Enough about GNSS, already

PLANS celebrates the ‘other’ technologies

For those in the navigation community who may be getting a little tired of all the focus on GPS and other GNSS systems, this year’s IEEE/ION-sponsored Position, Location, and Navigation Symposium (PLANS 2010) offered a welcome change of pace.

Navigation systems using cameras (vision-based), sonar, inertial (from tactical-grade to low-cost sensors), and terrestrial wireless RF technologies (such as RFID, ultrawideband, Zigbee, and Bluetooth) filled the program of the May 4-6 event at the Renaissance Esmeralda Resort in Indian Wells, California. While the Mojave Desert environment outside shimmered in temperatures in the high 90s — sure, a dry heat, but still pretty intense — more than 350 PLANS attendees had their pick of about 120 paper presentations.

In particular, the surge in production of microelectromechanical system (MEMS) inertial products for mobile devices such as smart phones has created a large installed base of positioning capabilities that researchers are trying to exploit. For example, Seung Hyack Shin from the Navigation and Electronics Systems Lab at Korea’s Seoul National University, described efforts to detect and model the motion of mobile phones containing three-axis gyroscopes as a way to measure a pedestrian’s movements.

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Accelerometers, compasses, and other inertial technologies are typically incorporated into mobile devices for non-navigational purposes, such as reorienting the user interface screen if a smart phone is turned on its side or a computer is dropped (to brace critical components against impact). However, because these technologies also have movement and location data content (as well as communication links), they may potentially be exploited for other purposes.

Shin and his colleagues have developed a set of algorithms that can determine whether a mobile phone is being held stationary (as the pedestrian looks at it or talks on the phone), in a front pocket, or being carried in the hand without viewing. The swing motion can be detected using the variance of the three-axis gyro from the norm and the difference of the pitch angle of the mobile phone.
FROM THE PRESIDENT
DR. MIKEL MILLER

Cavalcade of Events

A ll, my passion for promoting interest in navigation continues to grow at a healthy pace!

I am amazed almost daily with new information describing new navigation sensors, techniques, and especially applications. With this, my desire to see the ION heavily involved in educating current and next-generation positioning, navigation and timing (PNT) engineers, scientists, and users is at an all time high.

Thus, I was thrilled to participate in our second year of courses at the Satellite Navigation Science and Technology for Africa conference this past spring. The three week–long workshop, sponsored by Boston College and the Abdus Salam International Centre for Theoretical Physics (ICTP) was organized by Patricia Doherty. The Institute of Navigation (ION) again sponsored an impressive slate of ION member instructors.

During the workshop I had the honor of working with Prof. Jade Morton and USAF Lts. Carrie New and Casey Miller; as we taught a one-day tutorial on autonomous vehicle guidance, navigation, and control. As was the case last year, this proved to be a great day that provided a ton of knowledge and fun as African professors and graduate students learned and worked together to build their own “autonomous” vehicles using the LEGO® MINDSTORMS® robotic kits.

For many of the participants this was the first time they had ever seen a “LEGO.” The students this year were as interesting as those we worked with last year and challenged us with intriguing questions and comments. Their desire to learn and apply their new found knowledge was impressive.

I am very thankful to the ION organization for its mission to educate our international community on GNSS, related PNT technologies, and their associated applications. I also wanted to thank Pat and her team for their ability to make the best of any situation — including “volcanic eruptions” — by making real-time adjustments to the program and still providing a very educational experience for all the students.

This program has been a highlight for me during my tenure as ION president, and I know it provides great visibility to our organization and most importantly supports our mission.

On another international front, the Executive Committee recently approved a motion for the ION to become a technical co-sponsor of The International Association of Chinese Professionals in GPS (CPGPS) 2010 Technical Forum on Satellite Navigation and Positioning.

CPGPS 2010 meets the ION’s technical co-sponsorship requirements in that it is hosted by a non-profit, the ION has no financial commitment with the co-sponsorship, and a member of the ION Council, Dr. Jade Morton, will serve as a member of the meeting’s organizing committee. The ION will lend its logo for use to promote the meeting and will link from the ION’s web site to the conference’s web site.

I encourage you to familiarize yourself with CPGPS 2010, which will be held August 18-20, 2010, in Shanghai, China and is jointly sponsored by CPGPS, The Chinese National Remote Sensing Center/Department of the Chinese Ministry of Science and Technology, The Science and Technology Commission of Shanghai, Wuhan University, and our own Institute of Navigation.

I would also like to congratulate the IEEE/ION Positioning, Location and Navigation Symposium (PLANS) organizers on a successful symposium held this past May.

Emiola Olabode Gbobaniyi of Nigeria holding an award winning robot. See article on page 18 in this Newsletter for full details on the conference.
Just over 10 years ago, the U.S. government implemented an “enhanced 911” (E-911) policy for location of emergency callers using mobile phones — the kickoff to the consumer GPS success story.

Since then, GPS receiver sensitivity has increased almost 1,000 times, host-based GPS has become the norm, and more than 90 percent of all 500 million GPS units in operation today are found in mobile phones. This two-part series covers the technology revolution behind GPS in mobile consumer products, and looks ahead at the consequences for our industry in the next decade.

E-911 Catalyst

In 1999, the United States Federal Communications Commission (FCC) and Congress adopted E-911 rules that mandated automatic location identification whenever an emergency (911) call was made.

At first, assisted GPS (A-GPS) was adopted only in those mobile networks that were then synchronized to GPS time, predominantly the CDMA networks.

The largest networks in the world, GSM and now 3G, are not synchronized to GPS time. Consequently, it was originally assumed that non-GPS technologies (such as enhanced observed time difference, now extinct) would be the E-911 winners.

As we know, GPS and GNSS turned out to be the big winners for handset location.

E-911 became the major driver for GPS in the United States, and indirectly throughout the world, but only after GPS technology evolved far enough, thanks to the seven technologies I will now discuss.

Technology 1

Assisted GPS

“Faster, Longer, Higher.” Those are the three things to remember about A-GPS, to paraphrase the Olympics motto.

A-GPS replaces the orbit data transmitted by the satellite. A cell tower can transmit the same or equivalent data, and so the A-GPS receiver operates — faster.

The receiver has to search over a two-dimensional code/frequency space to find each GPS satellite signal in the first place. Assistance data reduces this search space, allowing the receiver to spend longer doing signal integration, and this in turn means higher sensitivity (Figure 1) — so, longer and higher.

Now let’s look at this code/frequency search in more detail, and introduce the concepts of fine time, coarse time, and massive parallel correlation.

Any assistance data helps reduce the frequency search. It is somewhat like scanning the dial on your car radio — but, in this case, the different GPS frequencies are affected by satellite motion, their Doppler effect. If you know in advance whether the satellite is rising or setting, then you can narrow the frequency-search window.

The code-delay is more subtle. The entire C/A code repeats every millisecond. So narrowing the code-delay search space requires knowledge of GPS time to better than one millisecond, before you have acquired the signal. We call this “fine-time.”

CDMA networks are synchronized to GPS time. GSM and 3G are not. They are within ±2 seconds of GPS time; we call this “coarse-time.”

Initially, only the fine-time networks adopted A-GPS. Then came Technology 2, massive parallel correlation, and Technology 3, high sensitivity.

Technologies 2 and 3

Massive Parallel Correlation, High Sensitivity

Traditional GPS had just two or three correlators per channel. Receivers would search the code-delay space until they found the signal, and then track the signal by keeping one correlator slightly ahead (early) and one slightly behind (late) the correlation peak. Thus, “early-late” correlators.

Massive parallel correlation is defined as enough correlators to search all C/A code delays simultaneously on multiple channels.

GPS REVOLUTION continued on page 4
GPS REVELATION continued from page 3

In hardware, this means tens of thousands of correlators. In massive parallel correlation, all code-delays are searched in parallel, so the receiver has more time to integrate the signal whether or not fine-time is available.

With three technologies, we have made GPS “faster, longer, higher”, and this gives us high sensitivity, regardless of the phone system on which we implement A-GPS.

At first, we thought the major consequence of high sensitivity would be indoor GPS, but instead it has led to something possibly more significant: really small, cheap antennas. Although small, cheap antennas hurt performance (as we will see later), they have facilitated the adoption of A-GPS into practically all new smartphones.

Technology 4
Coarse-Time Navigation
A-GPS assistance relieves the receiver from decoding orbit data (making it faster), and MPC means it can operate with coarse-time (longer, higher).

But the time-of-week (TOW) still needs to be decoded for the position computation and navigation: for unambiguous pseudoranges, and to know the time of transmission. Coarse-time navigation solves for TOW, instead of decoding it. A key part of the technique involves adding an extra state to the standard navigation equation, and a corresponding extra column to the familiar line-of-sight matrix.

With this technique, you can get a position in one, two or three seconds, faster than you can decode TOW. Or you can get a position when the signals are too weak to decode TOW. The result: longer battery life, since you can always get fast time-to-first-fix (TTFF) without waking the receiver to maintain it in a hot-start state.

Technology 5
Low TOW
Low TOW decode is a parallel effort to coarse-time navigation: it lowers the threshold at which it is possible to decode the time-of-week data.

In 1999, -142 dBm was considered the lower limit of signal strength at which you could decode TOW. (That is where the energy in a single data bit is just observable if all you do is integrate for 20 ms.) Since then, we have developed better ways of decoding the TOW message, so now it can be done down to -152 dBm.

Technologies 6 and 7
Host-Based GPS, RF-CMOS
If you’re still counting with me, we are now at technologies 6 and 7: Host-based GPS and RF-CMOS

We can understand the host-based architecture best by looking at traditional system-on-chip (SOC) architecture. An SOC GPS may come in a single package, but inside you’ll find three separate silicon chips packaged together: a baseband die with the central processing unit (CPU), a radio frequency tuner, and flash memory.

The only cost-effective way of avoiding the flash memory is to have read-only memory (ROM). This could be part of the baseband die, but that means you cannot update the receiver software and keep up with the technological developments we’ve been talking about.

The host-based architecture, by contrast, needs no CPU in the GPS. Instead, GPS software runs on the CPU and flash memory already present on the smartphone, or other host device.

Meanwhile, radio-frequency complementary metal-oxide semi-conductor (RF-CMOS) technology has allowed the RF tuner to be implemented on the same die as the baseband. Host-based GPS and RF-CMOS together allowed us to make single die GPS chips.

The happy effect: chip costs went down dramatically without any loss in performance.

In the next issue of the newsletter, we will continue with Dr. van Diggelen’s discussion of consumer markets and the “A-GPS revolution: Part II – Are We There Yet? The New Age of GPS-Plus.” The second part will discuss Moore’s Law as applied to GPS, the growth of mobile telephone markets, and how consumer expectations affect technology decisions.

About the Author
Dr. Frank van Diggelen is Senior Technical Director of GPS Systems, and Chief Navigation Officer for Broadcom Corporation. Dr. van Diggelen is the inventor of coarse-time navigation, co-inventor of long term orbits for A-GPS, and holds more than 50 issued U.S. patents on A-GPS. He has a Ph.D. in electrical engineering from Cambridge University and is the author of A-GPS: Assisted GPS, GNSS & SBAS, the first textbook on assisted GPS.

FIGURE 1. Summary Table: Seven Technology Enablers for Consumer GPS

<table>
<thead>
<tr>
<th>Technology</th>
<th>Consequence</th>
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<td>1. A-GPS</td>
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<td>2. Massive parallel correlation</td>
<td>Longer, higher with coarse-time</td>
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<td>3. High sensitivity</td>
<td>Small, cheap antennas</td>
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<td>4. Coarse time navigation</td>
<td>Fast TTFF without periodic wakeup</td>
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<tr>
<td>5. Low TOW</td>
<td>Decode time from weak signals</td>
</tr>
<tr>
<td>6. Host-based GPS, and</td>
<td>Single die</td>
</tr>
<tr>
<td>7. RF-CMOS</td>
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</table>
GPS doesn’t work underground. We all know that. But very low frequency radio signals do.

The U.S. military is studying the potential use of very low frequency (VLF) signals of opportunity for a new navigation system that works in tunnels deep underground.

Right this minute, soldiers are hunting a variety of enemies — from drug lords to terrorists — in tough-to-navigate tunnel systems all over the world.

Mountain rescue teams, EMTS, and first responders would find it equally useful to be able to locate people in building basements, sewers, snow caves and other underground places.

Enter DARPA, the military’s Defense Advanced Research Projects Agency.

In a recent study, they collected very low frequency (VLF) radio signals, or sferics, in underground and above ground locations.

These signals of opportunity (SoOP) came from lighting strikes, but they can also come from magnetic noise, gravity fields, and communications transmissions. Preliminary results indicate that “both horizontal and vertical (depth through the earth) position estimates with GPS-quality location accuracies are achievable.”

On March 16, DARPA held a mostly classified conference to pursue Sferics-based Underground Geopositioning or the S-BUG program. The agency is seeking proposals for a SoOP-based prototype for non-real-time mapping and surveying missions and real-time navigation underground.

Proposals should cover receiver and processing hardware, signal processing and navigation algorithms, system performance modeling and systems integration.

The project will need to verify that sferic signals received on the surface can be correlated with sferics received underground to provide geolocation with enough resolution. The ultimate goal of the S-BUG project is to design a full navigation and tracking system for underground uses.

The project coincides with another DARPA project (Nimbus), which aims to trigger and manipulate artificial lightning. For more info, contact: DARPA-BAA-10-48@darpa.mil.

Thanks to physorg.com, the science and technology news service, for parts of this story. More information: DARPA project: http://www.darpa.mil/sto/underground/sferic.html

ION Article Citations – USE THIS NEW WEB TOOL!

ION has introduced a beneficial new tool to improve the process of finding reference papers from the ION journal and ION conference proceedings. When you locate an article on the ION website, you can view the complete title, author and abstract. There is a new field, “Cite This Article”, which contains a pre-formatted reference citation for each paper.

To help cite the most recent version of the paper, navigate to a proceedings paper that has been published in the journal and a link will direct you to the updated citation. If you should notice an error in a citation, simply click on the “Report Error” link at the bottom of the screen. This will help ION staff keep the publication database as accurate as possible.
PART II: DID PRINCE HENRY EARN THE RIGHT TO THE SOBRIQUET, “THE NAVIGATOR”? — FROM THE ION HISTORIAN, MARVIN MAY

Henry the Navigator & Early 15th Century European Exploration

The first part of this column addressed the discoveries of the Portuguese maritime explorations — under the sponsorship of Prince Henry — from 1420 to 1460. In this concluding part of the series we focus more on Prince Henry himself. As is often the case in chronicling history, there are varying interpretations of the contributions of individuals, and such is the case with Prince Henry.

What can we expect from the only person in history labeled “The Navigator”? Perhaps interpreting Prince Henry’s accomplishments are unfairly biased by expectations, particularly among those of us in navigation.

One might expect Henry the Navigator (known by his Portuguese title as Infante Dom Henrique) to have invented navigational instruments and techniques, written treatises and published memoirs, demonstrated seagoing skills, and surrounded himself with learned scientists engaged in advanced astronomy and navigation.
Indeed, some chroniclers of Prince Henry do indeed attribute some of these accomplishments to him: most frequently crediting Henry with founding a famous school of navigation that attracted the leading cartographers, astronomers, geographers, instrument makers and seamen of his time.

Unfortunately, there are no contemporary records of Henry’s personal navigation accomplishments, nor did he ever command a ship. Even his affiliation with the navigation school at Sagres appears to have been mentioned for the first time by a 17th century British historian. The 19th/20th century Portuguese historian Duarte Leite speaks scornfully of the Sagres story saying, “Among the numerous legends which embellish our history, this one stands out for two characteristics: it is exotic, having come from England via France, and it contains not one whit of truth whatever in essentials or details.”

So, what made Henry such a vital force during Portuguese maritime dominance?

Third in line among the legitimate sons of King Joao himself, Henry was energetic, ambitious, and communicative and lost no opportunity to promote himself and Portuguese exploration.

In 1420, at the age of 26, Henry was made grand master of the Order of Christ, a Catholic award of honor of the highest possible standing sponsored by the Pope, which had replaced the crusading order of the Knights of Templar in Portugal.

Like all promoters of exploration of his time, his main quest was for gold and spices. Gold was the commercial incentive, yet Henry also took his religious responsibilities seriously and was keen to spread the Christian gospel to the people of Africa.

The evangelical motive was the reason why all of Henry’s ships bore a red cross on their sails; the explorers saw themselves as crusaders to the non-Christian world.

By today’s standards, this evangelical spirit was contradicted by the fact that much of Henry’s profits came from capturing Africans and bringing them back to Europe to be sold off at the quayside of Seville or other slave markets in the Mediterranean. In the 15th century, however, slavery was regarded as an acceptable activity necessary for a flourishing economy by Europeans, Africans, Asians, and religious authorities alike.

Henry controlled more wealth in Portugal than any other man with the possible exception of the King himself. He acquired the Madeiras, the Azores, the Cape Verdes; he held monopolies on dye and soap manufacturing, on river and tuna fishing, on fishing in the Atlantic and African coasts, and on coral gathering. Henry’s leadership in exploration was only part of his wide-ranging interests associated with his family and country.

He did not need to design ships, train sailors, educate pilots, or draw charts. All of these skills and resources were under his command and he enabled them to flourish.

Henry the Navigator died in 1460. The exploration of the African coast was continued by private ventures after his death but it was not carried out with the same enthusiasm as when it had royal support. In 1473 Lopo Goncalves crossed the equator. In 1487 Bartholomew Dias was the first European to take his ship around the southernmost point of the African continent.

Finally, in 1497, another Portuguese expedition commandeered by Vasco de Gama rounded the Cape of Good Hope and in May 1498 consummated the Portuguese goals of a maritime passage to India. Of course, around this time other powers were convinced that a sea passage from Europe to India and the Orient might be discovered by exploring to the west instead of the east around Africa, and some thought that the western passage might turn out to be the shorter route.

The English colonial powers eventually benefited the most from early Portuguese explorations. In due time, they remembered that Henry was, after all, the son of an Englishwoman, and they gave him the title of “navigator.”

The English colonial powers eventually benefited the most from early Portuguese explorations. In due time, they remembered that Henry was, after all, the son of an Englishwoman, and they gave him the title of “navigator.”

Henry the royal prince never actually took command of a ship, but he was the main force behind new ventures in seafaring. By his efforts, Portugal came to the forefront of exploration during his lifetime and for several generations after him.

Portions of this article were excerpted from Peter Laughton, Voyages that Changed the World, Quercus Publishing, London, 2007, and from Bailey W. Diffie et. al, Foundations of the Portuguese Empire, 1415-1480, University of Minnesota Press, USA, 1977.

Marvin B. May is the chief scientist at Pennsylvania State University’s Navigation Research and Development Center, Warminster, Pennsylvania.
The Walter Fried Award for Best Paper written for the PLANS conference includes a personalized plaque and a financial honorarium of $750. The selection criteria includes: technical content, innovation, importance and timeliness of the subject matter, conciseness, clarity and completeness of the written material.

The IEEE’s AESS Walter Fried Award was presented at the IEEE/ION PLANS Award Luncheon by John Weyrauch, IEEE AESS/ION Liaison, to the award winner Kathryn A. Daltorio of Case Western Reserve University for her paper, An Obstacle-Edging Reflex for an Autonomous Lawnmower. This paper was based on the ION Satellite Division’s 2009 Autonomous Lawn Mower Competition. Co-authors included Amaury D. Rolin, Jonathan A. Beno, Bradley E. Hughes, Alexander Schepelmann, Michael S. Branick, Roger D. Quinn, Case Western Reserve University; and James. M. Green, MTD Products, Inc.

The IEEE/ION PLANS Program Committee also presented awards for the best papers in each technical track and the best overall student paper as follows:

**BEST PAPER IN TRACK AWARDS**

**BEST STUDENT PAPER AWARD**

From Track A: Knowledge-based Error Detection and Correction Method of a Multi-sensor Multi-network Positioning Platform for Pedestrian Indoor Navigation: Yuwei Chen, Finnish Geodetic Institute, Finland

From Track B: A Valid Comparison of Vector and Scalar Tracking Loops: Matthew Lashley, Navigation Technology Associates, Inc.

From Track C: Comparing Detection Performance of Polarization and Spatial Diversity for Indoor GNSS Applications: Mohammadreza Zaheri, The University of Calgary, Canada

From Track D: GPS Experiment on the Balloon-based Operation Vehicle: Peter Buist, Delft University of Technology, The Netherlands

Development and Validation of an OFDM/DVB-T Sensor for Positioning: Damien Serant, ENAC/Tesa, France
The Kershner Award recognizes individuals who have made substantial contribution to the technology of navigation and position equipment, systems or practices over their lifetime. The IEEE/ION PLANS 2010 Kershner Award was presented to Dr. James Huddle for substantial contributions to the technology of navigation and position equipment, systems or practices over his lifetime.

Over his distinguished career, Dr. Huddle has performed and directed system mechanization, analysis, evaluation, and optimization of various multi-sensor navigation, guidance, and surveying systems. The sensors employed include inertial, Doppler radar and sonar, LORAN, Stellar-trackers, Laser and RF range and range-rate devices, EM-logs, TERCOM, NAVSAT, OMEGA, and GPS. Applications include air, marine and land navigation and referencing systems, strategic and tactical missile guidance, and position and gravity surveying systems.

Additionally, Dr. Huddle served on the Naval Studies Board Panel for Advanced Navigation Technology for the National Academy of Sciences from 1982 to 1984. He received the Institute of Navigation’s Thomas L. Thurlow Award in 1988, the Institute’s highest award granted for “Outstanding Contributions to the Science of Navigation”. He is a Fellow of the ION, the IEEE and the International Association of Geodesy. He has been awarded 11 patents and has several pending.
From this, Shin’s pedestrian dead reckoning method can detect the number of steps being taken, which in turn can provide estimates of direction and distance traveled.

It’s a Crash Test, Dummy
A far different application — also using MEMS-based inertial measurement units (IMUs) — appeared in a presentation by Peter Björkholm, of the Sweden’s Imego Institute: navigation in vehicle crash tests.

The stars of Björkholm’s paper, co-written by researchers in the Swedish auto industry, were crash test dummies outfitted with calibration rigs to measure their movements before and after simulated collisions.

As Björkholm pointed out, the dynamic range of motion in these tests is very high, with very strong acceleration reaching hundreds of g’s in the dummies, thousands of g’s on other parts of the car. Combined with the rotation rate (typically thousands of degrees per second) and rotation accelerations (millions of degrees per second²), these tests place high demands on sensor response bandwidth.

On the other hand, the duration of motion is rather short, consisting typically of 10-20 seconds of linear acceleration, a few parts of a second of impact, and finally a few seconds of less violent settling motion.

Inertial sensors have been used extensively in crash dummies — but mainly to monitor forces and motion in the direction of the individual sensor’s sensitivity direction. However, because these sensors are mounted and calibrated individually, combining data from several sensors to figure out the complete motion can prove difficult.

Traditionally, automakers have used camera systems that track markers spread out over the body of the car or the skin of the dummies to track this motion, but these cannot track objects that are obscured from the camera locations outside of the vehicle. These systems cannot track angles very accurately, often making determination of angular rate and angular acceleration data so inaccurate as to be unusable.

In order to allow complete six-degrees-of-freedom tracking of obscured objects, such as the dummy head during inflation of the airbag, Imego has developed a compact, lightweight IMU designed to fit into the head, chest, and feet of standard crash test dummies. These track the full range of motions normally experienced by the dummies during testing.

Björkholm described the sensor design and its use in tests, as well as results of those tests, which indicated that the IMUs worked as well or better than the optical systems.

To be sure, technical sessions on modernized GNSS, augmentation services, and receiver technology ensured a substantial amount of content about space-based positioning, navigation, and timing (PNT). And numerous presentations addressed the integration of GNSS with inertial and other PNT technologies.

Positioning Inside Out
Yuwei Chen reported on progress that he and colleagues at the Finnish Geodetic Institute have made in developing a seamless indoor/outdoor positioning system that combines a multi-sensor platform (DSP-based GNSS receiver, 3D accelerometer, barometer, and 2D digital compass) with a multi-network platform (Wireless Local Area Network or WiFi, Bluetooth) using received signal strength (RSS) indicators to generate a “fingerprint” database (radio map) for navigation indoors.
Indoor environment are challenging, not merely because they degrade or completely block GNSS signals but because they buildings contain other “disturbance” sources that affect sensor measurements: an elevator can generate magnetic emanations that contaminate a digital compass readers, or a ventilation system may cause jumps in the barometer’s measurements.

As Chen pointed out, however, the interior architecture of a building also restricts a person’s activity to defined areas — corridors, stairways, rooms, which in turn constrains the model of pedestrian dynamics and activity and thus provides additional opportunities to augment the positioning solution.

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**ION Announces Retirement of Carl Andren**

Carl Andren, The Institute of Navigation’s Technical Director, retired this past March. Carl worked professionally with the Institute for the past 14 years. Before joining the ION staff he worked for Racal for over 20 years. Prior to his employment at the ION he served on the ION Council for several years as Treasurer and Chair of the Finance Committee. He was also active in the Radio Technical Commission for Maritime Services, INMARSAT Users Association and the International Loran Association. Please join the Institute in wishing Carl all the best in his retirement.

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**AIR FORCE NAVIGATORS OBSERVERS ASSOCIATION**

**Last of the Real-Flight Navigators!**

Join the Air Force Navigators Observers Association, a 25-year old nonprofit organization that keeps you in touch with other:

- Navs
- Radar navs
- Bombardiers
- Navigator-bombardiers
- Electronic Warfare Officers (EWOS)
- Weapons systems Operators (WSOs)
- Radar operators (ROs, DSOs, OSOs)

AFNOA president and historian Ron Barrett calls the group “the last of the real-flight navigators. We will assist any and all to get the history right on flight navigator operations through our members who actually flew these positions. We also collect the tools of the trade — logs, maps, sextants, computers and more — for museums and official archives.”

Under an agreement with the USAF/Pentagon/Air Force Historical Research Agency, AFNOA’s research archives are maintained at Maxwell AFB, Alabama (under Dr. Charles O’Connor) and the operational (tools of the trade) archives are being inset in the Museum of the Mighty Eighth at Savannah, Georgia (under Dr. Vivian Rogers-Price).

AFNOA’s newsletter, document archives and roster will help you discover what happened to your USAF classmates and colleagues — from the very first Army Air Corps flight navigator classes at Coral Gables 40-A to today’s Randolph AFB/Pensacola Naval Air Station through Air Education and Training Command combat systems officers.

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A P-51 Mustang in a heritage flight during a 2007 air show at Langley Air Force Base, Virginia.

**More Than Hot Air**

This story will resonate with anyone who has tackled an “easy to assemble” toy on the night before Christmas.

Just try to plant the foundation for giant wind turbines very precisely in the North Sea’s deep and stormy waters.

The first commercial North Sea wind farm, Bard Offshore I is using high precision GNSS receivers made by Ashtech (formerly Magellan) to help them do the job.

Five of them are installed on board a custom-designed construction vessel, the *Wind Lift I*, to help it in its task of installing wind turbines in rough water of the North Sea.

The wind farm is in 130-foot deep water off the German island of Borkum. The turbines themselves can extend 200 feet above the sea.

The ProFlex receivers are part of a Danish positioning system that includes a survey grade gyrocompass and motion sensors.

One receiver is located on a separate platform and acts as a reference station. Two are on the long legs of the vessel. A third is high atop a tall crane in the stern of the ship, and a fourth is on an adjacent supply barge.

Together, they guide the *Wind Lift I* to the correct spot, help it jack itself up from the north shore seabed on legs nearly 235 feet high and help pile drivers position the turbines’ foundation pipes vertically into the seabed.

The German Environment Ministry believes half of the country’s power can come from renewable sources by 2050. They project that 24 percent of Germany’s energy needs will come from wind turbines in the North Sea and Baltic by that time.

Germany has invested heavily in wind power, and is retrofitting one of its largest shipyards and its skilled workforce — declared redundant during the recent economic crisis — to build offshore energy equipment.

The first North Sea wind farm, Alpha Ventus, with 12 windmills, started transmitting power in May. Bard Offshore I, with 80 turbines, is expected to be fully operational in 2011. ◆

**They’ve Got An App For That**

A 13-year-old boy from the San Bernardino, California, mountains wants to scale seven major peaks before he grows up. Jordan Romero is taking on the 29,304-foot Mt. Everest, and you can follow his achievement on his very professional website.

You can download a media kit, read the blog, twitter with Jordan, check in with his sponsors and supporters, watch videos, and donate at the Base Camp ($100) to Summit ($500) level.

Best of all, you can locate “Team Jordan-Live on Everest” with an ESRI GIS mapping application that integrates live data from a number of web services: GPS information integrated with SPOT satellite imagery updated as often as every 10 minutes, current elevation and distances, daily weather forecasts, map layers, and imagery of the mountain and the surrounding area.

The app includes social networking — Flickr for photographs and Twitter for messages from the team.

On May 15, the team started to head for the summit. As I write, I’m looking at a satellite photo of their location, their path lined in orange dots. A red dot blinks at the advanced base camp, location at 20,300 feet elevation. It includes an almost-live message saying, “We’re OK … we’re trekking.” All around the screen are the numbers — weather, elevation, wind speed, recent photos, and viewing options.

Pretty cool. And quite a change from Edmund Hillary and Tenzing Norgay in 1953. Then you had to wait for Movietone News to find out what was happening. ◆

**Where the Best Navigator Rules**

Human navigators may feel like they get no respect. But certain members of the animal kingdom give due honor to the wayfinders among them.

Homing pigeon flocks follow the best navigator on excursions to and from home, according to researchers from the Eötvös Loránd University in Budapest, Hungary.
They’ll even follow the slowest bird in the flock, if they trust it to know where it’s going.

Researchers studied a group of homing pigeons — all wearing the now-familiar teeny GPS backpacks. The found that the leader is immediately followed by three or four others, who will step up to the plate and lead occasionally. The rest of the flock follows the leaders.

Chief researcher Tamás Vicsek, a biological physicist, told *Science News* that the group dynamics are like humans deciding where to eat dinner. “Maybe someone knows the area restaurants best, or there is a person who’s a gourmand — or maybe they are the most outspoken,” he said.

The researchers followed 13 birds on long and short trips — around home, and as far as nine miles away. The GPS unit measured shifts in birds’ flight direction five times per second.

Videos of the birds’ positions during flight showed that if the best navigator moves a little to the left, it takes about a third of a second for other birds to do the same. But if the least savvy bird makes a move “the others don’t care,” Vicsek said.

See a video of a birds being tracked with their GPS units at http://sciencenews.org/view/generic/id/57997/description/Pigeons_usually_let_best_navigator_take_the_lead#video.

**Muscle Power for Your PND**

Lost in the woods? GPS handheld or locator beacon dead? Now you can generate some electricity and pad the heels of your hiking boots at the same time.

A Louisiana Tech University engineering professor developed a new MEMS technology for generating power from a soft transducer embedded in a shoe.

“This technology could benefit hikers that need emergency location devices or beacons,” said Ville Kaajakari, in a university press release. “For more general use, you can use it to power portable devices without wasteful batteries.”

The microelectromechanical system (MEMS) device has new, more efficient voltage regulation circuits that convert a piezoelectric charge from your movement into useable voltage for a battery or a small electronic device. It can run sensors, inertial navigation, RF responders, and GPS receivers.

Kaajakari’s breakthrough uses a low-cost polymer transducer that has metallized surfaces for electrical contact. Unlike conventional ceramic transducers, the polymer-based generator is soft and robust. The transducer can take place of the regular heel shock absorber and you’ll never know the difference.

He’s working on upping the power so walkers can charge their cell phones, too.

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**August 2010**

**18-20: CGPS 2010 Technical Forum on Satellite Navigation and Positioning, Sponsored by International Association of Chinese Professionals in Global Positioning System (GPS), Shanghai, China**

Contact: Jin Hong
Tel: +86 1347-628-3029
Web: www.ion.org/meetings/cgps2010.pdf

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**September 2010**

**21-24: ION GNSS 2010, Portland Convention Center, Portland, Oregon**

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

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**October 2010**


Contact: German Institute of Navigation
Tel: +49-228-20197.0
Fax: +49-228-20197.19
Web: www.dgon.de

**22-22: 16th Ka and Broadband Communications Navigation and Earth Observation Conference, Grand Visconti Palace Hotel, Milan, Italy**

Contact: Ms. Clotilde Canepa Fertini
Tel: +39 338-700-1650
Web: www.kaconf.org

**25-27: ION/AFRL Autonomous Weapons Workshop 2010, Emerald Coast Convention Center, Fort Walton Beach, Florida**

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

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**January 2011**

**24-26: ION International Technical Meeting (ITM) 2011, Catamaran Resort Hotel, San Diego, California**

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

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**June 2011**

**28-30: JSDE/ION JC 2011, Crowne Plaza Hotel, Colorado Springs, Colorado**

Contact: The ION
Tel: +1 703-366-2723
Fax: +1 703-366-2724
Web: www.ion.org
Global Programs Experience Ups and Downs

Up: GPS and GLONASS; Down: Galileo and Compass

GPS

Just over 14 years after the Rockwell Space Systems Division won the prime contract for a follow-on generation of GPS satellites, the first Block IIF spacecraft reached Cape Canaveral for a May 20 launch.

Targeted for the B2 slot in the constellation, the satellite — the first of 12 to be built by Boeing after its acquisition of the Rockwell division — will transmit the new civil L5 signal in the protected aeronautical radionavigation system (ARNS) band centered at 1176.45 MHz. It will also broadcast the modernized military M-code and civil L2C signals added with the modernized Block IIR spacecraft, as well as the other legacy GPS signals.

The initial three IIF space vehicles (SVs) were acquired under a billion-dollar research, development, test, and evaluation (RDT&E) contract, with the cost of the other nine approaching $60 million each, according to the GPS Wing. Taking the program expenditures altogether, each SV averaged about $121 million to produce a total program cost of $1.452 billion.

Meanwhile, the Federal Aviation Administration (FAA) is working to expedite restoration of full coverage of the GPS Wide Area Augmentation System (WAAS) after Intelsat lost control over a geostationary (GEO) carrying one of the WAAS transponders.

An electronic malfunction suspected to have been caused by a solar storm could subject users in the National Air Space (NAS) to temporary outages for the rest of this year, as the GEO drifts out of a usable orbit.

Intelsat S.A. announced the anomaly in Galaxy 15 (G-15) on April 8. Although the communications services provided by G-15, located at 133 degrees west longitude (WL), have not been affected, according to Intelsat, the satellite apparently is not responding to commands by controllers. The anomalous condition began on April 3, according to the FAA.

The Luxembourg-based Intelsat is moving an older spacecraft (G-12) that serves as a backup for G-15 from its location at 123 degrees WL. However, G-12 does not have an L-band transponder, which is needed for WAAS transmissions of differential GPS corrections and integrity messages.

G-15 is one of three GEOs currently in orbit that provide WAAS services and provides the farthest coverage west across much of the Pacific Ocean. In terms of absolute U.S. service coverage, WAAS signal unavailability will only occur at 16 airports in northwestern Alaska.

The impending outage would have caused those sites to lose the capability to support aircraft approach and landing procedures based on localizer performance with vertical guidance (LPV, sometimes called “lateral precision with vertical guidance”). However, none of those airports has a published LPV approach yet. Aviation users in the NAS outside the affected area will continue to have LPV service, according to the FAA.

Pilots flying into the 16 Alaska airports will still be able to use GPS-based published lateral navigation (LNAV) approaches so long as they check on the availability of receiver autonomous integrity monitoring (RAIM) before they depart on a flight.

In the continuing story of another GPS problem, the GPS Wing has settled in for
the long haul to sort out the best solution among a set of at least nine options that may be undertaken to reduce the effects of a signal anomaly on GPS satellite SVN49.

The Air Force expects to take up to a year to evaluate alternatives and implement one or more of them.

In a notice published in the Federal Register earlier this year, the U.S. government invited public comments until May 28 on the options. Lt. Col. James Lake, the wing’s deputy chief engineer, emphasized that some of the options could well improve the performance of some receivers while decreasing that of others.

The Federal Register notice describing the options as well as comments received about them can be viewed online by going to the Federal eRulemaking Portal at http://www.regulations.gov and searching for the docket ID number RITA 2010–0002.

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**GLONASS**

Russia currently has 23 operational GNSS satellites on orbit, following activation of three spacecraft launched March 2 and restoration of healthy transmissions from another satellite that had experienced difficulties with its signal generation.

Progress in rebuilding the system has allowed GLONASS operators to place two older satellites in one of the orbital planes (plane 3) on reserve status. With 21 satellites transmitting healthy signals, the system is providing global 3D coverage more than 98 percent of the time.

Grigoriy Stupak, deputy designer-general for GLONASS, said that, following two more triple launches scheduled this year, the system will provide 99.99 percent coverage by the end of this year. He predicted that by the end of 2011, the system accuracy and availability will be comparable to the performance for GPS.

In March, Stupak told a conference audience in Germany that Russia is “close to completion” of a coordination plan for the “whole set of GLONASS signals” that will include eight different CDMA signals on four frequencies, along with its existing FDMA transmissions.

Beginning with the launch of the GLONASS-K generation of satellites, CDMA signals will be broadcast on, first, GLONASS L3, and then later at new GLONASS frequencies, L1, L2, and at L5. The first launch of a demonstration flight GLONASS-K will take place later this year.

Stupak also said that Luch geostationary communications satellites would be in orbit by 2013 to provide complete ground coverage of Russia as part of the GLONASS System of Differential Correction and Monitoring (SDCM).

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**Galileo**

The long-awaited release of an updated “Galileo Open Service Signal-In-Space Interface Control Document” (OS SIS ICD) took place on April 13, providing the key specification document for receiver manufacturers, application developers and service providers.

No longer a “draft” document, the ICD may be used to build Galileo-capable products. The European Commission (EC) is granting free access to the technical information on the future Galileo open service signal, which specifies the interface between the Galileo space and user segments.

Anyone who wishes to use the intellectual property rights contained in the OS SIS ICD can simply send an e-mail to <oss-icd@ec.europa.eu> mentioning their request for a free license agreement, which is without any exclusivity or geographical limitation.

A first draft OS SIS ICD was published May 19, 2006, and a revised version, February 14, 2008. The new official ICD has a few important changes, but otherwise follows the outline of the earlier versions. It is organized into five chapters and several annexes and introductory sections, containing 15 figures and 81 tables.

Chapter 1 provides the scope of the document and an overview of the Galileo system. The other chapters cover the signal-in-space radio frequency characteristics, characteristics of the spreading codes, the message structures, and the navigation message data contents.


Another delay has occurred in the first launch of the Galileo in-orbit validation (IOV) satellites, with the IOV not being ready until probably February 2011. Moreover, full operational capability (FOC) — including a 27-satellite constellation — has been pushed back to the 2016–18 timeframe, according to Paul Verhoef, the EC's GNSS programs director.

The Engineering Model of the Galileo In-Orbit Verification satellites has completed several phases of testing in cooperation with the ground segment and is now being prepared for electromagnetic compatibility testing.

*GALILEO continued on page 16*
In the meantime, the EC is recruiting for an executive director of the Galileo Supervisory Agency (GSA), the new designation of the European GNSS Supervisory Authority. Pedro Pedreira, The agency’s current director will finish a five-year term in the position at the end of June.

The GSA’s current mission is to assist in the further implementation of the European GNSS Programs, composed of Galileo and the European Geostationary Navigation Overlay System (EGNOS), including the security accreditation of the systems and the operation of the Galileo security center. The GSA is also helping prepare for commercialization of the systems by performing market analyses and market development.

Compass

China’s GNSS program, also known as Beidou-2, continues to experience growing pains.

Researchers at Belgian GNSS manufacturer Septentrio have investigated and reported on what they describe as anomalies in the signal from the Compass (Beidou-2) M1 satellite, launched April 14, 2007.

According to Jean-Marie Sleewaegen, a systems architect for Septentrio, analysis of high rate Doppler data from the Compass M1 satellite’s E2 and E5b carriers revealed frequent spikes in frequency beginning earlier this year.

Sleewaegen believes the anomaly indicates a problem onboard the satellite, possibly due to malfunction of the frequency reference of the signal generation unit. The phenomena occur about two to three times per minute at seemingly random intervals, he said.

In a March 10 presentation at the Munich Satellite Navigation Summit, Jiao Wenhai, a senior engineer in the China Satellite Navigation Office, indicated that the regional system China hopes to have in place by 2011 will have 5 geostationary (GEO) satellites, 4 middle earth orbiting (MEO) spacecraft, and 5 inclined geosynchronous satellite orbit (IGSO) spacecraft. The full Compass system to be completed by 2020 will have 5 GEOs, 3 IGSOs, and 27 MEOs. ◆
Elizabeth Cannon To Lead University of Calgary

ION Kepler award winner takes helm in Canada’s GNSS Heartland

Geomatics expert Dr. Elizabeth Cannon has been named the eighth president and vice-chancellor of the University of Calgary in Alberta, Canada.

“The University of Calgary is now embarking upon a new era of momentum with a bold new leader,” said Jack Perraton, Chair of the University of Calgary Board of Governors. “Elizabeth Cannon is both visionary and practical. Her international reputation and her local knowledge and expertise will serve this institution well as we continue to build one of the best universities in Canada and in the world.”

The current dean and professor in the university’s Schulich School of Engineering, Cannon will take office on July 1.

“The [University of Calgary] has come along way, gaining recognition nationally and internationally and becoming known as one of Canada’s top research-intensive universities,” Cannon said in a press release. “Have we achieved our full potential? Not yet. So I look forward to working with the incredibly talented students, staff, and faculty here to realize that potential.”

Cannon is a longtime and active member of the Institute of Navigation who, among other roles, served as the chair of the ION Satellite Division in 2005–2006 and as ION president 1996–1997. In 2001, she became the first woman to receive the ION Satellite Division’s most prestigious honor, the Johannes Kepler Award and was named an ION Fellow in 2004.

Since 1984, Cannon’s work has focused on geomatics engineering and the commercial application of geomatics technology. She is known for taking an inexpensive, existing device and finding a new use for it that raises the bar for accuracy in navigation. For example, Cannon’s imaginative use of equipment available on most new cars — odometers, gyros, and the steering angle sensor — produced a patent-pending system that can be used to automatically avoid collisions and improve control of vehicle stability.

She has also led several very successful initiatives designed to increase the number of women and girls involved in science and engineering.

Cannon is the first woman president and a triple-alumna of the school she will lead. She earned her undergraduate degree in applied science from Acadia University (Canada) and undergraduate engineering (BSc’84), master’s (MSc’87) and doctoral (PhD’91) degrees at the University of Calgary.

She is married to geomatics engineering professor and ION member Dr. Gérard Lachapelle. The couple has two college-aged children.
Volcanic ash and space weather were hot topics at the second workshop on Satellite Navigation Science and Technology for Africa last month. (And LEGO® MINDSTORMS® robot kits and Boston College baseball hats proved as popular as they did at the first meeting last year.)

Held from April 6 to 23 at the Abdus Salam International Centre for Theoretical Physics (ICTP) in Trieste, Italy, the ION-sponsored event brought together U.S. and European experts in GNSS and African university professors and graduate students in an intensive program on uses of GNSS for social and economic development in Africa.

The two-week long program featured formal lectures with hands-on practice in GNSS architecture, signal structure, hardware design, state of the art applications, and scientific exploration using GNSS.

An on-site computer laboratory gave participants ample opportunities to perform positioning calculations; to plan a precision farming procedure; and to analyze atmospheric and ionospheric data — all from GPS measurements.

The 60 African participants included university professors and graduate students from 15 countries including: Algeria, Cote d’Ivoire, Egypt, Ethiopia, Ghana, Kenya, Madagascar, Malawi, Namibia, Nigeria, Rwanda, Senegal, South Africa, Uganda and Zambia.

Institute of Navigation members supporting the workshop included Chris Hegarty, Phil Ward, John Raquet, Mikel Miller, Carrie New, Casey Miller, Jade Morton, Reza Ehsani, Jim Doherty, Demetrios Matsakis, Susan Delay, Gopi Seemala, Cesar Valladares and me.

Volcano Eruption
The timing of the workshop was somewhat challenging because Iceland’s Eyjafjallajökull volcano erupted during the workshop generating an ash cloud that disrupted air travel over much of the European continent.

Naturally, the volcanic ash was a prime topic of conversation during our workshop; so, we spent an afternoon accessing and processing ionospheric data to determine if the volcanic ash had an effect on ionospheric propagation. Unfortunately, there were no effects on the ionosphere!

Equally unfortunate, the travel disruptions had significant effects on the lecturers traveling during the last week of the program.

In particular Jim Doherty, former ION President, had to delay his return to the U.S. by nearly a week. Since other lecturers had to cancel their participation for travel reasons, Jim helped out with a few more presentations — Thanks Jim! The very disappointed ION members who were not able to attend included Anthea Coster, Larry Hothem, Susan Skone, Todd Walter, and A.J. van Dierendonck.

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Second Time Around
Although this workshop was just the second of the series, we have already seen many benefits from these meetings between scientists and engineers of Europe, the USA and Africa.

We have had productive discussions about common interests. For example, a number of research programs use GPS ground and space based measurements to observe ionospheric and space weather phenomenon. Africa’s proximity to the magnetic equator makes the continent of great interest to space weather scientists.

Unfortunately, studies over the region have not been possible due to the lack of dependable, long-term measurements. This workshop gave us an opportunity to establish a base of measurements for joint studies with our African colleagues.

In the past year, we have also seen initiation of programs for GNSS studies and research at several universities in Africa, as reported in some of the presentations made by African scientists this year.

In addition, participants of the first workshop initiated regional workshops in Nigeria and Egypt to further introduce the topics and benefits of GNSS to university administrations and local officials.

In the coming months, another regional workshop will be held in Kenya. Sandro Radi-cella and I have acted as international advisors and participants for these programs.

Hands On!
Lectures, colloquia, meetings … they’re all fine. But engineering creativity requires something more.

One of the workshop laboratories was designed to demonstrate the basics of autonomous navigation with the use of LEGO® MINDSTORMS® robots. During this lab participants were taught the basics of autonomous navigation and then were coached to build a robot. This exercise continued with a contest for the most clever and sophisticated design.

The winning designs included a Segway-like robot with an impressive capability of maintaining its balance, and a robot who walked, spoke in several languages, recognized colors, and a great “moon walk” when he was pleased.

The MINDSTORM kits were donated to the workshop by The Institute of Navigation and they were awarded to the African universities with the greatest interest in using the kits in their university programs.

Participants were also involved in a dynamic precision farming laboratory where they designed a fertilization-monitoring scheme.

Precision farming software was donated to the participants by Reza Ehsani, as part of this laboratory.

AFRICA continued on page 20
Participants also went geocaching. They used single-frequency GPS receivers in a treasure hunt that was creatively planned by our instructors. Teams of four to six participants departed at 10 minute increments to navigate a course that spanned the ICTP campus.

The winning team returned in just over an hour while other teams took much longer.

At the end of the workshop, participants were given textbooks on GNSS, certificates of completion and, last but not least, Boston College baseball caps!

Next Workshop in Nigeria 2011

From all reports, the workshops are an enriching teaching experience for lecturers and useful for and appreciated by the African participants. Visiting dignitaries and sponsors from the African Union, the Economic Commission of Africa, the Italian Space Agency, the European Space Agency, The Institute of Navigation, Boston College, the ICTP, the United Nations, the National Science Foundation, the U.S. State Department and the U.S. Air Force Research Laboratory were impressed by the program and encouraged us to continue this effort.

We plan to continue with a workshop in spring 2011 in Abuja, Nigeria, which will make it more accessible to more participants.

We sincerely thank our prime sponsors for this workshop including: the ICTP, Boston College, The Institute of Navigation, the Federal Aviation Administration, the Air Force Research Laboratory, the Air Force Office of Scientific Research, NASA, NSF, the United Nations Office for Outer Space Affairs, and the Trimble Corporation.

About the authors: Patricia Doherty directed the Africa workshop with Sandro Radicella, head of the Radio-propagation Laboratory at ICTP. Doherty is ION Eastern Region Vice President and director of the Institute for Scientific Research at Boston College.
Sensonor Technologies is a leading manufacturer of Gyro and Pressure products based on MEMS technology for High Precision applications that offer high performance for demanding applications where the combination of size, performance and robustness matter.

Based out of Horten, a small town 100 km south of Oslo in Norway, Sensonor has for 25 years played a significant role in the development of the global MEMS industry. Sensonor has shipped more than 200 million pressure sensors, more than 200 million accelerometers, and more than 2 million gyros. Less than 0.1ppm field failures are the ultimate proof of long term dedication and capability.

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- First optical pressure sensor for Down Hole Well Monitoring (PP05 - 1990)
- First low cost Air Bag Accelerometer (SA20 - 1992)
- First integrated micro system for Tire Pressure Measurement (SP13 - 1998)
- First low cost Automotive Gyro (SAR10 - 2003)

For more information on Sensonor Technologies AS, visit www.sensonor.com.
My research partners Andrew Dempster and Mahmoud Efatmaneshik and I are on the road to evaluating a new technology that may one day speed the development of intelligent transportation system (ITS) infrastructure.

Dedicated Short Range Communications, or DSRC, enables fast, accurate and timely data transfers at 5.9 GHz and supports roadside to vehicle communications, and is already used for such purposes as collecting tolls or restricting building access. It has been eagerly adopted across many industry sectors with products already under evaluation.

Japanese company Oki Electric Industry, for example, has developed a pedestrian safety system in which DSRC-equipped mobile phones allow users to communicate with nearby vehicles that have been fitted with on-board DSRC units.

The Toyota Motor Corporation says they will soon launch DSRC-fitted vehicles that can communicate with roadside infrastructure and give drivers real-time traffic information about the immediate vicinity.

Both DaimlerChrysler and General Motors have demonstrated vehicle to vehicle communication under actual driving conditions.

**Vehicle Location and DSRC**

DSRC technology depends on GNSS for many safety-related applications, such as proximity warnings, speed advisories, and automated braking at level crossings.

Under ideal driving conditions, with clear sky visibility, GNSS can meet the positioning accuracy required for most DSRC applications. However, in tunnels and urban canyons, high multipath/weak signal environments will challenge the continuity and — more importantly — the integrity of the position solution.
To address this challenge, we are working on a new approach based on cooperative positioning techniques.

Cooperative positioning (CP) algorithms, such as those developed for wireless sensor networks, can be adapted to DSRC applications. Here, the vehicles within a “neighbourhood” form an ad hoc mobile network in which each vehicle is a “node.”

The positioning requirements for DSRC safety applications can be summarized as: real-time positioning accuracy of less than one-half meter available 100 percent of the time) with minimum latency, with the ability to adapt to traffic conditions and node density, while maintaining robust connections among vehicles.

To develop a vehicle localization capability that can meet these requirements, we propose an approach in which we fuse all signals available for positioning. These include GPS, on-board accelerometers, and the like as well as those sensed directly from the DSRC infrastructure. An accompanying schematic illustrates our concept.

To initialize the CP process, each node starts by estimating the inter node ranges (INRs) based on received signal strength values in the DSRC board.

The INRs and a vehicle’s own GPS reading are broadcast at the desired frequency.

At the same time a node sends the INRs, it receives the measured INRs and GPS positions from the entire neighbourhood, which enables each node to form the measurement vector combining the GPS and INRs in a Kalman Filter (KF) unit. This approach has three major research challenges. It requires:

- a ranging technique based on received DSRC signal characteristics, for example, signal strength
- a communication protocol for the frequency and range of inter-node communications
- a localization algorithm based on decentralized, sensor fusion theories.

Within the context of DSRC, the localization system results from a tight coupling of the ranging technique, localization algorithm, and communication protocol.

High accuracy ranging with DSRC is an open research problem and is the topic of much international research. Whilst other localization techniques such as Monte Carlo localization, convex optimization, iterative multilateration, and multidimensional scaling (MDS), are popular network localization techniques, the alternative approach that we are pursuing recognizes the contributions of map matching and logical navigation constraints to improving positioning accuracy.

To illustrate the positioning capabilities for DSRC from implementing our CP module design, Andrew, Mahmoud, and I undertook a simulation study. The accompanying figure shows the results obtained using simulated data and by implementing two intuitive map matching (MM) rules. Rule 1 always places the vehicle on to the closest road and Rule 2 constrains the heading of the vehicle to that of the road being travelled on within the Kalman Filter.

The simulation result demonstrates that the KF constrained by the MM rules have better accuracy performance than the KF without MM. This performance is further enhanced depending on the number of nodes in the “neighbourhood” being processed.

Robust ranging using DSRC is extremely challenging and perhaps the most significant limitation of the approach presented here.

We are absolutely certain, though, that DSRC infrastructure offers a wealth of environmental data that can assist in overcoming many of the limitations faced by GNSS and low-level integrated positioning solutions.

Pre-determined route navigation information from an in-car navigation system and roadside updates can improve the intelligence of any vehicle location system.

Our future work on this project will focus on resolving some of the map matching conflicts that occur in the complex intersections and roundabouts of real-world road networks.

We will also consider the effect of higher and CP frequency lower than 1Hz on the algorithm performance. And we will investigate ways to improve the robustness of the presented algorithm and other CP algorithms with respect to nodal connection failure.
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