Galileo –
Technology for Worldwide Air Traffic Control

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ABSTRACT

"The sky's the limit" is a phrase used by persons throughout the world to mean possibilities are limitless. For those involved with air transportation we know that the "sky is limited." As air transportation grows, our airspace has become more and more crowded, challenging aviation professionals to look for new and innovative air traffic control (ATC) procedures and technology to create more efficient use of airspace. The current air traffic control system uses radar along with specified sequencing and separation standards which provide a "safe zone" for each aircraft. However, over the past several years as technology has increased, few enhancements have been made to the air traffic control system to handle the ever increasing air traffic. This lack of technological growth has led to increasingly crowded airspace, more delays, and safety hazards due to the greater number of aircraft in the skies. The summer of 2000 was identified as the worst year for air traffic delays in air transportation history. Delays in 2000 showed a 20% increased over 1999 delays, and a 47% increase over air traffic delays in 1998, showing a need for improved air traffic control technology.

In an effort to provide alternatives for air traffic control, Purdue University researchers have been analyzing the European Galileo (GNSS) System. In response to the Air Transportation Association's *Top Ten List of Essential Air Traffic Control Programs*, Purdue researchers developed a study to analyze the Galileo system for implementation as the worldwide air traffic control system. The results of the study compare the various global positioning systems in use worldwide and their air traffic control applications; current air traffic control systems worldwide; and the U.S. concerns related to the Galileo system. Based on their findings, Purdue researchers present the advantages and challenges concerning the implementation of Galileo as a worldwide air traffic control system. The paper also addresses how the Galileo worldwide air traffic control system would not only increase the use of airspace and cooperative partnering among nations, but also provide an increased level of safety for the industry.

INTRODUCTION

Ever since early man decided to explore and navigate his new world, he has looked to the heavens for guidance. Early man observed that the moon and the stars were at predictable locations, depending on the time of the year, and used this information to formulate theories on the movement of the earth.

The first observations were made in the fourth century when Aristotle noticed that the earth appeared to be curved when projected onto the moon during a lunar eclipse. He also noticed that the elevation of the stars changed as one travels north and south, stars that were visible in Egypt could not be seen at all in Greece. So much for the theory that the earth was flat.

Eratosthenes in about 230 BC was able to measure the radius of the earth within one percent. By observing the position of the sun at a certain time of the day and knowing the distance between two points he was about to calculate the earth’s radius. He arrived at a figure of about 6400 Km and the actual radius is 6371 Km, it’s really amazing since he didn’t have a computer.

Observing the angular position of the pole star, that we now call Polaris, man was able to figure his latitude. The determination of longitude was much more difficult. In order to measure longitude early man had to measure the difference between the observed time of a celestial event, like an eclipse, and the corresponding time tabulated for a referenced location. He found that for each hour the difference in longitude is 15 degrees.

Christopher Columbus tried to estimate his longitude on his fourth voyage to the New World by observing a lunar eclipse. He was able to determine the latitude by numerous observations of the pole star. He calculated his latitude to 18 degrees, which was only off by less than half a degree, but his longitude was off by some 38 degrees.

It wasn’t until the 1700's that a British craftsman by the name of John Harrison invented the marine clock called a chronometer. Before the invention of the chronometer, the current scientific establishment felt that the only way to determine longitude was from observations of the moon. At that time these observations were referred as lunar tables. These two methods of determining longitude were tested at sea. The lunar tables calculated longitude within four minutes of arc, the chronometers precision was with in one minute of arc. This is why atomic clocks are so important in each GPS satellite.

In the twentieth century, with the development of the radio transmitters, the technology of the artificial satellite made possible navigation and position determination using line of sight signals.

Today the availability, accuracy, and reliability of a global navigation satellite system are of great importance to the air traffic control and the air transport industry. The current global positioning system constellation is unable to provide the total availability, accuracy and reliability needed for the future advancement of air traffic control.

In an effort to provide alternatives for the air traffic control and the air transport industry, this paper attempts to analyze the European Union’s implementation of the Galileo GPS system for the purpose of contributing to a Worldwide Global Positioning System. This paper will compare the various global positioning systems currently in use worldwide as well as their traffic control applications and current air traffic control systems. The paper also addresses how the proposed Galileo GPS system would not only increase the use of airspace and cooperative partnering among nations, but also provide an increased level of safety for the industry. This paper will attempt to explain the United States’ concerns related to the Galileo system.

WHAT ARE THE VIEWS AIR TRANSPORT INDUSTRY ON A GLOBAL POSITIONING SYSTEM

According to (ATA) Air Transportation Association President and CEO, Carol Hallet, the ATA has released their "top ten" list of essential Air Traffic Control (ATC) programs to be implemented immediately to reduce delays and improve the ATC system. Ms. Hallet stated, “The ten priorities we are proposing can be implemented over the next five year period and will result in real national aviation system capacity improvements.” In 2000, delays increased 20 percent above 1999, and 47 percent above 1998, making the summer of 2000 the worst in aviation history. [1]

One of the first priorities on the ATA list is: Full-scale Global Positioning Satellites (GPS) Satellite Navigation Implementation (including LAAS, Local Area Augmentation, WAAS, Wide Area Augmentation System), which will provide more accurate and reliable navigation capabilities, create an environment to facilitate reduced separation standards, and increase the availability of user-preferred routing. In addition, the FAA must complete standards development for new RNP/RNAV procedures that will support reduced separation standards between aircraft and obstacles. These systems should be developed and implemented so that they are fully compatible with similar systems and standards else where in the world, for example the upcoming European Galileo (GNSS) system. [1]

Galileo (named after the renowned Italian astronomer) is the European version of the United States’ Navstar Global Positioning System (GPS) and Russia’s Globalnaya Navigatsionaya Sputnikova Sistema (Global Orbiting Navigation Satellite System - Glonass GPS). The Galileo program is a joint initiative of the European Union and the European Space Agency and the first global satellite positioning and navigation system designed specifically for civilian use worldwide. Galileo is expected to go into service in 2008. Galileo is designed to deliver real-time positioning accuracy, down to the meter range, which is unprecedented for a publicly available system.

THE FIRST U.S. GLOBAL POSITIONING SYSTEM

The United States first attempt at a global positioning satellite system was conceived in 1950 and launched in the mid 1960’s. The Navy Navigation Satellite System, called Transit, was developed to provide accurate navigation information for the Polaris missile submarines. The Transit system used the Doppler frequency shifts from the first Sputnik satellite, launched by the Soviet Union in October 1957. The Doppler shift signals enabled a determination of the orbit using data recorded at one site during a single pass of the satellite. If the satellite’s orbit was known a receiver position could be determined. The accuracy of Transit was about 35 to 100 meters, only under favorable conditions.

THE CURRENT U.S. GLOBAL POSITIONING SYSTEM

Navstar was the second attempt at a GPS system, started in 1973 and fully operational by 1995, at a cost of $14 billion dollars. It was developed for and by the U.S military and maintained by the Joint Program Office (JPO) of the Department of Defense (DoD) and U.S. Air Force Space Command (AFSPC). The U.S. Coast Guard's Navigation Center (NAVCEN) is responsible for the civilian applications. The ultimate decision-making on GPS policies rests with the President of the United States.

The Navstar system consists of 21 active satellites and three spares. The satellites are arranged into six high orbit planes at height of 10,900 nautical miles (20,200 Km), at an inclination of 55 degrees relative to the equatorial plane. The satellites rotate around the earth every 12 hours and five satellites are in view at any one time. Navstar is planned for update by 2011 and that will increase the number of satellites to 33. The main ground control station is located in Colorado Springs, with five unmanned monitor stations and four ground antennae located throughout North America. Navstar transmits two different signals, the precision code or p-code and the Coarse Acquisition or C/A code. The P-code is for the U.S. military and the C/A-code is for civilian use. The C/A-code is not as accurate as the P-code and easier to jam. There are two types of receivers, civilian and military. The civilian receivers can be obtained for a few hundred dollars but military receivers are priced at $100,000 plus. The military receivers are under tight export control and the DoD must approve the civilian receivers that are imported from abroad. At the present time the FAA doesn't approve GPS precision approaches due to the reliability and accuracy of the satellites.

The United States realizes there is a deficiency in the system and plans to up-date the Navstar program with the latest technology. When the up-date is completed there will be 33 satellites in the system and additional ground stations added.

THE RUSSIAN GLOBAL POSITIONING SYSTEM

The Russian GPS (GLONASS) was first launched in 1982 and reached partial operation in 1996. The Russian government has indicated that it will try and revitalize the program by 2006. GLONASS is managed by the Russian Space Forces under the Ministry of defense. A fully operational GLONASS would provide better coverage of the north and south poles than Navistar. The system provides low performance, since less than half of the satellites are operational. Like Navstar there are 21 satellites and three spares. The GLONASS system is less vulnerable to jamming than Navistar, since each satellite transmits a different frequency. Most GLONASS receivers are only available to the military. There are some civilian receivers on the market, but due to the low level of accuracy these tend to serve as backup for Navistar GPS data.

GALILEO GLOBAL POSITIONING SYSTEM

Galileo will be a European GPS community project, providing a highly accurate position service under civilian control. The new European GPS will be inter-operable with the United States Navstar GPS and the Russian GLONASS GPS. The GPS user will be able to use the current receiver for both the United States GPS and the European GPS, which will give a more reliable and accurate location. The first experimental satellite will be launched the second half of 2005. If this experimental satellite proves the technology, four more satellites will be launched between 2005-2006 to validate space and related ground segments. If these launches are successful the rest of the satellites will be launched and reach full operational capability in 2008. The fully deployed Galileo system will consist of 30 satellites (27 operational plus 3 active spares) at a height of 15,000 miles, positioned in three circular medium earth orbit planes at an inclination of 56 degrees relative to the equatorial plane. The Galileo navigation signals will provide coverage even at latitudes of up to 75 degrees north. The large number of satellites and the spares will ensure that the loss of one satellite has no discernible effect. There will be two Galileo control centers, five monitoring and control stations and five mission data up-link stations to provide for the control of the satellites and to perform the navigation management. Each of the 30 satellites will have two clocks on board, one based on the Rubidium atomic and the other using a passive Hydrogen maser. Both clocks use different technology, but make use of the same principle. They use the principle of forcing atoms to jump from one energy state to another. This will radiate the associated microwave signal at an extremely stable frequency.

The new Galileo GPS system should have a huge impact on commercial aviation. The availability of both Navstar GPS and Galileo will ensure high accuracy through the redundancy and high reliability of the service. As the number of flights increase the two GPS systems will help reduce congested airspace. The two systems would also help in the critical flight phases, such as take-off and landing in bad weather conditions. Another benefit would be that some airports are not equipped with instrument landing system (ILS) and these two systems combined would help in monitoring and surveillance. Air traffic control can use this information to monitor position, heading, speed and time of any aircraft. Many areas in the world lack the appropriate infrastructure to provide this information. Air traffic controllers would also be able to use these systems for ground control. This would give them the capability to monitor aircraft on the ground, instead of the pilot reporting their position.

UNITED STATES' CONCERNS ABOUT NEW GALILEO GPS SYSTEM

When the European Union first proposed the launching of the Galileo GPS the United States had reservations. The United States felt that a new GPS system was not necessary as the current GPS was sufficient. The United States was also concerned about terrorism. If terrorists could get hold of the new system they would be able to disrupt the security of the United States and Europe. The United States Pentagon was concerned that the Galileo frequencies would overlap the new military service M code, proposed for the next generation of United States GPS system. The M code would allow the United States military and NATO commanders to jam GPS signals to the enemy within a radius of 62-124 miles. The European Union has assured the United States that the Galileo frequencies would not interfere with the M code or the total United States GPS system.

The other item of concern the United States State Department had is China's interest in participating in the Galileo program. At the present, U.S. law does not allow for certain kinds of space technology to be transferred to China. If the United States transfers any satellite technology to Europe, they must be assured that the technology will stay in Europe and not be provided to the Chinese.

The United States has stated that if the above requirements are met that they would cooperate and provide their knowledge of satellite technology to the European Union for the development of the Galileo GPS system.

The negotiations will continue between the European Union and the United States to resolve any issues that may arise in the future. With the United States giving their blessing to the Galileo program, this is seen as a milestone in the advancement of a world wide global positioning navigation system. This means that air traffic control; commercial air transport and civilian aviation will have access to approximately 60 navigational satellites, not including the Russian GLONASS system.

FIRST STEP TO A WORLDWIDE GLOBAL POSITIONING NAVIGATIONAL SYSTEM

The first step the Europeans are taking towards a full global navigation system is European Geostationary Navigation Overlay Service (EGNOS). EGNOS is Europe’s first venture into satellite navigation. EGNOS will be designed to tell if the signal you are receiving from either the U.S. GPS or the Russian GLONASS system can be trusted and it will give you your position and say by how much it could be out. It’s Europe’s contribution to the first stage of the global navigation satellite system and is a precursor to Galileo. EGNOS will become operational in 2005.

The first experimental satellite, part of the so-called Galileo System Test Bed (GSTB) will be launched in the second half of 2005. The first experimental satellite will be used to verify the critical technology. This will be followed by four additional operational satellites launched in 2006 to validate the basic Galileo space and related ground segment. Once the in-orbit validation phase has been completed, the remaining satellites will be launched to reach full operational capability in 2008.

BENEFITS OF A WORLDWIDE GLOBAL POSITIONING SYSTEM

The additional improvements that the United States plans for the Navstar GPS and the introduction of EGNOS and Galileo will assist air traffic control and pilots in all flight phases, movement on the ground, take-off, en-route navigation, and landing in all weather conditions. This would increase the level of safety that will be needed to cope with the increased number of flights.

The higher level of accuracy and service integrity that U.S. GPS and Galileo can provide for improve aircraft separation and reduction in congested airspace. Scheduled traffic has increased about 4 percent per year worldwide and will double in the twenty years. Due to this fact, reliability and accurate positioning systems are required for the future of aviation.

Galileo offers many benefits for safety and optimization of schedules and routes. It can also assist to increase runway capacity by shortening occupancy time. This would save time and fuel and reduce noise. Air traffic control would have better control over ground movement. There have been severe accidents during taxi that could have been prevented with integrated surface movement guidance and control.

Position, heading, speed and time information are needed by air traffic controllers for the continuous management of all aircraft. There are areas of the world that lack adequate ground infrastructures, including secondary radar and communication links. The navigational data obtained through Galileo can lead to advanced systems and techniques for safer air traffic monitoring.

The ATA and AOPA are requesting the FAA proceed with the following improvements to the navigational system:

1. Conduct an independent risk assessment to determine obstacles and solutions for GPS based sole-means navigation operations and other critical flight safety services.
2. Continue with the wide area augmentation system (WAAS) to provide the sole-means of navigation services in light of the results of the independent risk assessment.
3. Accelerate development airspace and flight procedures based on GPS augmented by WAAS system.
4. Implement the second GPS frequency for civil-use navigation as soon as possible.
5. Accelerate the implementation of public-use local area augmentation system (LAAS services under the FAA's flight 2000 program, with these LAAS systems serving as beta test sites for the Flight test program. [2]

The airlines are strong supporters of the LAAS and WAAS systems which broadcast local augmentation signals from equipment located at designated ground locations and would provide precision approach guidance to ILS Category I, II and III standards.

We believe that with the development of the Galileo system combined with the current U.S. GPS system that all the requirements for a sole-means navigational system can be accomplished in the near future.

SUMMARY

Throughout history man has been using the stars and the planets to navigate and calculate his position on earth. Today, we have put our own stars in the sky, in the form of satellites that can tell us our position anywhere on the earth without having to manually calculate their positions. This future form of satellite navigation will let us know if the information is any good and find us if we are lost.

A new era in aircraft navigation is on the horizon that will advance the control of our skies and make flying much safer. The implementation of Galileo will be a welcome improvement to the creation of a worldwide global positioning system. Galileo will vastly improve the accuracy, redundancy, integrity, reliability and availability of the current GPS system. This will mean improved air traffic control management, better route scheduling, reduce the workload of the pilots and insure better ground control.

The Galileo system and the current GPS system should become seamless to the everyday user, since the two systems can be a backup for each other. Galileo will augment the current GPS with a search and rescue (SAR) function and each Galileo satellite will be equipped to have a transponder installed, which will notify the user that his signal has been received and help is on the way.

There will also be an economic boon for both Europe and the United States related to receiver sales, better control of the shipment of goods, and saving of time and fuel by the airlines. Respectful cooperation between the United States and the European Union will develop an extremely successful Global Positioning Navigation System which will provide safer flights for everyone and also be a boost for the aviation industry.

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