high quality technical program and sufficient networking opportunities that makes the JNC valuable to DOD/DHS employees and their supporting organizations. We extend our deep appreciation and best wishes for the ION’s DOD/DHS participants during this politically difficult and trying time.

While it is impossible for us to predict the duration of the current federal climate, the ION is committed to keeping the Institute on a sure and steady track. At this time we are focusing our energies on JNC 2014, which will be held June 16-19, 2014 at the Renaissance Orlando at SeaWorld in Orlando, Florida with the classified session and Warfighter panel being held Shades of Green on Walt Disney World Resort on June 19. We are taking steps now to examine the structure and organization of next year’s conference to ensure its success in what will likely still be a federal cost-cutting climate.

This past month, the ION’s Executive Committee approved a motion for the ION to technically co-sponsor the 2013 Beacon Satellite Symposium (July 8-12, 2013 in Bath, U.K.) sponsored by the Beacon Satellite Group of the International Union of Radio Science (RSI) Commission G. The Beacon Satellite Group is interdisciplinary, serving science, research, application and engineering interests, including all aspects of satellite signals observed on the ground and by receivers’ on-board satellites. Boston College and the University of Bath are additional technical co-sponsors. For more information please see: http://bit.ly/BSS2013.

ION GNSS+ 2013 is being held September 16-20, 2013 in Nashville, Tennessee. Please join us for a dynamic international technical program and premiere pre-conference tutorials being taught by an elite group of internationally recognized experts. You will also find many related meetings, dynamic workshops and panel discussions, new product introductions and of course the opportunity to network and meet up with colleagues and friends. For more information on ION GNSS+ 2013, visit www.ion.org/gnss. I look forward to seeing you in September!

I would like to remind you that October 15 is the last day to submit ION Annual Award and Fellow nominations. Please start your nominations early for worthy individuals.◆

Patricia Doherty
U.S. Air Force study in the 1960s that identified and analyzed signal characteristics, some of which are only now being introduced into new and modernized signals.

Although the constraints on travel by U.S. agencies and prime contractors brought about by “sequestered” federal budgets reduced attendance, conference organizers considered the event a success because of the sizable contingent that arrived from the other side of the Pacific Ocean. About 43 percent of registrations came from Asia (a target audience for the conference), 46 percent from North America, 10 percent from Europe, and the remainder from other regions.

The event also attracted members of the International Committee and GNSS (ICG), which met in the wake of the ION conference for a three-day interoperability workshop, April 25–27. That ensured some high-level presentations from system providers in a “GNSS Policy/Status Updates” session. Among these were complementary presentations on BeiDou by Dr. Yuanxi Yang, with the China National Key Laboratory of Geo-Information Engineering/China National Administration of GNSS and Applications (CNAGA), and Dr. Xiancheng Ding, senior adviser for the China Satellite Navigation Office.

Other updates came from David Turner, U.S. State Department (GPS); Dr. Sergey Revnivykh, the Russian space agency’s PNT office (GLONASS); and Hiroyuki Noda, from Japan’s Office of National Space Policy (QZSS). In a new development, Dr. Changdon Kee, of Seoul National University, described plans for a Korean satellite-based augmentation system (SBAS). Many of these presentations are covered in greater detail in the “GNSS Program Updates” section on page 16.

Thanks for the successful inauguration of this new ION event should go to the Pacific PNT Program Committee: Dr. Mikel Miller, general chair; Dr. Frank van Graas and Dr. Jade Morton, program co-chairs; and Dr. John Raquet, tutorials chair.

Pacific PNT will be held again April 20–23, 2015 at the Marriott, Waikiki Beach Hotel, Honolulu, Hawaii. The Institute’s intention is to alternate the new event with the Position Location and Navigation Symposium (PLANS) takes place in even years.◆
38,000 Digital Maps and Counting
Ship’s Logs, Nautical Charts, Historic Cartography in New Public Portal

Anyone can discover, download, overlay, compare, remix, reuse, and rebuild a fine collection of 18th and 19th century maps at the new Digital Public Library of America, in addition to 2.4 million other geocoded records in the database.

The Digital Public Library of America (DPLA) opened in Boston with 2.4 million records but without fanfare the same week as the terrorist bombing of the 2013 marathon.

Shortly afterward, they received a well-known map collector’s donation of 38,659 digitized maritime charts, manuscript maps, and other items reflecting mainly 18th and 19th century cartography.

All open to anyone and everyone. It’s worth taking a look online at <http://dp.la>.

DPLA describes itself as a portal, a platform, and an advocate for libraries, archives, and museums that make the “full breadth of human expression” available to the world. (It’s still in beta, but that’s the goal). The digital library offers free, online, openly accessible pictures, maps, texts, sounds, video — all modes of expression.

Right now, you can use the search function plus a timeline and a geocoded map of the physical location of the archives, which allows you to locate and view items visually. Plus, there’s a page of apps (also in beta) made using the DPLA’s Application Programming Interface (API) at <http://dp.la/map>.

Many universities, public libraries, and other organizations have digitized materials, but these digital collections often exist in “silos,” the DPLA’s founders say. The DPLA seeks to bring these different resources together in a single platform and portal to provide an “open and coherent access to our society’s digitized cultural heritage.”

The DPLA planning process began in October 2010 with a meeting in Cambridge, Massachusetts, at which 40 leaders from libraries, foundations, academia, and technology projects agreed to work together to create “an open, distributed network of comprehensive online resources that would draw on the nation’s living heritage from libraries, universities, archives, and museums in order to educate, inform, and empower everyone in current and future generations.”

The effort received financial support from the Alfred P. Sloan Foundation that enabled the Berkman Center for Internet & Society at Harvard University, generously to convene experts in libraries, technology, law, and education to support work on the ambitious project.

David Rumsey’s Maps
The early donation of digitized maps came from David Rumsey, who had put together one of the largest private historical map collections in the world. The retired real estate developer and former Yale Art Student started digitizing his maps in 1999. They are updated monthly and are freely available via the DPLA websites and apps. Britain’s Daily Mail newspaper said of Rumsey’s donated materials, “Maps of London in the 19th Century, trade routes
through Africa from 1842, nautical charts of Cuba and how the globe looked in 1790 are just some of the incredibly detailed pieces in the collection.”

These digitized maps are much more than the scanned images we all know and love from our own homes and workplaces. Rumsey’s technical team turned the original historical maps into digital images by scanning them using a PhaseOne Powerphase digital scanning camera at a minimum of 300 pixels per inch as measured against the physical map’s dimensions.

The digital images are then georeferenced using geographic information system (GIS) software. Cities, coast lines, rivers and streets and other points on the physical maps are connected to the same geospatial data on a modern satellite map.

Up to 200 accuracy points can be taken for larger maps. These points are used to recreate the digital image so that it will fit into its current geographical space. Sometimes, this results in a curved image because locations change in size and shape over one or two hundred years.

The GIS software used includes Maplicity, Mapimager, Telemorphic, ESRI’s arcView and ArcIms software, and Blue Marble Geographics’ Global Mapper.

In addition to a number of navigation and nautical charts and maps, Rumsey’s collection includes an 1814 first-edition map of Lewis and Clark’s expedition (shown in accompanying image). The map and the written account of the expedition changed American mapping of the northwest by giving the first accurate depiction of the relationship of the sources of the Missouri, the sources of the Columbia, and the Rocky Mountains.

The map was copied by Samuel Lewis from William Clark’s original drawing, and was engraved by Samuel Harrison.

Another item in Rumsey’s collection is described further in the accompany article, “The Log of the H.M.S. Swiftsure.”

From the Rumsey Collection

The Log of the H.M.S. Swiftsure

This highly unusual illustrated manuscript is one of Rumsey’s historic maps of navigation available at DPLA.

The log records an 1884-85 journey from Honolulu to Esquimalt, British Columbia, then down the West Coast of North and South America, around Cape Horn and back to England. Sixteen beautifully drawn charts record the track of the steam- and sail-powered battleship, showing stops in San Francisco, Mazatlan, San Blas, Valparaiso, and Rio de Janeiro, among others.

Many drawings illustrate aspects of the ship and its equipment. The log itself records the weather and daily ship operations.

Commissioned in 1871, the H.M.S. Swiftsure was very fast for its time, with a top speed of 13.75 knots. It served as the Pacific Station flagship for the Royal Navy for a number of years in the 1880s.

DPLA website showing the physical location of records in the database (bottom left); illustration of Robinson’s boat disengaging gear from the H.M.S. Swiftsure log. From DPLA collection.
In an age smitten by burgeoning global navigation satellite systems and their applications, we sometime forget that there was a world of positioning and navigation before GPS.

March 28 this year marked the 30th anniversary of the premier launch of the Advanced TIROS-N satellite series, which carried the first search-and-rescue (SAR) payload on a U.S. satellite. The NOAA-E spacecraft, was designed and built at the Lockheed Martin (then RCA Astrospace Division) facility in East Windsor, New Jersey.

To date, more than 33,000 lives have been saved as a direct result of the Search and Rescue Satellite Aided Tracking (SARSAT) capability that grew from an agreement signed in 1979 by Canada, France, the United States, and the former Soviet Union establishing the International Cospas-Sarsat Program. Since then more than 325,000 emergency beacons have been registered in the National Oceanic and Atmospheric Administration (NOAA) database. As of 2012, 26 countries were providers of ground segments for the Cospas-Sarsat system, while 11 countries were user states.

In the midst of the Cold War, SAR-hosted payloads were sent into space as the result of an agreement signed in 1979 by Canada, France, the United States, and the former Soviet Union that established the International Cospas-Sarsat Program — a satellite-based SAR distress alert detection, location, and information distribution system.

Cospas-Sarsat provides the alerts to search and rescue authorities worldwide. A Russian navigation satellite launched nine months before the NOAA-E — on June 29, 1982 — carried the first Cospas SAR payload into space.

The SAR capability was piggybacking on the TIROS weather satellites that had been around for more than 20 years, the forerunner of NASA’s climate and environmental change missions of today.

**Satellite Mission of Opportunity**

“While NOAA’s weather satellites have indirectly been saving lives for over 50 years by making possible timely forecasts of dangerous weather, the initiation of the Cospas-Sarsat Program originated the use of satellite technology that enabled direct intervention in the rescue of people in distress,” said Mark Valerio, vice-president and general manager of Military Space at Lockheed Martin Space Systems Company (LMSSC) in Sunnyvale, California. Valerio served as the SAR mechanical integration lead at East Windsor during the Cospas-Sarsat program.
“It was NASA’s vision decades ago with its ‘missions of opportunity’ that underscored the value of hosted payloads, and the SARSAT program was an early pioneer,” Valerio continued. “Utilizing available space on satellites for small additional payloads added enormous new capabilities, and fostered innovation in satellite missions.”

Under the Cospas-Sarsat 1979 agreement, France provided the Search and Rescue Processor, developed by the Center for National d’Etudes Spatiales (CNES). Canada’s Department of National Defense developed the Search and Rescue Repeater. The United States provided the Search and Rescue Receive Antenna — designed and built by the East Windsor team, which also performed the integration, test, and fielding of the system.

In the United States, NASA developed the SARSAT system and, once it became fully functional, turned its operation over to NOAA where it remains.

How SAR Works

The Cospas-Sarsat system swings into action when a distress beacon is activated in a life-threatening emergency. The beacon is picked up by the satellites equipped with the SARSAT hardware. Satellites downlink the distress data to ground stations and mission control centers distribute the data to rescue coordination centers that dispatch personnel to effect a rescue.

Typical rescue beacon radios transmit a strong five-watt signal once every 50 seconds. Today, most beacons also include a GPS receiver that can provide a precise latitude/longitude location of the SAR requestor.

The SAR user equipment comes in a variety of forms. Aircraft emergency locator transmitters (ELTs) are automatically activated by g-force switches that detect sudden deceleration during a crash, while maritime emergency position indicating radio beacons (EPIRBs) are normally activated by contact with seawater. Personal locator beacons (PLBs) are activated manually.

Initially, SARSAT hardware was installed only on low Earth orbit (LEO) polar-orbiting satellites, such as the Advanced TIROS-N series. These operate in orbits at about 500 miles in altitude, making a single pass around the Earth each 100 minutes. On-board sensors view a different swath of the planet on each pass as it turns beneath them.

When a distress beacon is detected, its location can be computed based on the Doppler shift of the beacon signal as the satellite passes overhead — in effect, using the same techniques as the Navy’s TRANSIT satellites of an earlier era. Satellites in polar orbit provide emergency beacon users with global coverage (including the polar regions).

GEOS Join the LEOs

Beginning in 1998, SARSAT hardware was also installed on geostationary satellites (GEOS) that reside 22,500 miles in altitude above the equator, orbiting the Earth at the same rate at which it turns beneath them. Because of this, they appear to remain over a fixed point on the Earth’s surface.

This high perch is ideal for making uninterrupted observations of the weather or environmental conditions over an enormous area, and enables the immediate detection, in their field of view, of distress beacons. However, unlike polar-orbiting satellites, those in geostationary orbit cannot view the Earth’s polar regions.

The current constellation of operational SARSAT-equipped polar-orbiting satellites include NOAA-15, -16, -18 and -19 — all Advanced TIROS-N satellites, built by Lockheed Martin Space Systems. The European METOP-A weather satellite completes that constellation.

The six operational GEOS hosting SARSAT payloads are NOAA's GOES East (GOES-13) and GOES West (GOES-15) with two satellites in stand by (GOES-12, GOES-14), India’s INSAT-A satellite, the European Meteosat Second Generation satellites MSG-2 and MSG-3, and Russia’s Electro-L No. 1.

When the GOES-R series of satellites — also being built by Lockheed Martin — begin to enter service in 2015, all will host the SARSAT payload. In addition, the U.S. Air Force GPS III satellites, currently under development at Lockheed Martin, will also likely host the payload as that system evolves.
New NASA Explorer Mission to Explore Extra-Terrestrial Navigation Technology

The Neutron-star Interior Composition Explorer (NICER), which NASA recently selected as its next Explorer Mission of Opportunity, will gather scientific data revealing the physics of the densest matter allowed in nature, and — from the same platform — will demonstrate a groundbreaking navigation technology that could revolutionize the agency’s ability to travel to the far reaches of the solar system and beyond.

The multi-purpose mission, also known as NICER/SEXTANT (Station Explorer for X-ray Timing and Navigation Technology), consists of 56 X-ray telescopes in a compact bundle, their associated silicon detectors, and a number of other advanced technologies.

The X-ray instrument is roughly the size of a compact refrigerator and will be deployed on the International Space Station (ISS) in 2017 as an external attached payload on one of the ISS ExPRESS Logistics Carriers (see accompanying graphic). Both NASA’s Science Mission Directorate’s Explorers Program and the Space Technology Mission Directorate’s Game Changing Development Program are contributing to the mission’s development.

“NICER/SEXTANT represents the quintessential cross-cutting mission,” said Principal Investigator Keith Gendreau, a scientist at NASA’s Goddard Space Flight Center in Greenbelt, Maryland, who is leading NICER/SEXTANT’s development. “Our technology demonstration will establish the viability of spacecraft navigation using neutron stars, while the same instrument gives scientists an important new tool with which to better understand these stars that can serve as navigation beacons.”

In addition to NASA Goddard scientists and engineers, the mission team includes the Massachusetts Institute of Technology and commercial partners, who are providing spacecraft hardware. The Naval Research Laboratory and universities across the United States, as well as in Canada and Mexico, are providing science expertise. The Japanese HII-B Transfer Vehicle (HTV) or the Dragon, a carrier now being developed by Space Exploration Technologies Corp. (SpaceX), of Hawthorne, California, is expected to deliver the payload to the ISS, Gendreau said.

NICER/SEXTANT’s primary objective is to learn more about the interior composition of neutron stars, the remnants of massive stars that, after exhausting their nuclear fuel, exploded and collapsed into super-dense spheres about the size of New York
City. Their intense gravity crushes an enormous amount of matter — often more than 1.4 times the content of the sun or at least 460,000 Earths — into city-sized balls, creating the densest objects known in the universe. Just one teaspoonful of neutron-star matter would weigh a billion tons on Earth.

**Exploiting the Universe’s Living Dead**

Neutron stars have been called the zombies of the cosmos. They shine even though they’re technically dead, occasionally feeding on neighboring stars if they venture too close. Although the nuclear-fusion fires that sustained their parent stars are extinguished, neutron stars still shine with heat left over from their explosive formation, and from radiation generated by their magnetic fields that became intensely concentrated as the core collapsed.

Neutron stars emit radiation across the spectrum, but observing them in the X-ray band offers the greatest insights into their structure, the ultimate stability of their pulses as precise clock “ticks,” and the high-energy, dynamic phenomena that they host, including starquakes, thermonuclear explosions, and the most powerful magnetic fields known in the universe.

NICER’s array of 56 telescopes will collect X-rays generated both from hotspots on a neutron star’s surface and from its tremendously strong magnetic field. A neutron star has two hotspots, one at each magnetic pole, where the star’s intense magnetic field emerges from the surface. Here, particles trapped in the magnetic field rain down and generate X-rays when they strike the surface. As a hotspot spins through our line of sight, we perceive a rise and fall in X-ray brightness.

This subgroup of neutron stars rotates rapidly, emitting from their magnetic poles powerful beams of light that sweep around as the star spins, much like a lighthouse. At Earth, these beams are seen as flashes of light, pulsing on and off at intervals from seconds down to milliseconds, giving rise to the stars’ alternate name, pulsars.

Because of their predictable pulsations — especially millisecond pulsars, which are the mission’s prime target and are found to spin as much as 700 times per second — they can serve as extremely reliable celestial clocks and provide high-precision timing just like the atomic clock signals supplied through the Global Positioning System.

The latter technology, however, provides an Earth-centric service that weakens the farther one travels beyond Earth orbit and into the solar system, NASA researchers point out, while pulsar-based positioning could extend the navigable range of interplanetary vehicles.

NICER/SEXTANT will take advantage of the neutron star’s phenomenon to also demonstrate the viability of pulsar-based navigation.

“The hardware needed for neutron star science is identical to that needed for pulsar-based navigation,” Gendreau said. “In fact, the mission’s two goals share many of the same targets and the same operational concept. The differences are on the back end in terms of how the data will be used.”

To demonstrate the navigation technology’s viability, the NICER/SEXTANT payload will use its telescopes to detect X-ray photons within these powerful beams of light to estimate the arrival times of their pulses. With these measurements, the system will use specially developed algorithms to stitch together an on-board navigation solution.

If an interplanetary mission were equipped with such a navigational device, it would be able to calculate its location autonomously, independent of NASA’s Deep Space Network (DSN), Gendreau said. DSN, considered the most sensitive telecommunications system in the world, allows NASA to continuously observe and communicate with interplanetary spacecraft.

However, like GPS, the system is Earth-centric. DSN-supplied navigational solutions also degrade the farther one travels out into the solar system. Furthermore, missions must share time on the network, Gendreau said.

“We’re excited about NICER/SEXTANT’s possibilities,” Gendreau added. “The experiment meets critical science objectives and is a stepping-stone for technology applications that meet a variety of NASA needs. It’s rare that you get an opportunity to do a cross-cutting experiment like this.”
how revolutions in timekeeping over three centuries have influenced the means by which people find their way. (The original working title was “Finding Time and Space: From Chronometers to GPS.”)

Long in the making, this project involved a noteworthy collaboration between two of the Smithsonian’s largest and most popular museums: the National Air and Space Museum and the National Museum of American History. The Institute of Navigation was an early supporter of the venture, providing seed money for the exhibit more than seven years ago (See Spring 2006 ION Newsletter article).

The biggest challenge in putting the exhibit together was deciding the story, said Curator Andrew Johnston. “It took a long time to get that story line, and I’m really proud of what we came up with."

The exhibit sprang from a suggestion by Demetrios Matsakis, the head of the Time Service Department at Naval Research Laboratory, to commemorate the anniversary of the publication of Einstein’s “Special Theory of Relativity.”

“He suggested to me in early 2004 that wouldn’t it be a great idea to have for Einstein’s 100th anniversary in 2005 an exhibit about the relationship of clocks and GPS because GPS is one of the few things in everyday life that has to take into account the theory of relativity,” said Carlene Stephens, another of the exhibit’s four curators and co-author of the 2006 ION Newsletter article.

It took a little longer, however, than the yearlong preparation that Matsakis had in mind. Development of a three-case exhibition at the American History Museum, where Stephens is based, won approval — but then it became clear the building would be closed for renovation at the time the exhibition needed to be on display. Stephens got permission to find another venue, resulting in the much larger, joint effort.

“Time and Navigation is an ambitious exhibit because it traces the development of very complicated technologies and makes us think about a subject we now take for granted,” said Gen. J.R. “Jack” Dailey, director of the museum.

“Today, the technology needed to accurately navigate is integrated into mobile computers and phones: hundreds of years of technological heritage tell your handheld device where you are in a seamless manner, Dailey added. “This opens up new possibilities and challenging questions for the next generation of scientists and explorers who visit this exhibit to start thinking about.”

Five Sections, Three Centuries
The gallery is organized into five sections and spans three centuries of efforts to travel on Earth and through the solar system. In each section the visitor will learn about pioneer navigators facing myriad issues, but one challenge always stands out: the need to know accurate time.

Navigating at Sea is an immersive environment that suggests a walk through a 19th-century sailing vessel. Visitors learn how centuries ago navigators at sea relied on chronometers and measurements of celestial objects to determine location.

This section includes a mariner’s astrolabe, dating from 1602; a Ramsden sextant and dividing engine; several chronometers; a model of Galileo’s pendulum clock, as well as the earliest sea-going marine chronometer made in the United States, produced by Bostonian William Cranch Bond during the War of 1812. It also features an interactive display that allows visitors to use a sextant to navigate with the stars.

Navigating in the Air relates how air navigators struggled with greater speeds, worse weather, and more cramped conditions than their sea-going predecessors. It tells the story of the innovations that overcame these challenges, as represented by the gallery’s largest artifact, the Lockheed Vega “Winnie Mae,” flown by Wiley Post and Harold Gatty, shattering the around-the-world record in 1931.

Visitors learn that Charles Lindbergh required navigational tutoring after he flew to Paris and how he paved the way for a new system of navigation in the process. A personal account by a WWII navigator highlights wartime innovations. This section ends with an explanation of how clocks with tiny quartz crystals opened an entirely new era of navigation in the form of LORAN (LOng RAnge Navigation).

Navigating in Space traces how teams of talented engineers invented the new science of space navigation using star sightings, precise timing and radio communications. This section includes an Apollo sextant, a space
shuttle star tracker, timing equipment used at a ground tracking station and a flight spare (duplicate spacecraft) of Mariner 10, the first spacecraft to reach Mercury.

Inventing Satellite Navigation describes how traveling in space inspired plans to navigate from space. Innovators found that time from precise clocks on satellites, transmitted by radio signals, could be used to determine location. The U.S. military combined several breakthroughs to create the Global Positioning System.

Some of the artifacts in this section are the NIST-7 atomic clock that served as the U.S. time standard in the 1990s, the navigation system from the nuclear submarine U.S.S. Alabama, a satellite from the Navy’s Transit system used for global navigation before GPS, and a test satellite global navigation built at the Naval Research Laboratory.

A panel titled “Satellite Systems in Jeopardy?” notes some of the threats to satellite navigation, including jamming and the danger of being overwhelmed by communication signals from other nearby frequencies.

A sample of the personal navigation stories section of the Time and Navigation website.

. . . over the grasslands of east central Texas at 1,500 feet in a Cessna Cardinal. I was only seventeen and had only held my private pilot’s license for several months.

A friend and I decided to fly from Baton Rouge to check out the UT Austin campus as we were getting our undergraduate applications in order — what better way to build some flight time and satisfy a teenage wanderlust.

I was comfortable with using the VORs, so as we droned our way to Austin, I wasn’t overly concerned about the lack of roads or other obvious ground features to follow. I failed to notice the warning flag come in as the signal started to fade and I lazily followed the CDI needle as it drifted off to one side.

After a few minutes it occurred to me that I was flying East rather than West and the adrenaline began to flow as I realized there were no obvious ground features for pilotage. After a couple of anxious minutes, I decided to circle higher and as we gained altitude, we regained line of sight to the VOR station and the warning flag went out. Shortly after, I was able to raise Austin and get radar service into the airport.

By the standards of “there I was stories,” this was a pretty harmless episode, but it taught me much as I embarked on a career as a flight instructor, and it was the first and last time I was lost in an airplane.

Today, I am the curator for the aviation sections of the Time and Navigation exhibit. I have come to truly appreciate how much those black boxes — whether VOR or GPS - have made it possible to cross featureless landscapes. The long distance fliers of 1927 did not have the luxury of VORs or radar, and the few minutes of panic I had with good weather and a reasonable fuel reserve were but a drop in the bucket compared to the anxiety that those intrepid aviators experienced during much of their flights.

The sheer terror of getting vertigo in instrument conditions or a misfiring engine while offshore will fortunately not be known by most people, but it was a routine experience for those who pushed the boundaries of navigation eighty-five years ago. This exhibit is in part a tip of the hat to bravery that should not be forgotten.
Navigation for Everyone tells the stories of real people — a fireman, a farmer and a student — who use modern navigation technology in their everyday lives. It also addresses what might come next: the story is not over yet and many new technologies are being developed.

This section includes a disassembled mobile phone with a diagram showing all its parts and depicts how hundreds of years of navigation technology are now in the palm of a user’s hand. It also features “Stanley,” the robot car that won the 2005 Grand Challenge, a robot race sponsored by the Defense Advanced Research Projects Agency.

**Participatory Website**

The exhibition website at <http://timeand-navigation.si.edu> encourages professional navigators to submit their stories for potential inclusion in the “Meet the Navigator” section.

The exhibition organizers would like to include a variety of professional navigator profiles to inform the public of the types of jobs that exist and to encourage pursuit of careers in the positioning, navigation, and timing.
This is the first of a series of three articles about the 16th century Portuguese explorer Captain General Ferdinand Magellan. In this first article, the circumstances leading up to Magellan’s historic circumnavigating expedition are discussed.

It’s a small world, we glibly say. But when Ferdinand Magellan was born around 1480 in northwestern Portugal, most people experienced the world — at least those fortunate few who were able to delve into subjects beyond mere survival — as a fragmented, discontinuous, conflicted, and mysterious, series of forbidden territories.

Most early navigators (Polynesians excepted) avoided long expanses of open water by staying close to land and then voyages, to a large extent, without charts, compasses, or special purpose instruments for observing the sun and stars.

It’s not as if humans didn’t know how to get around. From Egyptians and Phoenicians to Greeks and Romans to Polynesians, and Norsemen, skilled seafarers carried migrating colonies hundreds or even thousands of miles. But prior to the 13th century they accomplished their
island-hopping from familiar landmarks separated by relatively short distances. The flight patterns of birds, the drift of seaweed, temperature, color and smell of the sea, and the types and population of marine life all supplemented the navigators’ directional and locational awareness. When it was necessary to traverse large expanses of water, the sun and major constellations provided visual guidance for coarse dead reckoning.

The records they kept of their methods and achievements, if any, were inaccessible or destroyed in the West.

Between the 10th and 15th centuries — the so-called High and Late Middle Ages — a number of factors hindered the spread of knowledge in Europe. The old Roman road system fell into disrepair, travel became more difficult and dangerous, and the Black Death killed 30 to 60 percent of Europe’s population in the mid-1300s.

The Christian church headquartered in Rome resisted scientific advances and evolved into an elaborate bureaucracy competing with kings for wealth and power. The Crusades consolidated the power of the church, but weakened the power of the great feudal lords and traditional society. They gave Europeans a glimpse of the wealthy civilizations beyond their borders.

Between 1357 and 1453, The Hundred Year’s War between England and France further sapped energy and wealth and population. Meanwhile, the Turkish Ottoman Empire grew and grew, until by 1453 it controlled a good deal of Western Asia, North Africa, and southeastern Europe. This led to the closure of Syria and Egypt to the west and stifled trading of luxury goods from the east.

One notable exception to the lack of transmission of information about early voyages came as a result of a battle fought in the Adriatic Sea in 1298 between the city-states of Genoa and Venice, both maritime powers. Genoa won, and among the Genovese prisoners was Marco Polo, the commander of a Venetian war galley.

**The Power of Story-Telling**

Marco Polo became friendly with another prisoner, Rustichello of Pisa, who wrote romances. The colorful tales of Marco Polo’s remarkable adventures in Asia, Persia, China, and Indonesia between 1276 and 1291 fascinated Rustichello. The storyteller embellished Polo’s dictation and co-wrote *The Travels of Marco Polo or Il Milione*. It became a bestseller in manuscript, well before printing was invented.

Christopher Columbus, another Genoese sailor, annotated Polo’s travelogue 150 years later. According to the Encyclopedia Britannica, “[Polo’s] description of Japan set a definite goal for Christopher Columbus in his journey in 1492, while his detailed localizations of spices encouraged Western merchants to seek out these areas and break the age-old Arab trading monopoly. The wealth of new geographic information recorded by Polo was widely used in the late 15th and the 16th centuries, during the age of the great European voyages of discovery and conquest.”

These tales stimulated a generation of European explorers and ambitious monarchs to find sea routes to the riches of silk, gold, and spices of what Europeans began calling the Far East. Spices were then at the epicenter of the world economy, much as oil today. Highly valued for flavoring and preserving food as well as masking the taste of spoiled meat in the days before refrigeration, spices such as cinnamon, clove, nutmeg and especially black pepper could not be cultivated in the cold climate of Europe.

The Iberian nations led those voyages of discovery, but first they had to settle a long-standing war with Muslim occupiers. Portugal’s Christian states reconquered territory held by the Muslims, or Moors, by the mid-1300s. But Portugal still remained a battleground as a result of dynastic struggles with the Castilians of Spain.

The continued power of the Moors in northwest Africa also continued to plague
the Portuguese until the early 1400s. Moreover, Portugal was alone among the European kingdoms in that it had no direct access to the Mediterranean Sea; so, if it were to fulfill its goals of economic and religious dominance, the nation had to turn towards the open waters of the Atlantic.

Under the leadership of Prince Henry “The Navigator” whose achievements were described in this column in the winter 2010 issue of the ION Newsletter, the Portuguese became Europe’s foremost maritime power by excelling in shipbuilding, geography, astronomy, cartography and navigation. The Portuguese navigators refined the use of magnetic compasses, astrolabes, quadrants and employed charts of wind patterns and ocean currents to improve their dead reckoning.

The Portuguese continued their series of “firsts” after Henry the Navigator’s death in 1460. Bartholomeu Dias sailed around the Cape of Good Hope — the southernmost point of the African continent — in 1488 and in 1497 Vasco De Gama finally navigated a long-sought maritime passage to India.

Education of a Navigator
Ferdinand Magellan grew up during these heady times. As a young nobleman and employee of the Portuguese agency responsible for overseas trade, he had ready access to these new geographic concepts and navigation theories. From the pilots, masters and mates who sailed with the exploratory fleets, including those of Columbus when he sailed into Lisbon on his return from his first voyage, Magellan absorbed the technical and managerial skills necessary for leading long, ocean-going explorations.

From 1505 to 1513 Magellan sailed eastward around Africa on several expeditions to Arabia, India, Ceylon and the Maluku archipelago (Moluccas) just west of New Guinea. An aside: It seems unlikely that either Magellan or Columbus would have undertaken their famous voyages had they been convinced of the findings made 1700 years earlier by the Greek astronomer Erastophenes that the circumference of the Earth was 30 percent larger than thought in 15th century Europe.

Europeans had reached the Moluccas, known then as the Spice Islands, by sailing east, but no one had reached them by sailing west. At the time, Europeans believed the Moluccas were the only place where cloves grew, and cloves, prized for their medicinal value, were worth their weight in gold. The Portuguese were highly motivated to capture these profitable Indian and Polynesian trade routes from the Arab and Indian empires.

Spain, the other great maritime power of the 15th and 16th centuries, renewed the search for a passage to the Far East, after Columbus’ Caribbean discoveries turned out not to be all that they had hoped. Subsequent explorations after Columbus’s second voyage in 1496 cast increasing doubt on his assertions that he found a westward route to India.

In 1494, Spain, Portugal and the Vatican negotiated the Treaty of Tordesilla that divided the world into equal Portuguese and Spanish hemispheres. It turned out to be an impossible job. The treaty and others that followed decreed that the longitudinal meridian of demarcation was 370 leagues west of the Cape Verde Islands and its antimeridian somewhere near the Moluccas. But these territories were unfamiliar to the negotiators. They had no reliable methods of determining longitude and the definition of “league” was controversial; so, the meridians were disputed for the next 200 years.

At the time, reliable methods for estimating latitude had been achieved using the astrolabe and quadrant, which measure the angles between the horizon and a celestial body. This was awkward to do at sea, and practical at-sea determination of longitude would eventually take another 240 years after Magellan’s circumnavigation to achieve.

Consequently, no one could accurately determine the longitude of the Spice Islands at the time, and that was fundamental to the Portuguese and Spanish rivalry in which Magellan became a central character.

Much of the information in these articles has been drawn from Tim Joyner’s book Magellan, (International Marine/ McGraw-Hill, 1992).

Marvin B. May is the Chief Scientist of Pennsylvania State University’s Navigation R&D Center in Warminster. He may be reached at <mbm16@arl.psu.edu>.
The additional features are part of a delta preliminary design review (dPDR) announced April 10 by the company based on an agreement with the U.S. Air Force. The innovative waveform generator will permit the addition of new navigation signals after launch to upgrade the constellation without the need to launch new satellites to bring that capability online.

In late February, Raytheon Company successfully completed the second launch readiness exercise for the U.S. Air Force’s next-generation GPS operational control system (OCX).

This represents a key milestone demonstrating that Raytheon’s OCX software meets mission requirements and is on track to support the first GPS III satellite launch, according to the company.

Completed over a three-day period, the joint industry and government exercise demonstrated OCX mission software capability. The exercise, building on the functionality tested in Exercise 1, simulated a liquid apogee engine burn to insert the GPS III vehicle into transfer orbit and evaluated vehicle telemetry, maneuver planning and execution.

Meanwhile, the U.S. Air Force Space Command (AFSPC) has invited comments on its proposed plans to test CNAV message capabilities on the civil GPS L2C and L5 signals between June 15 to 29.

No satellite outages are planned during the tests, according to AFSPC, which expects to conduct one to two CNAV tests per year over the next few years.

The broadcast navigation messages will be in compliance with technical specification documents, IS–GPS–200 and IS–GPS–705. The Air Force says that L2C/L5 CNAV testing will be “transparent” to GPS receivers that do not process L2C or L5 CNAV.

On the policy management side of things, a Department of Defense Directive (DoDD 5144.02) issued April 22 clarifies the positioning, navigation, and timing (PNT) responsibilities for Teresa Takai, the assistant secretary of defense for networks and information integration (NII) and the DoD’s chief information officer (CIO).

Signed by Ashton B. Carter, deputy secretary of defense who represents the department on the interagency Space-Based PNT Executive Committee, the directive is expected to clear the way for DoD to move ahead on a variety of GPS- and PNT-related initiatives that had been sidelined by reorganization following the change of administrations.

DoDD 5144.02 authorizes the DoD CIO, as a principal staff assistant (PSA) reporting directly to the Secretary of Defense, “to establish DoD policy in DoD issuances within the responsibilities, functions, and authorities assigned in this directive,” including policy, oversight, and guidance for matters related to PNT.

Under the directive, the ASD/NII-CIO The DoD CIO: (1) Serves as the lead for PNT policy within the DoD and the DoD representative for all interagency, domestic, and international forums related to PNT. (2) Develops and maintains the Federal Radio Navigation Plan. (3) Provides policy, oversight, and guidance on PNT enterprise-wide architecture and requirements.

Takai will also have similar responsibilities related to the electromagnetic spectrum, which involves such issues as the recent effort by LightSquared to launch a wireless broadband network operating in frequencies adjacent to the GPS L1 band.
GLONASS

First, the good news. Russia launched another GLONASS-M satellite on April 26 on a Soyuz 2-1b rocket from the Plesetsk Cosmodrome. Delayed more than once, it was the first GLONASS launch since November 2011.

The spacecraft (GLONASS Number 47) will replace an aging satellite in orbital plane 1 that is expected to fail soon, according to Sergey Revnivykh, director of the PNT Center, Central Research Institute of Machine Building, for the Russian Space Agency (Roscosmos), speaking at ION’s first Pacific PNT conference. That will maintain the system at its full operational capability constellation of 24 operational satellites several spares also on orbit, which generally provides full global coverage for 3D positioning capability.

A statement released on the website of JSC Reshetnev ISS — the company that designed, manufactured, and prepared the satellite for launch — confirmed that “the spacecraft is operating as designed, its mechanical systems deployed, Sun and Earth acquisition completed successfully.”

Launch of the second GLONASS-K1 satellite is expected before the end of the year, Revnivykh told the audience at Pacific PNT 2013.

Currently, real-time positioning accuracy is about 2.8 meters. GLONASS managers have set a goal of 0.6-meter accuracy by 2020. Revnivykh said that long-term expectations for the system are that GLONASS will operate at least until after the 2030s.

As yet, the Russian government has not named a replacement for Yuri Urlichich, the former chief designer for GLONASS who was dismissed from the position last November. A candidate may well be found at JSC Reshetnev ISS.

BeiDou

China will begin launching BeiDou-2 satellites again in 2013 as it begins its test program for the third generation of the nation’s GNSS program.

After launching 16 satellites since 2007 (including six last year) to establish the current regional constellation with 14 operational satellites and publishing an official interface control document December 27, China called a halt to further launches to evaluate the performance of the system and complete a development plan for the system.

Meanwhile, a shift of modernized civil signals to a new frequency, originally planned for 2016, will probably be delayed.

The updates came in presentations from Chinese officials at the ION Pacific PNT 2013 conference in Honolulu, Hawaii: Yuanxi Yang, an academician with the Chinese Academy of Sciences representing the China National Administration of GNSS and applications (CNAGA), and Xiancheng Ding, senior advisor with the China Satellite Navigation Office (CSNO).

The current (Phase II) B1 open service signal uses quadrature phase shift keying (QPSK) modulation with 4.092 megahertz bandwidth centered at 1561.098 MHz. The BeiDou Phase III plan for the B1 civil signal calls for shifting to the L1 frequency centered at 1575.42 MHz and transmitting a multiplex binary offset carrier (MBOC 6,1,1/11) modulation similar to the modernized GPS civil signal (L1C) and the Galileo L1 Open Service signal.

BeiDou’s current constellation of five geostationary (GEO), five inclined geosynchronous orbit (IGSO), and four middle Earth orbiting (MEO) spacecraft are also transmitting open and authorized signals at B2 (1207.14 MHz) and an authorized service at B3 (1268.52 MHz).
In his presentation, Yang offered results from recent BeiDou monitoring campaigns that indicated the system has a range error near to that of GPS, while revealing slightly different performance among the three types of satellites. The GEOs, for example, are less sensitive to the north and vertical components and exhibit “obvious multipath errors,” Yang said.

Real-time, stand-alone BeiDou horizontal positioning accuracy was better than six meters (95%) and vertical accuracy better than 10 meters (95%), Yang said. The current constellation is optimized for the regional service that China officially opened last December. The GEO satellites are operating in orbit at an altitude of 35,786 kilometers and positioned at 58.75°E, 80°E, 110.5°E, 140°E and 160°E respectively. The MEO satellites are operating in orbit at an altitude of 21,528 kilometers and an inclination of 55 degrees to the equatorial plane. The IGSO satellites are operating in orbit at an altitude of 35,786 kilometers and an inclination of 55 degrees to the equatorial plane.

The final global constellation will have will have a larger proportion of MEOs — 30, with 3 IGSOs and 5 GEOs.

The 4th China Satellite Navigation Conference (CSNC 2013) will be held on May 15-17, 2013 in Wuhan, China, with the theme, “BeiDou Application Opportunities and Challenges.” As it did for CSNC 2012, The Institute of Navigation will organize a half day of panel sessions on May 17, coordinated by Dr. Jade Morton, who chairs the ION Satellite Division.

**Galileo**

Europe’s GNSS program achieved a key milestone in March when the European Space Agency (ESA) announced the first determination of a ground location using the four operational in-orbit validation (IOV) Galileo satellites together with the system’s ground infrastructure.

Signals from a minimum of four satellites are required to make a position fix in three dimensions. The first two space vehicles (SVs) were launched in October 2011, with two more following a year later.

This first position fix of longitude, latitude, and altitude took place at the Navigation Laboratory at ESA’s technical center ESTEC, in Noordwijk, the Netherlands this morning. Positioning accuracy was between 10 and 15 meters — which reflects the limited infrastructure deployed so far, according to ESA. Various private companies, research organizations, and universities around the world soon began announcing that they had achieved positioning using the four IOV spacecraft.

This position fix relied on an entirely new European infrastructure, from the satellites in space to the two control centers in Italy and Germany linked to a global network of ground stations on European territory.

With only four satellites in orbit thus far, the entire Galileo constellation is only visible at the same time in a given location for a maximum two to three hours daily. This frequency will increase as more satellites join the first four SVs, along with extra ground stations coming online, eventually providing enough signals to support launch of Galileo’s early services now scheduled to begin at the end of 2014.

With the validation testing activities under way, users might experience breaks in the content of the navigation messages being broadcast. In the coming months the messages will be further elaborated to define the ‘offset’ between Galileo System Time and Coordinated Universal Time (UTC), enabling Galileo to be relied on for precision timing applications, as well as the Galileo to GPS Time Offset, ensuring interoperability with GPS. The ionospheric parameters for single-frequency users will be broadcast at a later stage to help improve real-time accuracy.

Politically, the program’s fortunes remain more ambiguous.
A proposed GNSS Regulation has not yet been adopted because it is closely linked with European Union (EU) budget, which was approved by the European Council of heads of state but rejected by the European Parliament. The European Commission (EC) submitted the regulation to the European Parliament and the Council more than a year ago.

“In order to implement a program or an activity and its budget, we need a Regulation to cover that program or activity,” says Paul Flament, head of the European Commission (EC) Satellite Navigation Unit. Flament hopes the budget will be approved sometime between June and next September.

The EC originally asked for 7 billion Euro (US $9.17 billion) for the Galileo program, but by the end of the budget talks that had been reduced to 6.3 billion Euro. “Obviously, we had to make some adjustments,” says Flament. “We had to reduce the duration of certain contracts, for example. And we had to readjust our risk management mechanisms.”

A long-standing dispute between Europe and China regarding an “overlay” of BeiDou signals on the frequencies on which Galileo’s Public Regulated Service (PRS) operates has been referred to the International Telecommunication Union.

**QZSS**

The Japanese government awarded contracts to Mitsubishi Electric Corporation and NEC Corporation to build the spacecraft and ground control system, respectively, for Japan’s Quasi-Zenith Satellite System (QZSS).

The Japanese Cabinet Office announced the contract awards on March 29. Mitsubishi will receive ¥50 billion (US$540 million) for building one geostationary satellite and two additional quasi-zenith satellites (QZSs) to join “Michibiki,” the first QZS launched on September 11, 2010.

The special purpose company — led by NEC and supported by Mitsubishi UFJ Lease & Finance and Mitsubishi Electric Corporation — established to build out the ground control segment under a private finance initiative will receive about ¥117 billion (US$1.3 billion). This will fund design and construction of the ground system and operation of the system for 15 years.

Each satellite will transmit the following signals: L1 C/A, L1C, L2C, L5, L1S (formerly called L1-SAIFF for L1-Submeter-class Augmentation with Integrity Function) as well as L6a (a public regulated service), L5S (an augmentation signal on the GPS L5 frequency), and L6b (formerly called LEX, L-band Experimental, a high-accuracy augmentation signal centered at 1278.75MHz, the same as Galileo E6). Plans call for the system to finish its in-orbit test by March 2018.

At ION Pacific PNT 2013, Hiroyuki Noda, from Japan’s Office of National Space Policy, said the satellites for this augmentation system will be launched by the end of the decade, with service beginning by the end 2018.

**Korean SBAS**

Also at the Pacific PNT conference, Changdon Kee, of Seoul National University, described plans for a Korean satellite-based augmentation system (SBAS). The system would provide GPS L1 augmentation and possibly L5 as well.

Driving the development is that satisfactory availability of positioning accuracy for precision approach and landing of aircraft based on Japan’s Multi-technology Satellite Augmentation System (MSAS) is only 49.4 percent in South Korea compared to 90.6 percent in Japan.

Korea’s SBAS will include open-service multifunctional GEO satellites that are interoperable with other SBASs. A pseudolite demonstration system will be completed in 2014, clearing the way for further development. Ultimately, the system would include five reference stations, two master stations, two ground uplink stations, and two GEO satellites (the primary GEO on orbit by 2018 and a backup by 2020). The system is expected to be fully operational by 2021, with service available throughout Asia. ♦

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**CALENDAR**

**JUNE 2013**
19-21: 10th International Conference on Marine Navigation and Safety of Sea Transportation “TransNav 2013”, Gdynia, Poland
Contact: Faculty of Navigation, Gdynia Maritime University
Web: http://transnav2013.am.gdynia.pl

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**JULY 2013**
8-12: 2013 Beacon Satellite Symposium, Bath’s Historic Buildings, Bath, UK
Web: http://people.bath.ac.uk/ee3jarr/beaconsatellite2013/

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**SEPTEMBER 2013**
16-20: ION GNSS+ 2013, Nashville Convention Center, Nashville, Tennessee
Contact: The ION
Tel: +1 703-366-2723
Fax: +1 703-366-2724
Web: www.ion.org

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**OCTOBER 2013**
22-24: International Symposium on Precision Approach and Performance Based Navigation (ISPA) 2013, Berlin, Germany
Contact: German Institute of Navigation
E-mail: dgon.bonn@t-online.de
Web: www.ispa2013.de

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**DECEMBER 2013**
Contact: The ION
Tel: +1 703-366-2723
Fax: +1 703-366-2724
Web: www.ion.org

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**JANUARY 2014**
27-29: ION International Technical Meeting (ITM) 2014, Catamaran Resort Hotel, San Diego, California
Contact: The ION
Tel: +1 703-366-2723
Fax: +1 703-366-2724
Web: www.ion.org
Would you be able to tell if you were living in a virtual world like the 1999 film *The Matrix*? UCLA scientists said maybe you couldn’t... but scientists studying your brain could.

The neurons known as “place cells” reside in the hippocampus, responsible for navigation and memory. These place cells use three different kinds of information — visual cues, motion cues from your physical body, and proximal cues from the rest of the environment.

Place cells fire in response to specific physical locations. *Science Now* magazine, a publication of the American Association for the Advancement of Science (AAAS), uses the example of a shrub planted by your front door to explain how this works. When you leave in the morning, the cells fire when you pass the shrub. When you return at night, they fire at the same place even though you are walking in the opposite direction.

But the cells may not behave the same way in Second Life’s 3D world, or on the holodeck of the Starship Enterprise.

A University of California Los Angeles test on rats showed some remarkable differences in response moving through a virtual track compared to a real one.

UCLA neurophysicist Mayank Mehta compared rats running along a physical track with those in virtual space. “In the real world, about 45% of the rats’ place cells fired at some point along the track. In virtual reality, only 22% did. Half of the neurons just shut up,” he said.

Not only that — even the neurons that stayed active behaved differently in the real and virtual worlds. When they fire in the world of soil, smells, other living beings, and touch, some of the cells seem to work with those proximal cues and turn them into spatial information. In the hippocampus mapping system, the proximal cues have veto power over the other information.

Without proximal cues, the neurons that create the map of virtual space seem to do it by noting relative distances along the virtual track.

Of course, rats depend on a different mix of stimuli — more smell and less vision, for example — than humans. So, the research is just beginning.

Still, when our mothers yelled at us to turn off the TV — or stop questing in World of Warcraft and go outside and play — they understood something profound about the brain and making our way in the world.

The experiment appeared in the AAAS journal *Science*, on May 2 in the article, Multisensory Control of Hippocampal Spatiotemporal Selectivity.

**TRACTOR ROLL!**

**Loud, Fast and Out of Control**

Farming is not for the faint of heart. Almost everything you do can maim you, from vaccinating hogs to mixing chemicals to rolling tractors.

If you drive a tractor, statistics say you have a 1 in 10 chance to roll that puppy at least once.

In fact, farm tractors kill their operators 250 time each year according to the National Institute for Occupational Safety and Health (NIOSH), the agency that tries to keep the workforce alive.

Farmworkers are usually alone when an accidental rollover happens and may not be in a state to calmly dial for help; so, the University of Missouri (MU) decided to develop an app.

The VRPETERS (Vehicle Rollover Prevention Education Training Emergency Reporting System) uses sensors and GPS capability built into smartphones that can detect rollovers. Once the app detects a rollover, it sends an automatic emergency e-mail.
and phone message with the coordinates of the accident location to family members or emergency responders.

You can’t farm without tractors, and roll-overs have been killing people forever, said the apps developer, Bulent Koc, an assistant professor at MU. But “more and more farmers are using their smartphones to monitor weather or calculate production inputs while operating machinery. Since they already have their phones with them, installing VRPETERS could help save lives.”

Koc and a research assistant, Bo Liu, are thinking beyond tractors. Their app ought to help the whole family, not just the farmer — gramps on the backhoe, Sis on the snowmobile, Buddy on the ATV, and mom on the riding lawnmower.

The developers tested their app on a remote-controlled model tractor. Once it’s tested on the full-size model, they’ll be looking for a business partner to market the product.

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**Good Dog, Big Dog**

**DARPA’s Four-Legged Robot May Be Foot Soldiers’ Next Best Friend**

One is tempted ask if the U.S. Army and Marines might not be barking up the wrong tree.

Or, considering the definitely bulldogish posterior view (accompanying photo) of their Legged Squad Support System (LS3), wonder whether DARPA’s latest robot might not suffer from hip dysplasia.

But for two weeks last December, in the woods of central Virginia around Fort Pickett, the Legged Squad Support System (LS3) four-legged robot — dubbed Big Dog by its manufacturer Boston Dynamics — has been showing off its capabilities during field testing. LS3 is based on mobility technology advanced by DARPA’s Big Dog technology demonstrator, as well other DARPA robotics programs which developed the perception technology for LS3’s “eyes” and planned “ears.”

Working with the Marine Corps Warfighting Laboratory (MCWL), researchers from DARPA’s LS3 program demonstrated new advances in the robot’s control, stability, and maneuverability. These capabilities include “Leader Follow” decision making, enhanced roll recovery, exact foot placement over rough terrain, the ability to maneuver in an urban environment, and verbal command capability.

Eventually, program goals include implementing a go-to-waypoint in which Big Dog uses its local perception to avoid obstacles on its way to a designated GPS coordinate.

Today’s dismounted warfighter can be saddled with more than 100 pounds of gear, resulting in physical strain, fatigue, and degraded performance. Reducing the load on dismounted warfighters has become a major point of emphasis for defense R&D, because the increasing weight of individual equipment has a negative effect on warfighter readiness. The Army has identified physical overburden as one of its top five science and technology challenges.

The LS3 program seeks to demonstrate that a highly mobile, semi-autonomous legged robot can carry 400 lbs of a squad’s equipment, follow squad members through rugged terrain and interact with troops in a natural way similar to a trained animal with its handler.

“The robot’s performance in the field expanded on our expectations, demonstrating, for example, how voice commands and “follow the leader” capability would enhance the robot’s ability to interact with warfighters,” Hitt added. “We were able to put the robot through difficult natural terrain and test its ability to right itself with minimal interaction from humans.”

Video from the testing shows the robot negotiating diverse terrain including ditches, streams, wooded slopes and simulated urban environments. The video — viewable online at <http://www.darpa.mil/NewsEvents/Releases/2012/12/19.aspx> also shows the map the LS3 perception system creates to determine the path it takes.
Living close to Washington, D.C., and fortunate enough to have received an invitation (courtesy of the ION), I had the unique opportunity to attend the 10 April opening of the Smithsonian Institute’s Air & Space Museum exhibit on “Time & Navigation: The Untold Story of Getting from Here to There.”

This ceremonial grand opening held for the exhibit’s sponsors, which includes the ION, was a first-class event, well attended, and — based on the press coverage it received — did much to help ensure the early success of this important exhibit. This Smithsonian endeavor has been a topic of discussion in the navigation community for almost eight years. Plans call for the exhibit to be in place for the next five years in the northeast corner on the second floor of the Air & Space Museum.

Three of the four Smithsonian curators of this exhibit hail from the National Air and Space Museum. They are Paul Ceruzzi, chair of the division of space history; Roger Connor, curator of aeronautics; and Andrew Johnston, geographer at the Center for Earth and Planetary Studies. The fourth is Carlene Stephens, curator of timekeeping at the National Museum of American History.

The exhibit seeks to convey to the general public the critical role time plays in our ability to navigate accurately. A collection of interactive displays, instruments of navigation, time devices, and examples of time and navigation driven technology applications are used to educate visitors to the museum.

Unemphasized, but evident in the exhibit’s story line, is the role that governments and national defense establishments have played throughout history in stoking the fires of innovation to meet the challenges of possessing accurate navigation capabilities.

The “Time & Navigation” story starts with an 18th century requirement to accurately determine a ship’s longitude at sea. Although the art and science of determining latitude was well understood and accomplished through observations of the sun and stars, early ocean navigators had to rely on dead-reckoning to estimate their longitude.

Dead-reckoning for long periods of time beyond the sight of land and known locations often proved disastrous, resulting in the loss of life and property. The grounding of a British naval fleet off the Isles of Scilly in 1707 resulted in the loss of four ships and over 1400 sailors and led to the Longitude Act of 1714. This legislation, enacted by the Parliament of the United Kingdom, established a Board of Longitude tasked with the responsibility of overseeing a Longitude Prize designed to encourage innovators to find simple and practical methods for the precise determination of a ship’s longitude.

The Longitude Prize offered several primary monetary awards: £10,000 for a method that could determine longitude within 60 nautical miles, £15,000 for a method that could determine longitude within 40 nautical miles; and £20,000 for a method that could determine longitude within 30 nautical miles.

Ultimately, the board distributed more than £100,000 sterling. John Harrison (1693-1776) received the largest sum for his efforts in building a series of chronometers (designated H1, H2, H3, and H4) designed to meet the rigors of providing precise time at sea.

Nothing like national priorities, good legislation, and money to spur innovation!

In addition to the exhibit, the Smithsonian has established a very informative website found at <http://timeandnavigation.si.edu>. This site offers a collection of dropdown tabs and links providing information on maritime, aviation, and space navigation challenges.

The exhibit website includes a brief history on the Cold War and the need for global access to precise positioning, navigation, and timing information to allow immediate and accurate military response to the Soviet threat under all conditions anywhere on the globe — the forcing function...
leading to radionavigation systems such as Omega, Transit, and GPS.

Additionally, the website hosts a link titled Timeline of Innovation. This link, beginning in 1280 with the first European mechanical clock and concluding with the Curiosity explorer landing on Mars in 2012, provides a high-level summary of the advances made in technology and computing capability.

Another interesting link is the opportunity for those visiting the website to answer a question and add their vote to a running poll. The currently posted question is: “Are we losing valuable skills as technology changes?” At the time of this article 89 percent of the respondents answered “Yes” and 11 percent answered “No.”

A few of the “Yes” votes included comments like this one from an experienced navigator: “As a pilot, navigation is key, and although we use GPS more than most, personally, I never go out without having a well planned “backup,” and all pilots expect that during a flight test, if they show reliance on the devices, the pilot examiner will turn them off, and say, “Uh Oh, your batteries just died, now what are you going to do? You better have a good answer!”

Another cautionary comment concerning the loss of navigational skills states, “You better have at least one good map and time piece. I have had to use them more than once when the computer took a break.”

The exhibit makes very clear the symbiosis that exists between time and navigation. It also underlines the advantages gained from technological development when national priorities are brought to bear in a cooperative effort between government and private sectors. Society’s growing reliance on these technologies is readily evident.

I was very impressed with the exhibit and the website. If you have the opportunity to visit the exhibit and the website, it will be time well spent. I salute the Smithsonian, the curators, and those within the ION’s ranks who helped make this exhibit a reality.

Well done to all. ◆
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