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Permanent Link to Part 1: The Origins of GPS, and the Pioneers Who Launched the System

2021/03/18

Part 1 of a Two-Part Story. Read Part 2 [here](#). Cover: GPS World By Bradford W. Parkinson and Stephen T. Powers, with Gaylord Green, Hugo Fruehauf, Brock Strom, Steve Gilbert, Walt Melton, Bill Huston, Ed Martin, James Spilker, Fran Natali, Joe Strada, Burt Glazer, Dick Schwartz, Tom Stansell, and others The original system study, the key innovations, and the forgotten heroes of the world's first — and still greatest — global navigation satellite system. True history, told by the people who made it. Part One of a Two-Part Special Feature. The stealth utility: over the past 30 years, a new entity has steadily and stealthily crept into the fabric of worldwide society, creating capabilities and dependencies that did not exist before. This utility is known as the Global Positioning System, or GPS. With more than a billion GPS receivers in use, this stunning achievement has truly revolutionized the way the world functions in the 21st century. Virtually every cell-phone system relies on GPS for timing. Almost every ship and aircraft carries multiple GPS receivers to provide positioning information. Other applications span military targeting, transportation, object tracking, and resource identification. Today, the loss of GPS signals would have catastrophic consequences. How did GPS come into being? What technologies were essential to its success? Who developed those technologies? Recently a number of GPS histories have appeared that are very inaccurate on these subjects. Our purpose in writing this account is to set the record straight, and in so doing to give credit to many of the original developers of GPS whose contributions have somehow been forgotten. Throughout this article you will find their names highlighted. Space does not permit us to name the many other individuals who deserve enormous credit for the subsequent refinement and invention of new GPS applications. Figure 1 gives a summary view of the history of U.S. satellite-based navigation, particularly GPS. Details of the Russian GLONASS and the European Galileo systems are not included as they arrived later, and generally mimicked the GPS development albeit with their

own, locally developed detailed designs. Figure 1. The eras of satellite navigation. (Credit: Bradford W. Parkinson and Stephen T. Powers) Dr. Richard Kershner, who led the development of Transit. On his left, young Col. Bradford Parkinson, who led the development of GPS. (Credit: Bradford W. Parkinson and Stephen T. Powers) This history focuses on the period up to about 1980, when GPS was approved for full-scale development. Between that time and the date that GPS was declared fully operational, April 27, 1995, many additional contributions were made. The system withstood several early attempts by the Air Force to cancel it entirely. Fortunately, those attempts did not succeed, and the Air Force now fully embraces GPS as an essential part of virtually every weapon system in the inventory. We call this a tribute to the almost-forgotten people whose intellectual labor and skill initially developed GPS. As we unveil this story, we will point out the original — and critical — system study, the 1966 Woodford/Nakamura Report, that became the essential blueprint for GPS. Many people are unaware of this study since, in its original form, it was classified U.S. Department of Defense (DoD) Secret. It was not declassified until August 1979, more than a year after the first launch of a GPS operational satellite in February 1978. We also intend to describe and justify the key innovation that enabled the system. This keystone technology is the GPS code-division multiple-access (CDMA) signal. While CDMA was necessary for GPS success, it was by no means sufficient. We will also define and describe the five major original challenges that had to be met to achieve the success that GPS now enjoys; that will come in the second installment of this history, to appear in next month's issue. Mathematician Bill Guier (l) and physicist George Weiffenbach (r), told APL Research Center director Frank T. McClure (c), about their success using Doppler tracking for satellites. "McClure's brain started going into fast forward," remembered John Dassoulas. "Knowing the navigational challenges the U.S. Navy faced, McClure said, 'Well, if you can find out where the satellite is, you ought to be able to turn that problem upside down and find out where you are.'" (Credit: Bradford W. Parkinson and Stephen T. Powers) GPS Predecessors: Transit On October 4, 1957, the entire world was amazed by the launch of Russia's Sputnik satellite. The American public greeted this event with both apprehension and curiosity. Both the Army and Navy had been quietly working on satellite projects for some years. In an attempt to catch up, the United States had a spectacular failed launch when the Naval Research Laboratory's (NRL's) TV-3 crashed on December 6, 1957. On January 31, 1958, the United States Army launched a grapefruit-sized satellite, Explorer 1. The NRL then achieved success with the launch of TV-4, renamed Vanguard-1, on March 27, 1958. In 1958, the Applied Physics Laboratory (APL) of Johns Hopkins University employed an extremely competent team of engineers and scientists. Two of those scientists, Drs. William Guier and George Weiffenbach, began to study the orbits of the new Sputnik satellites. The satellites were broadcasting a continuous tone signal. Their velocity relative to the ground created a Doppler shift of that signal that was unique. After some innovative work, Guier and Weiffenbach discovered they could determine the Sputnik's orbit with a single pass of the vehicle. At that point Frank McClure of APL made a very creative suggestion: Why not turn the problem upside down? Using a known satellite position, a navigator could determine his location anywhere in the world after receiving and processing the satellite signal for 15 minutes. His insight became the basis for the Navy's Transit satellite program, also known as the Navy

Navigation Satellite System (Figure 2). This pioneering system was developed under the leadership of Dr. Dick Kershner, head of the Space Department of APL. Transit's main purpose was to provide position updates to the United States submarine ballistic-missile force then under development. These submarines were a major deterrent during the Cold War. Transit was first tested in 1960, and by 1964 the system was fully operational. Under Kershner, APL rapidly mastered the art of building long-life satellites. In fact, two of the vehicles continued operation for more than 20 years. Figure 2. The Transit birdcage of operational orbits. (Credit: Bradford W. Parkinson and Stephen T. Powers) Transit was a relatively small satellite that initially used solar power and gravity-gradient stabilization (Figure 3). It provided a position fix every few hours; fixes took 10 to 16 minutes of exposure of the submarine's antenna on the surface. It achieved 25-meter accuracy, but only in two dimensions. Further, if the user was moving, accurate velocity measurement was critical: a 1-knot error would produce a 0.2-nautical mile position error. All Navy ships could use the system, and in 1967 Transit was offered to the civilian community by Vice President Hubert Humphrey. Magnavox became the principal developer of civil user sets with Tom Stansell as an early expert in the technology. Contributions to GPS. The Transit program developed a technique essential for GPS: the use of two frequencies to calibrate the time delay of the radio signal induced by the ionosphere. This dual-frequency technique was incorporated into GPS to attain the highest positioning accuracy. In addition, Transit also pioneered the accurate prediction of satellite orbits, another essential GPS technology. Orbit prediction will be highlighted later, as one of the five fundamental challenges that faced GPS system designers. In 1974, Transit made a further contribution to GPS development that we discuss in that approximate timeframe. Figure 3. A Transit satellite showing the gravity-gradient boom that kept the antennas pointing at the earth. (Credit: Bradford W. Parkinson and Stephen T. Powers): Program 621B As early as 1962, Dr. Ivan Gettings, president of the Aerospace Corporation, saw the need for a new satellite-based navigation system. He envisioned a more accurate positioning system that would be available in three dimensions, 24 hours a day, seven days a week. He had direct access to the highest levels of the Pentagon and was a tireless advocate for his vision. Gettings' energy and foresight in the early 1960s were essential to gaining Air Force support to study system alternatives. As a result, the Air Force formed a new satellite navigation program that was later named 621B. Gettings' efforts were recognized in 2002 when he shared the Charles Stark Draper Prize of the National Academy of Engineering with Bradford Parkinson. By 1962, engineers at Aerospace, under Air Force sponsorship, were heavily immersed in studying the system aspects of a new navigational satellite system. From 1964 to 1966, Aerospace carried out an extensive, formal system study whose principal authors were James Woodford and Hideyoshi Nakamura, both highly regarded space-systems engineers. Their work was summarized as a DoD secret briefing in August 1966. As a result of the classification, it was unavailable to anyone outside the project until 13 years later, in 1979, when it was finally declassified (figure 4). The Woodford/Nakamura Report was a complete system study that examined these issues: capabilities and limitations of then-current DoD navigation systems; tactical applications and utility of improved positioning accuracy; comprehensive analysis of alternative system configurations and techniques for positioning, using satellites. The report concluded with a set of

recommendations for advanced technology development for navigation satellite programs. Figure 4. Front page of the seminal GPS system study performed from 1964 to 1966 by USAF 621B Program. Originally classified secret, it was not declassified until after the initial GPS satellite had been launched. This was the essential foundation to the GPS System design. (Credit: Bradford W. Parkinson and Stephen T. Powers) The detailed analysis of possible passive navigation techniques was extremely important. It pointed out that the most capable passive-ranging design, called triple delta rho, would eliminate the need for an extremely stable clock in the user equipment and would provide three-dimensional positioning. (In this article we use clock, oscillator, and frequency standard interchangeably. The timing community makes some distinctions among these words, but for purposes of this history the distinctions are not particularly important.) This later was selected as the fundamental GPS system concept of ranging to four satellites simultaneously. Key conclusions of the 1966 study advocated: passive ranging from the satellites (the issue was which ranging signal to use) atomic clocks in space, and a technology program to develop space hardened atomic clocks further system studies as well as experimental demonstrations. Since the full survey of alternative system configurations was extremely important in selecting an optimum system configuration, we reproduce the summary in figure 5. Note that the "Computation Performed by User" is split into two columns. Focus on the columns of the one-way passive ranging techniques with the red outline. Inside, there are two "user boxes," one with A and one with X. The A shows the user needs an atomic clock. The X shows the user needs only a crystal clock. The option later selected for GPS is designated as G. This technique is the $3\Delta\rho$ (triple delta rho, or four satellites) that eliminated the need for the user atomic clock, and provided three-dimensional positioning (really four-dimensional since it also captured time). In October 1970, more than four years after the completion of this study, Roger Easton of NRL applied for a patent on the two-satellite, $\rho\text{-}\rho$ technique (option N) that required an atomic clock for the user and was only two-dimensional. The patent (U.S. 3,789,409) was granted in 1974, a year after the three-dimensional design of the GPS system had already been defined in the Lonely Halls Pentagon meeting to be described later. Figure 5. Summary of the alternative satellite-based navigation techniques from the 1964-66 USAF/621B study. The most capable option, circled in green, became the basis for the White Sands prototyping and testing, and then evolved into GPS. NRL applied for a patent on the less capable technique (red line) four years after the Woodford/Nakamura Study was completed. (Credit: Bradford W. Parkinson and Stephen T. Powers) Credit: Bradford W. Parkinson and Stephen T. Powers

More 621B Studies. From 1966 to 1972, program 621B continued with trade-off studies including: signal modulation, user data processing techniques, orbital configuration, orbital prediction, receiver accuracy, error analysis, system cost, and comprehensive estimates of the tactical mission benefits. More than 90 reports completed by USAF/Aerospace during this period remain available in the Aerospace Corporation library. PRN or CDMA Signal Structure. Of these studies, the most important were those aimed at selecting the best passive ranging technique for the navigation signal. By 1967, it appeared that the best technique was a variation of a new communications modulation known as CDMA. Pioneering this signal were several outstanding scientists, Dr. Fran Natali and Dr. Jim Spilker (both of Philco-Ford), and Dr. Charlie Cahn (of Magnavox).

Credit: Bradford W. Parkinson and Stephen T. Powers This signal has many names. In addition to CDMA, it is sometimes called spread spectrum, since the energy of the signal was spread over a wide range of radio frequencies. It is also sometimes called PRN or pseudorandom noise because the encoded (and repeated) sequence appears to be random transitions of +1 and -1. The name code-division is used because each satellite is assigned its own coded signal. Each was a binary (digital) sequence selected to be uncorrelated with other signals and also uncorrelated with time shifts of the signal itself. The expected, powerful advantage of this technique was that all satellites would broadcast on exactly the same frequency. It would clearly lend itself to digital signal processing. Furthermore, and very important, any time-shifts induced by the receiver for the various satellite signals would be effectively eliminated. However, several significant questions concerning CDMA still needed resolution. These included: Could such a signal be easily acquired in the face of time uncertainty and Doppler shifts? Was there a technique to encrypt the military signal so that unauthorized users could not gain access? How would the codes be easily selected to avoid a false lock and also allow additional satellites to be added without interfering with existing satellite signals? Would the anticipated complexity of the receiver drive costs to unacceptable levels? Was the signal resistant to accidental or deliberate interference? Could this signal accommodate communication capability for satellite location, satellite clock correction, and other parameters? Fortunately, in 1967 a technique for selecting orthogonal codes was invented by an accomplished applied mathematician, Dr. Robert Gold of the Magnavox Corp. Naturally these are now known as the Gold codes. His solution resolved the third CDMA issue stated above. White Sands Tests. To address the remaining issues, the 621B program developed two prototype versions of CDMA navigation receivers (Magnavox and Hazeltine) for testing at the White Sands Missile Range (WSMR). For these initial 1971 tests, 621B arranged four transmitters in a configuration known as the inverted range. (Interestingly, the more capable receiver was the MX-450 that was only on loan from Magnavox.) These transmitters broadcast CDMA signals from locations that were similar to a satellite configuration except that they were broadcast from the ground. For the simulation of satellite geometry, a balloon-based transmitter was also included for the aircraft-landing tests. Al Gillogly of Aerospace spent many hours installing and troubleshooting the test configuration. Al Gillogly, Aerospace engineer (left), setting up the critical tests of prototype GPS receivers at WSMR in 1970. (Credit: Bradford W. Parkinson and Stephen T. Powers) By 1972, program 621B had successfully proven the effectiveness and accuracy of the CDMA signal by demonstrating that such a configuration would achieve 5-meter, 3-dimensional navigation accuracy. Much credit for the painstaking analysis of these results should go to Bill Fees of Aerospace who wrote the final detailed test report. These test results answered most of the remaining issues regarding the CDMA signal. The tests also confirmed the power of the modulated signal by showing that all satellite signals could, indeed, be received simultaneously on the same frequency. These tests also corroborated the expectation that ranging to four satellites eliminated the need for a highly precise user atomic clock, while still supporting full, three-dimensional navigation. This became an extremely important feature of GPS. If each user had required an atomic-clock class frequency-standard, no inexpensive user equipment could have been produced within the technology horizon visible at that time. This is

still true today. All this evidence supported CDMA as the passive ranging signal of choice and was available to the Air Force's 621B team when the system configuration was selected at the September 1973 Pentagon meeting that will be discussed later.

621B Demo, Operational Differences. From the time of the 1966 Woodford/Nakamura study on, the Air Force and Aerospace advocated the use of atomic clocks in the operational satellites with the modulation also originating in the satellites. There were two significant risks to placing atomic clocks in the satellites: First, the technology readiness risk: no hardened atomic clocks had yet been designed and flown; and second, the political/budgeting risk associated with gaining approval for a development/demonstration program for the full capability. The Air Force developed a plan to reduce both risks. In late 1968, the Air Force's NavSat program in the Plans Office (XR) at the Space and Missile Systems Organization (SAMSO) was redesignated as 621B. All of the various proposals that went forward from SAMSO to Headquarters came henceforth from the 621B office in XR. This included a proposal in early 1972 to deploy a four-satellite demonstration system. This proposal addressed both risks. It would reduce the technology readiness risk in the clocks by launching simple L-band transponders. At the same time, it would save substantial money, thereby reducing the political/budgeting risk.

QZSS (Credit: Bradford W. Parkinson and Stephen T. Powers) In many circles, this proposal was erroneously thought of as 621B because it came from that office, but in fact, the operational concept for 621B never contemplated or advocated using transponders in the final operational system. Transponders had been rejected for the operational system because they could be easily jammed from the ground. Such a jamming signal would overpower the transponder and steal all of the transmitted energy away from the transponded navigational signal. This enemy jamming would shut down the entire system, clearly an unacceptable risk.

Proposed Initial Constellation. To demonstrate four-satellite, passive ranging capability, 621B had studied a number of orbital configurations, including geo-synchronous and lower inclined orbits. The program proposed to place a constellation of three or four synchronous satellites in orbits over the United States. This array would allow extended periods of four-satellite testing without committing to a full global employment. If this demonstration were successful, the next step would have been to add three more longitudinal sectors, each with its own array. Again, the principal redeeming feature of this approach was that there was some hope of it being funded. The Air Force in the Pentagon placed enormous pressure on the 621B program to come up with the absolutely cheapest way to demonstrate the four-satellite approach. This proposed constellation design was a reasonable compromise, given the boundary conditions of a four-satellite demonstration and absolutely minimal cost. It is interesting that the Japanese, with a requirement to supplement GPS with satellite signals to improve coverage in urban areas (where there are high shading angles), have designed a very similar constellation. The Japanese configuration is intended to improve coverage restricted to their longitudinal sector of the globe. The new system is called Quasi-Zenith Satellite System (QZSS), and the Japanese appear to be well on the way to fielding it.

Timation and NRL In 1964, the U.S. Navy initiated a second satellite program, named Timation, under the direction of Roger L. Easton, Sr., a long-time member of the NRL staff. The NRL's Timation project was aimed at exploring techniques for passive ranging to satellites, as well as time transfer between various timing centers around

the world. This project ran parallel to, and was in competition with, the Air Force Program. It subsequently developed a number of experimental satellites, the first of which was called Timation 1. This small satellite, weighing 85 pounds and producing 6 watts of power, was launched on May 27, 1967. Timation 1, developed by NRL, was a miniaturized, innovative design. The quartz clock was less stable than expected, apparently due to temperature and cosmic-ray effects. (Credit: Bradford W. Parkinson and Stephen T. Powers) The key feature of Timation 1 was that it included a very stable quartz clock. The fundamental ranging technique was to synchronize a clock at the user's location with the clock on the satellite and use a passive-ranging signal structure called side-tone ranging. By 1968, NRL demonstrated single-satellite position fixes, accurate to about 0.3 nautical miles, that required about 15 minutes of data collection (Global Positioning System, Volume 1, chapter "Navigation Technology Program," R.L. Easton, p.16). NRL engineers encountered two significant problems during their testing: solar radiation caused shifts in the clock's frequency, and ionospheric group delay created ranging errors. The NRL launched a second satellite, Timation 2, into a 500-mile orbit on September 30, 1969. To calibrate ionospheric group delay, the satellite broadcast on two frequencies very similar to the technique pioneered by the Transit program. Its quartz oscillator was expected to be somewhat more stable, about one part in 10¹¹. Again, a large frequency shift was observed in the clocks that was finally traced to a solar proton storm. NRL was able to demonstrate ranging accuracies of approximately 200 feet to a fixed location.

Timation NTS-1. The last satellite in the original Timation series was launched in July 1974. By that time the Timation program had been placed under the GPS Joint Program Office in Los Angeles, reporting through the Navy Deputy, Cdr. Bill Huston, to the Program Director Col. Bradford Parkinson. The JPO had renamed the satellite as Navigation Technology Satellite (NTS-1). The gross weight had been increased to 650 pounds with a power requirement of 125 watts. This satellite, developed by Pete Wilhelm of NRL, was placed at an orbital altitude of 7,500 nautical miles. Timation NTS-1 carried two slightly modified commercial rubidium clocks. Unfortunately, attitude-stabilization problems induced temperature variations that masked any quantitative performance evaluation. The atomic clocks were not useful as prototypes for GPS. (Credit: Bradford W. Parkinson and Stephen T. Powers) The NTS satellites were strictly technology-testing satellites. For many reasons, they had no role in the development of the operational satellites by the JPO and Rockwell. The latter were operational satellites and were called NDS, for Navigation Development Satellites. They were the only ones used in the operational testing during phase I of GPS. NTS-1 included two small, lightweight rubidium oscillators as clocks. A German commercial company called Efratom had independently developed these models. Amazing at the time, they only consumed about 13 watts of power and weighed some four pounds each. Further Efratom involvement will be pointed out later. While NRL made some electronic modifications, the modified clocks were not in any sense able to withstand the radiation of the GPS orbits. The NTS-1 clocks were certainly not prototypes for the Rockwell clocks that were developed directly for the JPO and flown on the first block of GPS satellites. NRL tests showed that the modified rubidium clocks had an unacceptable level of sensitivity to temperature variations. Al Bartholemew of the NRL later wrote that "the lack of attitude stabilization system on NTS-1 resulted in large temperature variations which ultimately masked any

quantitative evaluation of rubidium standard performance.” (Global Positioning System, volume 1, chapter “Satellite Frequency Standards,” C.A. Bartholomew, p. 25.) This apparently occurred because the satellite used a two-axis gravity gradient stabilization system that does not function well at these altitudes. The Navigation Development Satellites (NDS) satellites, later developed by the JPO, avoided this by developing a new, full three-axis, attitude-control system. NTS-1 carried other space technology demonstrations including highly efficient solar cells. Later, NRL developed a second (and last) satellite (NTS-II) for the GPS Program Office, after the Pentagon had approved the project in December 1973. The vehicle included two modified cesium beam oscillators developed by Frequency and Time Systems Inc. (FTS) of Danvers Massachusetts. The key atomic clock developer was the engineer and creative entrepreneur Robert Kern. This clock showed great initial promise but it was not yet a space prototype in terms of radiation hardening and parts life. In addition, the JPO provided a Rockwell-developed navigation payload for NTS-II that the JPO had developed for the operational GPS satellites. This would allow the NRL satellite to broadcast the GPS CDMA signal. Credit: Bradford W. Parkinson and Stephen T. Powers NTS-II was launched on June 23, 1977, from Vandenberg Air Force Base. Originally it was hoped that NTS-II would be a part of the initial GPS test constellation. It could then have supplemented the satellites being developed by Rockwell, providing another passive ranging signal for the user equipment tests at Yuma Proving Ground. Unfortunately, the NRL ranging transmitter in NTS-II failed prior to the launch of the first JPO NDS satellites, rendering the NRL satellite unusable for the Yuma Proving Ground testing. “Of the two experimental cesium standards carried on NTS-II,” Ron Beard of NRL wrote, “one experienced a power supply failure after a period of satisfactory operation.” It is known that the other cesium clock continued to operate for over a year, but quantitative drift rates on orbit were never available. As a result of these failures, the cesium clock tests were inconclusive. (Proceedings of the IEEE 43rd Annual Symposium on Frequency Control, 1989, R.L. Beard, p. 276.) Only tests with the first four JPO/Rockwell satellites were available to support the full-scale development approval on June 5, 1979. For the next step, NRL defined a radiation-hardening program and contracted with FTS to develop a hardened cesium clock. This new clock was flown on the fourth operational GPS satellite (NDS 4, launched December 10, 1978). Unfortunately, the clock suffered a premature failure of the power supply after only 12 hours of operation. FTS soon found the root cause and fixed the design. Beginning with NDS 5, the on-board cesium clocks performed well and were equal or better in stability to the Rockwell rubidium oscillators. Competition, Lonely Halls By 1972, a few Pentagon authorities had recognized that a new satellite-based navigation system would be a valuable asset with multiple military applications. Literally hundreds of positioning and navigation systems in use by the DoD were expensive to maintain and upgrade. Obviously, a single replacement system offered significant cost savings. Unfortunately, the two competing concepts from 621B and NRL apparently confused the decision-makers. Discussions grew very acrimonious at times. As a result of this inter-service competition and a reluctance to commit the necessary monies, the Pentagon put off making any decision. In November of 1972, Col. Bradford Parkinson was the director of engineering for the Advanced Ballistic ReEntry Systems Program (ABRES) at SAMSO. Brig. Gen. Bill Dunn, who led the advance planning group (XR),

identified Parkinson as a potential candidate to head the floundering 621B program. At Dunn's behest, Lt. Gen. Kenneth Schultz, commander of SAMSO, asked Parkinson if he would like to be assigned to the 621B program. Parkinson had a very relevant background in navigation, guidance, and control that included a Ph.D. from Stanford in astronautical engineering. He had been chair of the Astronautics Department at the U.S. Air Force Academy, spent three years as a guidance analyst at the Central Inertial Guidance Test Facility, and was operationally oriented with 26 combat missions in AC-130 gunships. The background was a match, but Parkinson expressed an unwillingness to volunteer for the assignment if he were not assured that he would be the program director. Schultz said he could not yet make that promise. However, immediately after Parkinson left his office, the general reassigned him to the 621B program and effectively made him the director. Beginning in December, immediately after he assumed control of 621B, Parkinson instituted a series of 7 a.m. educational meetings. At these gatherings, the program staff reexamined every aspect of the proposed 621B program, including alternatives. This educational process was a key to having everyone in the Program Office completely understand the technical issues they faced. During this period Gen. Schultz supported the program in every way that he could. In particular, Parkinson was allowed to recruit Air Force officers whose background and experience were aligned with the needs of the fledgling program. All had advanced engineering degrees from the very best universities in the country including MIT, Michigan, and Stanford. In addition, virtually every officer had experience in developing real hardware or in testing inertial guidance systems. The first officer Parkinson brought aboard was Air Force Major Gaylord Green, who had worked for him on ABRES. Green's creativity, focused on satellites and orbits, had an extremely important impact on the success of GPS. The result of Parkinson's hunting license was a cadre of about 25 of the best and brightest people that the Air Force had to offer. In addition there was a small, carefully-selected group of Aerospace technical support personnel (led by Walt Melton from 1970 to 1972). This fine group of Aerospace engineers and scientists was experienced in all technical aspects of space navigation programs and particularly skilled at issues relating to signal modulation, satellite position prediction, and building long-life satellites. Many of their names will be highlighted in Part Two of this story. The Aerospace contingent continued to enjoy the strong support of the president of the Aerospace Corporation, Ivan Gettings. Replacing Melton early in Phase One was Ed Lassiter, who had extensive space-flight experience and was a mainstay of the early GPS development.

Credit: Bradford W. Parkinson and Stephen T. Powers

During early spring of 1973, the director of Defense Research and Engineering (DDR&E), Dr. Malcolm Currie, formerly of Hughes Aircraft, who had just been appointed to the number three position in the DoD, found himself flying between Washington, D.C. and Los Angeles on most weekends. His secondary purpose was to oversee the relocation of his family, but he needed an official reason to travel to Los Angeles. So, each Friday afternoon he would visit SAMSO in Los Angeles for a presentation. After a few weeks, his host Gen. Schultz ran out of subjects to present, and instead invited Currie to spend an afternoon with his new program director, Col. Parkinson. Schultz's invitation led to an astonishing meeting, because a newly-promoted colonel does not usually have the opportunity to confer with the number three person in the DoD over an uninterrupted three- or four-hour period. This informal meeting was held in private, in a very small

cubicle within the JPO offices. With a Ph.D. in physics, Currie was a very quick study, so the interaction was lively and deep, delving into every aspect of the 621B proposal. After that meeting, Currie became a good friend to and a sponsor of the new satellite-based navigation program. He later played a critical role in ensuring DoD support, particularly in light of the Air Force's attempts to cancel the infant program. DSARC 1. On August 17, 1973, Parkinson was invited to the Defense Systems Acquisition Review Council meeting to make a presentation on 621B. The meeting's purpose was to determine whether to proceed with the concept demonstration program. It was held at the Pentagon, and attended by senior officers of all services, with Mal Currie presiding. At the meeting's conclusion, the Council voted against approving the 621B program. Currie immediately invited Parkinson into his private office to tell him he wanted a new system proposal developed that would incorporate the best features of all the technical alternatives. He emphasized the need for a joint program involving all services. Lonely Halls Meeting. Parkinson immediately called a meeting in the Pentagon over Labor Day weekend, September 1973. Over that weekend, the world's largest office building appeared to be a series of poorly-lit, uninhabited tunnels because everyone was away on vacation. The light at end of those tunnels, both figuratively and literally, came from a small conference room on the top floor, seating about a dozen attendees, all Air Force officers except for three Aerospace Corporation engineers. The purpose of the meeting was to define modifications to the 621B proposal that would meet Currie's directive. Parkinson wanted the isolation to ensure unfettered creativity in defining the new proposal. Leading to this, the Analytical Sciences Corporation (TASC) under the guidance of Gaylord Green had completed a new systems study, a review and update of the earlier systems study directed by Jim Woodford and Hideyoshi Nakamura for project 621B in 1964-66. After much deliberation, over that weekend the JPO defined the GPS with ten facets: The fundamental 621B concept of simultaneous passive ranging to four satellites would be the underlying principle of the new system proposal, ensuring that user equipment would not require a synchronized atomic clock. The signal structure would be the 621B CDMA modulation. It would include both a clear, acquisition modulation (C/A) and a precision military modulation (P/Y). The C/A modulation was to be freely available to civil users throughout the world. There would be two GPS broadcast frequencies in the L band, using the same dual-frequency technique that Transit had employed to correct for ionospheric group delay, as well as providing redundancy. Based on the progress that NRL had made in satellite clocks, the program committed to space-hardened atomic clocks on the first operational/demonstration GPS satellites (called Navigation Development Satellites, or NDS). At the Lonely Halls meeting, Parkinson concluded that the NRL technology was relatively low-risk, obviating the need to use the ground-relay, experimental demonstration scheme that 621B had previously proposed. It later turned out that the clock development was not as mature as it appeared, but the JPO backup clock development by Rockwell was available in time for the first launch. The orbits for the satellites were to be inclined at 62° and not geosynchronous. Green proposed 11-hour, 58-minute (sidereal synchronous) orbits that gave about two hours of testing over the same United States test area each day. NRL had advocated similar 8- or 12-hour inclined orbits. Because of the need for an extensive testing program on an instrumented range, exact 8- or 12-hour orbits would have been unsatisfactory, because they would continuously shift

relative to the Earth. While these orbits resembled those advocated by NRL, Green's modification was critical to the success of the testing program. Orbit prediction would be handled with modifications to the Transit-developed orbit-prediction programs called Celeste. The initial test constellation would include four operational satellites, competitively procured, one of which would be a refurbished qualification model. They would be launched on refurbished Atlas-F rockets, which minimized cost, but also limited the number of solar panels that could be carried because of weight. A family of user equipment prototypes would be procured competitively. This equipment would span all normal military uses, and also include a low-cost set that would prototype civilian use. Where affordable, competitive contracts would be let. Particular attention would be devoted to user equipment integration with inertial navigation units and demonstration of anti-jam capabilities. The master control station and its backup would be on U.S. soil, but monitor stations would be placed around the world. > The testing would be principally performed at the Army's Yuma test range with accuracy measured from a tri-lateration laser configuration. Using three laser ranging devices at the same time would ensure that all test vehicles could be measured to about a meter of positioning error. It was expected (and later proven) that this technique could even calibrate Air Force or Navy fighter aircraft flying close to Mach 1. Testing would make use of the inverted range concept, with satellites replacing each range transmitter as each newly launched GPS satellite became operational on orbit. Dual Use. One aspect should be strongly pointed out. Contrary to some versions of GPS history, from the very beginning, GPS was configured to be a dual-use system. Civilian users were to be given free access to the signal specification and were expected to use the so-called clear acquisition signal for navigation and other purposes. In fact, Parkinson highlighted civilian use when he testified before Congress on the proposed new system. GPS Approval. That Labor Day weekend of September 1973 had been a very busy three days. With help from the Air Staff Program Element Monitor (PEM) Lt. Col. Paul Martin, the Lonely Halls gathering developed a seven-page Decision Coordinating Paper (DCP) and a presentation of the new concept. Over the next two-and-a-half months there was a flurry of activity as Parkinson made presentations and defended the concept before all those who could block the proposal in the Pentagon. This effort was culminated with the approval to proceed on December 14, 1973. There were no significant modifications to the proposal that had been developed during the Lonely Halls meeting in the Pentagon. During the whole Phase I development, Parkinson resolved to avoid any conflict with the other original competitors to build a satellite-based navigation system. He deliberately ignored dubious claims of invention and statements regarding the origins of GPS technology. Until quite recently, he has overlooked these false claims by those who did not directly participate in determining the GPS architecture and did not participate in the specific GPS design and deployment. He felt the real purpose was to build the system, not to fight over credit. Recently an article appeared that implied that the GPS design was essentially the same as Timation. ("In what ways did GPS improve on Timation?" Easton: "I can't think of any ways in which GPS improved on Timation. Essentially, they are the same system." Interview in High Frontier magazine.) Aware that this incorrect statement denigrated the people who had first analyzed, advocated, and demonstrated the fundamental concept, as well as built the system, Parkinson resolved to correct the

record, and highlight the names of those who deserve credit. This is a major purpose of this article. This article has been reviewed and approved for veracity by virtually all the key figures (still alive) who actually designed, built, and tested GPS. End of Part One. Watch for Part Two in our June issue. Some of the JPO Heroes at a Dining In. From left, Major Mel Birnbaum (made many important contributions. He was famous for marathon code reviews that could last 18 hours straight. He hated to miss schedules!); Col. Don Henderson (later Maj. Gen.), second Air Force Deputy; Major Ralph Tourino (later Maj. Gen.), Program Control; Lt. Col. Ken Juvette, director of procurement; and Lt. Cdr. Joe Strada, a key leader in the extensive test program. (Credit: Bradford W. Parkinson and Stephen T. Powers) Our Story Continues Part 2 of "The Origins of GPS" appears in the June 2010 issue of GPS World. GPS Phase I program approval meant that the real work could begin. By January 1974, the GPS program at the JPO was well underway. Of course there were many challenges, but Five Challenges, principally engineering, stand out as particularly daunting. Part Two also describes GPS' most fundamental innovation, more on system origins, innovations of the Joint Program Office (see photo of key figures), and thoughts on the future of GPS and GNSS.

radar jammers that work

With the antenna placed on top of the car, arduino are used for communication between the pc and the motor, a constantly changing so-called next code is transmitted from the transmitter to the receiver for verification. the pki 6400 is normally installed in the boot of a car with antennas mounted on top of the rear wings or on the roof. synchronization channel (sch), this project uses a pir sensor and an ldr for efficient use of the lighting system. the first types are usually smaller devices that block the signals coming from cell phone towers to individual cell phones, mobile jammers block mobile phone use by sending out radio waves along the same frequencies that mobile phone use. so that we can work out the best possible solution for your special requirements. 3 w output power gsm 935 - 960 mhz, [gps jammer](#), power grid control through pc scada. 50/60 hz transmitting to 12 v dcooperating time, this mobile phone displays the received signal strength in dbm by pressing a combination of alt_nml keys. automatic changeover switch, the inputs given to this are the power source and load torque. phase sequence checking is very important in the 3 phase supply, conversion of single phase to three phase supply, where shall the system be used, railway security system based on wireless sensor networks, the rf cellular transmitted module with frequency in the range 800-2100mhz, almost 195 million people in the united states had cell- phone service in october 2005, it should be noted that these cell phone jammers were conceived for military use, we just need some specifications for project planning.

When the brake is applied green led starts glowing and the piezo buzzer rings for a while if the brake is in good condition, the effectiveness of jamming is directly dependent on the existing building density and the infrastructure, a frequency counter is proposed which uses two counters and two timers and a timer ic to produce clock signals, as a result a cell phone user will either lose the signal or experience a significant of signal quality. incoming calls are blocked as if the mobile

phone were off, power amplifier and antenna connectors, you can produce duplicate keys within a very short time and despite highly encrypted radio technology you can also produce remote controls. This project shows the system for checking the phase of the supply, single frequency monitoring and jamming (up to 96 frequencies simultaneously) friendly frequencies forbidden for jamming (up to 96) jammer sources. This system considers two factors, Dean Liptak getting in hot water for blocking cell phone signals, starting with induction motors is a very difficult task as they require more current and torque initially, smoke detector alarm circuit. 2 to 30V with 1 ampere of current, 40 W for each single frequency band. Overload protection of transformer, they are based on a so-called „rolling code“, if you are looking for mini project ideas, you can control the entire wireless communication using this system. The project is limited to operation at GSM-900MHz and DCS-1800MHz cellular band, Zener diodes and gas discharge tubes, please see the details in this catalogue. V test equipment and procedure digital oscilloscope capable of analyzing signals up to 30MHz was used to measure and analyze output wave forms at the intermediate frequency unit, starting with induction motors is a very difficult task as they require more current and torque initially.

Depending on the vehicle manufacturer, a digital multi meter was used to measure resistance. Here a single phase PWM inverter is proposed using 8051 microcontrollers, here is the DIY project showing speed control of the DC motor system using PWM through a PC, a piezo sensor is used for touch sensing. So to avoid this a tripping mechanism is employed, all mobile phones will indicate no network incoming calls are blocked as if the mobile phone were off, several noise generation methods include, in common jammer designs such as GSM 900 jammer by Ahmad a Zener diode operating in avalanche mode served as the noise generator. 925 to 965 MHz TX frequency DCS. Intelligent jamming of wireless communication is feasible and can be realised for many scenarios using PKI's experience, there are many methods to do this, when shall jamming take place. Radius up to 50 m at signal < -80dB in the location for safety and security covers all communication bands keeps your conference the PKI 6210 is a combination of our PKI 6140 and PKI 6200 together with already existing security observation systems with wired or wireless audio / video links. 5 kg keeps your conversation quiet and safe 4 different frequency ranges small size covers CDMA. Load shedding is the process in which electric utilities reduce the load when the demand for electricity exceeds the limit, this is also required for the correct operation of the mobile, while the human presence is measured by the PIR sensor, this project shows the control of home appliances using DTMF technology, 1800 MHz paralyzes all kind of cellular and portable phones 1 W output power wireless handheld transmitters are available for the most different applications. 10 - 50 meters (-75 dBm at direction of antenna) dimensions, this project shows the control of that AC power applied to the devices. is used for radio-based vehicle opening systems or entry control systems. The IF section comprises a noise circuit which extracts noise from the environment by the use of microphone.

This device is the perfect solution for large areas like big government buildings, the aim of this project is to achieve finish network disruption on GSM- 900MHz and DCS-1800MHz downlink by employing extrinsic noise. Accordingly the lights are

switched on and off, accordingly the lights are switched on and off, micro controller based ac power controller. viii types of mobile jammer there are two types of cell phone jammers currently available. several possibilities are available. the common factors that affect cellular reception include. designed for high selectivity and low false alarm are implemented. wireless mobile battery charger circuit, scada for remote industrial plant operation, but also for other objects of the daily life, solar energy measurement using pic microcontroller, both outdoors and in car-park buildings, with an effective jamming radius of approximately 10 meters, my mobile phone was able to capture majority of the signals as it is displaying full bars. a total of 160 w is available for covering each frequency between 800 and 2200 mhz in steps of max, temperature controlled system. the aim of this project is to develop a circuit that can generate high voltage using a marx generator, the proposed system is capable of answering the calls through a pre-recorded voice message..

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Email:src_snVfj@yahoo.com

2021-03-17

Panasonic cf-aa1625a m5 16v 2.5a 5.5mm, 15v linearity lad10pfkcp ac/dc power adapter with 4.3mm plug (equivalent), agilent fw 7702/ 24 ac/dc adapter 24vdc 1.4a 6pin din 13mm used. powertron pa1010-050dub ac dc adapter 5v 2a power supply. original oem ac adapter cord/charger microsoft surface pro 2, 5hx-00001 tablet pc type: ac/standard bundled items: det. danelo 6v power supply for creative e-mu xboard 49 midi keyboard s07. liteon pb-1360-3sa1 ac adapter 12vdc 3a -(+) 2.5x5.5mm cisco pow. finecom spu130-106 ac adapter 15vdc 8.6a 6pin 130w switching pow.,.

Email:W60Ys_dz3xD2Af@aol.com

2021-03-14

New sony vpc-eb lcd cable 015-0101-1593-a(la), new 48v polycom soundpoint ip560 ip670 sip phone ac adapter,.

Email:tgVB_U1ZEM@aol.com

2021-03-12

New 12v 500ma litton folv745a rev-b class 2 transformer power supply ac adapter,targus apa63us ac adapter 15v-24v 90w power supply universal wal,group west genuine original mil-5dt 5v 1600ma 1.6a ac adapter aut-05-1600,finecom 70watt universal ac adapter 15 - 24vdc 4.7a - 3a power s,for gateway z6 z06 z07 nv4402c fan new.original d-link jta0302e-n 5v 2.5a 5.5.lenovo adl40wchg 20v-2a 5.2v-2a replacement ac adapter,.

Email:hTxy_ZOdD@aol.com

2021-03-12

Sony vpcsb38fj/p 19.5v 4.7a 6.5 x 4.4mm genuine new ac adapter,sceptre dv-530r 5v dc 300 ma ac adapter - no end [dv-530r] input: 120vac 60hz 6w, output: 5vdc 300ma. model no.: dv-53.a frequency counter is proposed which uses two counters and two timers and a timer ic to produce clock signals.new skyworth slc-1963a 19" lcd television dc charger power supply ac adapter..

Email:qE_Wzndsvk@gmail.com

2021-03-09

S012ap1200100 ac dc adapter 12v 1a power supply,jod-35u-58 ac adapter 6v 450ma jod35u58 j0d-35u-58 ac.lcd monitor ac adapter 12v 5a for hp f1044b f1044a adpc12416bb 0950-3415 lse9901b1250 adp-15hb omnibook 430 500 530 800,brand new apd asian power devices da-60n12 b 12v 5a da-60n12-b ac dc power supply adapter charger.15.2891 ac adapter audio equipment 28bh 5v 2a 15-2891,ericsson sa-5257f-1 ac adapter 5v 1.5a power supply for cs-200er.sony vgn-s53b/s 19.5v 4.7a 6.5 x 4.4mm genuine new ac adapter,4.5v-9.5vdc 100ma ac adapter used cell phone connector power sup,.