Pre GPS History of Satellite Navigation

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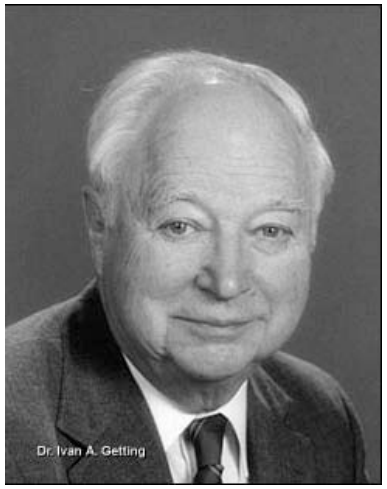
- What Does
  - The Slovakian independence movement of 1918
  - Development of RADAR
  - Nixon being elected to the second term in the White House

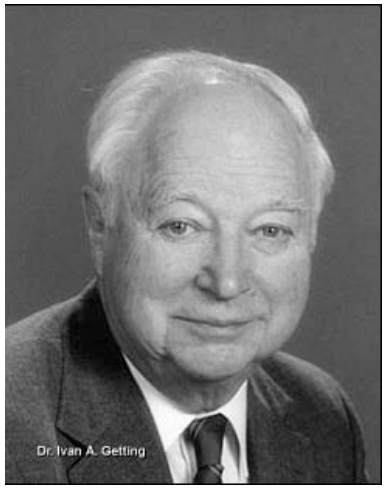
Have to do with GPS

Dr. Getting



- Born in 1912
- Parents ran a newspaper and fought for Slovakian independence
  - Frequently invited political figures into their home for night long strategy sessions
  - When independence was declared his father assume a role in the new government and move the family back to Europe
  - Independence didn't last long and the family returned to the US
- Showed technical prowess- Was his states entry into the search for next Edison – he lost

Dr. Getting



- At the start of the depression was given a scholarship to MIT
  - The scholarship soon ended and he paid his way through MIT by sleeping in a basement firing a coal furnace at night
- His academics got him a full ride to Cambridge
- At Cambridge he met with likes of Compton and others that worked on the English RADAR team
- When he returned to the States, war was breaking out and he was employed at MIT radiation Lab
- His Boss at the Radiation lab was Lee DuBridge

The First Step

- In 1957 the Navy started the Fleet Ballistic Missile program known as Polaris which:
  - Had to work in a salt vapor environment
  - Required an accurate position at time of launch or it could not accurately hit its target.
- The solution to the accurate position problem was to use an INS that was periodically updated by a star tracker fix
  - The proposed stellar update method would require a submarine to surface which could possibly compromise the sub position
- Another solution was needed

The Sputnik Influnce

- The answer to accurate position problem came with the launch of Sputnik in October of 1957.
- Two researchers at John Hopkins Applied Physics Laboratory (APL), by the names of Dr. William H. Guier and Dr. George C. Wieffenbach, "were struck by the predictable but dramatic Doppler frequency shift of the received radio signals"
- Guier & Wieffenbach shared there findings with Dr. Frank T. McClure developed application of determining one's position from observing Sputnik's Doppler frequency shift
- Dr. McClure suggested to APL's Polaris Support Division that this Doppler shift method could be used to update the INS solving the accurate position requirement.
- The head of the Polaris support division was Dr. Richard B. Kershner, assembled a team to study the concept which turned into an unsolicited proposal to the Navy. The proposal had four simple goals:
  - Develop the space hardware
  - Develop the ground support network
  - Develop the user equipment
  - Learn to determine and predict satellite orbit parameters with sufficient accuracy

Navy Navigation Satellite System or TRANSIT

At the Pentagon, Richard Kershner explains the workings of the Transit Navigational System, on the day its first satellite is launched into orbit.

- With goals in hand, "Dr. Kershner assembled a small team of highly skilled and highly motivated professionals who conceived, developed and tested Transit is (sic) an atmosphere mostly free of bureaucratic interface".
- Dr. Kershner personal and technical leadership, aided by an exceptional ability to communicate complex ideas in an understandable way, inspired his team to excel".
- Other major accomplishments of this team was
  - The delivery of the first test satellite in seven months after award
  - First launch two months later
  - Operational status of Transit system in five years.
- The accuracy was in the 15 to 25 meter range if the user had zero velocity component

SECOR (Sequential Collation of Range)

- Army Map Service contracted with Cubic Corporation to build the system
- System consisted of a satellite and 4 ground stations
- Accuracy of 30 meter was achieved with 10 meter goal
- Four ground stations were US based: Austin, Bolder, Las Cruces, Twin
- Theory of operation: Master ground station transmitted modulated 421MHz a signal to the satellite that would retransmit it back to the ground at 224.5MHz and 449MHz

The Second Step - MOSAIC

- In the fall of 1960 a Request for Proposal (RFP) was announced for the Mobile Railroad Minuteman Program.
- Raytheon responded to the RFP and it's proposal contained a method that did not require the exact location of the launch point to be known but would constantly derive it, This feature was called MOSAIC
  - MOSAIC was the developed by Raytheon as a means to enter the ICBM guidance market.
  - MOSAIC missile would contain a receiver that would make use of time difference of arrival from four land base transmitters to determine its location in three dimensions.
- Prior to the release of the RFP, Raytheon presented the MOSAIC concept to a group of AF officials on the 11th of May 1960. Shep Arkin and Dr. Ivan Getting. Dr. Ivan Getting gave the presentation.
- The MOSAIC concept made use of time difference of arrival to determine 3D position which was championed by Dr. Ivan Getting.
- Ivan Getting at that time was Vice President of Engineering and research at Raytheon.

Mobile System for Accurate ICBM Control (MOSAIC)

- The Mobile Railroad Minuteman Program was never awarded due to concern that it would spur on the arms race.
- The AF did not pursue the MOSAIC concept further deciding that inertial base guidance system is adequate for its land base missiles.
- One person that attended the 11th of May 1960 MOSAIC briefing was Joe Charyk, then Undersecretary of the AF.
- Dr. Getting had an illustrious career up to that point and soon after that meeting he would start another
- Joe Charyk offered Dr. Getting the job as first President of Aerospace Corporation.
- This act set the wheels of GPS in motion.

TIMe and navigATION (Timation)

- There was another Satellite Navigation effort underway in the NAVY called Timation
- This effort was led by Dr. Roger Easton at the Naval Research Laboratory
- “to explore the idea of providing both accurate position and precise time to passive terrestrial observers”.
- The concept the NRL explored was based on atomic clocks and ranging to a satellite.
- Timation employed a Side Tone Ranging Technique (STR).

TIMe and navigATION (Timation)

- Side Tone Ranging Technique (STR).
  - STR was not a modulation technique but a set of Continuous Wave (CW) sub-carriers space by tone frequencies.
  - This technique required the user and the satellite to be phase and frequency synchronized so that precise measurement of time of transmission could be made.
  - This concept was validated in Texas in 1964 along with the effort to build a small space qualified atomic clock.
  - Airborne experiments of the system were conducted in 1965
  - First space experiment was in 1967 and it was called TIMATION I, which showed that STR was a viable ranging technique.
- RCA (builder of the TRANSIT) did a study that showed that a STR combination with the proven Doppler method would provide near instantaneous positioning with a single satellite.
- The RCA study assumed four satellites distributed in a medium altitude orbit with the clocks synchronized to a master clock. The altitude to be chosen turned out to be dependant on the accuracy of the clock flown.

Project 57

- Dr. Getting tasked the newly formed Aerospace Corporation with Project 75 and 57 in 1963
  - Project 75 was to see what missile potential in 1975
  - Project 57 was to see what military potential could be achieved by new technology especially space technology
- Dr. Diamond carried out a portion of Project 57 that determine a need to position tactical aircraft with an accuracy of 50 ft and that a space base system could do the job.
  - This was two orders of magnitude better then Transit
- In October of 1963 that Air Force requested aerospace to continue studying the space based system to determine aircraft position
- By 1966 Aerospace completed all the preliminary work and two contracts were awarded in 1967 to TRW and Hughes to develop the space based system now called 621b

621B

- The satellite constellation was to be between 12 and 16 satellites
- The satellites were to fly at GEO altitude in clusters of 3 or four
- One satellite was to be at synchronous and the others were to “appear to be circling the synchronous one”
- 621b Attributes:
  - Wide area or global coverage
  - Continuous availability
  - 3D and Accurate velocity fixes
  - Useable on rapid maneuvering vehicles
  - No radiation from users – no system saturation

Navigation Satellite Executive Group (NAVSEG)

- Three competing systems caused the Government to form the Navigation Satellite Executive Group (NAVSEG)
- All three military services were represented on the NAVSEG
- Navy used it to advocate an enhance form of TRANSITs.
- No unified position was derived from these meetings but they did agree to work on space demonstrations of proposed 3D NAV systems.
- This agreement resulted in the flight of Timation II in 1969 and later the NTS series.

Dr. Getting act I

- In 1969, A Space Task Group (STG) was formed to suggest a post Apollo path for NASA.
- Dr. Getting tried to use his chairmanship on one of the technical subcommittees of STG to insert the need for space base navigation for both military and civil users as part of the final recommendation. Vice president Agnew did not select the navigation need but instead decided that the shuttle and the space station was the best choice for NASA after the Moonwalk.
- Dr Getting was not discourage by Agnew's disapproval and decided to present it directly to the White House. Dr. Getting's old boss Lee DuBridge from MIT's Radiation Lab. Lee was President Nixon's science advisor. Dr. Getting had the meeting and rendered the opinion that if he could find a sponsor with a need and the money then he could proceed with the program.
- Some would take this response as a polite way to decline the offer but Dr. Getting took this as permission to actively solicit support for space base navigation for both military and civil users.

Dr. Getting act II

- One of the functions the president of aerospace performs is to serve a majority of boards. One of the boards was the DoD Scientific Advisory Board(SAB)
- In the SAB Charter you find the line

  "SAB is to provide independent wisdom and insight to the Air Force senior leadership on science and technology for continued air and space dominance"
- On this Board is the Assistant Secretary of the AF for RD, Deputy of the Chief of Staff R and D, the commander of Systems Command and many other officers.
- Dr. Getting use this board to solicit support for GPS. In his book he states: "if GPS was not brought up as a solution to the appropriate mission, I brought it up" further more "GPS became subconsciously recognized as the solution to many of the AF problems".

Defense Navigation Satellite System - Nov. 1972

- Col. Parkinson was assigned as the Director of the Defense Navigation Satellite System (DNSS) in November of 1972. Dr. Getting in his book recounts that he was present during the first meeting between Gen. Schultz and Col. Parkinson. He did what he was instructed to; develop one concept from the three existing concepts. As you can see in the following passage from the interview that he was not given a free reign

"I initially spent perhaps three or four months digging deeply into the three existing concepts, technology, advantages and disadvantages. Meanwhile, I was getting enormous pressure from the Air Force, and in particular from the Aerospace Corporation contingent, to support the Air Force's version of 621B. By this time I'd already formed an opinion 621B was not the optimum system-that some aspects of the competitors were good features."[1]

[1] Bradford Parkinson, Electrical Engineer, an oral history conducted in 1999 by Michael N. Geselowitz, IEEE History Center, Rutgers University, New Brunswick, NJ, USA.

Dr. Malcolm Currie

- Dr. Currie started his career with Hughes Irvine
  - His positions ranged from Engineer to Vice President and Manager of the Engineering Division
  - As Vice President and Manager of the Engineering Division of the Hughes Aerospace Group, he was responsible for the development of airborne radar, electronic and sensor subsystems for communications satellites and spacecraft, and electro-optical systems including the first imaging infrared and laser systems
- He next worked as Vice President of Research/Development and Corporate Planning for Beckman Instruments located in Irvine
- Nixon administration selected, as one of it second term appointees, Dr. Currie as the Undersecretary of Defense Research and Engineering.
  - This appointment was the third highest post in the Department of Defense.
  - He was responsible for planning, managing, and guiding through Congress the weapons acquisition program of the Defense Department, from basic research through engineering development and production decision.
  - He did not like the Washington scene and spent a lot of his time at LAAFB being briefed by individual working space programs
  - One persons he spent a lot of time is with is with Col. Parkinson and developed a good relationship

The First Reshaping event - Black Thursday

- Up until now all three navigation concepts were being promoted. With the appointment of Col. Parkinson the decision was made to seek Defense System Acquisition Review Council approval of the AF 621B program.
- The Defense System Acquisition Review Council 621B meeting was scheduled for August of 1973.
- This was the first of two crucial meetings that morphed 621B concept to the GPS system we know today.
- One would think with an AF general being told that the AF was responsible for developing a single concept and with the support of Dr. Currie that whatever Col. Parkinson presented would be accepted.
- That DSARC meeting is referred to as Black Thursday and as the name implies it did not go as plan.

The Second Reshaping event - Labor Day 1973

- In a Labor Day meeting the best of all three systems were combined into the GPS system but they did not solicit help outside the AF for this meeting.
- With a design concept in hand, Col. Parkinson now had to get the Navy and the Army to buy into the design.
  - In a concession to the Navy he used their clocks and relied on them for orbit determination plus the satellites were placed at MEO.
  - To the army, he use their Yuma test range to validate the system instead of the AF ranges that were available.
- Col. Parkinson did such a good job of getting the Army and Navy to back his new design that Dr. Getting thought that he had given the program away.

A New Way

- With the "Labor Day" concept in hand, the next step was to make a fundamental change in the way the JPO was to execute

"Having finally sold the program concept, the next step was to sort out exactly how we were going to do it. We pioneered a number of new ideas. For example I never delegated system engineering or total system integration to a contractor. It was done internally, in house, by me and the Program Office people. Who were those Air Force officers with masters and Ph.D.s I mentioned before? Fortunately they had a lot of program experience. By retaining core Systems Engineering, we were separately contracting the pieces: the satellite, the ground segment, the user segment, and the test program"

A New Way sent up the flag pole

- **The use of the JPO to perform system integration functions was an unheard of concept. This concept was noted by Gen. Schultz and, in Col.. Parkinson's oral history noted that it almost got him fired.**

"I almost lost my job at one point because the officer I worked for, General Schultz, did not initially grasp how we could do the Systems Engineering. (Incidentally, he was an outstanding boss for me.) It happened one day when I was trying to tell him what my concept was. He got upset because he couldn't figure out how on Earth I could pull this off, how I could integrate all these pieces. I felt that it was essential. Unless I was at the center of the system engineering involved here, I didn't think I could pull it off either, because I knew the contractors would quickly close you out of all the essential decisions. Making the trades would be left to them on whatever motivation they had. Our motivation was quite pure; we wanted a system that worked and worked well. The near-firing happened at a meeting in which I was standing up making a presentation up on the ninth floor at the Space Systems Division. I had about half a dozen of my people in the room with General Schultz. I could tell he was getting very angry with me because he could not understand how this was all coming together. At the same time the essence of his problem was a mystery. Finally, I got it. Fortunately, I had a backup chart that showed the interface relationships between user equipment, the space segment, and the ground segment. It showed that these interfaces were fundamentally defined by signal structure in space, not defined by physical things, because that's how they interacted with one another. These interfaces I planned to manage directly. As soon as I showed this chart, General Schultz sat back in his chair, smiled, and nodded his head. That was the go ahead for us to contract for GPS in a relatively unusual way."

BLK I STARTS TO ROLL

- On December 22, 1973, the BLK I effort was authorized to develop 4 satellites, procure 4 Launch vehicles, develop a control segment, develop three types of user equipment and an extensive test program.
- Dr. Parkinson had a lot of opposition against GPS rooted throughout the AF. This opposition believed that the GPS concept would not work. He needed to quickly dissipate this opposition. An inverted range was developed with pseudolites on the ground acting as satellite on orbit. The pseudolites had space segment payloads that were use to validate the receivers that were either carried through or flown over Yuma.
- This was followed up with the launch of NTS II. NTS II carried a BLK I NAV payload as well as the NRL STR payload.
- As the JPO began to launch NAVSTARS the competing systems started to fade away.
  - NRL was resigned after the launch of NTS II to concentrate their efforts on a Cesium atomic clock replacement based on MASER technology.
  - Advance transit aspirations were crushed after meetings in which funds were transferred from the Navy to the JPO to procure the two additional satellites. In a single meeting, Col. Parkinson was able to convince the DoD that just two more GPS satellites could solve a Trident missile range need and provide a more robust test program.

Who is driving?

- In 1977 the initial driving forces behind GPS began to leave government service
  - Dr. Currie was not ask to continue under the Carter administration and he returned to the private sector.
  - Dr. Getting celebrated his 65th birthday and, as required by the policies he created forced him into retirement.
  - Dr. Parkinson had been with the program for 6 years, which is twice as long as one expect from a rising star, and he was offered an assignment in the Office of the Secretary of Defense. Dr. Parkinson decided to leave the military

Heading for the cliff

- **The GPS had detractors all along. Dr. Parkinson recants in his interview**

  "the Air Force never fully backed this system. They wanted it their way, but they didn't want to pay for it. It's sort of analogous to asking the richest person in the neighborhood to pay for the whole high school. That's how they viewed it. Here they were putting up a system, not just for DOD, but for all these civilians, and it was coming out of their Total Obligation Authority (TOA). They were not happy."

- **This view of the early times was echoed in Scott Pace's work**

  "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. This increased the need to sell the program, particularly to potential users. The JPO addressed this problem, especially during Phase I, by emphasizing one of the more tangible capabilities of the system: increased bombing accuracy. The fact that GPS was a joint program also increased the need to sell the program to multiple services. No one service was anxious to bear the entire financial load for a support system that was to be used by all services."

- **Without the guiding forces in place, one can only imagine that the GPS was not on solid ground.**

NUDET saves the day

- In 1978, the United States intended to become a signatory to the Comprehensive Test Ban Treaty.
  - Signing this treaty would require the United States to give up the right to test nuclear weapons and also the US needed a means to verify that other nations were complying with this treaty.
- This need happened at the same time that the DoD needed a means to detect nuclear weapon detonations, assess the detonations and determine the detonations strike damage.
- It was decided these requirements could best be met if the GPS satellites would carry a secondary payload composed of nuclear detonation (NUDET) sensors.
- The authorizing command for the GPS operational satellites came from the Strategic Air Command in 1979 and BLK II come of age.

Newborns have it rough

- Shortly after it was authorized, the Office of the Secretary of Defense (OSD) decided to reduce the FY81–FY86 planned expenditures by 30 percent ($500 million).
  - This forced the first restructure in which: satellite constellation size was cut from 24 to 18 satellites (plus three satellites serving as on-orbit spares)
  - Block II development satellites were dropped; and the design was scaled down in terms of weight, power, and nuclear and laser hardening
  - This reduction did not allow the system to achieved limited two-dimensional capability in 1981.
- Next year the AF leadership zeroed out 1980 funding for the program but the OSD reinstated the program.
- In 1982 the whole act was repeated again.
- In 1983 the budget battles subsided and BLK II production contacts were let and GPS was on its way

- What Does
  - The Slovakian independence movement of 1918
  - Development of RADAR
  - Nixion being elected to the second term in the White House

Have to do with GPS

Future Research Thrust

- Find the urinal in the Pentagon where GPS was adopted
- Find who attended and where the 1973 labor day meeting was held
- Get a copy of Aerospace 57 report that call out the need to determine the location of an aircraft to 50 ft.
- Find Dr. Currie
- Review Dr. Lee DuBridge files at Cal Tech to see if there is any meeting notes of the 1969 Getting meeting