A new look and feel make ION’s website easy to navigate, with a number of enhanced benefits for ION members.

“We are adding video from ION GNSS panel discussions and the online tutorials, an online membership directory, plus a syndication feed that allows members to get news and announcements from ION in their news reader software,” said ION IT manager Rick Buongiovanni of the re-designed website.

Video from the ION GNSS panel discussions will be added within the next month, he said. The website uses a custom content management system (CMS) that employs the ColdFusion application server and software language. Buongiovanni has developed the CMS over the past several years.

Other ION website improvements include drop-down menus to provide easier site navigation along with a fresh look and feel to the visual design. 

ION Online Video Classroom


ION members include many of the world’s leading navigation experts, some of whom will be coming soon to a website near you as The Institute of Navigation launches its new video classroom – a series of on-line tutorials at the recently redesigned ION website.

The first tutorial features Prof. Per Enge, director of the GPS Research Laboratory at Stanford University, in a
Fall Flurry

From the IoN President
Dr. Chris Hegarty

Fall is traditionally a very busy time of year for the ION, and this year is no exception.

ION GNSS 2008
Much of this issue is devoted to describing the highlights of the world’s largest GNSS conference, ION GNSS 2008. Many of you spent September 16 to 19 in Savannah, Georgia with us and contributed to the event’s success.

Thanks to General Chair Dr. Mikel Miller, Program Chair Dr. John Raquet, the other members of the Program Committee, and all who sponsored, presented, exhibited, attended, and worked behind the scenes.

GNC Challenges for MAS Workshop
The ION facilitated a new workshop with the Air Force Research Lab on Guidance Navigation and Control (GNC) challenges for Miniature Autonomous Systems in Fort Walton Beach, Florida in October.

Attendance was so encouraging that a second workshop is planned for October 26 – 28, 2009, again in Fort Walton Beach. (Story on page 4)

Member-Friendly Changes from the National Office
Welcome to Matt Korzan, who will be responsible for membership marketing and retention. He recently joined the full-time staff at the ION National Office in Fairfax, Virginia.

Take a look at the revamped ION website www.ion.org. Many thanks to ION IT manager Rick Buongiovanni, for leading this effort.

One very popular member service is the ability to search all ION conference proceedings and journal articles, and download 12 free papers each year from our website.

Now our new Premium Level Professional Membership allows you to download 25 papers per month! Please consider this new membership class when renewing this year. (Article on page 4).

ION Executive Fellow at DHS
I am very pleased that Dr. Frank van Graas has applied and has been selected to serve as the 2008–2009 ION Executive Fellow through August 2009. Frank’s service will be within the Department of Homeland Security’s Science and Technology Division. (See his column on page 3.)

The ION Executive Fellows program was created in 2003 through an alliance with the American Association for the Advancement of Science (AAAS).

Our goal is “to make practical contributions to the more effective use of scientific and technical knowledge in government, to educate the navigation and engineering community regarding the public policy process, and to broaden the perspective of the science, engineering and governmental communities regarding the value of such interaction.”

ITM and JNC Coming Up
The ION International Technical Meeting (ITM) 2009 will be held at Disney’s Paradise Pier Hotel in Anaheim, California, January 26 - 28.

The Joint Service Data Exchange (JSDE)/ION 2009 Joint Navigation Conference will be held at the Wyndham Orlando Resort in Florida, June 1–4.

Last But Not Least . . . Please Vote!
Online voting for the 2009 ION officers takes place between December 19, 2008 and January 9, 2009. Read about the nominees in this issue and vote for the candidates you believe will best serve the ION membership. (Story on page 14)
Avionics engineer Frank van Graas — ION past president and Kepler Award winner — is taking his first sabbatical in 20 years from his professorship at Ohio University for a one-year fellowship at the Department of Homeland Security in Washington D.C. This is his report.

This year’s group of Science and Technology (S&T) Policy Fellows numbers a record 165, an indication of a growing importance of S&T in the policy-making process.

The American Association for the Advancement of Science (AAAS) Executive and Congressional Fellowships attract a wide range of individuals to serve for a period of typically one year. Some of the Fellows are fresh out of school, but most of this year’s group is made up of mid-career researchers and scientists.

I met a few Fellows who are on academic sabbaticals such as myself, and who intend to return to their home institutions at the end of the year, while many others are in pursuit of new career directions.

The AAAS organizes a yearlong program of activities to increase the success of the program. It started with an intensive two-week orientation in September that was a great way to kick-start the fellowship year.

We were given a comprehensive, yet detailed, overview of Congress, the executive branch, and the role of S&T in the federal policy process. That process and the Federal budget are closely related; so, learning more about the budget procedure was crucial to understanding how S&T affects policy. And, since most of us have a scientific background, the necessary survival skills were presented for a successful migration from the world of science to the world of public policy.

The orientation sessions featured excellent speakers who shared their personal career insights. As the AAAS training sessions included generous question and answer periods, lively and very relevant interactions took place between the Fellows and the presenters, who provided candid answers to often challenging questions. And there was ample opportunity to network with other Fellows as well.

Although some of the presentations were specific to the fellowships, most of the topics would also have been helpful to my career at an earlier stage.

Before I participated in the AAAS orientation, my placement at the Department of Homeland Security was already being arranged with the help of Carl Andren; Jim Doherty, 2005-6 ION President; and former ION Congressional Fellow Phil Ward.

Knowing where I would be placed allowed me to initiate contacts with several Fellows and presenters that work in similar areas.

This is my first sabbatical after 20 years at Ohio University. If I had realized sooner how extraordinary and valuable this program is, I would certainly not have waited this long!

I greatly appreciate ION’s sponsorship for this unique educational experience and look forward to an exciting year in Washington, D.C., — and to applying my navigation technology experience to federal policymaking.

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Avionics engineer Frank van Graas begins his 2008 Executive Fellowship at Homeland Security

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ABOUT THE ION GOVERNMENT FELLOWS

ION participates in a program sponsored by the American Association for the Advancement of Science (AAAS) that bring scientists and engineers into yearlong government service in a variety of executive-branch agencies and in Congress.

The AAAS Science and Technology Fellows Program provides scientists and engineers a ground-level view of federal policy making and gives members of Congress and agency staff access to expert advisors on complex scientific and technical issues - a mutually beneficial relationship.

The ION is one of 35 AAAS Society Partners for the congressional fellows program, and one of 7 for the executive branch fellows program. The Institute provides the stipends, pays for relocation and travel, and sets the professional requirements for its own fellows.

Frank van Graas is this year’s Executive Fellow from ION. Past Executive Fellows include Dr. Jennifer Gautier who served as NASA’s liaison to the Space-Based Positioning, Navigation, and Timing (PNT) Executive Committee in 2005-6 and Dr. Bill Klepczynski who served in the State Department Office of Space and Advanced Technology in 2003-5.

The application deadline for 2009 fellowships is March 15, 2009

INFORMATION: Carl Andren candren@ion.org
WEBSITE: ion.org/outreach/fellowship_programs.cfm

Photo credit: Wiki Commons
With a new “Premium Professional” status, ION members will gain greatly expanded, free access to the Institute’s rich trove of technical papers — as many as 25 per month vs. the 12 complimentary downloads per year available to professional, retired, and student members.

And, of course, ION Premium Professionals get all of the benefits of regular membership:

• Professional networking with peers — and world leaders — in the positioning, navigation, and timing communities
• Online access to ION conference proceedings and journals going back to 1990
• Discounts and special rates on meetings and conferences
• Member-only directory and career tools
• *Navigation* — subscription to the quarterly peer-reviewed journal
• *ION Newsletter* — seasonal news, articles, and reports on ION activities
• Voting participation in the ION and one of 12 regional chapters in the United States and Canada.
• Scholarships and awards eligibility

The annual cost for premium professional membership is U.S. $160 ($180 for international members).

For more information, e-mail membership@ion.org.

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**Miniature Autonomous Systems Workshop:**

**Smaller Is Better**

It’s almost become a movie cliché in popular films such as Enemy of the State or Syriana: the unsuspecting target, the remotely piloted Predator or Raven nearly invisible overhead, the ominous background music.

But the technical and operational challenges of autonomous platforms are serious matters for military personnel and program managers who are placing a growing reliance on them for surveillance, communications, electronic warfare, weapons delivery, and other applications in challenging physical environments (for example, indoors, in cities, in mountains) or unconventional combat situations.

And despite the almost magical ease and fail-proof execution of missions reflected in Hollywood’s imagination, the reality of such systems’ design, manufacturing, and implementation remains much more unresolved.

So, the recent GNC Challenge for Miniature Autonomous Systems Workshop — hosted by the Air Force Research Lab (AFRL) and facilitated by ION — offered a timely exposition of the state of the art and current challenges in this field.

Drawing more than 100 participants to a three-day program October 20–22, 2008, in Fort Walton Beach, Florida, the workshop brought together the U.S. Department of Defense (DoD) technical and user community, academia, and industry to review and discuss advances in guidance, navigation, and control (GNC) for miniature autonomous systems. The first-time event’s organizers consider the workshop a great success and plan to continue the event next year.

**Micro Munitions**

Workshop attendees heard from a wide variety of experts in the micro munitions community. Col. James Geurts of USSOCOM shared his perspective on the emerging micro-munitions technology and the applications for and requirements of our nation’s warfighters.

Lt. Col. Dean
Bushey, a Predator pilot, also shared his operational perspective.

Speakers described diverse physical platforms, including aircraft with foldable wings, coaxial rotorcraft, small robots, and nano-sized unmanned aerial vehicles (UAVs) as small as birds or insects. Miniature autonomous systems incorporate a remarkable range of GNC sensor technologies: laser detection and ranging (LADAR), Earth observation (EO), pre-registered imagery, inertial navigation systems (INS), swarm navigation, magnetometers and baro-altimeters, and software defined radio (SDR) with relative ranging capabilities, and, of course, GPS.

Animal Behavior
One session addressing miniature multi-function sensors drew extensively on studies of animal behavior and sensory capabilities. A presentation by Patrick Shoemaker, of Tanner Research, Inc. and Sean Humbert, Department of Aerospace Engineering, University of Maryland, described biomimetic algorithms for visual motion detection, and flight control for local guidance and collision avoidance inspired by the physiology of the visual motion detection pathway in flies.

Johnny Evers, with the AFRL Advanced Guidance Division's Biomimetic Signal Processing and Control (RWGI) research area, predicted that insect-scale or small autonomous robots will certainly develop using mechanisms associated with biological locomotion.

Some of the workshop's acronyms alone made for fascinating, such as Intelligent Navigation and Sensing for Cooperative Tasks (INSeCT), Simulink Experimentation Testbed for Advanced Navigation Technology (SEXTANT), or LADAR EO GPS/INS Atomic Clock Navigation Demonstration (LEGAND).

Attendees heard from experts on mini-munitions work as well as others who are just beginning their careers. For example, 2nd Lt. Joe Czabaranek, of the AFRL Assessment and Demonstration Divisions’ Flight Vehicles Integration Branch (RWAV), showed riveting videos of an autonomous air launch of a micro unmanned aerial system (UAS).

Smaller Is Better
Current trends show that future systems will be miniature — less than 20 pounds of total system weight — for a number of reasons. First, they will be much cheaper to develop and build than current systems. Second, their smaller size will allow them to be carried in large numbers and be compatible with small UAVs for air-launched systems. Also, miniature autonomous systems could potentially fill the current capability gap so as to provide access to difficult targets, such as hardened command and control facilities.

Military use of such systems will include acquiring, tracking, and engaging non-traditional targets. A potential benefit of miniature weapon systems is an ability to greatly limit collateral damage in urban scenarios. However, very precise engagement is required to achieve the desired effects in defeating targets.

These miniature systems will use economies of scale and synergies in time-space trajectories to compensate for individual small payloads and corresponding capacity limitations in chemical and kinetic energies. Miniature autonomous systems capable of agile locomotion or flight in urban, forested, and indoor (including transitions from outdoor to indoor) environments present many unique technical challenges to the controls and systems engineer.

Because small, agile vehicles will be required to traverse the complex flight environment in “urban canyons,” such systems will probably encompass both outdoor and indoor applications. “Tight” operating environments, clutter, obstacles, and RF interference can create situations where extremely agile GNC techniques are required.

Technical Gaps Remain
Many fundamental technical gaps remain that prevent building these systems today. Miniature systems imply small sensor apertures with, as a consequence, poor resolution. This, in turn, lessens the system's observability and renders it harder to control.

Miniature systems, either airborne or ground-based, have built-in plant non-linearities and instabilities because some physical forces (such as viscosity and friction) become comparable in magnitude to inertial forces. Miniature systems also must face fundamental matters of insufficient actuation, requiring them to exploit small but dense power systems and (perhaps distributed) computational resources with limited performance.

The GNC Challenge for Miniature Autonomous Systems Workshop provided a review of active programs in the field, a window on significant trends, and the opportunity to present new technology to the community.

The workshop was co-chaired by Fred Davis, AFRL/RWA (Assessment and Demonstrations Division) and Dr. Mikel Miller, AFRL/RWG (Advanced Guidance Division) with support from a planning committee consisting of 2nd Lt. Caroline New, AFRL/RWGN (Advanced Guidance Division, Navigation and Control Branch); Dr. William Humbert, AFRL/RWGS (Advanced Guidance Division, Seeker Branch); Dr. Robert Murphy, AFRL/RWGN; Dr. John Raquet, Air Force Institute of Technology; Dr. Jacob Campbell, AFRL/RYRN (RF Sensor Technology Division, Reference Systems Branch); and Dr. Gregg Abate, AFRL/RWGN.

Based on the great interest and lively participation from the workshop's attendees, a second workshop will be held October 26–28, 2009, at the Emerald Coast Conference Center in Fort Walton Beach, Florida.
The Toys of Engineering: LEGOos, Cars, and Robots
ION will do whatever it takes to get high school students excited about science and engineering

By next year, 27 percent of America’s engineering workforce will be eligible to retire.

And the next generation-in-training isn’t there. What to do?

Two young Department of Defense (DoD) engineers from Florida and Ohio have decided to pump up the volume. They are joining The Institute of Navigation in a new contest to excite U.S. high school students about careers in science and engineering.

1st Lt. Casey Miller and 2nd Lt. Caroline New, along with DoD colleagues, are organizing the first Mini-Urban Challenge (MUC) for teenagers, using LEGO Mindstorms NXT, high-tech versions of the ubiquitous snap-together plastic building toys scattered around living rooms everywhere.

They intend to lure high school students with the thrill of cars and robots in an event inspired by the DARPA Grand Challenge automated car race and the ION Dayton section’s Robotic Lawnmower Competition.

MUC organizers are also looking for sponsors to finance awards for winners and support team travel to the competitions. Overlook Systems Technologies has come on board as a sponsor and the organizers are talking with other companies, many of whom expressed interest when visiting the MUC exhibit at ION GNSS 2008.

Middle- and high-school teams will use the branded kits to design and operate completely autonomous robotic ground vehicles. The miniature AVs will be powered by six AA batteries and be built entirely of LEGO components.

The Challenge course, “LEGO City,” features 10-centimeter-wide streets with speed limits, stop signs, intersections, and mandatory timed stops at a grocery store, gas station, and high school. Co-sponsors will be there in spirit with miniatures of their company buildings along the course.

The team that navigates most effectively, gives the best presentation, and has the best design, will win at the national finals. Regional Competitions will be held on May 16 at Wright-Patterson AFB, Ohio, and Eglin AFB, Florida. National Competition will take place June 13 in Dayton, Ohio, at the same time as the
Robotic Lawnmower Competition.

The Challenge provides each team with the LEGO Mindstorms kit and sensor package. The brain of the kit is the NXT 32-bit ARM7 microcontroller, which can be programmed by the students to acquire data from available sensors and control one or more motors.

The kit also has an extensive sensor package, which includes two touch sensors, a sound sensor, a black and white light sensor, a color light sensor, and an ultrasonic sensor. In addition, teams are also provided three interactive servomotors and numerous LEGO pieces — including LEGO’s aliens, trolls, and pirates, gears, pulleys, and wheels.

They may also use any other LEGO components in their unmanned car (including LEGO’s aliens, trolls, and pirates, we hope).

Miller and New presented a paper on the new project during the Novel Competition.

Applications session at ION GNSS 2008. Both are concerned about the low level of interest high school students have in studying science and engineering in college: less than six percent plan to do so, according to a recent Aerospace Industries Association study cited in the ION paper.

New said, “The root of this problem is [students] lack of understanding for what the field of engineering has to offer because of the fact they were never introduced to it during high school. We want to show how much fun problem-solving can be.”

1st Lt. Casey Miller is a target/treat evaluation engineer for the ATR Assessment Branch, Air Force Research Lab Sensors Directorate, at Wright-Patterson AFB, Ohio. 2nd Lt. Caroline New is a guidance/navigation engineer with AFRL, Advanced Guidance Division, Navigation and Control Branch at Eglin AFB, Florida.

Could robotic autonomous vehicles built with LEGO help American teenagers discover the joys of engineering?

Next Up: Dr. Frank van Graas & Inertial

The second expert in the on-line tutorial series will be Dr. Frank van Graas addressing “Basics of Inertial Navigation.” His video classroom will be available later this fall.

Dr. van Graas has been involved with GPS research since 1984, including the first real-time GPS attitude and heading flight experiment on a DC-3, and the first code-phase differential GPS system to satisfy both sensor accuracy and total system error requirements for Category IIIb automatic landing operations using a Boeing 757.

Dr. van Graas is the Fritz J. and Dolores H. Russ professor of electrical engineering and computer science in the Russ College of Engineering and Technology at Ohio University.

Find out more: http://www.ion.org/tutorials/.
For its 21st anniversary, The Institute of Navigation broke new ground — programmatically and geographically — with a successful ION GNSS 2008 conference held September 16–19.

Meeting for the first time in Savannah, Georgia, the eastern- and southern-most locale for the event, ION GNSS 2008 introduced a well-received series of panel discussions and a theme, “Operating in a Multi-GNSS World,” that fully embraced the broad coverage of subject matter reflected in the opening plenary session and technical sessions.

Attendance reflected the continuing internationalization of both GNSS and the conference itself with 38 percent of pre-registered 2008 participants coming from outside the United States. The regional breakdown of non-U.S. participants was: Western Europe 19 percent; Asia, 9 percent; Canada, 7 percent; South America and Eastern Europe, 1 percent each; Middle East, 0.7 percent; and Africa, an honorable mention with one attendee.

Perhaps even more impressive, 71 percent of the ION GNSS 2008 technical papers’ primary authors came from other countries as well. European delegates led the latter list with 32 percent, followed by the United States, 29 percent, and Asia, 21 percent.

More than 250 presentations were made in 31 technical sessions arranged in six parallel tracks. (See the list of winners of the best presentation award in each of the sessions on page 18.) The papers are available for download and/or purchase on the ION website.

Following its introduction at ION GNSS 2007, an “For Official Use Only” session took place on Tuesday before the opening of the conference, with a set of Department of Defense speakers headed by Brig. Gen. David Ehrhart, Judge Advocate of the Air Force Materiel Command.

Booths representing more than 80 companies and organizations filled the exhibition hall at the Savannah Convention Center on Hutchinson Island, located a picturesque ferry ride across the busy Savannah River from one of America’s most historically rich and architecturally distinctive cities.

**Plenary Highlights Cooperation**

The opening night’s plenary session brought together high-ranking officials responsible for GNSS activities in the United States, Europe, and Russia — John Grimes, U.S. Assistant Secretary of Defense for Networks and Information Integration (ASD-NII) and also Department of Defense (DoD) Chief Information Officer; Paul Verhoef, Head of Galileo Unit in the European Commission, Directorate General for Energy and Transport; and Dr. Yury Nosenko, Deputy Head of the Russian Federal Space Agency (Roscosmos).

In introducing the program, plenary organizer and moderator Dr. John Betz, of The MITRE Corporation, said, “We asked the speakers to provide a 30-minute speech that looks beyond the current phase of GNSS development and use, and considers a future where compatibility and interoperability . . . have been achieved.”

And that they did — although first bringing their audience up to date on salient aspects of their respective programs. “When it comes to navigation, GPS is likely to go down in history as the most important invention since the compass,” Grimes told his audience. “Of course, GPS does not satisfy every PNT need . . . Using GPS in concert with other GNSS and
PARKINSON AWARD

WINNER

The Bradford Parkinson Award was presented during the ION GNSS 2008 awards luncheon on Friday, September 19, 2008 to Dr. José Ángel Ávila Rodríguez for his thesis entitled, “On Generalized Signal Waveforms for Satellite Navigation.”

Dr. Rodríguez is a research associate at the Institute of Geodesy and Navigation at the University of the Federal Armed Forces Munich. He is responsible for research activities on GNSS signals, including BOC, BCS, and MBCS modulations.

The Satellite Division of The Institute of Navigation presents the Bradford W. Parkinson Award annually to an outstanding graduate student in the field of Global Navigation Satellite Systems (GNSS). This award, which honors Dr. Parkinson for his leadership in establishing both the U.S. Global Positioning System and the Satellite Division of the ION, includes a personalized plaque and a $2500 honorarium. The award will only be presented when deemed worthy. Any graduate student who is a member of the ION and is completing a degree program with an emphasis in GNSS technology, applications, or policy is eligible for the award. The Institute of Navigation must receive all entries no later than June 30.

PNT services and technologies require a stable foundation of policies and performance standards built on a sound architecture that includes spectrum utilization.”

The official vision of the GPS future is enshrined in the recent completion of a U.S. National Positioning, Navigation, and Timing (PNT) Architecture study. As outlined by Grimes, the architecture study, prompted by a 2005 Defense Science Board recommendation, identified four “development vectors” to reinforce GPS over the next 25 years: access and use of diverse sources of PNT information, interchangeable use of PNT information sources — possibly including signals from multiple GNSS service providers,” exploiting synergy in PNT and communications technologies, and cooperative organizational structures and processes to promote technology development, acquisition, management, and operation.

Drafted by an interagency team from the U.S. departments of defense and transportation, the national PNT architecture was briefed to the Civil GPS Service Interface Committee (CGSIC) on Monday and industry representatives on Tuesday afternoon. (In his remarks, Grimes pointed out an article in the Summer 2008 issue of the ION Newsletter, authored by leaders of the interagency team, that provides extensive details of the architecture study’s recommendations.)

“Satellite navigation systems are becoming a part of the unified global information space,” said Nosenko, who manages the Roscosmos’s GNSS portfolio and guides its strategic direction.

GNSS 2008 continued on page 12
The Institute of Navigation’s (ION) Satellite Division awarded Mr. Phil Ward its Johannes Kepler lifetime achievement award September 19, 2008 at the ION GNSS 2008 conference in Savannah, Georgia. The Kepler Award is designed to honor an individual during their lifetime for sustained and significant contributions to the development of satellite navigation. Ward received the 2008 award for his pioneering work in GPS receiver development and continued teaching, consulting and publishing aimed at advancing the utility of both commercial and military applications of the Global Positioning System.

During his acceptance Ward thanked the Satellite Division of The Institute of Navigation for honoring him with the award. He said, “I am deeply honored by this recognition and thank the Satellite Division and acknowledge my wife Nancy and the role she played in the receiving of this award.”

Phillip W. Ward is a pioneer in the design and development of GPS receivers. He has been active in the field of navigation since 1958 and with GPS receiver design since 1976. He developed the first commercial GPS receiver, the Texas Instrument’s TI 4100. He also served as the lead systems engineer on several of TI’s advanced GPS receiver designs. He has been awarded multiple patents, one of which was for the multiplexing technique employed in the TI 4100 GPS receiver. His patents include various aspects of receiver design and a patent on a single receiver attitude determination technique. His most recent patent application involves an unambiguous detection scheme for the new MBOC modulation codes on GNSS systems.

Ward has been active in passing on his GPS knowledge by teaching, consulting and publishing. He is the author of more than 30 papers on GPS topics and has made multiple presentations at ION conferences and IEEE PLANS conferences. He teaches seminars on “Advanced GPS Receiver Design” and “GPS Receiver Jamming Mitigation Design Techniques” for NavtechGPS Seminars. He is president of Navward GPS Consulting which he founded in 1991. He was the invited author of “Navigation Satellites” for the Academic Press Encyclopedia of Physical Sciences published in 1993. He is a coauthor of the book, Understanding GPS: Principles and Applications, edited by Elliott D. Kaplan and published by Artech House Publishers in 1996. He also co-authored the second edition by the same title and publisher, co-edited by Christopher J. Hegarty and Elliott D. Kaplan, which was released in 2005. Ward has also served as a member of the GPS Independent Review Team which was chartered to evaluate the GPS system and suggest improvements.

Ward served with distinction from 2001 to 1Q 2002 as the ION’s first Congressional Fellow in the office of Senator James M. Inhofe (R-OK), a high ranking member of the Senate Armed Services Committee. While in this position Phil helped the GPS community establish a relationship with Congressman Joseph Pitts (R-PA), who co-chaired the Congressional Electronic Warfare Working Group, and who became actively involved in the countermeasures to the threat of both civil and military GPS denial. Ward was the first science fellow working for Sen. Inhofe, and as a measure of his success was asked by the senator to help find a science fellow to replace him when he left. In addition to serving as the first ION Congressional Fellow, Ward previously served as the President of the ION (1992-1993) and as Chair of the Satellite Division (1994-1996). He received the ION’s Thurlow award in 1989 as a result of his development of the TI 4100 GPS receiver which was the first receiver widely used in the survey industry. He is a Fellow in the ION and is also a Senior Member of the IEEE.

Ward received his B.S.E.E. degree from the University of Texas at El Paso in 1958. He obtained an M.S.E.E. degree from Southern Methodist University in 1965. He also took postgraduate courses in Computer Science at the Massachusetts Institute of Technology from 1967 to 1970.
Pictured from left, The ION GNSS 2008 Program Committee: Dr. Jinling Wang, Technical Chair; Dr. John Betz, Panels Chair; Dr. Mikel Miller, General Chair; Dr. John Raquet, Program Chair; John Langer, Technical Chair; Dr. Gary McGraw, Technical Chair. Not pictured: Dr. Richard Klukas, Technical Chair; Dr. Angela Dorsey, Technical Chair; Dr. Jan Skaloud, Technical Chair.
“In these conditions, one can expect the interests of providers and users to coincide.”

Providers want global use of their systems, he pointed out, and users are interested in using more than one system. “Thus the providers’ objective is to make the simultaneous use of several systems the least complicated for the user,” Nosenko said. “In this regard, the priority task in international cooperation is to provide compatibility and interoperability between navigation systems.”

He pointed to the experience of TV and cell phone development and production, in which cost is no longer significantly affected by the number and types of frequencies, coding and standards.

In his presentation, Verhoef paraphrased the late baseball great Yogi Berra by noting wryly, “Predictions are difficult, particularly predictions of the future.” Verhoef, who has program management responsibility for Galileo on policy issues and infrastructure, looked ahead to the evolution of the “GNSS Spacescape” in a multi-constellation world, where he foresees two trends.

“Firstly, whatever the policy mix behind the various systems, we can observe today an element of GNSS patriotism — alive and kicking,” he said. “We all want our own systems and for quite legitimate reasons. That trend is likely to continue sometime in the form of states or groups of states deciding to build their own regional systems or integrity networks. In this business, added security or sovereignty qualifies as return on investment just as well as service quality, new jobs or straight cash.”

The other somewhat countervailing trend of GNSS cooperation and interoperability is reflected in the rise of the International Committee on GNSS (ICG), a United Nations–aided voluntary association of GNSS and augmentation program sponsors and key user communities.

“Already the conception years of this new forum have created somewhat of the ‘we are in the same boat’ atmosphere among GNSS providers,” Verhoef said, adding, “I would expect to see cooperation emerging among the providers in constellation and ground segment management from a pure cost point of view. It is like owning a sports car; as the mileage accrues over the years, the talk shifts from tuning options to maintenance bills.”

**Crowded Panel Discussions**

A major innovation in ION GNSS 2008 was a parallel track of thematic panel discussions organized by Betz to complement the technical sessions. The sessions were well attended — in some cases with standing-room-only crowds filling the halls.

**“Satellite navigation systems are becoming a part of the united global information space. In these conditions, one can expect the interests of providers and users to coincide.”**

“Lisa Betzy, [ION director of operations] asked me to put together a track that doesn’t have an equation in it,” says Betz, who admitted it was quite a challenge since his own presentations are highly technical in nature.

Panel topics included “Program Updates of Global and Regional Systems,” that covered GPS (Col. David W. Madden, Commander, GPS Wing), GLONASS (Dr. Sergey Revniykh, Deputy Director General, Central Research Institute of Machine Building and Head of PNT Information Analysis Center, Russian Federal Space Agency), Galileo (Marco Falcone, Galileo System and Operations Manager, Navigation Department, European Space Agency), and Japan’s Quasi-Zenith Satellite System (Koji Terada, QZSS Project Manager, Japan Aerospace Exploration Agency).

Betz said he had personally invited engineering leaders from China’s Compass program to take part in the conference as well, but that they ultimately declined, citing the recent devastating earthquakes in Sichuan province.

Other panel discussion topics and moderators included an update on programs, such as satellite-based augmentation systems, that require assured integrity systems and services (moderated by Dr. Todd Walter, Stanford University); intellectual property (IP) issues in the development and use of GNSS systems and services (moderated by Keith McDonald, NavtechGPS); “Global Influences of GNSS” (moderated by Alice Wong, U.S. State Department, and Sharafat Gadimova, UN Office on Outer Space Affairs); and the competitiveness of the Galileo receiver industry in the global GNSS Market (moderated by Guenter Hein, University FAF Munich).

The ION invested a considerable amount of resources into videotaping the panel discussions, and these will be available for viewing soon on ION’s newly re-designed website (see accompanying article).

**New Satellite Division Officers**

The conclusion of ION GNSS 2008 marked the beginning of new leadership for the ION’s Satellite Division, which among other activities organizes the annual ION international GNSS conferences.

Chosen during ION-wide elections this past summer, the following officers will comprise the Satellite Division Executive Committee and serve two-year terms: Chair, Dr. Pratap Misra, The MITRE Corporation; Vice Chair, Dr. John Raquet, Air Force Institute of Technology; Secretary, Dr. Demoz Gebre-Egziabher, University of Minnesota; Treasurer, Patricia Doherty, Boston College.

Raquet will serve as the general chair for the ION GNSS 2009 conference, which will return to Savannah. At its September executive committee meeting, the Satellite Division board approved Dr. Naser ElSheimy, a professor at The University of Calgary, as the GNSS 2009 program chair.

Dr. A.J. Van Dierendonck, an international GNSS consultant as principal of AJ Systems, will continue to serve on the
Satellite Division Executive Committee for an additional two years as the Immediate Past Chair.

Dr. Christian Tiberius, Delft University of Technology, The Netherlands and Dr. Andrew Dempster, University of New South Wales, Australia, have been appointed as international technical advisors. Dr. Guenter Hein, University EAF Munich, who has served in recent years as an international technical advisor for ION GNSS conferences, will continue on the Satellite Division Executive Committee as a non-voting advisor in matters pertaining to Galileo.

Core Business

The GRC team includes experienced research scientists and engineers as well as PhD and graduate students able to support a range of geospatial technologies and disciplines including:

- Positioning and orientation
- Imaging and image analysis
- Communications and signal analysis
- Sensor integration
- GIS

Real-World Application and Research Areas

The GRC team works closely with industry, tertiary education institutions and government bodies in New Zealand and overseas, across a range of real-world application and research areas including:

- surveying
- precision agriculture
- underwater positioning
- defense
- environmental monitoring and management
- transport

Founded in 2006, GRC is a joint venture between the University of Nottingham, the University of Canterbury, and Canterbury Development Corporation.
Section News

**ALBERTA CANADA SECTION**
Attendees at the October 3 meeting heard presentations by Mr. Pejman Kazemi and Mr. Jared Bancroft, two PhD candidates in the PLAN Group at the University of Calgary. The presentations had been given at the ION GNSS 2008 conference in Savannah, Georgia. Mr. Kazemi’s presentation was titled “Comparison of Assisted and Stand-Alone Methods for Increasing Coherent Integration Time for Weak GPS Signal Tracking” for which he won a Best Presentation Award. Mr. Bancroft’s presentation was titled “Twin IMU-HSGPS Integration for Pedestrian Navigation”.

The next meeting of the section is planned for November 21 and will be held again at the Calgary Centre for Innovative Technology (CIT) building at the University of Calgary. The meeting will feature a presentation by NovAtel Inc. ◆

**SOUTHERN CALIFORNIA SECTION**
On September 11 the Southern California section held a meeting, hosted by NavCom in Torrance, California. The meeting included a presentation from Dr. Todd Walter of Stanford University entitled, “The Ionosphere and its Effect on Satellite Navigation.” About 50 people were in attendance for the meeting and an abstract of the meeting follows. Slides used during the meeting can be viewed at www.ion.org/sections/southern-california.cfm.

The ionosphere creates some of the most significant challenges to the use of precise GPS. Its spatial and temporal variations limit the accuracy of position solutions. The uncertainty of its influence limits the availability of high accuracy and high integrity systems.

In equatorial areas the ionosphere can cause a form of self-interference, called scintillation, that can prevent the tracking of the signal altogether. Yet, despite these serious obstacles, the ionosphere itself is not well understood. As the use of GPS becomes more demanding and more wide-spread, it is important to examine the ionosphere and understand the range of possible effects.

The FAA has a network of redundant measuring stations throughout North America that has been used to continuously observe ionospheric behavior for the last 8 years. These data have been used to identify the largest gradients observed at middle latitudes.

Our emphasis, in this research, has been on identifying the extreme behavior that, fortunately, occurs rarely over the United States. We have also examined data from other parts of the globe where large variations can be much more common.

A partial solution to the challenges from the ionosphere is under development in the form of modernization of the GPS signals. However, this solution comes at a cost: the combination of signals to create an ionospheric-free measurement greatly inflates the magnitude of other error sources. Users who are particularly affected by the ionosphere will welcome these new signals that will do much to reduce extreme behavior.

The talk focused on observations of ionospheric effects ranging from typical observed variations to the extreme behavior of ionospheric superstorms. The effects on satellite navigation was discussed as well as how to place confidence limits on the possible magnitude of its effect. ◆

2009 ION Officers Nominated

The following nominations were submitted by the 2009 Nominating Committee for officers of The Institute of Navigation. The nomination committee was chaired by John Lavrakas and included three representatives from each region.

- **President:** Dr. Mikel Miller, Air Force Research Laboratory
- **Executive Vice President:** Dr. Todd Walter, Stanford University and Dr. Dorota Grejner-Brzezinska, The Ohio State University
- **Treasurer:** Dr. John Betz, The MITRE Corporation and Dr. John Studenny, CMC Electronics, Inc., Canada
- **Eastern Vice President:** Patricia Doherty, Boston College Institute for Scientific Research and Dr. Jade Morton, Miami University

- **Western Vice President:** John Clark, The Aerospace Corporation and Dr. Susan Skone, University of Calgary, Canada
- **Eastern Council Member-at-Large:** Dr. Jacob Campbell, Air Force Research Laboratory and Dr. Anthea Coster, MIT Haystack Observatory
- **Western Council Member-at-Large:** Chuck Bye, Honeywell and Frank Czopek, Boeing
- **Space Representative:** Dr. Mark Petovello, University of Calgary, Canada and Dr. Angela Dorsey, Jet Propulsion Laboratory
- **Air Representative:** Frank Lorge, FAA Technical Center and Lt. Casey Miller, Air Force Research Laboratory
- **Land Representative:** Dr. David Bevly, Auburn University and Dr. Sunil Binsath, York University, Canada

- **Marine Representative:** Dr. Sherman Lo, Stanford University and Doug Taggart, Overlook Systems Technologies

**Voting.** Voting will be conducted electronically via the ION website. On-line ballots will be available after December 19. On-line voting must be completed by January 9, 2009 to be counted. To vote on-line, follow these simple instructions: (1) Go to www.ion.org. (2) Click on the voting button. (3) Enter your User I.D. and password. The default User I.D. is your member number and the default password is your last name. If you changed your default User I.D. or password, use those instead. (4) Mark your selections, and submit your ballot!

**Paper Ballots.** If you do not have Internet access or prefer to receive a paper ballot, please contact us by phone, fax, or mail at The Institute of Navigation, 3975 University Drive, Suite 390, Fairfax, VA 22030; 703-383-9688, voice; 703-383-9689, fax. Please allow sufficient time to receive your ballot via mail or fax. Completed ballots must be received at the ION Office by January 9, 2009, to be counted. Ballots received after January 9 will NOT be counted.

**Election Results.** Results will be announced at the ION 2009 International Technical Meeting, January 26–28, 2009, in Anaheim, Calif. Newly elected officers will take office on January 28, at the conclusion of the meeting. Election results will be reported in the ION Newsletter. ◆
WASHINGTON SECTION

The Washington D.C. section met on October 15 at Buca di Beppo restaurant in Washington D.C. to hear Dr. Alfred Wicks of Virginia Tech present The DARPA Urban Challenge. Dr. Wicks presentation used video and slides to cover the DARPA Grand Challenge in 2004 where Virginia Tech qualified in fifth position in Barstow to the second Grand Challenge in which Virginia Tech placed at Primm, Nevada. Dr. Wicks was the co-leader in the Grand Challenge and team leader for Team Rocky in the second Grand Challenge. In the Urban Challenge, the Virginia Tech team finished third. The next meeting of the section is scheduled for February, 2009.◆
**Blackbeard’s Secret Weapon**

Piracy is enjoying a dramatic, and very violent, resurgence, according to London’s International Maritime Bureau October 2008 report.

In the first nine months of this year, one-third of the world’s reported pirate attacks occurred in the waters off Somalia: 26 vessels were hijacked, and 537 crew members were taken hostage.

Somalia has been without a central government for 17 years. Militias and warlords control it — and the area off its coast, including the Gulf of Aden, is pirate infested.

They use rocket-propelled grenades instead of cutlasses to threaten their prey (although they still rely on grappling hooks to get aboard.)

But that’s not the only modern technology that makes them surer, swifter, and more effective than pirates of yore.

Armed with GPS systems, satellite phones, and laptops, the pirates are able to navigate as far as 300 miles into the Indian Ocean. They can locate rich targets, identify their cargo, ownership and destination, map their routes, coordinate attacks with others in the area and negotiate much more effectively than the buccaneers of the Spanish Main.

**Shanghai Express**

Bicycles used to be a major Shanghai industry — then automobiles took the roads in China.

With a rapidly growing logjam on the nation’s streets and roads, Shanghai’s bike advocates are striking back. In September, a free civic bicycle-lending service began at a metro station in the Pudong New Area and three other Shanghai districts. The city hopes to have 60,000 bikes and 1,500 bike service stations in operation by 2010, when the World Expo will be held there.

Will it work? Trust but verify, they say. Each bike is equipped with a GPS receiver and a communications link to a control center. The bicycle locks automatically if an important part of this tracking system is lost. If the borrower forgets to return the bike — or swipes it — the control center will be able to tell exactly where it is.

**Roaming Mobile Homes**

Just when the housing market has tanked — you’ll be able to access a national real estate database on your mobile phone and guide yourself to houses available for purchase.

ATT, Sprint Nextel, Google Android, and Apple iPhone subscribers are now able to browse more than two million Multiple Listing Service houses on RealEstate.com for a monthly fee in the $3 to $5 range.

There you can find photos, maps, price, and other details — if you’re willing to look at them on your teeny tiny cell phone screen.

For GPS-enabled phones, the program will show “for sale” listings on an interactive map showing your current location and nearby available properties. Or GPS-deficient users can type in an address and call up that listing and others in the area.

Trulia, one of RealEstate.com’s competitors, offers Trulia Mobile, a free sales listing and neighborhood search application, downloadable from Apple for the original iPhone, the iPhone 3G, and the iPod touch. Trulia also offers an application for DASH Express GPS (an internet-connected automotive navigation service) that maps the listings for you.

One real estate agent blogger noted that the new mobile home sales applications would be really useful if they specialized in foreclosed properties.
Text messages from elephants are part of the normal workday for rangers in a Kenyan wild life conservancy. The telltale “blips” on their cell phones let them know when a crop-raiding herd member is going off the reservation. 

Using Google Earth and GPS, a virtual “geo-fence” has been mapped around the actual boundaries of the 90,000-acre Ol Pejeta wildlife park in the country’s Laikipia District.

Mobile phone cards on the elephants’ GPS collars are programmed to beep messages whenever the animals get too near the “geo-fence.”

The elephant herds have been squeezed into smaller and smaller areas, with bulls in particular roaming outside the park’s boundaries for food. Nearby farmers have suffered the destruction of entire crops — and occasionally, human lives. During harvest season, neighbors sometimes have to spend the night in front of blazing bonfires and beat on kitchen pots to frighten the animals away.

Proximity hasn’t been good for either side.

The park is testing the new tracking solution, which has helped prevent poaching and shooting of the animals and has notably decreased crop raiding.

Elephants, the park rangers say, act like teenagers. They copy each other; so, tracking and controlling one habitual crop raider can make a whole group change its habits.

* The elephant is saying “Forget It, I’m Out Of Here. Got to Run — (worried face with long nose)”

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**GPS High Crimes and Misdemeanors**

In September, California Governor Arnold Schwarzenegger signed a bill that makes it legal to attach your GPS device to an automobile dashboard. (A little late, now that Investor’s Business Daily has told us that Apple’s iPhone cut the growth rate for personal navigation devices by 40 percent — but hey . . .)

After January 1, 2009, California drivers will be able to mount their navigation devices away from the airbag deployment zone in the lower right or left corner of the dash . . . but not in the middle.

Schwarzenegger also signed a bill forbidding Californians to hold animals on the lap or text message while driving (Note to Ol Pejeta Park rangers, above: warn the elephants.)
Session A1: GNSS-Inertial Navigation Systems
Session A2: Multiphase and Satellite Applications
Session A3: Space and Satellite Systems
Session A4: Algorithms for Multi-sensor Fusion
Session A5: GNSS Civil Interference and Spectrum Aspects
Session A6: Alternatives and Backups to GNSS
Session B1: Integrity Multi-constellation RAM
Session B2: Space and Satellite Applications
Session B3: Algorithms and Methods 1
Session B4: GPS & GLONASS Modernization, QZSS, and Other GNSS
Session B5: GPS & GLONASS Modernization, QZSS, and Other GNSS
Session B6: Modeling and Simulation
Session C1: GNSS Receiver Algorithms
Session C3: New Products
Session C4: Indoor Positioning
Session C5: Software Receivers (GNSS) Design and Analysis of Reconfigurable Embedded GNSS Receivers using Model-Based Design Tools: S. Ramakrishnan, C.X. Gao, D.De Lorenzo, T.Walter, P.Enge, Stanford University
Session C6: GNSS Antenna and Radio Technology
Session D1: Atmospheric Effects on GNSS
Session D3: Algorithms and Methods 1
Session D4: Algorithms and Methods 2
Session D5: Atmospheric Effects on GNSS
Session D6: Multiple-Frequency GNSS Algorithms
Session E1: Marine Applications
Session E2: Novel Applications
Session E4: GNSS Space Based Augmentation Systems A Simple Algorithm for Dual Frequency Ground Monitoring Compatible with ARAIM: J. Blanch, T. Walter, P. Enge, Stanford University
Session E5a: GNSS Civil Interference and Spectrum Aspects
Session E5b: Marine Applications A Feasibility Study on L1/L2C Software RSM for Maritime DGPS: S.H. Park, D.J. Cho, K.Y. Seo, S.H. Suh, Korea Ocean Research and Development Institute, South Korea
Session E6: GNSS Ground Based Augmentation Systems Trimble’s Marine Reference Station Modernization: K.E. Ferguson, M.K. Albright, M. Brand, Trimble Terrasat GmbH, Germany
Session F2: Galileo Signal Structure, GPS/Galileo Interoperability Revised PRN Code Structures for Galileo E1 OS: S. Wallner, J.A. A. Rodriguez, H.J. Won, G.W. Hein, University FAF Munich, Germany; J.L. Isser, ONES, France
Session F4: Integrated/Integrated GNSS Performance Evaluation of L2C Data/Pilot Combined Carrier Tracking: R. K. Muthuraman, University of Calgery, Canada; R. Sukas, University of British Columbia, Canada; Canada; S. Lachapelle, University of Calgary, Canada
Session F5: Galileo System Design and Services Galileo System Performance for Different Users and Constellations: V. Oehler, J.M. Krueger, H.L. Trautenberg, J. Daubrauwa, EADS Astrium GmbH, Germany
Session F6: Surveying and Geodesy Multiple UWB Range Assisted GPS RTK in Hostile Environment: G. MacGougan, K. O’Reilly, D.S. Chiu, University of Calgary, Canada
Progress and Problems as the World’s Four GNSS Programs Push Ahead

**GPS**

While launch delays continue for the next GPS IIR-M satellite with its L5 signal payload and the first Block IIF spacecraft remains stuck in thermal-vacuum testing, program leaders have announced progress on the programmatic front.

In Fall 2009, the U.S. Air Force will begin broadcasting a transitional civil navigation (CNAV) message on the GPS L2 civil signal (L2C) now being transmitted on the six IIR-Ms in orbit satellites as a dataless sequence without modulation. And, on October 31, the GPS Wing completed an integrated baseline review (IBR) of the GPS IIIA program.

The Federal Aviation Administration (FAA) has issued a performance standard for the Wide Area Augmentation System (WAAS) and reported that it has now published 1,333 localizer performance with vertical guidance (LPV) approach procedures based on WAAS. The LPVs cover runways at 833 airports.

Publication of the WAAS Performance Standard (PS) on October 31 follows on the heels of an updated version — the first since 2001 — of the GPS Standard Positioning Service (SPS) Performance Standard in September.

Copies of both performance standards can be found on the website of the National Coordination Office for Space-Based Positioning, Navigation, and Timing: http://pnt.gov.

Meanwhile, in a September 23 notice in the Federal Register, the U.S. government has committed itself to maintaining the signals characteristic needed for semi-codeless GPS applications until December 31, 2020. The plan will ensure that civil users can continue employing codeless or semi-codeless techniques to use encrypted GPS signals, L1 P(Y) and L2 P(Y), for high-accuracy, dual-frequency applications.

**GLONASS**

Three more modernized GLONASS satellites (GLONASS-M) have begun transmitting healthy navigation messages, bringing the total of operational satellites to 17 — a milestone for the Russian GNSS constellation.

The last of a trio of satellites launched September 25 — GLONASS-M space vehicle (SV) SVN 112 (726) — began transmitting a healthy navigation message on November 13, giving the rebuilt GLONASS constellation the highest number in more than a decade. GLONASS SVN 110 (724) began transmitting on October 26, and SVN 111 (725), on November 5, according to the Russian Space Agency (Roscosmos) GLONASS Information-Analytical Center.

Another triple GLONASS launch is scheduled for December 25 this year.

**Galileo**

Eleven contenders have been selected to build elements of the Galileo system — the so-called fully operational capability (FOC) infrastructure.

The European Commission (EC) and the European Space Agency (ESA) have chosen 11 companies for the initial phase of the procurement process to build a fully operational capability (FOC) Galileo system. Candidates were named in six separate procurement areas or “work packages.”

The next step of the procurement procedure — a dialog phase — is taking place over a 15–30 week period. If the European agencies can stick to their schedule, that would place the final award of the FOC contracts sometime between early March and late May 2009.

Under the current schedule for the public acquisition of Galileo’s ground and space infrastructure, four in-orbit validation (IOV) spacecraft will be launched beginning in 2010 with the full 30-satellite constellation in place by 2013.

**Compass**

China’s Compass navigation system (Beidou II) will offer 10 services — five free “open” services, and five restricted “authorized” services — centered at eight different carrier frequencies.

Compass signals will include a variety of modulations (quad phase skip keying, binary offset carrier [BOC], and multiplex BOC) both in phase and in quadrature, PRN code chip rates and navigation data bit rates, and bandwidths. (See accompanying table.) Open services will be transmitted on the B1 in-phase, B1-BOC, B2 in-phase, B2-BOC, and L5 frequencies; authorized service will appear on B1 quadrature, B1-2, B2 quadrature, B3, and B3-BOC frequencies.

Chuang Shi, deputy director of the GPS Research Center at Wuhan University, provided the details during a presentation on Compass at the ICG Experts Meeting held July 15 in Montreal, Canada, in conjunction with the 37th assembly of the International Council for Science’s Committee on Space Research (COSPAR).
Global Navigation Satellite Systems are an enabling technology that can provide sustainable social and economic benefits for developing countries. International organizations have initiated the deployment of GNSS infrastructure for numerous programs that include geodetic applications and scientific exploration. The ION ITM plenary session will include speakers involved in some of the innovative programs allowing developing nations to exploit this technology.

Session Topics

- Algorithms & Methods
- Applications in Surveying, Geodesy, Science and Timing
- Autonomous Vehicle Navigation
- Aviation Applications
- Emerging Navigation Technologies
- Enhanced and Developing GNSS Systems
- GNSS Interoperability & Compatibility
- GNSS Receiver and Antenna Technology
- GNSS for Global Development
- GPS Modernization/GPS III
- Ground and Satellite Based Augmentation Systems
- Integrated Navigation Systems
- Interference and Spectrum Management
- Land Based Applications
- Marine Applications
- MEMS & Inertial Navigation Sensors
- Military Applications
- Probing the Neutral Atmosphere with GNSS
- Space Navigation
- Space Weather Monitoring
- Urban & Indoor Navigation Technology
- Ground and Satellite Based Augmentation Systems
- Integrated Navigation Systems
- Interference and Spectrum Management
- Land Based Applications
- Marine Applications
- MEMS & Inertial Navigation Sensors
- Military Applications
- Probing the Neutral Atmosphere with GNSS
- Space Navigation
- Space Weather Monitoring
- Urban & Indoor Navigation Technology

January 5 is the last day to pre-register to avoid a late fee and to obtain the discounted hotel rate!

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