GPS Aids World Trade Center Recovery Effort

Photo provided by Links Point, Inc.

By Shelby Wheeler, GPS TAC

It's hard to imagine a crime scene the size of the World Trade Center. By now, most of us have heard the statistics; millions of tons of rubble encompassing a vast 16-acre site. Indeed, the recovery effort at ground zero is no small task.

In fact, within a week of the WTC disaster, the Fire Department of New York (FDNY) was waiving the white flag. The recovery method being used was just not working. Firefighters were tagging items and jotting down descriptions and information regarding the date, time, and estimated location by hand, often guessing on an item's "exact" location. This was not an easy task on such an immense site, containing few landmarks and changing every day. The items were assigned a tracking number, and transported to the landfill, warehouse, or medical examiner's office. The information was then manually entered into a database, in order to track the items found. This process was laborious and inefficient, and often resulted in mismatched tracking numbers and inaccurate location data.

Considering the importance of the exact location of evidence to fire officials, engineers, and the ongoing criminal investigation, the battalion chief in charge of the recovery effort, Joseph W. Pfiefer, started looking for a better way. On September 19, the ground-zero team met with numerous technology companies to discuss possible technological solutions.

The solutions selected by the FDNY, along with other Federal and state agencies, were hand-held computers and bar codes, from Symbol Technologies, and global positioning satellite applications and real-time tracking database, from Links Point, Inc.

Within three days, Links Point created database software to run on the Symbol PPT 2800, a modified handheld rugged enough to withstand heat, dust, and long hours. Using the PPT 2800 with a GPS attachment, firefighters select a description of the item found and can automatically capture the time, date, and location of the item with an accuracy of three to nine feet. Additionally, the firefighters are able to tag the items with a barcode and scan that barcode with the device in order to match the item with the electronic record. The data is then uploaded directly from the handheld and connected with a database, which uses Geographic Information System (GIS) technology with mapping software.

In the past, GPS has not worked very well in Manhattan, due to the canyon effect of the city's skyscrapers. However, the large space created by the WTC's collapse has opened up the skyline enough for sufficient signal reception. The exceptions to this are some of the outlying edges of the site, where GPS coverage stops. To remedy this situation, officials are examining the idea of erecting an antenna across the highway from the site, on 3 World Financial Center, which would improve reception of the satellites' signals in those areas.

In addition to the tireless New York firefighters and rescue workers, GPS, along with other cutting-edge technologies, is lending a helping hand in the effort to "get back to normal." With the new technology in place, data capture rates have increased and data errors have decreased. The FDNY now has accurate location information on all items recovered from the site, and the human error associated with the manual tagging of items and input of data has been eliminated. It seems technology has come to the rescue.

Coastal Waypoints to Enhance VFR Flight

By Jack Schroeter, GPS TAC / Southern Region (ASO-520)

Beginning this winter, VFR pilots transiting the coastal areas of the southeastern United States will have a new tool for navigation. Sixty-eight VFR waypoints have been developed and are being published on Sectional Charts along the coastal areas from Gulfport, Mississippi to Elizabeth City, North Carolina. The VFR Coastal Waypoints Project, which has been enthusiastically endorsed by the Aircraft Owners and Pilots Association (AOPA) and State Department of Aviation representatives, has been selected by the Government and Industry Aeronautical Charting Forum to establish VFR waypoints as a unique navigational tool for VFR operations.

VFR waypoints have been developed to ease navigation for VFR pilots using Global Positioning System (GPS) for supplemental navigation; operating around, under, and between airspace, which may require ATC clearance or be restricted from their operation. These waypoints will provide pilots with an additional tool to improve situational awareness. VFR waypoints will allow pilots to fly from point to point on sectional charts using pre-programmed waypoints to avoid congested terminal areas or special-use airspace.

Each VFR waypoint will be assigned a discrete non-pronounceable five-letter identification beginning with the letters "VP," which will be added to navigational databases for flight planning use. The waypoints will be depicted on sectional charts using the familiar Instrument Flight Rules (IFR) waypoint symbol. VFR waypoints may be collocated with a Visual Check Point, in which case only the magenta flag will be depicted with the five-letter identification. VFR waypoint identifications should not be used in pilot/controller communications other than those collocated with a Visual Check Point, where the checkpoint name is used. VFR waypoints will also be listed on the flap of the appropriate sectional chart and in the Airport/Facility Directory (AFD).

VFR waypoints have been in use on terminal area charts (TAC) and helicopter route charts in various parts of the country since 1999. This is the first time they will be published on sectional charts. Sectional charts depicting VFR waypoints will be New Orleans, Jacksonville, and Miami with charting cycles after November 1, 2001. VFR waypoints will be published on the Charlotte and Washington sectional charts in early 2002.

WAAS and Agricultural Aviation

By Shelby Wheeler, GPS TAC

In an August 24, 2000 press release, the Federal Aviation Administration announced the availability of the Wide Area Augmentation System (WAAS) for some aviation and all non-aviation uses. The 21-day stability test that had been conducted prior to this declaration demonstrated required system stability, allowing immediate use of the WAAS signal by a broad range of users. WAAS continues to be developed to provide the necessary integrity for the WAAS-required safety-critical applications. Until the system design is completed and initial operational capability is declared, the WAAS is not an approved source of aircraft navigation under instrument flight rules (IFR), the release states.

However, WAAS is currently being used in many different applications, such as agriculture, surveying, marine application, military, and data collection, just to name a few. WAAS has become an integral part of its users' guidance systems, and the agricultural aviation industry is no exception.

Satloc, a CSI wireless company, has been in the business of providing guidance systems and differential GPS (DGPS) receivers for the past nine years to markets all over the world, and is the leading provider of DGPS guidance systems in the aerial application industry. Since the beginning, Satloc has expanded into a number of other DGPS guidance markets, but aerial application is still a primary focus. "We have been providing receivers that use the WAAS signal to the industry for over two years now," says Greg Guyette, Director of Sales (Air Division) for Satloc/CSI Wireless.

Satloc established its roots in the agricultural aerial applications field, in which the GPS guidance market rapidly expanded after its introduction in 1992. DGPS guidance systems soared in popularity in this community due to the market's willingness to try new technological enhancements and their eagerness for efficiency in the work place.

The agricultural user has, indeed, tried numerous new technological enhancements to improve aircraft guidance. Pat Kornegay, president of the National Agricultural Aviation Association (NAAA) and 28-year veteran ag-pilot states, "In the beginning, a locally transmitted differential source was used by ag-pilots, which entailed the installation of a GPS receiver, computer system, and differential transmitter. Despite system accuracy, the limited range necessitated hundreds of stations across the country. Unfortunately, in many cases each station was on a separate frequency, and a different band, so aircraft were limited to a 40-mile operational radius. For operators working multiple locations, it was necessary to install several receivers and pay several differential fees. In most cases the cost of differential service was in excess of $1000 per receiver per year"

In 1995, the Coast Guard low frequency differential service became available, and began its use by agricultural aircraft in areas where transmitters were maintained. "This service, although free, is limited to areas in the vicinity of navigable waterways, and the low frequency band used is susceptible to electromagnetic interference from thunderstorms. Since the operating aircraft might be as far as 100 miles from the transmitter, thunderstorm activity over any part of the area surrounding the transmitter could cause loss of signal integrity," says Mr. Kornegay.

Mr. Kornegay adds, "Recently, several companies have begun transmitting differential correction information using satellites as signal repeaters. This enables the agricultural aircraft operator to work anywhere with one subscription, usually costing about $800 per year per aircraft. The problem encountered with this service has been the instability in the market, with several companies ceasing to exist, and the discontinuation of the original "C" band system. These events have caused operators to buy new receivers and change service companies on several occasions, sometimes resulting in revenue losses when the changes occurred mid-season."

"The advent of the WAAS system has finally given agricultural aviation a secure, stable system of differential correction that is available throughout the United States. There are no annual fees associated with its use, and the accuracy is excellent," says Kornegay. Truly this has benefited many users. According to Ron Deck of Sky Tractor Supply, a former NAAA official, "WAAS is very important to the users in the upper Red River Valley in North Dakota and Minnesota because we are over 180 miles from the nearest 300khz tower; too far to give us consistent accuracy. The paid subscription for most farm users in the tight ag-market just isn't a viable choice."

WAAS acceptance in the agricultural aviation industry "is strong," according to Greg Guyette at Satloc. "WAAS is an instrumental part of most users' guidance systems and without its continued use, there would be some dramatic changes that would need to take place that would be highly inconvenient and costly to today's ag pilot," he adds.

WAAS user satisfaction in the agricultural aviation industry is very strong, for that matter. Dennie Stokes, an NAAA official says "The WAAS signal has been our most reliable source this year. As operators upgrade their equipment and purchase new GPS equipment, I think WAAS will dominate the market. WAAS in my opinion is the best source of GPS correction in the ag-industry."

"Satloc has thousands of WAAS receivers in operation today and nearly all feedback is positive. The accuracy of the WAAS with a Satloc SLXg receiver has certainly proven to be highly accurate (submeter) and reliable. We have collected a great deal of data supporting this case, and we continue to monitor performance," says Guyette. "The SLXg Receiver with WAAS is a part of many ag-users' everyday necessities," he adds.

"All of the primary manufacturers of DGPS equipment for agricultural aviation are currently offering WAAS receivers as standard equipment. There have been no apparent problems with the system and it has attained widespread acceptance throughout the industry," says Pat Kornegay, adding, "Approximately 90 per cent of all agricultural aircraft in the United States utilize DGPS guidance and a large portion of them have converted to WAAS. In the very near future, WAAS will probably become the primary source for ag-aviation, if it has not already done so."

Satellite Navigation- Helping to Meet Environmental Requirements

By Joe Bellabona, GPS TAC / New England Region (ANE-520)

We are all aware of the extraordinary navigation capability of GPS. GPS has been the panacea to many aviation navigation problems and the aviation community has aggressively applied this new technology in many ways. In 1998, the New England Region Air Traffic Division decided to capitalize on the unprecedented accuracy of GPS. Aircraft departing RWY 27 at Logan International Airport in Boston, MA, fly over highly populated areas of metropolitan Boston. In 1996, a Boston RWY 27 Environmental Impact Statement (EIS) Record of Decision (ROD) was signed that directed RWY 27 departures to fly a specific ground track to minimize noise to the underlying communities. The

Figure 1.1

Figure 1.2

ROD directed aircraft to track RWY heading to approximately 2 miles then turn left to track 235 degrees over industrial areas and a designated green space located southwest of the city. (See figure 1.1)

In addition to the 235-degree track identified in the ROD, a capture corridor was designed to measure and monitor flight track compliance. (See figure 1.2) This funnel-shaped corridor was designed beginning with a throat just 1400 feet wide with an end point of 6300 feet wide. The departure procedure requires a climbing aircraft to turn approximately 35 degrees to hit a target just 1400 feet wide several miles from the runway. This maneuver is difficult to do even using outside visual ground references. This is comparable to a precision approach ILS, where full-scale deflection at the RWY end is just 700 feet wide, however an aircraft on an ILS approach is stabilized with straight in-course guidance.

Also, notice the series of lettered gates A through E. These gates provide a means of measuring the progress of aircraft within the corridor. The ROD requires that 68% of the flight tracks pass through each of the corridor gates. This type of accuracy is out of the reach of most conventional navigational capabilities. In addition, ground based Navaids are not conveniently aligned to provide course navigation through the corridor. Therefore, a Vector Departure Procedure was initially utilized. Even after adjusting departure headings, the vector departure met with limited success; what was needed was a navigational aid to provide all weather capability to remain within the corridor.

The original WYLYY FMS Departure procedure was published in February 1998. This procedure provided the first method to accurately navigate through the departure corridor in all weather conditions. Early results were less than satisfactory. Many variables impacted the first FMS procedure such as a Jeppesen waypoint coding error, pilot technique, and aircraft with early FMS navigation equipment; non-SatNav. Each revision to the WYLYY has improved the operations of the procedure and compliance to the ROD. Northwest Airlines (NWA) has been instrumental in helping to improve operations and compliance. NWA briefed their crews on the importance of departure compliance. In addition, NWA established pilot proce-
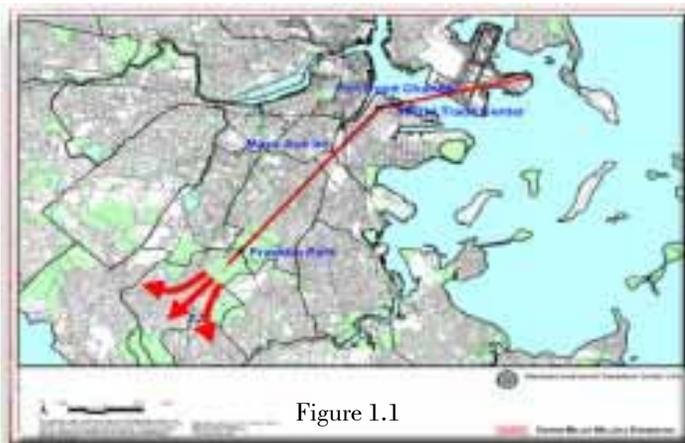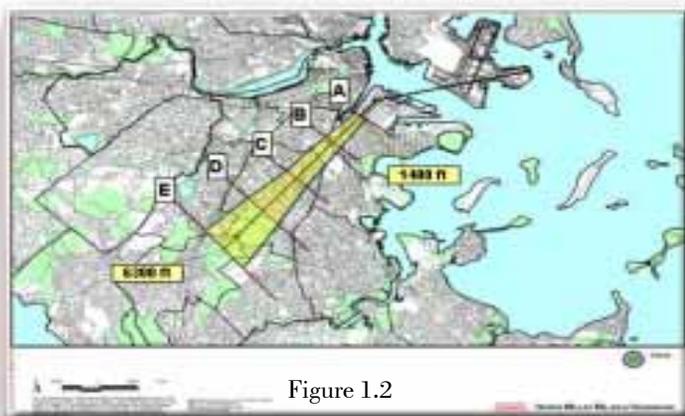
dures to arm their aircraft FMS lateral navigation (LNAV) prior to take off then aggressively follow their flight director command bars. The results of a NWA study showed a 20 percent improvement in corridor compliance that almost meets the ROD objectives of 68 percent compliance. (See figure 1.3)
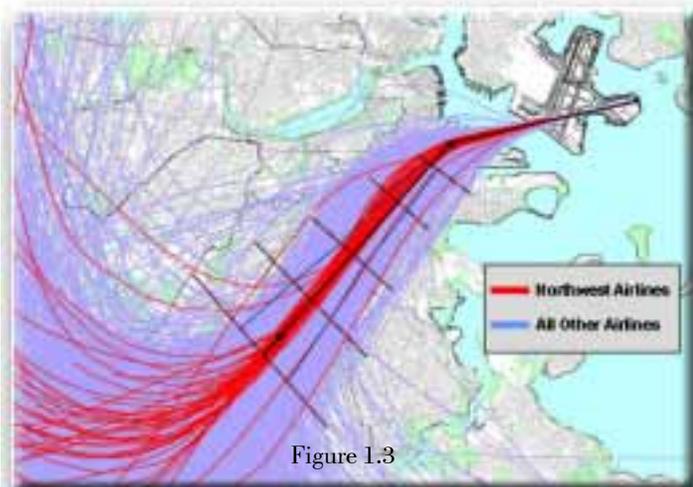

Figure 1.3

Since the WYLYY 3 has shown potential for full ROD compliance through all corridor gates and NWA recommendations for changes, the departure was revised and the WYLYY 4 was published on November 1, 2001. The WYLYY 4 Pilot RNAV departure procedure is authorized for all E, F, and G aircraft. The revised departure incorporates a NWA recommendation and a TARGETS modeling study to move the first waypoint "GARVY" to help acquire greater accuracy for aircraft flying through the 1400-ft throat. The final answer for improved noise abatement compliance is for all operators to develop pilot procedures that mirror NWA operations. As all operators upgrade and equip with FMS that have SatNav sensors, even greater accuracy can be expected.

The success of the WYLYY FMS RNAV departure to enhance operations and noise abatement has paved the way for Boston ATCT to design RNAV departure procedures for all runways. The "BEANN Town Departure" has been proposed as a single graphic departure design for all runways at Boston. This single graphic prototype is currently under study by the Boston Procedures Office and will be published after charting and automation issues are resolved. When the BEANN Town Departure is published, then other communities surrounding Boston Logan International Airport can benefit from the extraordinary navigation capability of SatNav.

The WAAS and PRN 22

By Bill Klepczynski, GPS TAC / WAAS Team (AND-730)

The basic premise for the existence of the WAAS is that GPS, by itself, cannot promptly provide the information to commercial air navigation users that a problem has occurred. On July 28, 2001 this conjecture was proven to be true. At about 10:08 p.m. on July 28, the rubidium clock on the GPS satellite designated as PRN 22 began to fail. Failure of a clock on board a satellite is a matter of great concern because it affects the ability of user navigation sets to correctly determine their range to a satellite and, consequently, their position.

A navigation receiver needs to measure or determine its range to four different satellites in order to get a position fix. A three-dimensional position fix yields latitude, longitude and altitude. The navigation receiver determines its range to a satellite by measuring the offset of the clock that is within the user's receiver to each of the satellite clocks to which it is measuring its range. It must be kept in mind that each of the satellite clocks is a free-running clock and has a unique offset and frequency that differs from all the other clocks in the system. It is the task of the GPS Master Control Station (MCS) to determine and model the performance of each satellite clock with respect to some uniform time scale. In this case, the uniform time scale is GPS System Time. The parameters that are used by the model to describe the performance of each satellite clock with respect to GPS System Time are transmitted within the navigation message coming from each satellite and used by the receiver to determine its range to each satellite.

It is important to keep in mind that one of the errors that contribute to the accuracy of a position fix is the ability to correctly model the performance of a satellite clock with respect to GPS System Time. The satellite clock governs the transmission of the navigation message. The navigation message from each satellite must be transmitted on time with respect to GPS System Time if the user is to

correctly determine its position. If a satellite clock goes awry and deviates from its modeled performance, then the navigation message will not be transmitted on time, resulting in an error in the user-determined position.

This is exactly what happened on July 28th: The clock on the GPS satellite PRN 22 failed. Unfortunately, the failure occurred in a region where the GPS MCS was not able to monitor its performance and, hence, update its model. However, the WAAS was monitoring the performance of PRN 22 and immediately started to transmit corrections so the user could continue to use PRN 22 in its navigation solution. When the corrections exceeded the maximum value that it could transmit, at 10:14 p.m., the WAAS told its users to no longer use PRN 22 in a navigation solution. Users were given the ability to use PRN 22 for an extra 6 minutes before it no longer could be used for a reliable position fix by a WAAS augmented receiver. The GPS MCS declared the navigation signal from PRN 22 unusable at 11:58 p.m.

LAAS Testing at the University of Oklahoma

By Dusty Somerville, GPS TAC / Flight Procedures Standards Branch (AFS-420)

Since August 2001, the University of Oklahoma (OU) has been conducting Category A and B flight-testing of LAAS. Their mission is to provide flight test data to support Minimum Operational Performance Standards (MOPS) and procedure criteria development by AFS-420.

This is a cooperative effort between the Department of Aviation, which operates the test aircraft, and the Department of Electrical and Computer Engineering, which is responsible for conducting the tests, collecting the data, and analyzing the results. Dr. John Fagan, world-re-
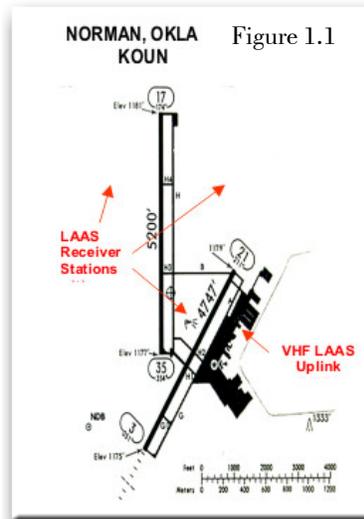

Figure 1.1

NORMAN, OKLA
KOUN

LAAS Receiver Stations

VHF LAAS Uplink

nown for his work with solar-powered and battery-powered cars, directs a team of graduate students who conduct the testing.

The approach and departure procedures are primarily flown at Max Westheimer airport in Norman, Oklahoma (See Figure 1.1) where an airfield has been configured with three LAAS receiver stations. (See Figure 1.2) Dr. Fagan and his team have used their solar car experience with solar cells and high performance batteries to develop very unique LAAS stations. Unlike other hard-wired LAAS systems, these stations are battery/solar powered and self-contained. These "low cost" LAAS stations avoid the expensive installation costs associated with providing power and communications capability to remote locations around an airfield. A simple concrete pad for each LAAS receiver station is the only airfield preparation required.

Conducting these tests at OU has some significant advantages. OU instructor pilots fly OU-owned aircraft at a bargain price. The close proximity to the Mike Monroney Aeronautical Center in Oklahoma City allows AFS-420 personnel to supervise the flight-testing and analysis conducted at OU.

Although the testing is designed to collect data on flight technical error and navigation system error for use in establishing TERPS standards, experience with this leading edge technology has yielded many other benefits.

OU students and faculty have gained valuable expertise in satellite navigation systems, particularly GPS precision

Figure 1.2

Heli-bowl GPS Antenr

Dipole GPS Antenn

Spread Spectrum Antenna

Solar Panel

Battery and Receiver

approaches since they began WAAS flight-testing in 1997. Lessons learned from WAAS testing have been applied to ongoing LAAS tests. They also perform the initial data analysis so they can quickly identify trends or testing problems in accuracy, integrity, or availability. Test adjustments can be made after meet-

ings with FAA personnel to review the preliminary test results.

Because OU is exclusively conducting Category A and B testing under typically windy Oklahoma flying conditions, they are in a unique position to evaluate the effects of turbulence in light airplanes on satellite navigation systems. Additionally, these tests provide critical feedback on the human factors of a single pilot conducting a SatNav approach in a light aircraft.

Category A tests are flown in a Piper Seneca, while Category B tests are flown in a Rockwell Turbo Commander. A low cost LAAS Gamma Navigator is combined with LAAS/WAAS Multi-Mode Receiver and Ashtech truth system (a system that uses a Z-12 GPS-based precision surveying instrument, utilizing two receivers—one on the ground at a precisely surveyed location and the other in the aircraft—to record precise differential GPS signals which are then processed post-flight to determine the exact position of the aircraft with extreme accuracy). This test equipment has been mounted into a portable rack that allows quick equipment installation into either aircraft.

OU testing has already resulted in significant improvements to SatNav procedures, equipment, and specifications. For example, their experience with small aircraft undergoing rapid position changes led to a change in MOPS from a 1 Hz update rate to 5 Hz. They have developed statistical models that have been transferred to the FAA for incorporation into the Airspace Simulation and Analysis (ASAT) for TERPS model, which is a high fidelity computer simulation, run by engineers in AFS-420. This models various aviation scenarios, and is used to examine the risk factors of various approach configurations. OU personnel are also in a unique position to work with manufacturers to identify and correct any potential equipment hardware or software problems.

These tests have laid the groundwork for low-cost LAAS installations worldwide, and have the potential to add precision approach capability to hundreds of airports and thousands of aircraft throughout the United States and abroad.

For more information, please visit http://terps.faa.gov *and* http://www.ashtech.com/.

RNAV Route Development

By Bob Brekke, GPS TAC / Western Pacific Region (AWP-520)

The Western-Pacific and Northwest Mountain Regions have developed twenty-one Area Navigation (RNAV) off-airway direct routes between key cities. The cities include Seattle, Portland, and Vancouver in the Pacific Northwest, and Los Angeles, San Francisco, San Jose, Oakland, Ontario, Palm Springs, John Wayne-Orange County, Las Vegas, and Phoenix in the Western-Pacific Region. The RNAV routes were developed in conjunction with Alaska Airlines as the lead carrier and the Western-Pacific and Northwest Regional National Airspace Review (NAR) Teams and Air Traffic Control Facilities. The objective of these routes is to provide a seamless RNAV departure, en route, and arrival between the selected airports for all appropriately equipped RNAV aircraft. Annual savings, provided by Alaska Airlines, are projected to approach more than $800,000.

This is an on-going effort that will continue in the Northwest and Western-Pacific Regions to provide all RNAV-equipped aviation customers with the benefits of this GPS technology.

General Comments on the Characteristics of Test And Evaluation of Augmented GPS for NAS

By Barry Billmann, FAA William J. Hughes Technical Center (ACT 360)

GPS/WAAS/LAAS implementation and utilization in the NAS involves gathering information on the performance and perceptions of the aviation industry pilot regarding the new system. Total system performance evaluation must involve the pilot in the evaluation process and address these issues:

✔ Pilot assessment of the flyability of the new system.

✔ Pilot assessment of performance deviations from ex isting systems.

Note: WAAS will provide four levels of approach service, versus the established standard of two levels of service (precision and non-precision). These additional levels of service will provide a better fit of Standard Instrument Approach Procedure (SIAP) development to airports and heliports with existing SIAPs and enable the FAA to provide IFR capability to airports/heliports that do not now have IFR service. However, new procedure charting concepts must be evaluated, such as depiction of distance to threshold with LAAS. Also, system requirements to support an entire new repertoire of cockpit annunciations must be evaluated.

✔ Pilot assessment of the workload associated with the new navigation system.

✔ Pilot assessment of the safety associated with the new approach procedures.

If the appropriate avionics are not available or the pilot perception and performance issues are not addressed, there is no commissioning of the system.

In order to address both pilot and procedure factors, compliant or near Minimum Operational Performance Standards (MOPS) compliant avionics must be available. With GPS, and it augmentations, much more of the system processing is the responsibility of the airborne avionics than with classical navigation systems. For example, ILS provides a signal-in-space, which airborne avionics systems use as is. However, for GPS (even unaugmented), the avionics must evaluate the usability of the signal-in-space by applying Receiver Autonomous Integrity Monitoring (RAIM) and/or Aircraft Autonomous Integrity Monitoring (AAIM) techniques. With GPS system augmentation (WAAS & LAAS), the burden of determination of system usability is significantly increased beyond basic GPS. For instance, WAAS avionics must evaluate the signal-in-space and determine what type of one of four procedures may be flown. LAAS avionics must support a procedure selection process that is different than tuning an ILS and requires interaction with the LAAS ground facility.

Experience has shown that the development and acquisition of compliant avionics must be done in cooperation with

industry. Avionics must be available to validate WAAS and LAAS system performance during Developmental Test and Evaluation (DT&E) and Operational Test and Evaluation (OT&E). An example when this philosophy was not used and the resulting negative impact on the system deployment, is presented below. Additionally, examples of the application of the philosophy and the benefits to the Program are cited, as well.

An Example Where We Waited for Industry to Produce Certified Avionics

It was agreed to wait for the first TSO C129 receiver to be certified prior to starting TERPS data collection for GPS non-precision approach operations, since the GPS signal in space was already well established and being used without augmentation. However, when testing began, the avionics were totally incapable of supporting test requirements. The following deficiencies existed in certified equipment:

✔ The sensor could not provide adequate guidance on a "T" procedure

✔ Leg segment switching logic did not provide usable guidance at waypoint transitions

✔ Departures were in the database and could be flown, but terminal operation integrity was not met

✔ The sensor could not fly an "arc" overlay procedure

These problems required the manufacturer to issue service bulletins resulting in a significant delay and substantial cost increase to the program. Other sensors that were certified, at the time, had significant human factors issues associated with control and display. The FAA system safety goal requires that such issues be addressed before commissioning.

Benefits that have been Derived when Avionics Development was Undertaken in Cooperation with Industry

With both WAAS and LAAS, funding has been provided to acquire near MOPS compliant avionics to support the activities mentioned above. It must be noted that the avionics standards do not exist in a vacuum. With both WAAS and LAAS, the FAA is fielding systems to augment the GPS constellation and control segment. Near MOPS com-

pliant avionics testing has resulted in numerous changes, not only to the avionics standards, but also to the augmented system standards under test. In many cases, such as with message types 0, 1 and 27, the required changes were system changes; not just avionics changes.

Cooperative avionics development permits the FAA to collect representative flight test data enabling procedure design criteria to be available for commissioning. The biggest impact is the availability of avionics for flight inspection. Without certified avionics there is no flight inspection to support commissioning. Without flight inspection there is no commissioning.

Global Positioning SystemApproach Minima Estimator(GAME)

By Dr. S. Vincent Massimini, MITRE Corporation

The MITRE Corporation's Center for Advanced Aviation System Development (CAASD) has developed a software capability that assesses the benefits of potential instrument approach procedures. The goal of the GPS (Global Positioning System) Approach Minima Estimator (GAME) is to provide insight into the impact of approach design criteria on the expected minima at thousands of runway ends.

Instrument approach procedures are designed according to Federal Aviation Administration (FAA) criteria. New systems, like the FAA's GPS Wide Area Augmentation System (WAAS), have opened the way for new thinking about the criteria for approach design. For example, the initial WAAS procedures will provide a lateral/vertical navigation (LNAV/VNAV) instrument approach capability, equivalent to that which is available from qualified baro-VNAV systems that use unaugmented GPS for lateral navigation and barometric altimetry for vertical navigation. However, the LNAV/VNAV approach design criteria do not take advantage of the improved horizontal accuracy and integrity of the initial WAAS (relative to unaugmented GPS). So, the way is open to define new criteria with potentially better minima. GAME uses databases of terrain, obstructions, and runway

configurations to estimate the height above-touch down (HAT) for a future approach, based on actual or postulated approach design criteria. GAME then uses an airport infrastructure database, in conjunction with the HAT and the aircraft approach category, to estimate the visibility minimum for the approach. This process can be repeated for thousands of runway ends to compute the statistics of the HAT and visibility minima, and to compare them with the statistics of minima resulting from other approach design criteria, thus obtaining valuable insight into the impact of design criteria on airport access benefits. Current GAME capabilities include LNAV (non-precision RNAV approaches), LNAV/VNAV, Instrument Landing System/Wide Area Augmentation System/Local Area Augmentation System (ILS/LAAS/WAAS) Category I, and several approach types that are still being developed by the FAA.

Navigation Workshop

By Carol Wheeler, ANN TAC (AND-700)

The FAA Navigation Integrated Product Team (IPT), AND-700, opened the first National Navigation Community Workshop in San Antonio, Texas on Monday, September 10 with registration beginning at 4:00 pm,. A reception followed registration, which provided two hours of time for team members to renew acquaintances and meet new members. A total of 196 members of the National Navigation Community attended the workshop.
The first day of the workshop was a General Session, including all workshop participants. The Navigation Integrated Product Team Lead, Jack Loewenstein, and IPT Staff Dennis Kolb made introductory and welcoming remarks. A new video titled "The FAA, Proudly Serving the Air Navigation Community" was shown and received an enthusiastic response. The credits, for the excellent production of this video, go to Mary Ann Davis, GPS TAC, and Bill McDonald, ASU-400. The day continued with several outstanding speakers.

Mr. Gerald Lavey, Executive Assistant to the FAA Administrator for Internal Communications was the keynote speaker. Mr. Lavey has over 27 years service with the FAA and is highly respected within the community for his forth-

right style of communicating and reporting the agency's activities. He provided examples of successes made by the dedication and hard work of the agency's personnel that does not get recognition in the press. He accurately outlined the challenges faced by the FAA to perform a monumental task with limited resources and acknowledged some things could always be improved upon. He further stressed the importance and need for diverse thinking, and warned not to allow preconceptions to stifle unification or creativity. Last, he advised that knowledge management and proper communications give people the power to operate successfully and solve problems. As he left the podium he received a resounding thunder of applause and a standing ovation from the team.

Dr. Therman Evans, founder and CEO of WholeLife Associates, was the workshop motivational speaker. Dr Evans received his M.D in 1971 from Howard University and is the recipient of several honors, recognitions, and awards. Dr. Evans's principle message centered on wellness, stress management, and dealing with change, which could not have been more timely with the horrific events that were unfolding in New York and Washington, D.C. that morning. Some of the quotes and key points from Dr. Evans inspirational talk include "Blessed are the flexible for they shall never be bent out of shape," "talk does not cook rice," "you cannot change where you are unless you change what you do," "nobody wants to be sick, but we choose the things that make us sick," and "people do not like change, even if it's better for us; yet in the course of natural human life, everything changes." These quotes quickly summarize a wonderfully detailed explanation of the impact of stress on our physical and emotional health and therefore the enjoyment of our work and play. Dr. Evans is a huge proponent for taking time to play, in the midst of managing multiple responsibilities: Good words to remember!

Also on the agenda for the first day were Claire Robinson, AOZ-500, who provided an overview on the on the NAS Operational Evolution Plan (OEP); Bob Wright, AFS-400, spoke on the "Future of Navigation;" Jack Nager, ANI-1, and Trevor Henry, ARN-200, addressed "ATS Challenges Today and in the Year 2010; and Nelson Spohnheimer gave an excellent overview on the "State of Navigation, A Regional Perspective."

On Wednesday, September 12, all participants selected one of four working sessions to attend. The four sessions were divided into "Policy," "General Issues," "Technical" and "Satellite Navigation." Each session was lead by a facilitator using a prepared agenda of topics to be briefed and discussed. The agenda for each session was built from the issues recorded and compiled from the Navigation team visits to the FAA Regions and Centers earlier this year. Action items, agreements and significant discussion items were noted during the sessions and compiled into a report to the entire group on the last day of the session.

The Deputy Navigation IPT Lead, Harry Kane closed the workshop on September 13. Harry provided a comprehensive summary of the accomplishments made during the workshop and thanked everyone for their participation and the hard work done to make the workshop a success.

Each participant that attended the workshop will receive a compact disc (CD) that includes a copy of the video seen at the opening of the Workshop, a copy the briefings, both from the General Session and the Working Groups, minutes and action items taken from each of the four working groups, participant list, and candid photographs covering the three days of the workshop.

Code-Carrier Coherence (CCC) Monitor

By Bill Klepczynski, GPS TAC / WAAS Team (AND-730)

The navigation signal coming from the GPS satellites has three components; the carrier wave (its phase and frequency), the tracking codes (called pseudo-random noise [PRN] codes) and the navigation message. Information on the satellite's position is contained in the navigation message. The PRN code allows the user to determine the range to a satellite. With the data contained in the navigation message, users can determine their position if the range to four satellites is measured. Some receivers use the phase of the carrier to improve the accuracy and precision of the computed range. As one can imagine, the process by which a position is computed is a complex one. There are many factors that can influence

the derived user position, including the properties of the atmosphere through which the GPS signals travel, the characteristics of the various hardware components within the GPS satellite and the user receiver, as well as the nearby surroundings of where the user receiver is located. Some of these errors can be overcome or mitigated by the differential GPS process. However, some cannot because they are unique to the user and the reference station.

The WAAS Integrity Performance Panel (WIPP) has been dealing with two separate effects that could surreptitiously degrade the accuracy of the WAAS if not properly handled. Analysis has shown that it is possible to determine their presence with one algorithm (procedure) and take appropriate action to mitigate their effects. This algorithm is called the Code-Carrier Coherence (CCC) Monitor and reports potential errors to the user in the form of the User Differential Range Error (UDRE) broadcast by the WAAS.

Before going into the problems, a very brief explanation of how a receiver works might be useful. Within every GPS spacecraft, there is a local oscillator (clock), which generates the frequency that gets multiplied up to the transmitted frequency. There is also equipment that generates the PRN code for each satellite through a device called a correlator. That code and the navigation data for that satellite are impressed on the transmitted signal. Thus, there is a relation between the PRN code and the phase of the carrier frequency of the transmitted signal. The user receiver has similar equipment that generates a PRN code and compares it with the received code. Through information contained within the navigation message the user receiver can determine the time at which the code left the satellite and compare it with the time of its local clock and determine the travel time of the signal and, hence, the range to the satellite. However, this range is not the actual range to the satellite because many systematic effects affect it. These systematic effects must be taken into account before the true range can be derived from this so-called *pseudo-range*.

The first problem that affects the accuracy of ranges to GPS satellites deals with code-carrier divergence. Code-carrier divergence is a change in the relationship between the PRN code and the phase of the carrier frequency. In theory it should remain constant, but there are reasons why it could

change. The passage of the signal through the ionosphere will cause a shift because the ionosphere is a dispersive medium, but this phenomenon can be modeled. Multipath, the reception of a reflected signal by the user receiver, will also cause this phenomenon, but this error is dependent on the location of the user's receiver. Multipath manifests itself by a shift in the code-carrier phase relation from its original one.

The second problem is called the SV19 Problem. In March 1993, a GPS satellite, designated as SV19, transmitted an anomalous signal (sometimes called an Evil Wave Form) that caused an error in the estimated ranges to that satellite to vary between 3 to 8 meters in differential GPS systems. Two instrumental problems can cause this error. First, the correlator in the satellite developed a minor glitch that caused some parts of the PRN code to be elongated and some to be shortened. Second, the spacecraft correlator uses a different correlator spacing than the correlator in the user receiver. Any discrepancies or perturbations in the PRN code sequence will affect the user's determination of the range to the satellite. Upon further investigation, it was apparent that, while this was the one and only known instance that such an error was observed, the satellite design is such that it is possible that it could occur again. This problem also manifests itself in a shift of the code in the receiver correlator with respect to the original carrier phase.

The CCC algorithm looks at the difference between the phase and code of a signal from a GPS satellite obtained from all the WRE receivers tracking that satellite at the same instant. It then forms a weighted average of the deviations for all the receivers viewing the satellite. If there is code-carrier coherence, i.e., no change in the relation between code and carrier, the average should be near zero. In the presence of incoherence or divergence, the result will be non-zero and this number will represent an error in the pseudo-range. It means that multi-path or, possibly, the SV19 problem affects one of the WRE receivers. When this happens, the UDRE is bumped higher for that satellite to reflect the fact that there is a larger potential error associated with this satellite. The CCC algorithm doesn't necessarily know what caused the larger error, code-carrier divergence or the SV19 problem, but it knows that something is wrong with the estimate for the

range for that satellite and lets the user know through a "*Don't Use*" UDRE value.

New Special Copter RNAV Approaches and Departure Procedures Under Development In California

By Bob Brekke, GPS TAC / Western Pacific Region (AWP-520)

New Special RNAV Helicopter Instrument Approach and Departure Procedures, developed by Satellite Technology Implementation, L.L.C. (STI), a non-federal source, and approved by FAA, are in the final stages of coordination.

These GPS-based procedures are Special RNAV COPTER approaches and departures to various hospital heliports in Northern California for a single-helicopter operator and are not charted for the public.

In total, there are six Special COPTER RNAV Approach Procedures and six Special COPTER RNAV Departures Procedures in development that will serve area hospital heliports in the Sacramento Terminal Radar Control (TRACON), Stockton TRACON, and Oakland Center area.

GPS-based enhancements will continue to be developed in the Western-Pacific Region for the vertical flight community, so that the benefits of this technology can be realized by all RNAV equipped Rotorcraft operators.

Results of Early LORAN-C Modernization Testing

By Mitch Narins, Systems Engineering (AND-702)

The LORAN-C navigation system, developed by the U.S. Department of Defense (DoD), has been operated by the U.S. Coast Guard since the 1950's. Initial installations were primarily outside the continental U.S., but by the early 1970's, the Coast Guard had determined the LORAN-C system should be used as a federally provided maritime navigation system throughout the coastal areas of the United States. The system was expanded to provide coverage in the coastal waters of the continental U.S. and Alaska.

Interest by the Federal Aviation Administration (FAA) led to additional installations that provided coverage throughout the continental U.S. Through the mid- to late-1980's the FAA also undertook the development of requirements, procedures, and ground system support to allow certification of LORAN-C system for use in the non-precision approach phase of navigation. Initial attempts by user equipment vendors to achieve aviation certification disclosed the need for significant hardware and software improvements that primarily involved the need for improved aircraft antenna systems and advanced receiver processing to take advantage of all available LORAN-C signals. These and other related problems produced shortcomings in the "availability" and "continuity of service" parameters of the certification requirements.

Despite the lack of certification, there was widespread use of "VFR LORAN-C" in the general aviation community through the mid-1990s. However, as the Global Positioning System (GPS) began to mature, users found a comparable niche for this new system and a migration from LORAN-C began. The migration was accelerated when the U.S. Government announced in its 1994 Federal Radionavigation Plan (FRP) plans to terminate LORAN-C in the year 2000.

Following the 1994 FRP announcement, support to continue LORAN grew from some groups within the aviation community that resulted in directions from the U.S. Congress, via the budgetary process. This resulted in the 1999 FRP announcement that LORAN services would continue "in the short term", while the merits of its long-term operation are evaluated. Over the past several years, Congress has continued to provide substantial LORAN-C funding to the Federal Aviation Administration (FAA) ($25M in FY 01) and has requested it to continue the development of LORAN.

In compliance with these Congressional mandates, the FAA initiated a LORAN-C evaluation program to determine whether LORAN could benefit aviation, and if so, by what means. While LORAN-C currently can be used as a secondary navigation system in both terminal and enroute environments, it does not support the approach phase of flight. The FAA established an Interagency Agreement with the U.S. Coast Guard (USCG), the operators of the LORAN system, and formed an evaluation team to help determine whether LORAN would be capable of providing lateral navigation (RNP3) services to the National Airspace System (NAS) and/or other ancillary capabilities.

The FAA's Wide Area Augmentation System (WAAS) is the means by which differential GPS corrections will be provided to aircraft operating in the NAS to support both lateral (LNAV) and vertical (VNAV) navigation. The current WAAS architecture includes geostationary satellites, which transmit differential correction messages to aircraft at L-band frequencies. WAAS messages are currently transmitted on the GPS L1 frequency for non-safety related services via two leased INMARSAT geostationary (geo) satellites. It has always been known that the combination of high angles of elevation, or look angle, in some northern areas of the NAS in combination with high terrain elevation could cause masking of the WAAS geo signal. So, many alternatives are currently under investigation to solve this problem.

LORAN is one of those alternatives that are being studied to solve this masking issue. LORAN's significant coverage of the NAS (see Fig. 1), its robust-signal (400 – 1600 kW)
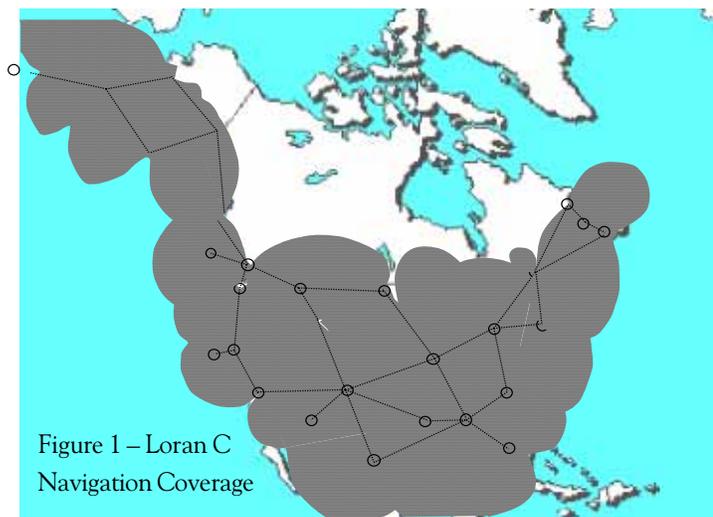
and its diverse spectrum (between 90 kHz and 110 kHz), made it attractive for further exploration.

The problem – how could LORAN transmit the entire WAAS message at the 250 bit/second rate without significant modification of the signal specification and, thereby, denial of service to existing legacy sers?

The FAA Navigation IPT's System Engineering Office and the U. S. Coast Guard LORAN Support Unit (LSU), in cooperation with Stanford University, are developing an enhanced LORAN-C Communications capability for Global Positioning System (GPS) integrity, and potentially for GPS correction data. The LORAN Recapitalization Project LRP is a multi-year FAA/USCG initiative to modernize the U.S. LORAN-C system to meet present and future radionavigation requirements while leveraging technology and funds to optimize operations, support and training, and reduce total cost of ownership.

Very early analysis of the testing in Alaska appears to show that transmission of WAAS data via LORAN at the required 250 b/s is feasible and that use of all-in-view receivers and H-field antennas are promising mechanisms to allow LORAN to support lateral navigation within the NAS. Although showing promise, much more work must be done before LORAN can be considered for broadcasting the WAAS corrections in areas that can't receive the WAAS corrections via the WAAS geos.

Stay tuned for further developments. For more information on this research, including the current status of this project, please visit http://www.uscg.mil/hq/lsu/webpage/projects.htm, *choose the desired time period, and reference the* FAA34: LORAN DATA CHANNEL COMMUNICATIONS *project.*

Figure 1 – Loran C Navigation Coverage

The Lighter Side
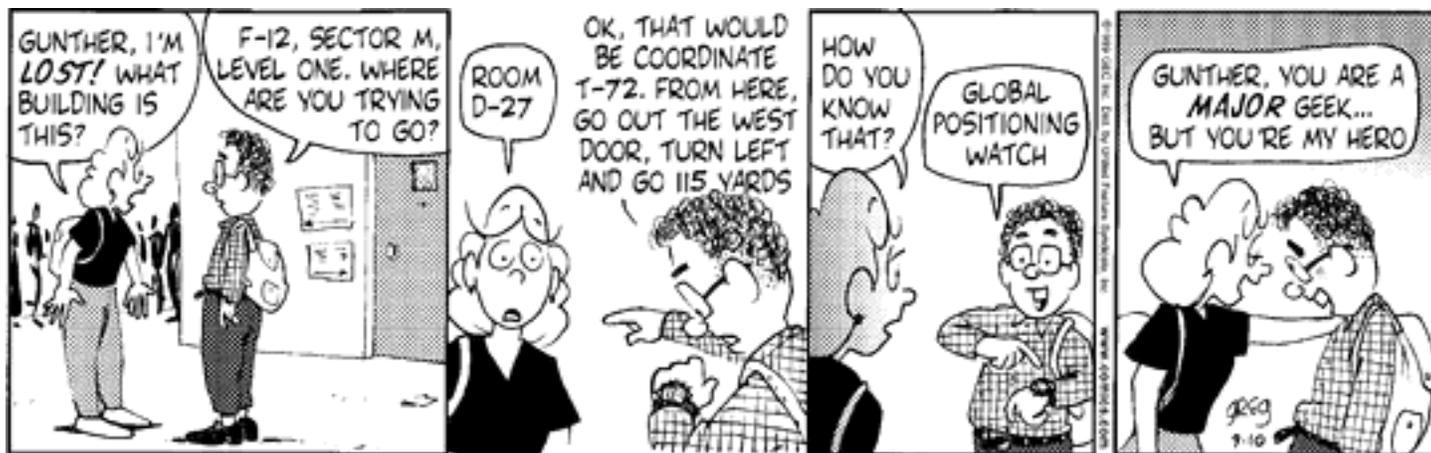
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