

PRE HISTORY OF GPS

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REV B

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Frank Czopek

- Has worked Space and armor systems for all his career
- 35 years on GPS
 - Hired at the start of the GPS operational era
 - Held numerous jobs on GPS from Responsible Engineer to Program Manager
 - Unofficial GPS Space historian



WHAT YOU WILL LEARN

What Does the following have to do with GPS

The Slovakian independence movement of 1918

Development of RADAR

Nixon being elected to the second term in the White House

Sputnik

AC 130 Gunship

The significance of

A GPS satellite hosting a Nuclear Detection (NUDET) payload

Interface Control Document (ICD)

Why Raytheon claims to have invented GPS

The cast of Individuals who we need to thank

Dr. Ivan Getting



Dr. Ivan A. Getting

Born in 1912

Parents ran a newspaper and fought for Slovakian independence

Parents invited political figures into their home for night long strategy sessions

When Czechoslovakia independence was declared in 1918, his father assume a role in the new government and move the family back to Europe

Parents returned the family back to the US a few years later

Showed technical prowess, was his state's entry into the search for next Edison – he lost

Dr. Getting



Given a scholarship to MIT at the start of the depression

The scholarship soon ended and he paid his way through MIT by sleeping in a basement firing a coal furnace at night

Academics at MIT 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 found employment at MIT radiation Lab. MIT radiation Lab developed RADAR

His Boss at the MIT Radiation lab was Lee DuBridge

The Beginning

In 1957 the Navy started the Fleet Ballistic Missile program known as Polaris which:

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 – method proven on USS Nautilus

The proposed stellar update method would require a submarine to surface which could possibly compromise the sub position

Another solution was needed

The Sputnik Influence

Accurate position problem was solved with the launch of Sputnik (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 who then developed an 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 who assembled a team to study the concept which turned into an unsolicited proposal to the Navy.

The proposal had four simple goals:

1. Develop the space hardware
2. Develop the ground support network
3. Develop the user equipment
4. Learn to determine and predict satellite orbit parameters with sufficient accuracy

NNSS or TRANSIT



With contract in hand, Dr. Kershner developed and tested Transit in 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

Team's accomplishments

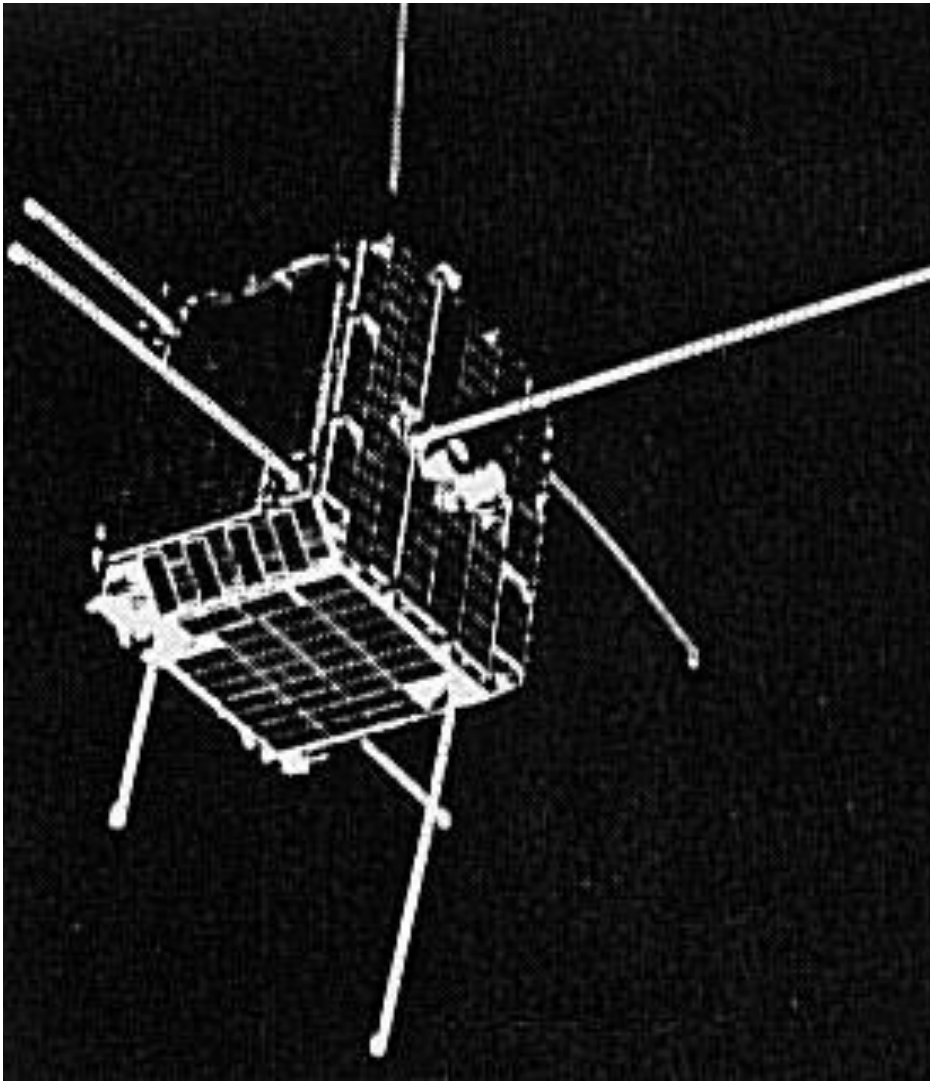
- The delivery of the first test satellite in seven months after award

- First launch two months later

- Operational status of Transit system achieved 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 needed a system to provide geodetic coordinates of a ground point located from 160 to 4800 kilometers from known geodetic positions.

SECOR was developed to meet this need

SECOR System consisted of a satellite and 4 ground stations

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

Army Map Service contracted with Cubic Corporation to build the system

Accuracy of 30 meter was achieved with 10 meter goal

MOSAIC

AF planned to issue a Request for Proposal (RFP) for the Mobile Railroad Minuteman Program in the fall of 1960.

CONOPS was that missile would travel to a predetermined location for launch

Dr. Getting at that time was Vice President of Engineering and research at Raytheon.

Raytheon started a research effort to respond to the RFP and thought the CONOPS suggested would make the system vulnerable

The MOSAIC concept place a MOSAIC receiver on the missile which listen to four continuous wave transmitters with known positions. The receiver made pseudo range measurements to the receivers to determine 3D position. MOSAIC was championed by Dr. Getting

They developed a method that would constantly derive the exact location of the launch point allowing the missile to stop any where, This feature was called Mobile System for Accurate ICBM Control (MOSAIC)

Raytheon presented the MOSAIC concept to a group of AF officials on the 11th of May 1960. Dr. Getting gave the presentation.

The First Step

The Mobile Railroad Minuteman Program was never awarded due to cost concerns (Silos cost less)

Silos use inertial base guidance systems, the MOSAIC concept was dropped

One person that attended the 11th of May 1960 MOSAIC briefing was Joe Charyk, then “Undersecretary of the AF” but was the first Director of the NRO

Joe Charyk offered Dr. Getting the job as first President of Aerospace Corporation. Dr. Getting accepted the job and moved to California

This act set the wheels of GPS in motion.

The “other” Navy Program – Timation

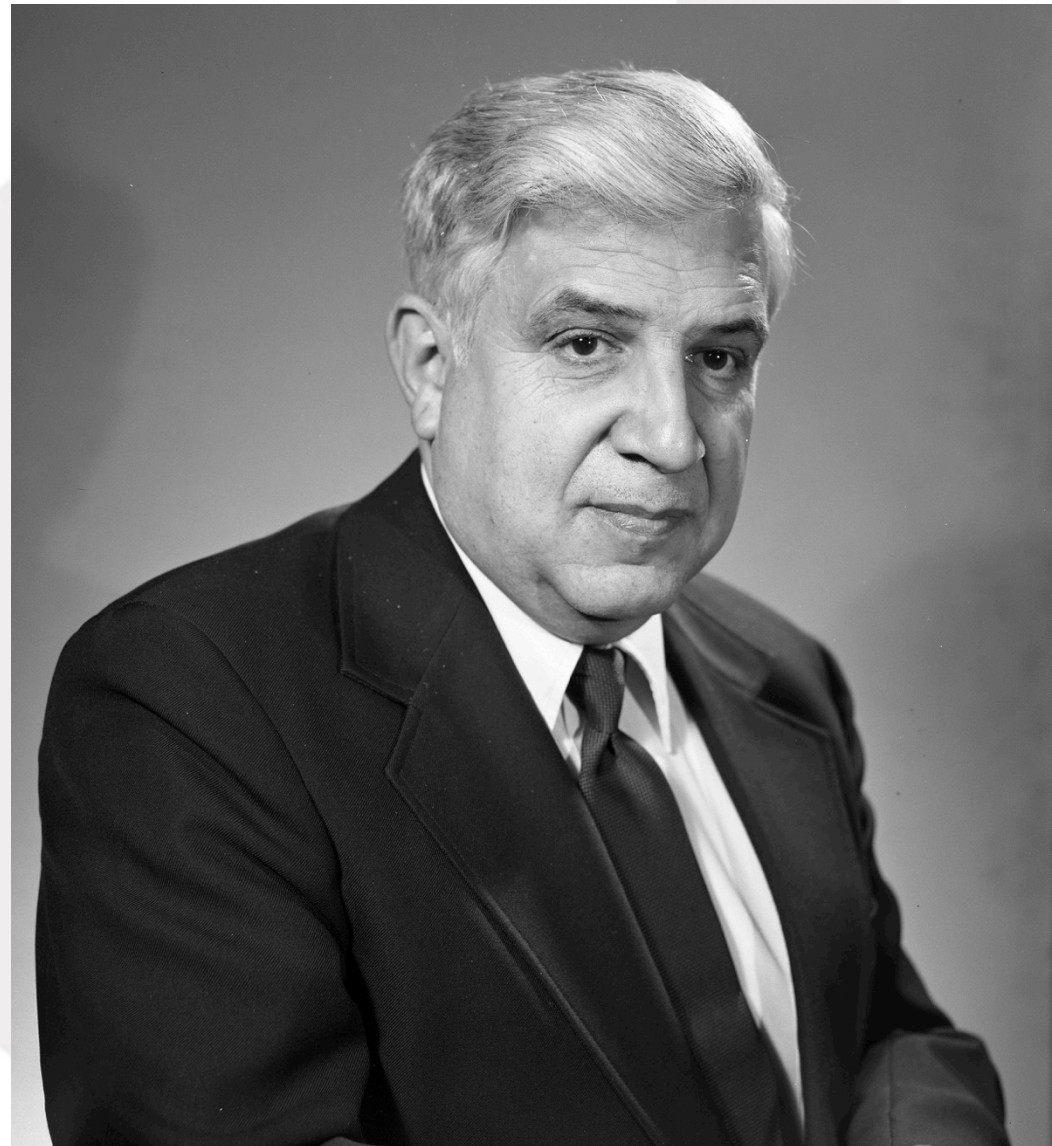
There was another Satellite Navigation effort underway at the Naval Research Laboratory called Timation (TIME and navigATION)

This effort was led by Dr. Roger Easton at the Naval Research Laboratory

The Vision was “to explore the idea of providing both accurate position and precise time to passive terrestrial observers”

The concept NRL explored was based on atomic clocks and ranging to a satellite

Timation employed a Side Tone Ranging Technique (STR)



STR Description and Analysis

Side Tone Ranging Technique (STR).

STR was not a modulation technique but a set of Continuous Wave (CW) sub-carriers spaced 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 dependent on the accuracy of the clock flown.

Back At Aerospace

Dr. Getting tasked the newly formed Aerospace Corporation with Project 75 and 57 in 1963

Project 75 was to see what would be the 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

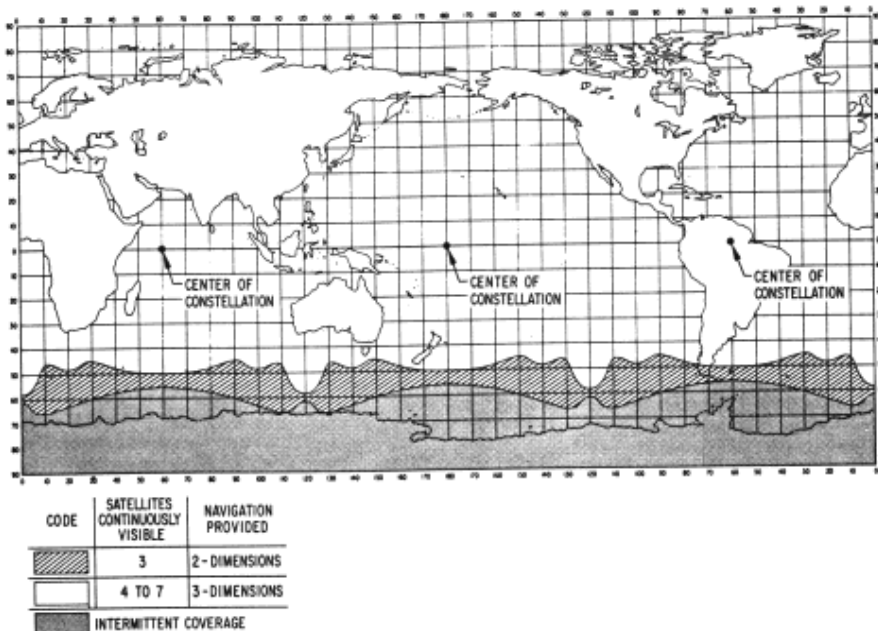
In October of 1963 that Air Force requested aerospace to continue studying the space based system to determine aircraft position

1966, Aerospace completed all the preliminary work

1967, two contracts were awarded to TRW and Hughes to develop the space based system now called 621b

621b

Coverage Analysis of the 621 constellation



The satellite constellation was to be between 12 and 16 satellites

The satellites were to fly at GEO altitude in clusters of 3 or 4

One satellite was to be at synchronous (GEO) orbit 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

Too Many NAV Systems

Office of the Secretary of Defense notice that budget request from various service branches contained Line Items for Space Based Navigation systems

They asked, How many NAV systems do we need?

That question caused the Office of the Secretary of Defense to form the Navigation Satellite Executive Group (NAVSEG) to sort out what to fund

All three military services were represented on the NAVSEG

Navy used it to advocate an enhance form of TRANSITs.

Because the of the outcome, NRL must have been in their pitching as well as the AF

No unified position was derived from these meetings but they did agree to work on space demonstrations of a proposed 3D NAV system.

This agreement resulted in the flight of Timation II in 1969 and later the Timation III/
NTS I

Mandate to Sell

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 discouraged by Agnew's disapproval and decided to present it directly to the White House. Lee DuBridge (MIT's Radiation Lab) was President Nixon's science advisor. Lee DuBridge took the meeting, listen to his arguments and rendered the opinion that if Getting could find a sponsor with a need and the money, 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.

Pushing the Concept

One of the functions the president of aerospace performs is to serve a various scientific boards. One of the boards was the DoD Scientific Advisory Board (SAB)

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 R&D, Deputy of the Chief of Staff R&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”.

* GPS did not exist at the time and I believe he was pushing for space base navigation system for both military and civil users

Dr. Brad Parkinson



Early life spent in Minnesota

Only child

Father attended MIT

BS U.S Naval Academy

MS MIT, studied controls engineering, inertial guidance, astronautics and electrical engineering

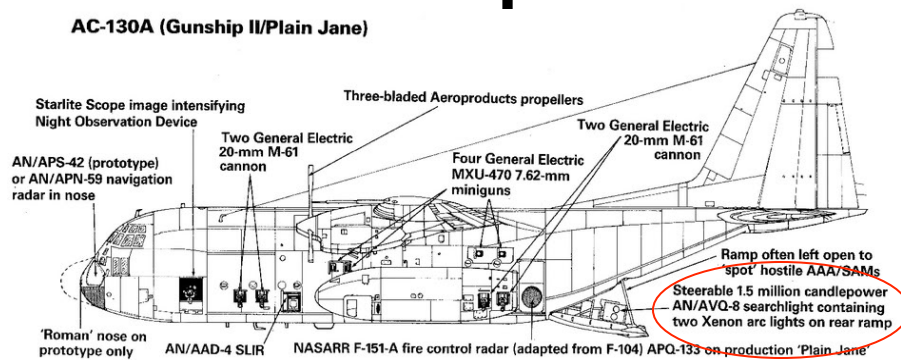
PhD Stanford in Aeronautics and Astronautics

As a Lt. Col, was assigned to USAFA as an orbits instructor but ended up on the Gunship program

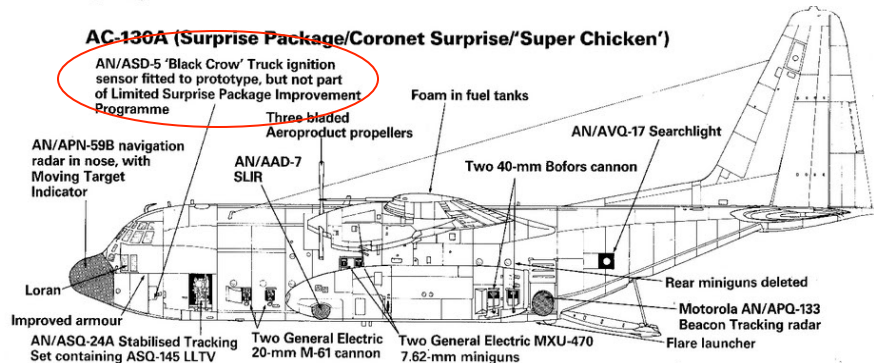
Gunship influence on GPS

Gunship II

AC-130A (Gunship II/Plain Jane)



AC-130A (Surprise Package/Coronet Surprise/'Super Chicken')



Surprise Package

Gunship Configurations

Gunship II was developed to hunt at night, added search light to ramp and retained 20mm guns

Surprise Package brought more fire power (40 mm), a "Black Crow truck ignition sensor" and was very effective at night but had many **problems**

Problems and Lessons Learned

PROBLEMS: erroneous computations, uncertain target storage, accidental memory "wipes," incorrect azimuth, wander of sensor input angles and fire-control issues caused by the Black Crow sensor tied into the system

PROBLEMS RESOLVED: In the summer of 1969 Aeronautical Systems Division personnel spent a great deal of time on the fire-control system malfunctions.

*"They went over the gunship carefully to discover and resolve the problems. Officers from the Air Force Academy's Department of Astronautics and Computer Science offered valuable assistance. **Lt. Col. Bradford W. Parkinson** and Maj. Richard E. Willes."

*From the history of the Gunship

Brad's Team did system engineering and integration for Gunship

An order came down to add LORAN to Gunship, maybe it taught Brad a thing or two

The order reflected the understanding that precise navigation was an absolute "**must**" for armed reconnaissance missions in Laos. As added advantages, loran provided target coordinates for later strikes by loran-equipped F-4D fighter bombers, accurately pinpointed radar sites, and assured strict adherence to rules of engagement. It served in addition as a cross-check for Surprise Package's inertial navigation/targeting subsystem, which generated accurate attitude and velocity inputs to the digital fire-control system computer and kept minimum positional error over the entire flight.

The loran set's cross-checking function was particularly valuable in light of the computer's sensitivity to variations in the aircraft electrical power, the changes that caused the system to be unreliable in storing targets and in generating synthetic azimuth."

Additional capabilities requires more crew

"With the increase of more sophisticated equipment (on Gunship), the pilot became overburdened with firing data while flying the aircraft. The new position-called "Mission Commander" and later "*Fire-Control Officer*"-became part of Surprise Package's crew when the gunship began combat operations. "

Brad flew 26 AC-130 missions, two as Mission Commander

Gunship Political Problems

Technically, Surprise Package was a better aircraft compared to other Gunships

Weekly summaries from the field showed another issue: Maintenance/Support

Surprise Package had poorer performance relative to AC-119K and AC-130A

Surprise Package's performance exacerbated long-standing, high-level debate in the Air Force on gunship limitations and the size and nature of the gunship force.

TAC opposed converting additional C-130 aircraft to gunships unless a "new buy" of C-130 aircraft was approved

In the end, limited numbers of new AC-130E were approved for the 70's in part due to the White House influence (Dr. Lee A. DuBridge)

Brad had a front seat to this battle and got his first taste of how Politics can drive a solution

Life After Gunship

Col. Parkinson was assigned to SAMSO

First Job was program manager to ABRES

His second was 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 was instructed to; develop one concept from the three existing concepts.

Brad has a different take of events from that same period of time

"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 and rose to Vice President and Manager of the Engineering Division Hughes Aerospace Group

In this position, 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 appointed Dr. Currie as the Undersecretary of Defense Research and Engineering for its second term

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 and spent a lot of time in the LA basin talking to various firms and organizations that he had control over. At LAAFB he was briefed on the full portfolio of space programs

One persons he spent a lot of time is with is with Col. Parkinson and developed a good relationship

The First Act - Black Thursday

Col. Parkinson had brief Dr. Currie extensively on 621b, through the spring and summer so decision was made to seek approval of the AF 621B program at the August 1973 Defense System Acquisition Review Council (DSARC) meeting.

This was the first of two crucial meetings that morphed 621B concept to the GPS system we know today.

That DSARC meeting is referred to as Black Thursday and as the name implies it did not go as plan.

They did not approve the 621B plan and told Brad to come back with something better!

The Second Act – Labor Day 1973

Brad called a Labor Day meeting with all stake holders to build a response to the DSARC mandate

At that meeting, the best of all three systems were combined into the GPS system but it was done by making deals

In a concessions to the Navy, they would use the NRL clocks, relied on them for orbit determination and the satellites were placed at MEO not LEO

To the Army, they used the 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 the new design that Dr. Getting thought that he had given the program away.

New Way Needed to Make it Work

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”

* Gunship influence

A New Way Sent Up the Flag Pole

The use of the JPO to perform system integration functions was an unheard of concept.

The briefing of the concept to Gen. Schultz is covered in Col. Parkinson's oral history, that briefing 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."

The Third Act – December 1973

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.

The authorization exposed a wall of opposition against GPS rooted throughout the AF who believed that the GPS concept would not work. He needed to quickly dissipate this opposition (Gunship political lesson).

The concept was validated on the Yuma inverted range which simulated all aspects of GPS

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 faded 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.

1977 – A Year of Change

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 A Cliff

The GPS still 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. 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 driving forces in place, one can only imagine that the GPS was not on solid ground.

NUDET is the reason we have GPS

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.

Lt. Col. A.H. (Howard) Hayden asked if GPS had room for a suite of nuclear detonation (NUDET) sensors .

After multiple studies, it was found that GPS was the ideal host (GPS atomic clocks and orbit).

The Operational Requirements Document (GPS Birth Certificate) was signed by Strategic Air Command in 1979 and BLK II comes of age.

Newborns have it rough

Office of the Secretary of Defense (OSD) decided to reduce the FY81–FY86 planned expenditures for GPS by 30 percent (\$500 million) which did not let the system 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

YOU HAVE LEARNED

The Slovakian independence movement of 1918

Gave Ivan the skill set to advocate relentlessly for 621b (GPS)

Development of RADAR

Brought Lee Dubridge into the story who gave Ivan the green light to advocate and was a white house ally (suspected due to Ivan & Gunship political battles)

Nixon being elected to the second term in the White House

Caused the appointment of Malcolm to the #3 person in the DoD, who then spent a lot of time with Brad going over all the plus and minus of the Pre-GPS system.
Suspected he recognize that GPS was best solution and advocated for it.

Sputnik

Caused a group of people at APL to solve the a Navy accurate position problem by a radio navigation method that required a space asset

YOU HAVE LEARNED

AC 130 Gunship

Showed the DoD world how good Brad was, taught Brad the benefit of precise NAV to a mission (LORAN addition to Gunship), taught Brad that the political solution beats the technical and needs to be address early in the program (inverted range) and laid the foundation for a new way to do business (*never delegated system engineering or total system integration*)

NDS payload

We would not be here today without it. Addition of the payload is what got the AF to approve the need which authorize the system.

ICDs

The glue that hold GPS together an showed the way to allow “a new way to do business ”

Why Raytheon claims to have invented GPS - NO

Future Research Thrust

Find who attended and where the 1973 labor day meeting was held
– Many articles have been published

Get a copy of Aerospace 57 report that call out the need to determine the location of an aircraft to 50 ft.

Not Going to happen, but please refer to the audio presentation of Dr. Diamond from the So. Cal ION section archives

Find Dr. Currie

Closed – Awarded the GPS Hall of Fame

Review Dr. Lee DuBridge files at Cal Tech to see if there is any meeting notes of the 1969 Getting meeting, Gunship battles and see if Brad is mention

Determine the influence of GPS on the CDMA cell phone technology