PILOTS OF ALL EXPERIENCE LEVELS AND DISCIPLINES GO TO THE NATIONAL AERONAUTICS ASSOCIATION OF AMERICA (NAA) WHEN THEY WANT RECOGNITION FOR FLYING FASTER, HIGHER OR LONGER THAN OTHER PILOTS. THE NAA SANCTIONS NUMEROUS RECORD-ATTEMPTS BY PILOTS WISHING TO SET NATIONAL OR WORLD RECORDS FOR AIRCRAFT TRAVEL.

SPEED RECORDS CAN BE SET OVER DISTANCES AS SHORT AS 3KM TO AS LONG AS AROUND THE WORLD. NOW, WITH THE HELP OF NOVALTEL INC’S GPS EXPERTISE, THE 3KM SPEED RECORD CAN BE VERIFIED USING AN EXTREMELY ACCURATE GPS RECEIVER PLACED ON THE RECORD-HOPEFUL AIRCRAFT.

THE 3KM LOW-ELEVATION RECORD IS CONSIDERED BY SOME TO BE THE MOST PRESTIGIOUS OF THE RECORDS. OVER SUCH DISTANCES, AIRCRAFTS REACH SPEEDS OF SEVERAL HUNDREDS OF KMH. PILOTS MUST NAVIGATE THEIR PLANES UP AND DOWN A 3KM COURSE AND TWO 1KM APPROACH ZONES FOUR TIMES AS SHOWN IN FIGURE 1. DURING THE FLIGHT, THE PLANE MUST STAY WITHIN A 200M WIDE CORRIDOR AND CANNOT RISE MORE THAN 150M ABOVE THE GROUND WHILE IN THE COURSE.

TIMING CONTINUED ON PAGE 16

RUSSIA AND THE UNITED STATES HAVE SIGNED A JOINT STATEMENT THAT SAID THAT BOTH SIDES INTEND TO COOPERATE ON MATTERS OF CIVIL SATELLITE-BASED NAVIGATION.

THE STATE DEPARTMENT’S STATEMENT SAID, “DELEGATIONS OF THE UNITED STATES AND THE RUSSIAN FEDERATION MET IN WASHINGTON D.C. ON DECEMBER 9-10, 2004, TO CONTINUE DISCUSSIONS ON MATTERS RELATING TO GPS AND GLONASS COOPERATION.”

“BOTH SIDES RETERATED THEIR COMMITMENT TO CONTINUING THESE TALKS AND REAFFIRMED THAT THE UNITED STATES AND THE RUSSIAN FEDERATION INTEND TO CONTINUE TO PROVIDE THE GPS AND GLONASS CIVIL SIGNALS APPROPRIATE FOR COMMERCIAL, SCIENTIFIC AND SAFETY OF LIFE USE ON A CONTINUOUS, WORLDWIDE BASIS, FREE OF DIRECT USER FEES.”

THE STATEMENT ALSO SAID THAT BOTH SIDES INTEND TO ESTABLISH WORKING GROUPS ON MATTERS OF DEVELOPMENT AND USE OF GLONASS AND GPS AND THEIR RESPECTIVE AUGMENTATIONS AND THAT BOTH SIDES WILL START PRELIMINARY NEGOTIATIONS ON AN AGREEMENT FOR GPS-GLONASS COOPERATION. ◆

FLIGHT RECORDS AND THE SPEED OF GPS

ION FUNDS DEVELOPMENT OF NOVAHEL FLIGHT RECORDER SYSTEM FOR NAA

BY TREVOR BROPHY

Pilots of all experience levels and disciplines go to the National Aeronautics Association of America (NAA) when they want recognition for flying faster, higher or longer than other pilots. The NAA sanctions numerous record-attempts by pilots wishing to set national or world records for aircraft travel. Speed records can be set over distances as short as 3km to as long as around the world. Now, with the help of NovAtel Inc’s GPS expertise, the 3km speed record can be verified using an extremely accurate GPS receiver placed on the record-hopeful aircraft.

The 3km low-elevation record is considered by some to be the most prestigious of the records. Over such distances, aircrafts reach speeds of several hundreds of km/h. Pilots must navigate their planes up and down a 3km course and two 1km approach zones four times as shown in Figure 1. During the flight, the plane must stay within a 200m wide corridor and cannot rise more than 150m above the ground while in the course.

Timing continued on page 16
The President authorized a new GPS national policy on Dec. 8 that establishes guidance and implementation actions for space-based positioning, navigation, and timing programs, augmentations, and activities for U.S. national and homeland security, civil, scientific, and commercial purposes.

The policy provides guidance for: (1) development, acquisition, operation, sustainment and modernization of the Global Positioning System and U.S.-developed, owned and/or operated systems used to augment or otherwise improve the Global Positioning System and/or other space-based positioning, navigation, and timing services; (2) development, deployment, sustainment, and modernization of capabilities to protect U.S. and allied access to and use of the Global Positioning System for national, homeland, and economic security, and to deny adversaries access to any space-based positioning, navigation, and timing services; and (3) foreign access to the Global Positioning System and United States Government augmentations, and international cooperation with foreign space-based positioning, navigation, and timing services, including augmentations.

The Goal

The fundamental goal is to ensure that the United States maintains space-based positioning, navigation, and timing systems that: (1) provide uninterrupted access to U.S.-based global, precise positioning, navigation, and timing services for U.S. and allied national security systems and capabilities through the Global Positioning System, without being dependent on foreign positioning, navigation, and timing services; (2) meet growing national, homeland, and economic security, and scientific and commercial demands; (3) remain the pre-eminent military systems based on the Global Positioning System and its augmentations, and systems based on the Global Positioning System. Seek to ensure that foreign space-based positioning, navigation, and timing systems are interoperable with the civil services of the Global Positioning System and its augmentations and that foreign systems are compatible with the Global Positioning System and its augmentations and address mutual security concerns with foreign providers to prevent hostile use of space-based positioning, navigation, and timing services; and (5) remain essential components of internationally accepted positioning, navigation, and timing services; and (6) promote U.S. technological leadership in applications involving space-based positioning, navigation, and timing services. To achieve this goal, the United States Government will:

• Provide uninterrupted access to U.S.-based global, precise positioning, navigation, and timing services for U.S. and allied national security systems and capabilities through the Global Positioning System, without being dependent on foreign positioning, navigation, and timing services;

• Provide on a continuous, worldwide basis civil space-based, positioning, navigation, and timing services and timing services free of direct user fees for civil, commercial, and scientific uses, and for homeland security through the Global Positioning System and its augmentations, and provide open, free access to information necessary to develop and build equipment to use these services;

• Improve capabilities to deny hostile use of any space-based positioning, navigation, and timing services, without unduly disrupting civil and commercial access to civil positioning, navigation, and timing services outside an area of military operations, or for homeland security purposes;

• Improve the performance of space-based positioning, navigation, and timing services, including more robust resistance to interference for, and consistent with, U.S. and allied national security purposes, homeland security, and civil, commercial, and scientific users worldwide;


• Encourage foreign development of positioning, navigation, and timing services and systems that exceed or are compatible with foreign civil space-based positioning, navigation, and timing services and augmentation systems; and

• Remain essential components of the U.S. space-based positioning, navigation, and timing policy is posted at www.opsc.gov.

REACHING OUT!

GPS Monument Installed at Maryland High School

Under an agreement between Peter Cahill, principal of the Watkins Mill High School in Gaithersburg, Maryland, and ION Washington, D.C. Section Chair Jim Doherty, the Section’s Stipend Steering Committee (SSC) installed a GPS monument on the hall floor overlooking the football field of Watkins Mill High School.

Students in the Earth science class of instructor Erin Miller will use the monument to calibrate the accuracy of the Garmin GPS 72 and 76 receivers which they used last year and will use this year in the “Survey your football field” activity. When SSC member Franck Boynton has surveyed the monument, its coordinates in datums of WGS 84, NAD27, NAD83 and the Maryland Grid will be posted on the school web site together with the method of survey. The survey measurement data will be preserved for use by students. Using a $2,500 stipend from the ION Council in FY04, the SSC bought twelve GPS receivers and ten books for activities to interest high school students in the art and science of navigation.
The Aviation GNSS Receiver

By John Studenny, CMC Electronics and Barbara Clark, Federal Aviation Administration

The airspace above us is an unnatural place for humans to be. We don’t have wings. Only through human ingenuity are we able to travel and live above solid terra firma. The one thing that differentiates traveling and living on terra firma from the airspace above us is that the airspace doesn’t easily forgive error, or failure of any kind. Gravity will quickly demonstrate just how unforgiving the airspace can be. The real question is how likely are those errors and failures to be and how will they affect the aircraft. Avoiding the dire consequences of error or failure is the subject of safety. Aviation, and civil aviation in particular is about safety first and foremost.

The subject of safety is complicated. Safety practitioners, such as aviation equipment suppliers, go through a significant learning curve to understand, and then apply the concepts of safety to their trade. “Certification” is a cornerstone of aviation safety. To “certify” is to approve and declare that something or someone, whatever or whomever that might be, has met an established set of standards. The standards and approvals are provided by the Civil Aviation Authorities (CAA). Each nation-state has such a CAA, in the United States that body is the Federal Aviation Administration (FAA).

Ever try navigating in a car at night in rain or slick snow? A little stressful? Ever try it with no lights whatsoever? How about at 11,000 feet above terra firma and descending? That is the environment an aircraft can and does fly in routinely.

The ‘Guarantee’ of Safety

One of the systems that gets the aircraft through the skies back to terra firma, with “guaranteed” safety, is the navigation and precision approach guidance systems onboard the aircraft. The key is the guarantee of safety. But can we ever really guarantee anything? Perhaps not in the strictest sense. However, high confidence is built through establishing standards that mitigate risk and by applying a disciplined, systematic certification process. This high confidence is our safety assurance, “our guarantee.”

GNSS is an exceptional navigation system offering positioning accuracy that is unmatched by other navigation systems. GPS navigators have become ubiquitous; they are available in stores as consumer items. Shopping for aviation GPS systems does fly in routinely.

In aviation, every system is characterized by its intended function and at least its probability of continuous operation, probability of failure and types of failure modes, impact of failures on the aircraft operation, and expected operating time between failures.

In aviation, every system is characterized by its intended function and at least its probability of continuous operation, probability of failure and types of failure modes, impact of failures on the aircraft operation, and expected operating time between failures.

The buyer finds aviation GPS systems cost more. They’re bigger and weigh more. But don’t all GPS receivers do the same thing? If they were to provide navigation without any guaranteed safety assurance, the answer would be yes.

In aviation, every system is characterized by its intended function and at least its probability of continuous operation, probability of failure and types of failure modes, impact of failures on the aircraft operation, and expected operating time between failures.

Performance specifications on these parameters are either an indirect or direct result of safety requirements, and if that weren’t enough, an additional performance parameter is specified—system integrity. Integrity is roughly the self-verification of a system’s performance or a measure of trust in the system’s performance. For navigation systems, performance generally equates with accuracy and precision. The navigation receiver is expected to be able to determine when conditions exist that may result in the receiver presenting misleading or erroneous navigation information.

Safety practitioners use quantitative analyses to establish and provide evidence of the certified aviation system’s compliance with these specifications.

Receiver Requirements

Let’s take a closer look at what an aviation receiver has to do. The first thing it has to do is demonstrate it reliably captures GPS signals within a fixed amount of time. This sounds pretty easy. The receiver has to be able to do this with one satellite set 18 dB above all the rest, a worst case satellite cross-correlation scenario while being subject to the presence of radio frequency interference. Navigation performance, and integrity, are tough things to guarantee under these conditions. A non-aviation GPS receiver could get confused under such conditions and output erroneous positions—they weren’t designed to cope with such environments. After signal capture, the received satellite data has to be validated. There are various, and proprietary techniques on how best to do that. Then, the receiver must compute a position fix—and validate it. One method is to use a Fault Detection and Exclusion (FDE) algorithm. Another complimentary technique is Step Error Detection. Readers with a technical slant can refer to RTCA DO-229C, a specification for aviation WAAS/GPS receivers.

Advanced WAAS/GPS receivers implement Built-In-Test Equipment (BITE) to carry out self-diagnosis. Satellite diagnostics are done at power-up and are performed continuously while in use.

While this is going on, the receiver is being exposed to the harsh aviation environment. This environment is characterized by extreme temperature swings (from -55 to +75 Celsius), lots of vibration, shock of landing, humidity, salt fog, corrosive fluids, sand and dust, exposure to fungus, electromagnetic radiation and conducted currents, high power radar, and lightning, to name a few. Aviation equipment is exposed to this environment routinely, and must operate without fault, and not impair the aircraft or its occupants.

Each certified aviation system goes through a “qualification program” that proves it can safely and continuously operate in the aviation environment.

Design and Production

Design and production approvals for aviation equipment can be granted by CAs to manufacturers based on the equipment’s compliance with a CAA established set of requirements. The FAA may ask the manufacturer to produce evidence of adherence to sound engineering practices and/or adherence to approved development processes such as RTCA DO-178B and RTCA DO-254. The evidence are the detailed plans, documented development work, work products, and test results. In short, these practices require that the engineering team demonstrate verifiability and validation of their development and production from start to finish.

Finally, although this type of approval does not cover the installation of the equipment into an aircraft, the manufacturer documents the operating procedures, aircraft installation procedures, and any relevant limitations. Sometimes, aviation equipment is approved in conjunction with the entire aircraft and is granted to airplane “type certificate” or “supplemental type certificate” holders. In these cases, flight tests may also be required for the first approval of equipment on a given aircraft type to demonstrate that the installed aviation receiver integrates safely with the rest of the aircraft, pilot included.

Yes, there is a great difference between aviation GPS receivers and the consumer GPS receivers found in stores. And it all has to do with your Safety-of-Life.

—Dr. John Studenny is the Aerospace Systems Engineering manager at CMC Electronics, Montreal. He has been involved with GPS receiver development since 1990 and with GPS/GNSS integration since 1981. His technical areas span receiver architecture, receiver performance analysis, algorithm development for RAIM, navigation, and GPS signal processing.

Barbara Clark is an engineer with the FAA’s Aircraft Certification Service. She has worked in the areas of modeling and simulation of aircraft aerodynamics and performance, in the analysis of flight control systems, and in the development of airborne equipment standards development for ground based augmentations to GPS.
A libration point concept advocated for many years by Farquhar [2] is a lunar relay satellite operating in the vicinity of the translinear Earth-Moon libration point, often designated L2, providing “Earth-to-lunar face-side and long-range surface-to-surface navigation and communications capability.” Reference [2] lists several advantages of such a system in comparison to a lunar orbiting relay satellite constellation. Among these are one or two vs. many satellites for coverage, simplified acquisition and tracking due to very low relative motion, much longer contact times, and simpler antenna pointing; however, access from lunar polar sites is challenging. An obvious additional advantage of such a system is that “in the blind,” when direct communications to Earth is not possible.

Estimated Stationkeeping Cost

Farquhar also described an interplanetary transportation system that would use libration points as terminals for an interplanetary shuttle. This approach would offer increased operational flexibility in terms of launch windows, rendezvous, aborts, etc. in comparison to elliptical orbit transfers. More recently, other works [6, 7] have shown that patching together unstable trajectories departing Earth-Moon libration points with stable trajectories approaching planetary libration points may also offer lower overall fuel costs than elliptical orbit transfers. The lunar navigation infrastructure should evolve to support such concepts.

Another concept Farquhar described was a deep space relay at an equalilateral Earth-Moon libration point (L3 and/or L5) that would serve as a high data rate optical navigation and communications relay satellite. The advantages in comparison to a geosynchronous relay are minimal Earth occultation, distance from large noise sources on Earth, easier pointing due to smaller relative velocity, and a large baseline for interferometry if both L3 and L5 are used. Such a relay could initially support lunar missions as well.

GPS Navigation

Barton et al. [8] studied the use of the Global Positioning System (GPS) for navigation en route between the earth and the moon. Assuming modest modifications that would improve GPS receiver sensitivity by approximately 10 dB and a high-gain directional receiver antenna, they showed that GPS signals viewed over the earth’s limb would support post-translunar injection (TLI) navigation out to about half the lunar distance. They also showed GPS navigation could support a mid-course trim burn for at least several hours after TLI, but if the trim burn was more than 8 hours after TLI, there was not enough GPS information to estimate the post-burn state. This level of GPS coverage might support the L1 lunar rendezvous scenario, especially if augmented by additional signals from NASA’s Tracking and Data Relay Satellite System (TDRSS), or from navigation assets in the vicinity of the moon. Using new, datless GPS signals and interferometry if both L3 and L5 are used. Such a relay could initially support lunar missions as well.

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In late 1955, the Secretary of Defense author-
ized a sea-based Intrumental Gyrocompass Sys-
tem (ICSBM) to help negate the Union of So-
viet Socialist Republics' nuclear threat. In De-
ceember of the same year, the Navy estab-
lished the Special Projects Office to rapidly
pursue a program to develop a submarine-
launched missile capability, known as the Pola-
ris submarine: Admiral Arleigh B. Burke,
Chief of Naval Operations, appointed Rear
Admiral William F. Raborn to become the first
director.

A ship's inertial navigation system (SINS) was
deemed crucial for the submarine's navi-
gation and its primary role of initializing the
missile system's guidance. Navigation was
seen as a critical aspect of the Fleet Ballistic
Missile's (FBM) feasibility because of the
effect it had on overall system accuracy and
because of inter-service rivalry, which
prompted the Air Force to doubt the Navy's
ability to successfully launch an ICBM. Ex-
mittorizing the time between exposures for
the missile's 'cat's whisker' and dancer
transmitter circuit. The gyro was an
extension of the research work then in prog-
gress on gas bearings for gyro rotors.

The MK 2 SINS fiberglass float from the Polaris
through Trident I have shown some of the MDL SINS from 1959 to
the present time. Although MK 2 SINS were
retained on retired SINS submarines that
were converted to other programs, the last
two Trident I submarines, the two MDL SINS
by its industrial partner the Sperry Gyroscope
Corporation, pioneers of gyrocompass tech-
tology, for use in bomber aircraft and long-
term navigation. In this configuration, the
inertial sensors (gyroscope and acceler-
ometers) remain fixed in orientation with
respect to the stars.

The major breakthroughs of gyro
design were the improvement in rotor
bearings, the air-lubricated bearings of
the output axis, and the symmetrical rotor
drive motors. These changes resulted in
great improvement in mass shift under
acceleration, and an inertial system,
the XN1 was flown as early as 1959. This
required accuracy of this system was maintained for 1960.

Although many improvements were made since
the original XN1, the embedded Markn
computer is of the same obsolete 1950s
technology of cat's whisker diodes and
continuous performance. This improved by using
both of the sensor's rotor to drive in its
memory size. The Mark I is still in use on
the few remaining operating MK2 SINS.

The Fleet Ballistic Missile submarines
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For more than thirty years, Dr. Charles R. Cahn has been a pioneer and a major contributor in the analysis and design of GPS signal structures and receivers. His work on the 621-B program and during Phase I of GPS was vital in defining the GPS signal structures we enjoy today.

More recently, he has made critical contributions to the GPS modernization program, including the analysis and design of key elements of the military GPS signal while a core member of the GPS modernization signal development team.

Dr. Cahn has been first to propose essential portions of the L2 and L5 civilian signal structure, and L1/L2 military signal structure that would not exist today without his insight and analysis. He subsequently designed and conducted a performance analysis of the ranging codes to be used for the new L2 Colinear Signal (L2C) and a Time Division Multiplexing scheme used to implement these signals on the IIR-M and IIF GPS satellites. Dr. Cahn was also instrumental in the development and analysis of a similar Time Division Data Multiplexing approach for the M-code signal, enabling benefits of a datalss signal component.

Dr. Cahn’s most recent contribution to the modernized GPS signal structure was the discovery of a flaw in the forward error correction algorithm for the M-code and a recommended correction that is being implemented in the IIR-M and IIF satellites. Without Dr. Cahn’s involvement, this flaw would have likely been overlooked until a time when it was far too costly to fix.

While Dr. Cahn has made several notable contributions to the GPS modernization efforts in recent years, his contributions to GPS signal and receiver developments have spanned a lifetime. Drawing upon a decade of experience in the design of direct-sequence spread spectrum signals and receivers for line-of-sight and satellite communication systems, Dr. Cahn made key contributions to the design of the L1 civilian signal structure, and L1/L2 military signal structure that would not exist today without his insight and analysis. He subsequently designed and conducted a performance analysis of the ranging codes to be used for the new L2 Colinear Signal (L2C) and a Time Division Multiplexing scheme used to implement these signals on the IIR-M and IIF GPS satellites. Dr. Cahn was also instrumental in the development and analysis of a similar Time Division Data Multiplexing approach for the M-code signal, enabling benefits of a datalss signal component.

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**Section News**

**ALBERTA SECTION.** The October meeting was held at the Calgary Centre for Innovative Technology. Flashlight presentations were given by the 5 GNSS 2004 papers from The University of Calgary that received Best Presentation Awards at ION GNSS 2004 in Long Beach, CA. The presentations were as follows:

4. Four Dimensional Fuzzy Logic-Based Map-Matching Algorithm for Location-Based Service Applications in Urban Canyons: S. Syed, M.E. Cannon, The University of Calgary, Canada.

**NEW ENGLAND SECTION.** On August 25, the section held its thirtieth meeting at The MITRE Corporation in Bedford, Mass. Alan Zorn, formerly of Dynamics Research Corporation, gave a presentation on the “Navigation of Submarine Platforms.” Since the onset of the cold war, accurate submarine navigation has been a technological challenge. Mission correctness severely limits access to usual fix sources such as stellar and GPS. Yet point-to-point navigation by pure inertial means is not sufficiently accurate to meet this strategic mission. In his talk, Zorn investigated how the strategic submarine meets this navigation challenge through tradecraft and technology.

Navigation developments from Polaris to Trident were briefly surveyed, and future trends were explored. Stringent accuracy requirements are met by a combination of highly accurate (“strategic grade”) inertial navigation systems and various types of both conventional and unconventional fix sources. GPS remains the most accurate and convenient fix source, but concerns over the vulnerability of the GPS satellites and exposure of the submarine during fix-taking operations limits its usefulness in this mission. Various alternative “quiet” fix sources were reviewed, and these include correlation sonar velocity, bottom map matching, gravity map matching, and gravity estimation techniques.

Zorn is currently a National Science Foundation fellow in the Ph.D. program in Aeronautics and Astronautics at Stanford University. He is also chair of the New England Section. In May, Zorn retired from Dynamics Research Corporation where he managed the Navigation Systems Department.

**HOUSTON SECTION.** On July 27, the Houston section held its meeting at Rudi Lechner’s Restaurant. Ian Florence of Kongsberg-Simrad gave a talk on the application of Autonomous Underwater Vehicles navigation for conventional uses, such as the Prestige tanker investigation and the positioning of sonic nodes.

Florence spoke about the problems faced in transferring this technology both in on-line operation and post-processing, and he touched on what is planned for the next phase of this technology, including which companies may be interested in using it.

At its September meeting, Tim Frintingon of Seamount presented “Locating Whales.” He discussed the current mitigation measures for protecting marine mammals that rely primarily on visual observers stationed on the survey vessel. The Mineral Management Services have recently completed an environmental assessment evaluating the potential environmental impacts of geological and geophysical activities in the Gulf of Mexico. Potentially adverse, but not significant impacts were identified for marine mammals and mitigation guidelines continue to encourage the use of passive acoustic monitoring systems. The problem in locating a Sperm Whale through passive acoustics was a variety of positioning-related issues. He explained some of the ways this problem is being addressed to improve the accuracy of the detection methods.

The newly elected Houston Section officers are as follows: Stephen Brown, chair; Elaine Moss, vice chair; Dave Gentile, secretary; Chuck Holt, treasurer; Keith Vidyarthi, membership; and Phil Summerfield, speaker liaison.

**WASHINGTON SECTION.** The Washington, D.C. section held its Aug. 24 meeting at the Department of Transportation headquarters. Ralph Brabrand, director of the Department of State’s Office of Advanced Technology, discussed the latest events in the negotiation process, and the challenges that lie ahead since the U.S. European Union Satellite Program in Ireland where Secretary of State Colin Powell and the European Commission Vice President Loya de Palacio signed an agreement on GPS and Galileo cooperation.

**SOCIAL SECTION.** The Southern California Section’s Oct. 20 meeting was hosted by Boeing Space Systems and held in the Boeing Seal Beach Conference Building 86. The meeting was well attended even though freeways were flooded and it was raining heavily. Frank Cozpek, GPS Block I/IIA Satellite program manager, presented an historical overview of the GPS satellite program at Seal Beach and showed slides of the manufacturing floor facilities in its heyday.

After his very interesting presentation, Frank led a walking tour of the facilities, highlighting the immense Thermo-Vac chambers, spin table, and manufacturing room area. He described what the areas were like during the 3-shift GPS IIR manufacturer schedule and also discussed a little known incident by eco-terrorists that resulted in actual damage to a space vehicle—the infamous arson incident where a space vehicle was attacked and damaged with an ax.

The tour ended with a look at the glass enclosed, chrome plated shovel that Werner Von Braun used to dedicate the facility for the Saturn Project in 1966. The property used for the manufacture of the Block I, II, and IIA satellites is designated to be sold later this year because it is surplus to Boeing’s needs.

At the end of the meeting the attendees all grouped around the Nascoar Monument for a photograph. The monument depicts each satellite manufactured in the facility, and when it was launched.

**ANNUAL AWARD NOMINATIONS REQUESTED**

Members are encouraged to submit nominations for one or more of the following annual awards given by the Institute of Navigation for excellence in navigation:

- **Early Achievement Award**—for an individual early in his or her career who has made an outstanding achievement in the art and science of navigation.
- **Superior Achievement Award**—for outstanding contributions to the advancement of navigation.
- **Thomas Thrall Award**—for outstanding contributions to the science of navigation.
- **Tycho Brahe Award**—for outstanding achievement in space navigation.
- **Captain P.V.M. Weems Award**—for outstanding contribution to the art and science of navigation.

Official nomination forms, along with brochures on the background and purpose of each award, are available from the ION National Office by phone, 703-383-9688, or via the Web site at www.ion.org. Nominations must be received by February 21, 2005.

The awards and accompanying engraved bronze plaques will be presented at the ION’s Annual Meeting, June 27–29, 2005, in Cambridge, Mass. The ION urges you to participate in the nomination process so that a representative group of deserving individuals from the navigation community will receive appropriate recognition.

In addition to the above awards, the winner of the Samuel M. Burka Award—for outstanding achievement in the preparation of papers advancing navigation and space guidance—as chosen by the editorial panel of ION’s journal, NAVIGATION, will be honored.

Address correspondence to Award Nomination Committee, The Institute of Navigation, 3975 University Drive, Suite 390, Fairfax, VA 22030, phone: 703-383-9688, fax: 703-383-9689, e-mail: membership@ion.org.
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Delta II Launch

A Delta II launch vehicle on Nov. 6 carried the latest replacement GPS satellite, putting the GPS IIR-13 spacecraft on en route to its 11,000nm orbit at slot 1, plane D of the 29 satellite constellation. It will replace GPS IA-11 in 1991.

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The flight speed is recorded as the average speed through any four consecutive passes of the course.

**Current Challenges**

Until now, these records have been verified using stopwatches, high-speed cameras and barometric altimeters. As aircraft technology improves and speeds increase, these methods no longer provide the required accuracy of 0.25 percent. Furthermore, there are a number of issues with the current systems that make them expensive and inconvenient.

Obviously, using stopwatches is prone to human error – especially when human eyes are trying to track aircrafts traveling at hundreds of km/h. People can inadvertently stop the watch at the wrong time, lose sight of the plane, or acquire other number of problems.

Alternatively, high-speed cameras can be used at each end of the 3km course to avoid human errors. The cameras take time-tagged pictures many times a second. These pictures must then be manually reviewed post-flight to determine exactly when the aircraft crossed a particular line. Unfortunately, these cameras are expensive to use and have limited storage capacity so camera recording must be closely monitored. Also, synchronizing the times on two cameras 3km apart has proven difficult. In fact, at a recent record attempt, where high-speed cameras fell out of synchronization and data from the stopwatches was required.

The record’s restrictions on height and width are also cumbersome to officiate. These methods have worked, but require a good deal of setup and organization to work properly.

**NovAtel’s Solution**

To combat these challenges, the NAA contacted the ION to see if a GPS system could be used to verify the 3km record attempts. GPS is already in use by the Fédération Aéronautique Internationale (FAI) to record glider flights. This was thought that such systems could be adapted for use in powered aircrafts. The ION agreed to provide funding for the project and released a request for proposal to GPS companies around the world.

NovAtel Inc. of Calgary, Alberta, Canada responded with a proposal that would use existing GPS units and modified post-processing software. Two highly accurate GPS receivers would be funded and an engineering internship student would modify the software used in the existing “DL-4” GPS receivers log data at rates of up to 20Hz. This data is transferred onto a PC and processed using differential GPS to produce aircraft position data as accurate as 2cm. The newly-developed software then interpolates the data points to find precise start and stop time for the aircraft as it travels through the 3km course. The result is speed calculations that greatly exceed the 0.25 percent accuracy requirement. The software also performs checks to make sure that pilots stay within course width and height boundaries, removing the need for other height and width monitoring.

Another key added feature is that digital security was added to the DL-4 firmware and post-processing software. This ensures that would be cheaters are unable to provide bogus data. All flight data from the DL-4 can be guaranteed as legitimate. 

**Handoff to the NAA**

Once development was complete, the system was handed over to the NAA for testing on actual planes. The system passed its first test with flying colors and was soon put to another test to compare it with current timing methods. With NovAtel’s leading GPS technology and ION funding, the NAA now has a timing system that greatly exceeds its accuracy requirements, protects against cheaters and is very convenient for record attempt officials.

**With Novatel’s leading GPS technology, and ION funding, the NAA has a timing system that greatly exceeds its accuracy requirements, protects against cheaters and is very convenient for record attempt officials.**

The flight data is collected onto both receivers. After a flight, data from both receivers is transferred onto a PC and processed using differential GPS to produce aircraft position data as accurate as 2cm. The newly-developed software then interpolates the data points to find precise start and stop time for the aircraft as it travels through the 3km course. The result is speed calculations that greatly exceed the 0.25 percent accuracy requirement. The software also performs checks to make sure that pilots stay within course width and height boundaries, removing the need for other height and width monitoring.

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During a flight, data is collected onto both receivers. After a flight, data from both receivers is transferred onto a PC and processed using differential GPS to produce aircraft position data as accurate as 2cm. The newly-developed software then interpolates the data points to find precise start and stop time for the aircraft as it travels through the 3km course. The result is speed calculations that greatly exceed the 0.25 percent accuracy requirement. The software also performs checks to make sure that pilots stay within course width and height boundaries, removing the need for other height and width monitoring.

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**Figure 1: 3km Course Flight Path**

**Items approved by the committee and the reports of select work groups follow.**

**Special Committee 159 met in plesnary session on October 8 at RTCA. The committee approved an update to DO-245 Minimum Aviation System Performance Standards for Local Area Augmentation System (LAAS). That will be considered for approval at the December 9 PWC meeting. The committee also established an Antenna Working Group (WG-7) to develop a MOPS for operation with L1, L5, and Galileo E1/E2 and E5A frequencies.**

**The SC 159 plenary reviewed current Working Group activities.**

**WG-1, 3rd Civil Frequency, met jointly with WG-2 & 6 on L5/Galileo issues. The update of DO-261 NAVSTAR GPS L5 Signal Specification was discussed. WG-1 currently recommends that DO-261 not be updated and that the DoD Interface Control Document be used in conjunction with DO-261 for guidance on L5 signal specifications. This issue will be discussed again at the next meeting.**

**WG-2, GPS/WAAS, is addressing WAAS open issues and L5 WAAS. An update to DO-229C is planned for early 2006.**

**WG-2A, GPS/GLONASS, continues to monitor GLONASS activity. No new information was available.**

**WG-2C, GPS/Inertial, continues to focus on ionosphere, carrier methods, coastline performance, tight LAAS/inertial integration, gravity modeling and testing. The interim agenda in DO-229C will be updated.**

**WG-4, GPS/LAAS, approved the update to DO-245. This update still needs harmonization with EUROCAE when they define their Category II/III requirements. An update to DO-246 GNSS Based Precision Approach Local Area Augmentation System (LAAS) Signal-In-Space Interface Control Document (ICD) will be submitted to the committee in March 2005 for approval.**

**WG-6, GPS/Interference, is continuing to work on an update to DO-253A Assessment of Radio Frequency Interference Relevant to the GNSS. A new target date of March 2007. Galileo effects and new operational scenarios will be included.**

**WG-8, GPS/GLONASS, has developed a draft MOPS with 18 open issues. This MOPS is scheduled for completion by October 2005.**

**RTCA, Inc. is a private, not-for-profit corporation that develops consensus-based recommendations regarding communications, navigation, surveillance and air traffic management (CNASS) system issues. RTCA functions as a federal advisory committee, its recommendations are used by the Federal Aviation Administration (FAA) as the basis for policy, program and regulatory decisions, and by the private sector as the basis for development, installation and other business decisions.**

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**Travis Bigrify is a computer engineering student at The University of Calgary, Canada.**

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**CMC Electronics** is a private, not-for-profit corporation that develops consensus-based recommendations regarding communications, navigation, surveillance and air traffic management (CNASS) system issues. RTCA functions as a federal advisory committee, its recommendations are used by the Federal Aviation Administration (FAA) as the basis for policy, program and regulatory decisions, and by the private sector as the basis for development, installation and other business decisions.
telemetering the GPS navigation message via a distinct communications link to lunar navigation receivers, avoiding the need for the users to decode the GPS ephemeri- des, could likely achieve more significant improvements in GPS receiver sensitivity. Such a system might support limited GPS navigation all the way to the Earth-side lunar surface.

NASA-Goddard has made a preliminary assessment of a lunar navigation infrastructure based on the concepts described by Farquhar and Burton et al. This study [9] indicates that accuracies of better than 1 km and 5 cm/sec may be feasible for a cis-lunar transfer scenario that uses GPS pseudoranges in combination with one-way Doppler measurements from one or more Earth–Moon L2 Orbiters that Figure 2 shows. These are quite promising in comparison with the trans-lunar post-maneuver results on the order of kilometers and dou- bles of centimeters per second that Beckman and Concha [10] achieved during Lunar Prospector using two-way Doppler from Deep Space Network 54- and 26-meter tracking sites. It should be noted that the real-world results of Reference [10] were achieved in the face of all the constraints posed by an operational environment, including, most notably, imperfectly performed maneuvers that this study did not address. Nevertheless, these results would appear to support the need for further investigation of the Earth–Moon L2 Orbiter concept as a means to provide a great deal of capability with minimal investment, as a starting point for a comprehensive lunar and planetary navi- gation and communications infrastructure beyond near Earth orbit.

And the Answer is C

References

Portrey’s Corner from page 7

Found at Stonehenge were the famous mounds and the mysterious Aubrey holes whose significance became evident when correlated with the Moon’s 18.61 year orbital period. The Moon and the Earth are in the same relative positions after 18.61 years. To the nearest whole number year, those orbital periods (5 x 18 2/3) yield the 56 year lunar cycle. The motion of the Moon around the Earth is affected principally by the Earth and the Sun. The resolution of the Moon and its rotation around the Earth are both equal in duration. This is the reason that the same side of the Moon faces the Earth (the libration of the Moon allows us to see up to 59 percent of the Moon). As the Moon orbits the Earth, the excentricity of its orbit varies slightly. The Earth’s orbit about the Sun is an ellipse that causes the distance to the Sun from the Earth to vary. The distance of the Moon to the Earth varies as its path is an ellipse. The change in the gravitational pull upon the Moon varies from a maximum when it is on the side of the Earth closer to the Sun to a minimum when it is on the opposite side of the Earth. An observer in celestial space would notice a wiggle in the Moon’s orbit about the Sun as a result of this effect. This occurs when correlated with the Moon’s 18.61 year orbital period.

As the Moon and Earth are in the same relative position with respect to the Earth in 56 years, the Moon and Earth’s relative positions with respect to the Sun is the same. This means that the traditional concept of the eclipse-making complete a journey in 18.61 years when the Moon and the Earth return to their same relative positions. When the Moon makes a journey of 18.61 years, it is on opposite sides of the Moon, the Earth and Sun; the next time the Moon returns to its original position, it will be in a full Moon. This occurs when the Moon, Sun and Earth are in alignment and the Moon is in the Earth’s shadow. The descending node is located when the Moon crosses the ecliptic in its journey from south to north marks the ascending node and the arrival of a full Moon’s eclipse. This occurs when the Moon, Earth and Sun are in alignment and the Moon is in the Earth’s shadow. The ascending node is located when the Moon crosses the ecliptic in its journey from north to south.

Aubrey Hole 56

Hawkins found that Aubrey hole 56 could be used to predict the year when an eclipse of the Moon or Sun will occur within 15 days of midsummer. He concluded that the Aubrey holes could act as a digital comput- ing machine by moving two sets of stones, at the winter or summer solstices, one position at a time. This would begin at the solstices each year ultimately reaching hole 56. At this time, the predicted critical based on the alignment of the stone (at hole 56) through the center of the circle of holes and the sighting on the heel stone to view the midwinter eclipse of the moon would be verified.

The number 56 is a perfect multiple of 18 and the closest whole number multiple of 18.61 which is the actual period of the nodes of regression of the Moon. It is to be emphasized that any specific lunar event such as a full Moon will recur in its same relative position with respect to the Earth in 56 years to the closest whole number year. It is to be noted that the ancient Greeks were aware of a 19 year lunar cycle which marked the repetition of eclipses on the same calendar date (but not with the same consistent Moon-Earth relative position as occurs when the Moon makes a complete journey through a cycle of the regression of the nodes of 18.61 years). The metonic cycle of 19 years marks the eclipse of the Moon on the same calendar date. Meton observed that 235 lunar months were very close in duration to 19 solar years. This knowledge was used as the basis for the ancient Greek calendar.
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Session Topics

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