The Global Positioning System – emergence and early development.

Francis Hunger, francis.hunger@irmielin.org, unpublished manuscript, 2012

A beep

The history of the Global Positioning System (GPS) development starts with a beep. A looped beep which could be easily received by ham operators, transmitted alternately on the popular bands 20,07 and 40,002 MHz. Six times a day for 21 days in October 1957 you could hear this particular sound from above the sky of the United States of America: Beep, beep, beep, beep, beep, beep, beep, beep, beep, beep, beep, beep, beeeeeeeeeeeeeeeep.[1]
The source of the beep was orbiting earth and it was not American. The Russian satellite Sputnik Zemlyi (companion of the world) which was started on October 4th, just a few days before the 40th anniversary of the Bolshevist revolution, was the source of the signal.[2] The surprise was complete and nourished fears that the Soviet Union would be able to attack the United States when ever the wanted with Inter-Continental Ballistic Missiles (ICBM) that transport nuclear payload.[3]

It led to a broad confusion about the abilities and power of the Soviet Union civil and military space program and eventually caused the beginnings of giant, state subventioned scientific and military program in the US, the „Men on the moon" program. This was after the Russians where not just the first to have a satellite in orbit but where the first again to send a human, the Cosmonaut Jury Gagarin into orbit 4 years later in 1961. It was also the period of the Cuban Missile Crisis (October 14 – November 20, 1962) when the Soviet Union tried to place medium range and short range ICBMs on Cuban soil.

The Sputnik had great influence to the development of GPS in two ways: First of all it led to the political support for the military and scientific space program in the US on the administrative level. Following the „Sputnik shock" the Department of Defense (DOD), in parallel to many other research programs, enforced the research on a global, continuous available, all-weather, highly accurate navigation system, which resulted in separate programs of the US Navy and the Air Forces. And second: on a more personal level the beep sound of the Sputnik radio transmitter inspired US scientists to research one of the basic ideas of what would eventually become the Global Positioning System. George Wieffenbach and William Guier at the Applied Physics Laboratory[4] „discovered that measurements of the Doppler shift as the satellite passed by were adequate to determine the entire satellite orbit. Dr. Frank T.

---

[1] http://nssdc.gsfc.nasa.gov/sound/sputnik.wav
[2] McDougall and Dickson, give a detailed description of how the Sputnik could be observed and how it was perceived by a broad American public.
[3] It turned out Krushchevs' propaganda tricked the American public for several years until they had their first own successful reconnaissance sattellite named Discoverer XIV in August 1960 to deliver photos of the expected Russian military launch pads. (Dickson p 211-214, McDougall p 250 -252)
[4] The JHU APL is located in 11100 Johns Hopkins Road, Laurel, MD 20723, 10 miles from Washington

McClure of APL noted conversely, if the satellite orbit were known, position on the earth could be determined using these same Doppler measurements.“[5]

The APL is a 145-hectare campus of the Johns Hopkins University, situated about 30km north of Washington near the route 29 between Washington and Baltimore.

> “That evening, we were receiving and recording complete passes of the satellite from horizon to horizon with no modulation on the 20-MHz frequency, what we would later call a ‘pure Doppler shift.’ It took a while to realize that we could use the shifting frequency to advantage, assuming we were receiving the Sputnik. We estimated the total swing in frequency, substituted it into the simplest equation for the Doppler shift to an estimate of the speed of the source, and confirmed that it was about right for an orbiting body near the Earth. We could positively identify our source as a near Earth satellite! Somewhat later that evening, we remembered that we could estimate the closest approach of Sputnik to George’s antenna by determining the maximum slope of the Doppler shift – a method APL used in estimating the distance of closest approach of a guided missile to its target. From that time forward, we focused increasingly on quantifying the Doppler data and inferring the satellite’s orbit from the data.” (Guier / Weiffenbach 1998)[6]

The next steps: Transit, Timation, MOSAIC and B612

The next steps happened partly in parallel, originating in the rivalry of the US Air Forces’ missile program and the US Navy’s aircraft carriers and ballistic missile submarine needs. Both entities where relying on fast and reliable navigation tools and had their separate research divisions with the particular goals to provide navigation at the sea and respectively in the atmosphere. Both drew their former particular expertises from different navigation tools: The then newly developed radar and the well-proven lighthouse for navigating the sea on the one hand and missile guidance systems on the other lead on separate ways towards a common development.

It was the APLs director R. E. Gibson who proposed a 50-page concept of Transit to the Navy Bureau of Ordonance in cooperation with McClure who had presented the basic concept for satellite-based navigation at APL in March 1958.

> „In particular, Mac [Frank McClure] had been spending part of his time downtown in the Navy’s Special Projects Office, which was responsible for development of the Polaris system[7] and was aware of this serious problem in submarine navigation. He realized that the Doppler satellite tracking method, when ‚turned on ist head’, had the potential for a solution. Learning of our latest progress on a Friday, Mac had the idea to invert the process, called his close friend, Dick [Dr. Richard] Kershner, and over that first weekend designed the essentials of the complete Transit Navigation System: multiple polar orbiting satellites radiating two ultrastable frequencies encoded with their orbit parameters, a satellite tracking system receiving these same two frequencies to solve the ‚direct problem’, and an injection station to transmit the resulting orbit parameters to each satellite, which would continue to obit the Earth so that submarines with navigation receivers/computers could determine submarine position about once an hour anywhere on Earth.“ (Guier / Weiffenbach 1998)

---

[5] Pace et. al. 1995, p. 238 fn3

[6] cf. Guier, William H./ Weiffenbach: The early days…

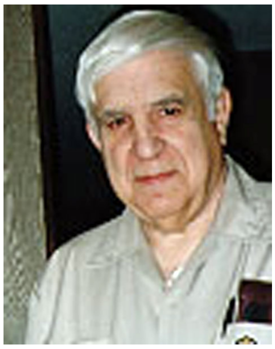
[7] Polaris ballistic missile, to be mounted on submarines, where they could be launched from submerged submarines. For correct and targeting the Polaris needed a fast and reliable navigation system. cf. http://en.wikipedia.org/wiki/Polaris_ballistic_missile

Transit (Navy, Applied Physics Laboratory)

The Navy started the research on the two-dimensional satellite based system, which eventually led to the start of the first Transit satellite in April 1960.[8] The system consisted of 3 satellites (and 3 additional spare satellites) in a low polar orbit with a 1100 kilometre altitude, 3 ground control stations and the on-board receivers on naval vessels. Only one signal at a time was needed to determine the own position with a accuracy of 500 up to 15 metres. Depending on the own position the time between the measurements could take from 30 minutes up to 6 hours. In 1967 the system was opened for non-military ships as well and made it to 60.000 sold receivers until the cessation of Transit in 1996. Thus it is also a successful predecessor to GPS, demonstrating the broadening of a solely military application towards civil uses. Besides its stability and reliability Transit had a few drawbacks: It was slow, required a long observation time and provided only two-dimensional positioning data.

Timation (Navy, Naval Research Lab)

The Navy in parallel developed another satellite based navigation system called Timation, starting in 1964.[9] The Naval Research Lab, which was founded in 1923, is situated at the Potomac River bank opposite of the Ronald Reagan Airport Washington.[10] The complex of over 100 buildings spreads on a 130-acre (0.5 km^2) site along the Potomac River.[11] Two experimental satellites were developed at the Naval Research Lab under Roger Easton[12] as „proof of concept", successfully incorporating new time-standard techniques which later became useful for GPS. Each satellite would have its own clock, which would be updated continuously by ground signals. The Timation satellites included the first atomic frequency clocks (rubidium and caesium) in space which were much more reliable and precise than the former used quarz clocks.



Img. 1: Roger Easton (1997)

> „The atomic clocks had better frequency stability than earlier clocks, which greatly improved the prediction of satellite orbits (ephemeredes) and would eventually extend the time required between control segment updates to GPS satellites. [...] In fact the last two Timation satellites were used as prototype GPS satellites." (Pace et. al. 1995, p 239)

---

8 The funding body was the Advanced Research Projects Agency (ARPA) later renamed to Defense Advanced Research Projects Agency (DARPA) in March 1973, which beside many others also funded the development of the TCP/IP protocol in the mid-1970s

9 The Soviet Union in parallel developed an satellite called Tsyklon (cyclone), which was launched in late 1967 and is also based on Doppler techniques.

10 Naval Research Laboratory, 4555 Overlook Ave. S.W., Washington, DC 20375

11 It was also at NRL, where the project Vanguard was developed to place the first US-Satellite in space. Cf. http://en.wikipedia.org/wiki/Project_Vanguard

12 c.f. http://www.nrl.navy.mil/pao/pressRelease.php?Y=2005&R=60-05r; c.f. Easton 2006

MOSAIC (Air Forces and Raytheon Corp.)

In the same period, starting in 1960, the US Air Forces contracted the Raytheon Corporation[13] with Ivan Getting[14] and Shep Arkin to develop a three-dimensional navigation system, based on the Doppler-principle.[15]
It was called Mobile System for Accurate ICBM[16] Control (MOSAIC) and should enhance the precision of Mobile Minutemen ICBM launch pads. The idea of Mobile Minutemen was to mount Minuteman ICBMs on transportable railroad launch pads, enabling the Air Forces be less vulnerable than with fixed launch pads, that could more easily targeted if their position was known. The work on MOSAIC was dropped one year later, in 1961, when the complete Mobile Minutemen was cancelled.


Img. 2: Ivan Getting

B 612 (Air Force/ Space division and Aerospace Corp.)

On August 1, 1960 Ivan Getting (1912-2003) became president of the newly formed Aerospace Corporation, a non-profit organisation to serve the Air Forces' needs for planning and managing the missile and space program. Getting was central for Aerospace and also for the project B 612, being able to integrate other researchers into the corporation because of his widespread personal contacts in academic research, industry and administration.[17] Being formerly involved in both Polaris and MOSAIC, projects, which required fast and reliable navigation and trajectory tracking, he was the ideal candidate for heading the B612 program. He managed to attract many of the developers who had worked on MOSAIC and thus accumulated knowledge capital at Aerospace. About 1500 scientists and engineers were employed by Aerospace three years after its establishment.
Several teams at Aerospace were working on ballistic missile systems and the question of military use of the space exploration. This intensivation of work was an outcome of the Men on the moon program, which was announced by Johns F. Kennedy in May 25th 1961 and lead to huge subventions for the military and non-military space flight sector. In 1963 the Air Force/ Space division contracted Aerospace with the project that would later become the project 612 B with the main goal of using satellites as a means for three-dimensional navigation and avoiding the drawbacks of the other systems.

The specification for B 612 was

- high accuracy

---

[13] Raytheon was founded in 1922 and became a major developer of navigational systems and missiles. In 1945, as a by-product of military research, Percy Spencer invented the microwave oven at Raytheon.
[14] Getting in the same period also served on the Undersea Warfare Committee of the National Research Council where he was involved in the proposal for the Polaris missile.
[15] Basic research on this system was already started in the early 1950s, building on the experiences of LORAN (Long Range Navigation) a nautical navigation system which still is in use, cf. http://en.wikipedia.org/wiki/LORAN
[16] Intercontinental Ballistic Missile
[17] Before Aerospace Ivan Getting worked at the MIT Radiation Laboratory (1940-1950), where he was involved in the development of radar. Then he became Vice President at the Raytheon Corporation (1951-1960). During WWII he served as special consultant to Secretary of War Henry L. Stimson on the Army's use of radar. He also was invoved in the planning process of the Semi-Automatic Ground Environment (radar) system, in short SAGE.

- weather independence, location independence
- provide three dimensional location data
- unlimited number of users
- passive user equipment (e.g. non-radiating)

These specifications laid the path to GPS as we know it now. The engineer Hideyoshi Nakamura proposed to use 4 separate satellite signals at the same time for three-dimensional position calculation. The aircraft could then measure the four distinct differences in the signals' arrival times and compare them with an on-board quartz clock.
Another major contribution to the concept was to base the signal on pseudo-random noise (PRN). „The PRN technique had distinct advantages over other techniques, among them the ability to reject noise, which implies a strong ability to reject most forms of jamming or deliberate interference. With this technique, all satellites could transmit on the same frequency without interference. Also a communication channel could be added which allowed the user to receive ephemeris (satellite location) and clock information." (Pace et.al. 1995, p 239, fn 9) Basically PRN is a sequence of 1's and 0's, which seem to be randomly distributed, and thus the signal looks like random noise. However a block of a lot of 1's and 0's forms a unique signature of a satellite.

SECOR (Army)

To add even one more entity, the US Army was working on its own proposal, the Sequential Correlation of Range (SECOR) with 13 satellites launched 1964 - 1969.[18]

Contributions

contribution	contributor
Observing Sputnik: Use of Doppler shift	Johns Hopkins University / Applied Physics Laboratory
Transit: 1 satellite providing two-dimensional positioning data for ships	US Navy and Johns Hopkins University Applied Physics Laboratory
Timation: Use of atomic clock	US Navy, Naval Research Lab
MOSAIC: incubator for engineers who later followed Ivan Getting to Aerospace	US Air Forces and Raytheon Corp.
B612: Use signals of four satellites for three-dimensional positioning data / Use of pseudo-random noise	US Air Forces/ Space division and Aerospace Corp.

Getting the pieces together – A NAVSTAR is born

Over this years of basic research which contributed to satellite based navigation systems, the world politics were shaken by a couple of events and crisises which led to the enforcement of the technical developments. An important factor was the space race between the US and the USSR, which resulted in the men on the moon program and thus in many technical inventions around the concept of missiles, navigation, digital computers for complex number

[18] c.f. Krebs 2005

computation in aerodynamics and so on. The construction of the Berlin Wall (1961), The Cuban Missile Crisis (1962), the Vietnam War (1965 to 1972) were major events of the ongoing Cold War. The already mentioned Space Race was accompanied by an Arms Race, especially through the development of Intercontinental Ballistic Missiles with atomar warheads. It was also the time, when digital computers grew out of the experimental phase and where available for most scientific research facilities. The microchip, which was invented in 1959, went into mass production in the mid-1960s, replacing the slower and bigger transistor based calculation machines. The demand for microchips was not insignificantly enforced through the demands for Minuteman II cruise missiles on-board navigation computer[19] and the Apollo Guidance Computer.[20]

Basically all necessary technologies were in place in the late 1960s. The problem was that they were located at several distinct places and entities, which wouldn't cooperate and it was difficult to get funding for a system of 16 satellites as it was envisioned for B621 while other military services were working on concurrent systems. After this dead end became an obvious thread, the DoD established a coordination group called Navigation Satellite Executive Group (NAVSEG) which should produce an agreement between the Army, the Navy and the Air forces in 1968. Although the group produced a compromise – the number of satellites, their altitude, the signal codes and the costs – it lacked the power to advocate the adoption of this compromise. This is where Bradford Parkinson, a Colonel at the Air Force, was assigned to manage the satellite navigation program.[21]

> On April 17, 1973, DoD authorized the creation of a joint, three-service program office and selected the Air Force as the lead military service. [Bradford] Parkinson was appointed to be the first program manager of the newly created GPS Joint Program Office. The program's headquarters were located at the Los Angeles Air Force Station (as it was then known), the headquarters of the Space and Missile Systems Organization (SAMSO) in El Segundo, California.[22] The Los Angeles Air Force Station was adjacent to The Aerospace Corporation, which established a GPS program office in July 1973 […]. (Strom 2002)

So the Joint Program Office under Colonel Parkinson started to work out a proposal, which was oriented on the experience of B612. The Defense System Acquisition Review Council (DSARC)/ DoD rejected the first version and Parkinson had to rework it. The DoD acknowledged the second version, which included also the viewpoints of the other military services, in December 1973 under the name NAVSTAR Global Positioning System.[23] The acronym NAVSTAR stands in for *Navigation System using Timing And Ranging*. In the 1974 and 1977 two refurbished Timation Satellites are launched as NAVSTAR test satellites for proof of concept, the first satellites to be equipped with atomic clocks.

Img. 3: Brad Parkinson of JPO © United States Air Force, reprinted with

---

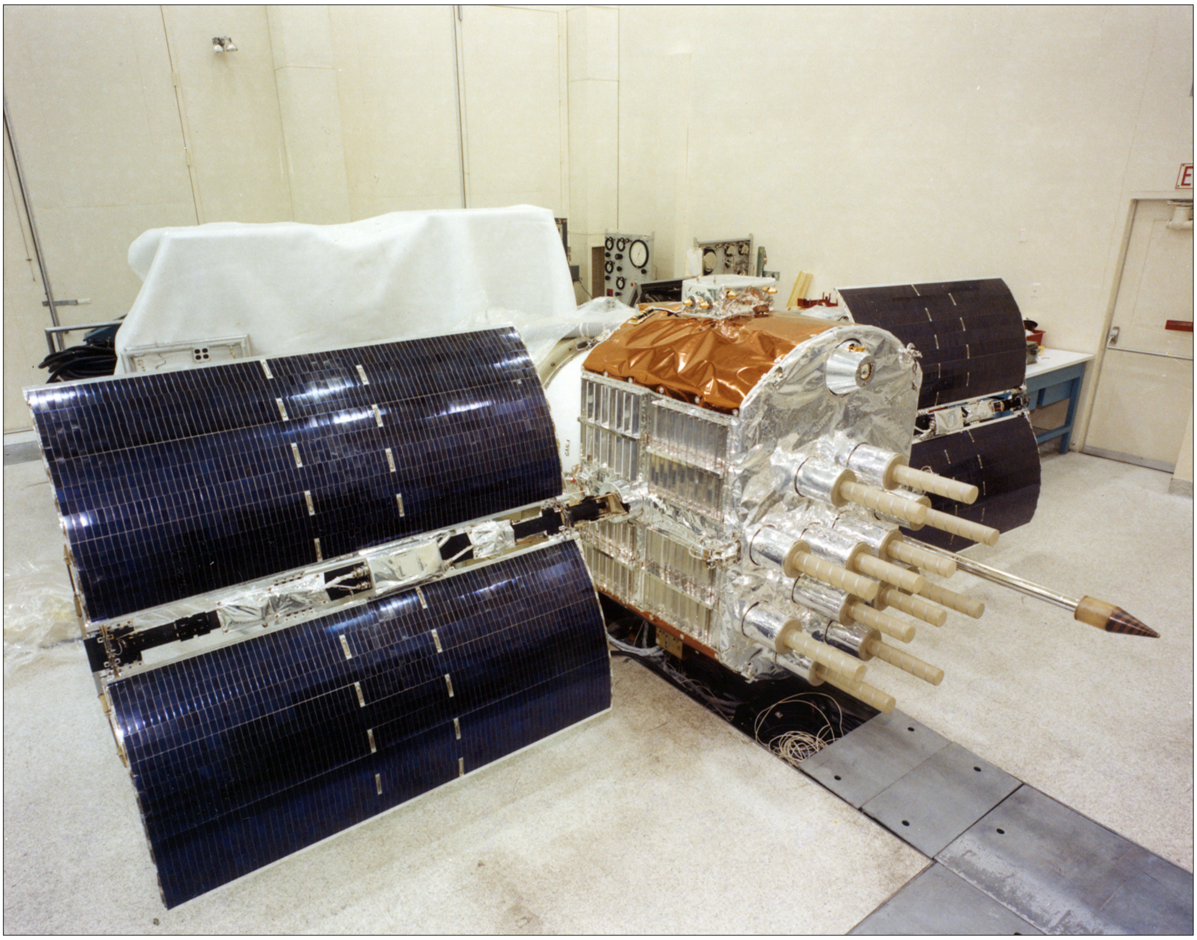
[19] Ceruzzi
[20] Australian Broadcast Cooperation, 1999
[21] A similar blockade between the Army and the Air Forces can be seen as one of the reasons for the delay in the American space and missile program in comparison to the early success of the Soviet Union. C.f. Beadles
[22] As of 2006 the JPO is located next to LA International Airport, at 483 North Aviation Blvd., El Segundo, CA 90245-2808 as a part of the Los Angeles Air Force Base.
[23] Strom 2002; This is somewhat shortened. For more details see Strom 2002 and Pace 1995 p 240f

Block by Block

The following stages of technical development were marked by the launches of several satellites combined into so-called blocks. The first generation would be called Block I and subsequently the second generation was called Block II. Basically Block I satellites were used to test the technological concepts, while Block II, Bloc IIA and Block IIR satellites made up the current operational constellation.

Block I

The first block contained a total of 11 satellites, launched from 1978 through 1985, produced by Rockwell International (now Arvin Meritor)[24] for the costs of $ 20 million each. Over the same period also the user equipment matured in precision and reliability. A prototype ground control, the Air Force Space and Missile Systems Center „ Hoyt S. Vandenberg“ was established 240 km northwest of Los Angeles in Santa Barbara County, California, a site that was used as for rocket launches since 1958.[25] Much of the currently 400 km^2 base is rugged, mountainous, and about 85% undeveloped, making it a remote site for missile testing and development.



Img. 4: GPS Block I, © United States Air Force

[24] North American Rockwell, a forerunner of Rockwell International was also involved in the Apollo spacecraft production.

[25] On February 28, 1959 the world's first polar-orbiting satellite, Discoverer I, started aboard a Thor/Agena booster at Vandenberg. c.f. http://en.wikipedia.org/wiki/Vandenberg_Air_Force_Base

The swiss company Wild-Herbrugg (now Leica Geosystems) which was involved in Timation and B612 as well, received among others a contract to produce user equipment for GPS Block I in 1974.[26]

The Nuclear Weapon Non-Proliferation Treaty that got implemented on an international level in 1970 marked another step towards international relaxation. Parallel to general efforts in lowering the intensity of the cold war, US-President Ronald Reagan (in office 1981-1989) also pursued the Strategic Defense Initiative (SDI), also known as Star Wars, where satellite based weapons are intended to destroy intercontinental nuclear weapons. On a more technical level both political developments are reflected by the inclusion of nuclear detection sensors onboard of the GPS satellites starting in 1980. They were capable of detecting nuclear explosion and providing data to estimate the caused damage.[27]

Still the GPS program experienced setbacks. One hindrance was rooted in monetary funding which was segmented between several military services, especially as GPS was a military system of second order – rather a supporting system than an attacking system. „Because GPS is a support system and not a standard weapon system with a clear mission and a history of well-defined operational concepts, early understanding of the value of the system was less straightforward than with tanks or aircraft.“[28] From 1979 -1982 the Office of the Secretary of Defense (OSD) restructures funding which leads to a cut of $500 Million, resulting in a constellation of 18 instead of 24 formerly designated satellites.

In the same period, the Soviet Union started to launch their satellites for the GLONASS system. On October, 12 1982, the GLONASS I satellite was put in orbit, and the first experiments with the new system where conducted.[29]

Following this period of restructuring, in June 28, 1983 the US Defense Department announces a groundbreaking policy change for the NAVSTAR system, which would allow civil users to use the Standard Positioning Service with an accuracy of 100 meter and 95% maximum horizontal error. The change was introduced after an agreement between a study panel of several US governmental organisations: Office of the Secretary of Defense (OSD), Office of the Joint Chiefs of Staff (JCS), Defense Mapping Agency (DMA), branches of the Armed Forces and intelligence services. The panel also agreed to include an option where the preciseness could be degraded if necessary, the Selected Availability[30], an option which was used for instance during the first Gulf war in 1991.
On the political stage this future policy decision receives international recognition following the Soviet downing of the Korean Air Flight KAL-007 in August 31, 1983, which in the official statements was „mistaken as an reconnaissance flight“ by the Soviet Union. It stayed nebulous until 8 years later, what caused the Korean Air Flight to cross Soviet territory and why Soviet air jet pilots shoot down the civilian aircraft with 269 people on board.

> „The 'official' resolution of the puzzle came in 1991 when the hitherto-concealed voice and data recorders were released by Moscow, confirming the original professional accident investigation

---

[26] Dedual
[27] The sensors on GPS Satellites had their predecessors in the Vela program which provided satellite based nuclear explosion detection following the Limited Nuclear Test Ban Treaty, signed be the USA and USSR in 1963.
[28] Pace 1995, p 243
[29] It was planned to get GLONASS into full operation in 1991 but due to the political changes and instable funding in the early 1990s it took until 1996 until the system was fully operable.
[30] c.f. Beadles, Selected Availability was turned of in 2000 to enforce the strong growth of GPS in the civil sector.

judgments that overconfident carelessness allowed a simple navigation error to go undetected. The Soviet failure to properly attempt communication with the crew, and their urgency to stop the flight as it was passing out of Soviet airspace led to this tragedy." (Wikipedia, Korean Air Flight 007)

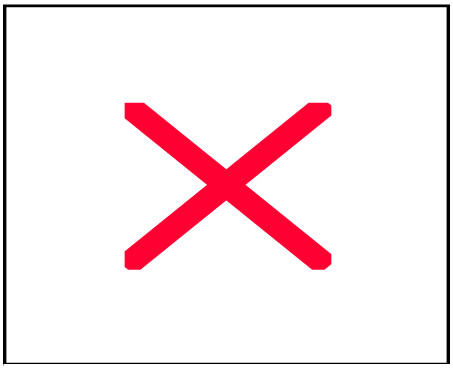
Two weeks after the incident the White House in Washington issued a press release stating:

„… World opinion is united in its determination that this awful tragedy must not be repeated. As a contribution to the achievement of this objective, the President has determined that the United States is prepared to make available to civilian aircraft the facilities of its Global Positioning System when it becomes operational in 1988. This system will provide civilian airliners three-dimensional positional information." (Speakes, 1983)

Some sources suggest, that Reagan announced the decision to make GPS available to a general public under the impression of the Korean Airflight incident. It is obvious that in the context of the interagency meeting in June 28 this public announcement is the culmination of a longer process of internal GPS policy discussion. Still this announcement was a clear statement for GPS military and non-military use and thus overthrew the issues of under-financing that went crucial in the years before.

Block II and IIA

Rockwell International was contracted in 1983, the year when President Reagan announced the civil availability of GPS in 1988, to produce 28 second-generation NAVSTARs. Of the 9 Block II satellites ($ 50 million each) and 19 IIA satellites ($ 40 million each) there would be 21 working in orbit, 3 were planned as working spares in orbit and 4 spares were aquired to be launched on demand, replacing aging satellites.



Img. 5: Space Shuttle Challenger explodes shortly after take-off. © bv NASA

But a major setback for the overall schedule occurred in early 1986, when the Space Shuttle Challenger and its 7-member crew were lost due to a launch failure. This tragical event led to a three-year delay because in the beginning of the 1980s the design of NAVSTAR GPS Satellites got adapted to be launched with the Space Shuttle, a decision that had to be reversed after the 1986 Challenger accident. The satellites had to be adapted to be launched with the Atlas 6000 booster, which lead to a 3 years break in launching NAVSTAR Satellites. The first Block II Satellite, a refurbished Block I satellite, produced by Rockwell International (now Arvin Meritor)[31] was only launched on February 14, 1989.[32] Block IIA satellites

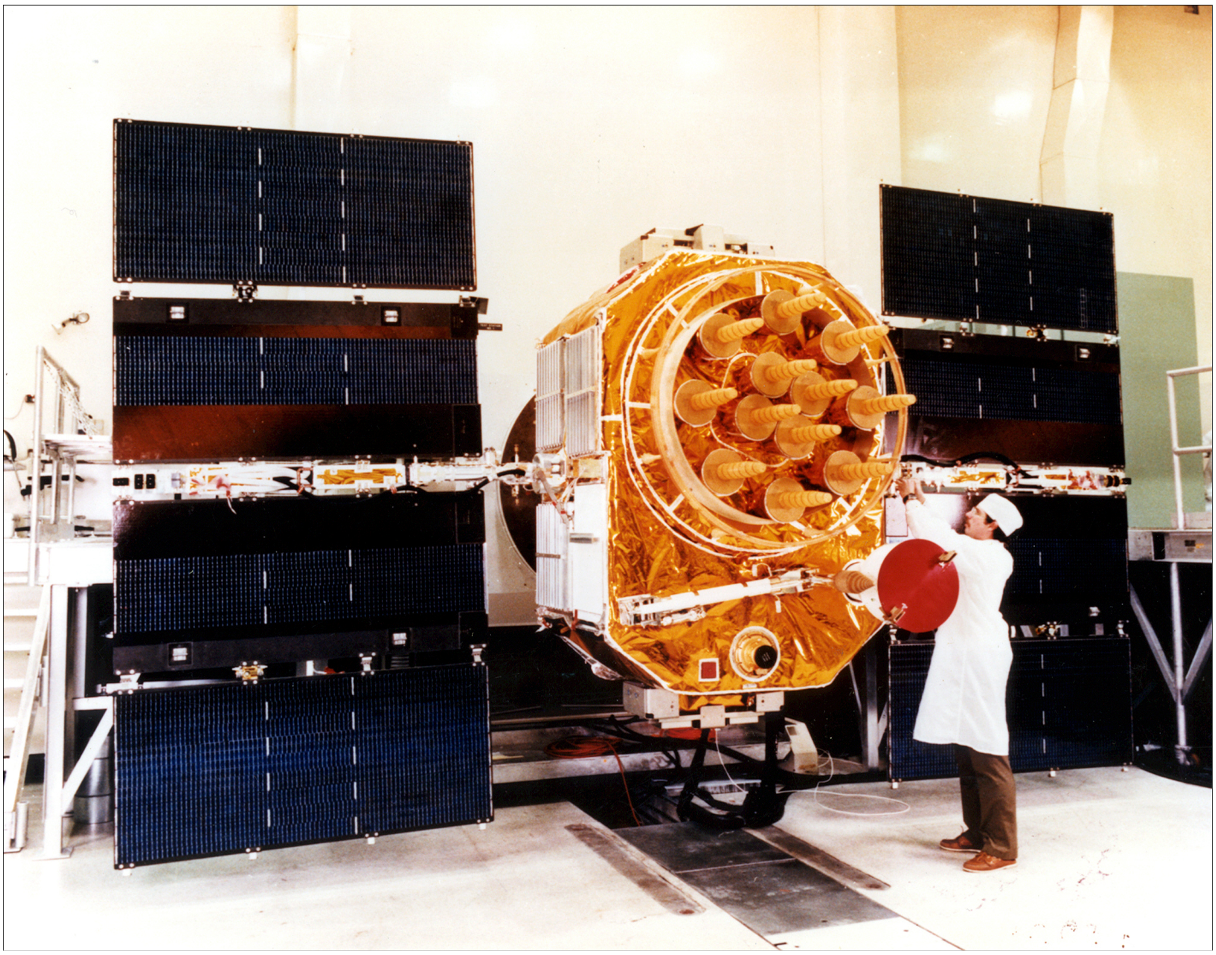
In November 6, 1997, the final Block IIA satellite was successfully launched, completing the envisioned GPS constellation of 24 satellites (21 working + 3 spares in orbit).

[31] c.f. http://en.wikipedia.org/wiki/Rockwell_International

[32] From nowadays perspective it would be quite interesting to discuss, in how much the prestige project of the Space Shuttle has slowed down technological development.

Block IIR

1997 July 23 - USA 132. Spacecraft: GPS Block 2R. Mass: 2,030 kg (4,470 lb). Launch Site: Cape Canaveral. Launch Vehicle: Delta 7000.
http://www.astronautix.com/project/navstar.htm



Img. 6: GPS Block II, © United States Air Force

Dual use: maturing the civil and military use

In 1985 The Joint Program Office (JPO)[33] as the specific organization responsible for program coordination and acquisitions contracted Rockwell Collins, a subsidiary of Rockwell International, to research, develop and optionally produce GPS user equipment. One of the first portable GPS units available to soldiers in the field was the "PSN-8 Manpack" receiver. About 1400 PSN-8 were manufactured between 1988 and 1993, for $40.000 - $45.000 per

[33] "The JPO oversees launches, completes on-orbit checkouts, and then transfers systems over to the USAF Space Command for operation. From that point, the Space Warfare Center (SWC) at Schriever AFB, Colorado plays a major role in fully integrating space systems into the operational Air Force. From that point, the 2nd Space Operations Squadron operates and maintains the GPS constellation and the ground support systems." (Federal Aviation Administration).

unit.[34] Similar receivers were in use for helicopters (AN/ASN-149), vessels (AN/WRN-6) and aircrafts (MAGR).

In 1985 the Swiss company Wild-Heerbrugg developed the full range of military Phase II GPS user equipment und in parallel also some of the first commercially available GPS receivers.[35]

The US Army Space Institute[36] describes the futher developments in the publication *Army Space Reference*:

> „From September 1989 through July 1990, the Army Space Command, assisted by the U.S. Army Space Institute, conducted demonstrations of the capabilities of GPS receivers through the Army Space Demonstration Program. Approximately 400 Small Lightweight GPS Receivers (SLGRs) were temporarily issued to a variety of tactical units for their use during normal tactical training at Fort Irwin, CA; Fort Chaffee, AR; Grafenwöhr, GE; Korea and other locations. These were not formal tests of the SLGRs but rather opportunities for tactical units to use GPS during their normal tactical operations. […] GPS receivers had never before been used in such a high density in as many tactical units. Valuable operational experience was gained through this portion of the Army Space Demonstration Program […]. (US Army Space Institute, 1993)

After the DoD requested the civil Departement of Transportation in 1997 to assume responsibility for the needs of civil users, the US Coast Guard establishes itself in 1989 as lead agency and contact point for civilian issues regarding GPS. This decision basically reflects that the most common use of civil navigation systems could be found in commercial logistics navigation, which used the Loran-C[37] system until the advent of GPS.

> Following Iraq's invasion of Kuwait in August 1990, many of the units which had participated in the Army Space Demonstration Program were deployed to Saudi Arabia. These units, and others which had learned of GPS's capabilities, immediately requested GPS receivers be issued to them. The Army Space Command collected more than 500 SLGRs and provided them to many of the deploying units. In addition, 377 AN/PSN-8's, 170 AN/PSN-9's were also deployed. Demand far exceeded the number of available sets, therefore the Army, through the GPS JPO, purchased about 7,500 more Trimpacks from Trimble Navigation and about 1,000 NavPro 1000M receivers from Magellan Systems. Since these sets had to be built, shipped to the theater of operations and then distributed, only slightly more than half were delivered to users before the end of hostilities.
>
> The original NavPro 1000M is a single channel C/A-code GPS receiver capable of providing only SPS. The set can be powered by AA size batteries or through a vehicle power adaptor. Later models have 2-channels. About 1,000 of these sets were purchased for the Army for use during Operation DESERT STORM. (US Army Space Institute 1993)

---

[34] The AN/PSN-8 Manpack GPS receiver is a 1-channel PPS set that weighs about 17 lbs. The set is commonly called the Rockwell-Collins manpack, in reference to the manufacturer. It is designed to be carried on a rucksack frame. A cryptographic code can be loaded into the set, thus giving it the capability to provide PPS. The AN/VSN-8 is the vehicular version of the AN/PSN-8. There are 247 of these receivers in the Army. (US Army Space Institute, 1993)

[35] Dedual

[36] The Army Space Institute was created to Army Space Institute to direct the Army's work with Advanced Communications Technology Satellites. It is situated at Ft. Leavenworth, Sheridan Drive, Leavenworth, Kansas

[37] c.f. http://en.wikipedia.org/wiki/LORAN

1993
May 27 - DoD and DoT issue a press release announcing a joint study group chartered to investigate management issues of NAVSTAR system.

July 9 - U.S. Federal Aviation Administration approves use of GPS by civil operators.

December 8 - Secretary of Defense Les Aspin sends a letter to Secretary of Transportation Les Pena that Navstar system has achieved Initial Operational Capacity (IOC).

December 21 - Joint DoD/DoT task force releases issues a press release stating that NAVSTAR system should be jointly managed. Statement is based on increasing civilian use of the system.

"NAVSTAR GPS played a key role and has many applications in all functional war-fighting areas. Land navigation was the biggest beneficiary, giving Coalition forces a major advantage over the Iraqis." (Dept. of Defense Report to Congress, "Conduct of the Persian Gulf War," Vol II, April 1992)

"GPS was a godsend for ground troops traversing the desert, especially in the frequent sandstorms....Tanks crews and drivers of all sorts of vehicles swore by the system. Meal trucks were equipped with GPS receivers to enable drivers to find and feed soldiers of frontline units widely dispersed among the dunes." (Air Force Magazine, Aug 91, pp. 35)

"The Kuwait war was the first combat use of the system, and it was hugely successful. It made possible all the big night manoeuvres that in the past would have required numerous scouts and guides along the routes of advance. GPS can be switched to coded transmissions that can be used only by special receivers. In the event, not enough special receivers were available, so the GPS network could not be switched to the coded mode. That meant anyone, including the Iraqis, who had a standard GPS receiver (which is widely available commercially) could use GPS to find his own position. Considerable publicity was given to this apparent lapse in U.S. equipment, but it made little difference, since the GPS itself does not give away the positions of attackers.

GPS made it possible for the attackers to shift their attack plans back and forth virtually up to the moment of attack, since forces using it had no need for fixed markers on the ground. The marines reported that they kept aadjusting their breaching point as they received fresh intelligence of Iraqi positions, and as the Iraqis moved their forces." --From: "Desert Victory - The War for Kuwait" by Norman Friedman Naval Institute Press 1991.

1994
February 17 - FAA announces that GPS is now operational and is an integrated part of US air traffic control system.

July 1 -U.S. Coast Guard's Navigation Center (NAVCEN) is commissioned. Event is announced in a press release issued on June 23.

July 17 - U.S. Air Force issues a press release announcing that NAVSTAR system officially reaches full operational capability.

New material: http://www.gpsinventor.com/?page=memoir

http://www.nrl.navy.mil/media/news-releases/2010/father-of-gps-and-pioneer-of-satellite-telemetry-and-timing-inducted-into-national-inventors-hall-of-fame

http://books.google.de/books?id=l_OPEUEg2MwC&pg=PA179&lpg=PA179&dq=apl+navy+gps&source=bl&ots=FgpW1N3Szi&sig=d1-m4XKVcf_lZVJvQ8OfDlZbTIY&hl=de&sa=X&ei=r1l8UOSjD8XPsgb7s4HYAg&ved=0CFEQ6AEwBTgK

Bibliography

Australian Broadcast Cooperation, 1999: „The Lunar Module Computer“, http://www.abc.net.au/science/moon/computer.htm

Beadles, Johns T.: GPS Timeline, http://www.redsword.com/GPS/apps/general/timeline.htm, 1995-1998

Ceruzzi

Dedual, Juerg: Milestones of technology, http://www.wild-heerbrugg.com/milestones_of_technology.htm, abgerufen am 12.10.06

Dickson

Easton, Richard 2006: Who invented the Global Positioning System? The Space Review, May 22, 2006, http://www.thespacereview.com/article/626/1

Federal Aviation Administration: Joint Program Office, http://gps.faa.gov/gpsbasics/JPO-text.htm, accessed June 11, 2006

Guier, William H./ Weiffenbach: The early days of Sputnik, http://sd-www.jhuapl.edu/Transit/sputnik.html

Guier, William H./ Weiffenbach, George C. 1998: Genesis of satellite navigation. the Johnss Hopkins APL Technical Digest, January-March 1998, Volume 19, Number 1, Reprinted from the Johnss Hopkins APL Technical Digest 18(2), 178–181 (1997). http://techdigest.jhuapl.edu/td1901/index.htm

Krebs, Dirk 2005: SECOR 1 … 13, http://space.skyrocket.de/doc_sdat/secor-1.htm

McDougall

Pace et. al. 1995: Global Positioning System. RAND Corp 1995

Storm, Steven R: Interview with Dr. Ivan Getting, 2001, http://www.aero.org/corporation/getting.html

Strom, Steven A: Charting a course towards global navigation, Crosslink, 2002, http://www.aero.org/publications/crosslink/summer2002/01.htm

Wikipedia contributors: Korean Air Flight 007, Wikipedia, The Free Encyclopedia, http://en.wikipedia.org/w/index.php?title=Korean_Air_Flight_007&oldid=29020071, accessed November 27, 2005

Speakes, Larry M.: Statement by Deputy Press Secretary Speakes on the Soviet Attack on a Korean Civilian Airliner, Ronald Reagan Presidential Archive, 16.9.1983, 12:30, http://www.reagan.utexas.edu/archives/speeches/1983/91683c.htm

US Army Space Institute 1993: US Army Space Reference Text, Fort Leavenworth, KS, July 1993, chapt. 7, sect. 3, cited after http://www.fas.org/spp/military/docops/army/ref_text/chap07c.htm, accessed 12.6.2006

One of the most comprehensive biliograhpies (until 1995) can be found in Pace et. al.1995.

Unused image material

provided by George W. Bradley III

George W. Bradley III
Command Historian
HQ AFSPC
DSN 692-3081
Com (719) 554-3081
FAX DSN 692-5168
FAX Com (719) 554-5168