The Evolution of the Global Positioning System

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ABSTRACT – As society benefits from the new technologies related to the Global Positioning System (GPS), they probably do not realize the trials and tribulations surrounding its planning, development, and implementation. This paper will discuss the evolution of the system starting with the conceptual idea in 1838 by two brothers and ending with the utilization of the system in surveying applications. Although, the initial purpose behind the system was based on specific requirements related to the Department of Defense, it was adapted to provide numerous resources and applications to civilian partners.

Keywords: Department of Defense, Global Positioning System, technologies, evolution, civilian, surveying.

INTRODUCTION

Since the release of the United States' military global positioning system (GPS) technology in the mid-1980s, new innovations have been developed that have had a positive affect on modern life. Michael Specter, a reporter for "The New Yorker" pointed out in an article titled "No Place to Hide" that "The satellites function as reference points- the way stars once did for mariners- and not since the twelfth century, when the compass came into use, has a navigational tool promised to more fundamentally alter the way we live"[11].

Advertisements run daily announcing products that utilize the location and navigation satellite system that was initially developed for military use. Automakers are offering GPS on most models and cell phone manufacturers are placing receivers in their products to aid in locating the lost and injured. The surveying industry has reduced the man-hours involved in every aspect of their operations. Before the aid of the GPS system, a substantial investment in labor to measure and collect the data was necessary for creating topographical maps by hand. A well constructed map that once took several weeks to create can now be generated in a matter of hours with fewer errors. GPS technology has benefited millions of people throughout the world and in many different ways.

A former Air Force Space Command Chief Historian George W. Bradley III said,

> …most do not know the legacy of this technology. And this is important technology, technology that is a fundamental part of a revolution that the Chief of

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> Air Force History, Dr. Richard Hallion, referred to in a presentation he made recently on the future of the Air Force: the precision revolution. While much still remains to be done in that revolution, its impact is already upon us. Understanding the origins of this aspect of the precision revolution is a useful prelude to understanding its future [1].

EARLY HISTORY

The concept behind space navigation systems can be traced back to 1838. Two brothers, Nathan and Edward Hale, drew plans and sketches of a satellite navigation system. Although the satellites were made of brick, the similarity to our current satellite system astonishes today's researchers. The brothers actually completed their plans and sketches of the system. In 1870, a fanciful story was written and published in the Atlantic Monthly called *"The Brick Moon."* In the story, the idea was to build giant brick structures at 200 feet diameters, put light inside of them and send them into orbit around the world. Like the moon, they could be used as navigational tools by the world's navigators [1]. Even though the similarities are few, satellite technology has grown from a fantasy in the 19th century to a complicated, versatile and precise system that has been developed through trial and error during a 40 year period and continues its evolution today.

The current GPS system uses 30 satellites arranged in six orbital planes with four satellites per plane. A world wide ground control/monitoring network monitors the health and status of the satellites including uploading data to the satellites. GPS can provide service to an unlimited number of users since the users' receivers operate passively (i.e., receive only). The system utilizes the concept of one-way time of arrival using radio frequencies and precision clocks [5]. By computing the distance to four satellites, it is possible to establish the coordinates of a user's position (latitude, longitude and altitude) as well as GPS time [4]. Civilians will never know the complete description of the military GPS technology because part of the technology remains classified. "GPS answers the questions, 'what time, what position, and what velocity?' quickly, accurately, and inexpensively anywhere on the globe at any time" [5].

DEVELOPMENT OF THE GPS SYSTEM

The development of this new technology required the collaboration of several different groups and organizations such as the Department of Defense (DoD), Rand Corporation, International Civil Aviation Organization (ICAO), Federal Communications Commission (FCC), National Aeronautics Space Administration (NASA), Advanced Research Projects Agency (ARPA), National Oceanic and Atmospheric Administration (NOAA), Communications Satellite Corporation (ComSat), International Telecommunications Satellite Consortium (INTELSAT), plus many more.

In 1957 the Eisenhower Administration implemented organizational and policy measures that provided the foundation of the nation's space program. The President's dual military and civilian space program reflected his "space for peace" focus [5]. In 1957 the Soviets launched the Sputnik satellite, an example of their focus on developing military and/or technological power and superiority, which motivated the United States military to develop a similar satellite technology to enhance its military forces [4]. In January 1958, the United States launched its

first successful satellite, Explorer I [1]. The successful launch of Explorer I convinced the DoD to begin the development of a "global, all weather, continuously available, highly accurate, positioning and navigation system that could address the needs of a broad spectrum of users" [4].

The National Space Act of 1958 established a dual space program made up of separate civilian scientific and military applications. This led to the formation of the National Aeronautics Space Administration (NASA) which quickly took over the majority of the facilities and personnel concerned with the future of space technologies [5]. By late 1958, the foundation was laid for the United States' involvement with space technology. National policy restricted space technologies to peaceful purposes. While organizing and promoting the dual effort with civilian, scientific aspects were managed by NASA. Military research applications were managed by the Advanced Research Projects Agency (ARPA) [5]. The Wiesner Report, initiated by President elect John F. Kennedy to review the development of the space program and presented by committee chair Jerome B. Wiesner of MIT, criticized the organization and management of NASA. The report recommended the Air Force be made responsible for all the military space development since it already supplied 90% of the support to the program [5].

In the early 1960s, the major restriction in the development of a unified satellite navigation system was the competition between the military branches to produce the first system. Each had its own agenda as to what the navigation system had to provide [2]. The Navy needed a system that could locate enemy submarines and other ships at the ocean surface. The Air Force needed a three dimensional system to aid in the navigation and landing of aircraft. The Army needed to be able to control various munitions systems used in ground assaults. The different military services worked independently, and each had their own facilities and experts involved in planning and developing the navigation system that fit specific needs [2]. The division of development between the different branches generated problems that eventually led the Comptroller General to take action.

In 1968, since military forces were not coordinated in the design efforts and nothing had been achieved in the past seven years. The DoD established a joint tri-service steering committee called NAVSEG (Navigation Satellite Executive Group) [4]. NAVSEG spent the next several years determining the necessary specifics and requirements of the satellite system. Included were the number of satellites, their altitude, signal codes, modulation techniques and cost [4]. In 1973, the Secretary of Defense designated the Air Force as the lead agency to consolidate the military's concepts into a single system to be known as the Defense Navigation Satellite System (DNSS) [4]. It was from this combination of features that made it possible to adapt the technology to multiple users.

The requirements for the military's space satellite navigation system were taken seriously and monitored by those that had the authority to do so. In 1979, a report sent to the Secretary of Defense from the Comptroller General mentioned that the General Accounting Office (GAO) had been instructed to monitor the pending three phases of the development of the navigation system; phase I was validation, phase II was full-scale engineering, and phase III was production [2]. The findings relate to the requirements that were established in the 1960s concerning the purpose behind the DoD's satellite navigation system. They were to report if the original navigation system requirements were being met before further funding was allocated for the next phase [2]. The recommendation set by the report established two areas of concern that needed the Secretary of Defense's attention before the approval of the 1980 full-scale engineering

development funds, and time was running out for submittals [2]. According to an assessment of the satellite navigation program written by the Rand Corporation, funding was unstable during the early stages of the program because it was not considered a critical defense weapon. In 1979, the budget allotted to the program was reduced by $500 million over the fiscal years 1981-1986 and was put on hold during 1980 -1982 [4].

Although part of the current GPS technology is still considered classified, the United States promised to partially release the technology to civilians in 1983 after its completion. According to the Philadelphia Inquirer Newspaper on September 17, 1983, the United States government was prompted to release their future navigation technology to civilian users because of an international tragedy involving the downing of Korean Airliner 007 by the Soviet Union with over 200 civilians aboard. Soviet fighter jets followed the airliner for over two hours before the shoot down. The markings on the airliner were distinctive and ruled out the possibility it was a military operation [9].

The Korean government called for an international meeting of the ICAO in Montreal in 1983 to review the actions of the Soviets. President Reagan sent the head of the Federal Communications Commission (FCC), Lynn Helms, to the meeting to offer the full support of the United States government in further actions against the Soviet Union. In this meeting the United States announced the planning and development of a global satellite location and navigation system that could eliminate or reduce this type of tragedy from happing in the future [10].

Although the press attributed the United States' action on releasing the GPS technology to the Korean tragedy, the actual reasons why the United States military would share confidential and expensive DoD technology with the global civilian communities is much more complex. A huge amount of documentation has to be researched before a decision can be made when different entities of the government involved in one project.

The implementation process was postponed over the next few years due to unforeseen tragedies such as the space shuttle explosion in 1986 and the Gulf War in the 1990s. All challenger missions were placed on hold until the cause behind the tragedy could be determine. This postponed the means used to conduct the necessary activities behind preparing the GPS technology for full operation [3]. In 1990, some GPS functions were temporarily suspended, as the military needed more receivers to use for military purposes in the ongoing Gulf War. It was made available for public use again in 1993. It was then decided to provide GPS free of cost, all over the world. By 1995, the Global Positioning System had become a considerably advanced navigation system. It had achieved full operational capacity, and the number of satellites had also increased, improving the availability and accuracy of the technology [3]. On May 1, 2000, then President Bill Clinton announced that the military's limitations had been overcome, so civilians could have more access related to the new GPS technologies utilizing the one time Department of Defense navigation system. In a White house press release he stated:

> "Today, I am pleased to announce that the United States will stop the intentional degradation of the Global Positioning System (GPS) signals available to the public beginning at midnight tonight. We call this degradation feature Selective Availability (SA). This will mean that civilian users of GPS will be able to pinpoint locations up to ten times more accurately than they do now……. My decision to discontinue SA was based upon a recommendation by the Secretary of Defense in coordination with the Departments of State, Transportation, Commerce, the Director of Central Intelligence,

and other Executive Branch Departments and Agencies. They realized that worldwide transportation safety, scientific, and commercial interests could best be served by discontinuation of SA……." [11].

Utilization of GPS Technology

Surveying engineering and technology has made great strides with the invention of the computer and global positioning satellites. Since the 1980's, the tool of choice among professional land surveyors is the total station. The total station is an electronic distance measurement (EDM) devise that collects and stores all surveying data for processing. Robotic total stations can detect and track remote field prisms, relay the collected data to central processing, and be installed into modeling software. "Robotic total station instruments can automatically and repeatedly measure distances and angles to a moving reflector and store the values in memory without the need of an operator" [13]. The skills required to successfully operate this equipment efficiently and effectively and to produce the data in various ways so to meet client demands is based on computer science and information technology.

Future Utilization of GPS Technology

Surveying will continue to play an important part in the construction and engineering industries. Leaders in the surveying industry are attempting to adopt a new term that better reflects the changing dynamics of the industry. The term that appears to be most commonly used is geomatics. Geomatics is "a term used to describe the science and technology dealing with geospatial data, including the collection, analysis, sorting, management, planning and design, storage and presentation" [8]. Geomatics data can be inserted into interoperable software that creates models for construction and maintenance of facilities. Building Information Modeling (BIM) uses many different kinds of data from various sources that are then used to virtually build a project. Geomatics information can also include the building components, such as structural steel or heating/ventilation/air conditioning (HVAC) components that are attached with radio frequency identification (RFID) tags. Geomatics technology can use an on-site instrument to track and verify when building components have been installed in their correct locations using the relative coordinates of adjacent components.

The rapid change that is currently taking place is creating a paradigm shift requiring an adaptation to current curricula within the surveying industry. "In the future, large numbers of well educated and dedicated professionals will be needed in the surveying and mapping area" [13]. The technology of surveying will continue to evolve and allow for an input of the spatial relationships associated with construction. The evolving field of surveying will become more comprehensive and technical. Information technology/Computer Information Systems and data management are two good examples of courses of study that will be required for the development of a comprehensive curriculum in geomatics.

CONCLUSION

The Global Positioning System has generated numerous opportunities for civilians since its release by the Department of Defense. The research behind this story is very interesting because

of all the different entities involved. The reference concerning the two brothers in 1838 would probably not be included in most research behind the GPS technology because it was only a conceptual idea in a society without today's advanced technologies. The history of the democratic American society has always been affected by international affairs. It is hard to imagine the total number of man-hours that were spent during the planning, development, and implementation of this technology that is currently supplying the World with accurate, safe, and reliable navigation applications, as well as other technologies that greatly influence our daily lives.

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