GPS DECLASSIFIED

From Smart Bombs to Smartphones

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Foreword by Rick W. Sturdevant

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To my father, Roger Easton, for his support and kind assistance in creating a field for me to write about; ~~to my mother, Barbara Easton, for fostering in me a love of history; and to my wife,~~ Kathleen, for her support and assistance.

—RICHARD D. EASTON

To my father, Arvel Frazier, who gave me his love of geography and history; to my mother, Isabel Frazier, who gave me her penchant for accuracy and thoroughness; and to my wife, Margie, whose support and encouragement made it possible for me to undertake this project.

—ERIC F. FRAZIER

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Foreword

For one who has been writing a portion of the official history of Global Positioning System (GPS) operations since the 1980s, it is startling to realize that young people entering college in 2013 have never known a world without GPS. Even those who are aware of the system's transparent presence on their personal phone devices, in their daily business transactions, or amid their recreational activities undoubtedly take its benefits for granted. It would be surprising if more than a few could explain, at even a rudimentary level, how this amazing space-based positioning, navigation, and timing (PNT) system works. How many know GPS is the world's only global utility? Who stops to remember that it signals are available free of charge to anyone with a GPS receiver?

Here, at last, Richard Easton and Eric Frazier present in plain, simple language how a PNT system originally developed for military purposes—one that Air Force Space Command continues to operate and maintain—became essential for countless civil and commercial activities around the world. The authors deftly place the concept and development of GPS within two broader historical contexts: navigation and robotic spaceflight. Their description of the dissimilar problems that compelled visionaries in each of the military services to pursue a three-dimensional positioning and navigation system substantiates the adage, sometimes attributed to Plato, that necessity is the mother of invention.

On the way to fostering what emerged as GPS, however, ample participation occurred to justify multiple paternal claims. Eventually, different individuals garnered high-level recognition based on, and bolstering, their respective claims. One (Roger Easton) received the 2004 National Medal of Technology from President George W. Bush. The National Academy of Engineering awarded two others (Ivan Getting and Brad Parkinson) the 2003 Charles Stark Draper Prize. All three, in recognition of their seminal GPS roles, became inductees to the National Inventors Hall of Fame. In 2012 the National Space Club named the same trio among the "GPS Originator Team " that received the prestigious Dr. Robert H. Goddard Memorial Trophy. Numerous others also contributed, without fanfare or subsequent recognition, to the conceptualization and development of GPS.

Easton and Frazier explore the debatable parentage of GPS through sources previously ignored by o unavailable to other scholars. While not the definitive history of the origins of GPS and its place in th centuries-old panoply of navigational systems, their study certainly advances our knowledge of the "who, what, when, where, why, and how " behind this amazing technological accomplishment. This book represents a solid foundation upon which future scholars can build their research and writing about GPS, or what has become more broadly identified as global navigation satellite system (GNSS) technology.

Beyond the origin of GPS and how it works, these authors deliver an impressive survey of the historical evolution of GPS applications among military, civil, and commercial users, not to mention private individuals. Although certainly not all-inclusive, their astounding coverage of the many ways in which people rely on precise PNT from outer space boggles the mind. When the authors describe th system's vulnerability to interference, whether intentional or natural, the potentially devastating military, societal, economic, and political effects of GPS disruption take on sinister proportions.

Whenever historians venture into the future, based on their understanding of the past and their perception of the present, they generally fare no better than nonhistorians. All confront largely incomprehensible terrain. Nonetheless, Easton and Frazier dare to conclude their GPS study with an overview of possibilities. Indeed, advocates of vector analysis in history might perceive that these tw authors discern probabilities based on chronological patterns or trends—scientific, technological, economic, political, military, and social. Still, they recognize that if history teaches us anything, it is to remain watchful for unexpected twists and unanticipated turns. That is precisely what keeps past, present, and future particularly interesting and occasionally controversial, as the following narrative demonstrates.

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Abbreviations

2SOPS: 2nd Space Operations Squadron
ABMA: U.S. Army Ballistic Missile Agency
ALCM: air-launched cruise missile
APL: Applied Physics Laboratory
ARPA: Advanced Research Projects Agency
ASAT: antisatellite
AVL: automatic vehicle location
BCCI: Bank of Credit and Commerce International
CALCM: conventional air-launched cruise missile
CBO: Congressional Budget Office
CDMA: code division multiple access
CPU: central processing unit
CSEL: Combat Survivor Evader Locator
CTIA: Cellular Telecommunications Industry Association
DARPA: Defense Advanced Research Projects Agency
DART: Demonstration for Autonomous Rendezvous Technology
DGPS: differential GPS
DNSDP: Defense Navigation Satellite Development Plan
DNSS: Defense Navigation Satellite System
DOD: Department of Defense
DSARC: Defense Systems Acquisition Review Council
DSP: Defense Support Program
EASCON: Electronics and Aerospace Systems Convention
EGNOS: European Geostationary Overlay System
EOSAT: Earth Observation Satellite Inc.
ESA: European Space Agency
EU: European Union
FAA: Federal Aviation Administration
FBCB2: Force XXI Battle Command Brigade and Below
FCC: Federal Communications Commission
FDMA: frequency division code modulation
FOC: Full Operational Capability
GAGAN: GPS-Aided Geo-Augmented Navigation
GAO: General Accounting/Accountability Office
GBAS: ground-based augmentation system
GDM: Generalized Development Model
GIS: geographic information systems
GNSS: global navigation satellite system
GPS: Global Positioning System

ICAO: International Civil Aviation Organization
ICBM: intercontinental ballistic missile
IEEE: Institute of Electrical and Electronics Engineers
IGEB: Interagency GPS Executive Board
iGPS or HIGPS: High Integrity GPS
IGY: International Geophysical Year
INS: inertial navigation systems
IOC: Initial Operational Capability
IONDS: Integrated Operational Nuclear (Detonation) Detection System
IRBM: intermediate-range ballistic missile
IRNSS: Indian Regional Navigation Satellite System
ISS: inertial surveying systems
JPO: joint program office
LBS: location-based service
MBOC: multiplex binary offset carrier
MSAS: Multifunctional Transport Satellite Augmentation System
NANU: Notice Advisory to Navstar Users
NAPA: National Association of Public Administration
NASA: National Aeronautics and Space Administration
NAVCEN: Navigation Center
NAVSEG: Navigation Satellite Executive Steering Group
NAVSMO: Navigation Satellite Management Office
NAVSPASUR: Naval Space Surveillance System
NDAA: National Defense Authorization Act
NDGPS: Nationwide DGPS
NES: Navigation Experimental Satellites
NNSS: Naval Navigation Satellite System
NORAD: North American Aerospace Defense Command
NRC: National Research Council
NRL: Naval Research Laboratory
NTIA: National Telecommunications and Information Administration
NTS: Navigation Technology Satellite
OCS: Operational Control System
OCX: Operational Control Segment
PDAS: personal digital assistants
PLGR: precision lightweight GPS receiver
PND: personal navigation device
PNT: positioning, navigation, and timing
PPC: Portable Professional Computer
PPS: Precise Positioning Service
PRN: pseudorandom noise
QZSS: Quasi-Zenith Satellite System
RAIM: Receiver Autonomous Integrity Monitoring

RAM: random access memory
READI: Real-Time Earthquake Analysis for Disaster
SAMSO: Space and Missile Systems Organization
SBSS: Space Based Space Surveillance
SDI: Strategic Defense Initiative
SLAM: standoff land attack missile
SLGR: small, lightweight GPS receiver ("Slugger ")
SLVS: space launch vehicles
SPS: Standard Positioning Service
SVN: space vehicle number
SVS: space vehicles
TERCOM: terrain contour matching
TLAM: Tomahawk land attack missile
UAV: unmanned aerial vehicle
UTC: Coordinated Universal Time
V2I, V2X: vehicle-to-infrastructure
V2V: vehicle-to-vehicle
VMT: vehicle-miles-traveled
WAAS: Wide Area Augmentation System
WGS-84: World Geodetic System 1984

Introduction

There is no “middle of nowhere ” anymore, Agent Scully.

The Shadow Man in “Trust No. 1 ,” X-Files, *season 9, originally broadcast January 6, 2002*

The stolen 2009 Chevrolet Tahoe was pushing 100 mph on a residential street in Visalia, California, by the time Sgt. Randy Lentzner and his partner, Officer Robert Gilson, got their police cruiser into position behind it.[1] High-speed chases often end in collisions and always endanger innocent bystanders, so the time—about 3:30 a.m.—was in their favor. But on this morning, October 18, 2009 the police had another advantage. Some 12,500 miles overhead, a network of satellites was helping to track the vehicle’s exact position, and new technology was in place to eliminate the need for hazardous spike strips or bumping tactics traditionally used in police pursuits.

Minutes after a shotgun-wielding assailant forced the Tahoe’s owner, Jose Ruiz, and his cousin ou of the vehicle, Ruiz reported the theft to police and told them it was equipped with General Motors’ OnStar navigation, communication, and security system. A call to OnStar quickly provided police with the location of the vehicle, and when the officers confirmed they were ready, OnStar call-center advisors transmitted a wireless signal to the Tahoe, activating its “Stolen Vehicle Slowdown ” featur

Behind the wheel of the Tahoe, the driver pressed the accelerator harder. To his surprise, the pedal became unresponsive, and the SUV’s engine gradually slowed to idle speed. He jumped out and ran bu was soon in handcuffs—roughly fifteen minutes after Ruiz reported his vehicle stolen. Twenty-one-year-old Albert Roman Romero became the first person caught and charged with carjacking as a dire result of GPS technology.[2]

The Global Positioning System, now so universally recognized that the Associated Press uses the GPS acronym without elaboration, was not yet complete when Romero was born.[3] The first GPS satelli was launched in 1978, two decades after the Soviet Union surprised the West with its launch of Sputnik, but the twenty-fourth satellite—the minimum number required to provide uninterrupted, round-the-clock coverage worldwide—did not go into orbit until 1994. That was three years after the Soviet Union dissolved and three decades after the first conceptual schemes for such a system emerged in the 1960s.

Over the course of five decades, the development of GPS has featured scientific genius and foresight, interservice rivalries among the branches of the military, defense contractor controversies, cancellations, delays and budget cuts, stunning success on the battlefield, and impressive entrepreneurial innovation—all against the backdrop of shifting foreign policy, wars, recessions, and unexpected events beyond the confines of the program. By the fall of 2009, when OnStar recorded th first successful carjacking intervention, what began as a classified Cold War military program had spawned a private-sector GPS industry with a multitude of uses dwarfing those related to defense and global market in the tens of billions of dollars. Despite varying estimates of the size of the global market, most analysts predict a combined annual growth rate above 20 percent through 2016.[4]

GPS is at once a simple concept and a vastly complex technology. Stripped of the intricate math an physics—in this case, it *is* rocket science that makes the system possible—GPS may best be understoo as a set of free radio signals available worldwide that enables scores of individual applications requiring precise positioning, navigation, or timing. Although GPS achieved fame first for its ability t guide bombs accurately and later for changing the way people find their way around, its ability to synchronize time across vast distances—a key element of its origin—now enables the smooth flow o ~~electronic data across worldwide networks. The degree to which private industry has leveraged~~ this free service is phenomenal, making GPS a vital public utility today.

For example, OnStar, with more than 2 million subscribers in 2009, generated a billion dollars for GM, even as the automaker faced bankruptcy and survived only with a federal government bailout.[5] B 2013 OnStar boasted more than 6.4 million subscribers in the United States, Canada, and China, and nearly a million GM vehicle owners used its RemoteLink mobile phone app to remotely access OnSta services.[6] The company also created FMV (For My Vehicle), an aftermarket replacement rearview mirror with an OnStar button, making many of its services available in other manufacturers' vehicles but rival carmakers have quickly ramped up their own similar systems. Considering that more than four hundred people die and many more sustain injuries each year in high-speed police pursuits, it is no surprise that law enforcement officials share vehicle owners' enthusiasm for the vehicle slowdow feature.[7] "It helped us not only recover a vehicle for a local citizen, but also prevented a dangerous high-speed chase and allowed us to quickly apprehend a suspect ," said Sgt. Steven Phillips of the Visalia police. "It's a win for everyone. "[8]

Or nearly everyone. Cable news channels televise high-speed police chases hoping viewers will stay glued to their screens in anticipation of a dramatic conclusion. The advent of electronic news gathering using helicopters made live aerial coverage of automobile chases a common feature of television newscasts by the mid-1990s.[9] With the emergence of a twenty-four-hour news cycle, the ability of local news operations to instantly uplink their video to national cable networks, and the celebrity factor embodied in the iconic 1994 slow-speed chase of O. J. Simpson's white Ford Bronco cable news found a winning formula that presaged the era of "reality " TV. Cable executives may appreciate this irony: just as satellite technology enabled video crews to take live coverage aloft, the ever-expanding use of GPS satellites now offers the means to make high-speed police pursuits obsolete.[10]

A few naysayers worry that GPS will do to our innate sense of direction what keyboards have done to penmanship. Longstanding concerns persist about the technology's misuse by terrorists or governments, even against their own citizens. But for the most part, the march of GPS technology fro the laboratory to the battlefield to everyday life has gained momentum with each passing year, especially since 2000, when the government stopped deliberately degrading the signal provided for civilian use. The boost in accuracy unleashed a torrent of consumer electronics aimed at helping motorists find their way, avoid traffic jams, and locate points of interest. Industry watchers estimate at the end of 2009 that more than a third of U.S. households had at least one personal navigation device (PND), and when in-dash vehicle systems and GPS-enabled phones were included, the figure ros to more than 55 percent.[11]

When CNN launched, in mid-2008, a new program covering world events, *Fareed Zakaria GPS*, viewers had no trouble making the connection when the host announced, "Welcome to the very first edition of 'Global Public Square.' "[12]

By the end of 2009, GPS had become such a household word—used interchangeably for the system and the gadgets that use it—that numerous television advertisers were tying their products to its popularity:

Big-box jewelry retailer Jared showed a man sitting in his car asking a voice navigation system fo directions. The unit's sultry female voice comments on his purchase and refuses to cooperate until he placates "her " by hanging a necklace around the GPS unit.[13]

TurboTax touted its tax preparation software as being as easy to follow as GPS: "These days, if I need to get someplace, I just use the GPS on my cell phone. I get turn-by-turn directions, which show me right where I need to go. I do my taxes the same way, with the TurboTax Federal Free Edition. ”[14]

Fidelity Investments adopted a moving green line and the slogan “Turn Here ” to promote its financial and retirement planning services, a clear allusion to turn-by-turn GPS guidance.[15]

An *ABC News* online article in December 2009 listed GPS among its “Top 10 Innovations of the Decade. ”[16] A WashingtonPost.com blogger that same month asked his online readers to rank a list of the decade’s top ten consumer tech developments. One week into the voting GPS placed fourth, behind the iPhone, Mozilla Firefox, and the iTunes store.[17]

For individuals the GPS revolution is most visible in how they shop and travel in their cars and on foot. From 2005 to 2010, consumers accounted for 59 percent of GPS equipment revenues in North America.[18] Mobile phone apps are increasing consumer exposure to GPS. By January 2013, 129.4 million Americans owned smartphones, or about 55 percent of the nation’s 235 million mobile phone subscribers.[19] By 2016 there are projected to be 1 billion smartphones in use worldwide and 340 million mobile subscribers using a turn-by-turn navigation app or service.[20] While analysts expect PN sales to decline by about 40 percent through 2016 as users shift to phones, at the end of 2011 there were 150 million PNDs in use worldwide and 60 million factory-installed and aftermarket in-dash systems, ensuring they, too, will remain a key part of many people’s daily lives.[21]

Most GPS users need not know and probably do not care how the technology works or where the satellites and ground stations transmitting the signals are located. But casual users should be aware that the satellite platform they rely upon for GPS service is one more example of public infrastructure—like bridges, highways, and water mains—that ages and that government finds increasingly costly and challenging to maintain. Those who do not personally own or use GPS devices—from the standpoint of mobile phones, that is becoming a rarity—might consider the issue irrelevant, but they should know that the technology now touches virtually everyone and every sector of society. In addition to military use and personal navigation, GPS has become indispensable for a host of commercial applications in aviation and space operations, trucking and shipping, fishing and boating agriculture and forestry, surveying and mapping, grading and construction, and mining and oil exploration. Beyond positioning and navigation, GPS now provides atomic-clock accuracy for the synchronization and split-second timing needs of telecommunications and data systems, financial networks, and electric power grids.[22] A recent study estimated that GPS technology would provide U.S commercial users annual direct economic benefits between $67.6 billion and $122.4 billion as its adoption by commercial users approaches 100 percent.[23]

As entrepreneurs have imagined new uses for GPS, demand for better accuracy has led to multiple ground- and space-based systems that augment the satellite signals. Other nations are developing the own versions of GPS, giving rise to the generic term *GNSS*, for any global navigation satellite system. While nations pledge to make their GNSS systems work together, they actively compete with one another as they do in all other areas. These systems contribute to an increasingly interconnected and complex world in which the systems’ interoperability, sustainability, and security create political and economic issues affecting the entire population.

Recognizing the growing demands for positioning, navigation, and timing (PNT) services and the need to set clear policies involving the use of GPS, President George W. Bush issued a directive in 2004 creating a National Executive Committee for Space-Based PNT.[24] President Barack Obama reaffirmed the commitment to GPS in 2010 as part of his National Space Policy directive.[25] Addressing the PNT advisory board in November 2009, Scott Pace, director of the Space Policy

Institute at George Washington University, said that global navigation satellite systems today are better understood as information technology infrastructure than merely as aerospace products.[26] With such a large installed user base, he said, introducing new signals or systems resembles rolling out ne computer operating software, with similar concerns about backward compatibility and users' willingness and ability to upgrade. Everyone who has endured the learning curve of a new software program or deliberated over the purchase of a new computer that would necessitate costly upgrades can identify with that statement and appreciate where the GPS marketplace now stands. But, far more than the computer or consumer electronics industries, how GPS evolves depends on what the government does. That makes understanding the history of GPS development helpful for anyone hopi to construct informed opinions about public policies regarding its future.

This book attempts to present that history—from the scientific breakthroughs that made such a system possible to the people and institutions that oversaw its development—in an accessible manne for a general audience. As with planning a trip using GPS guidance, multiple options were available to tell this story. This work aims to strike a balance between following the shortest, most direct route an making sure readers visit the most important points of interest. At the end, you should have a better understanding of a technology that continues to revolutionize how humans travel, how we work and play, and perhaps even how we think.

1

New Moons Rising: The Satellite Age Arrives

From the vantage point of 2100 A.D., the year 1957 will most certainly stand in history as the year of man’s progression from a two-dimensional to a three-dimensional geography. It may well stand also, as the point in time at which intellectual achievement forged ahead of weapons and national wealth as instruments of national policy.

Geophysicist Lloyd V. Berkner, Foreign Affairs, *January 1958*

Two seconds after liftoff and four feet into its flight, the Vanguard rocket stalled as if held by an invisible tether and sagged back toward the launch pad. As the bottom of the first stage, filled with liquid oxygen and kerosene propellant, crumpled against the platform, the engine’s orange exhaust erupted into a massive fireball that engulfed the tottering seventy-two-foot rocket. In the final moment before flames obscured its tip, the nose cone could be seen breaking free.[1] Under that cone was a grapefruit-size aluminum sphere with batteries and transmitters packed inside and a half-dozen solar cells and antennas attached outside. The entire twenty-two-thousand-pound, three-stage rocket assembly, which an Associated Press story described as “a ton of metal and 10 tons of fuel ,” had bee designed for the sole purpose of hurling the three-and-a-quarter-pound ball three hundred miles abov Earth.[2] For the United States, the effort of putting its first satellite into orbit had gotten off to a disma start—in full view of millions of Americans who watched televised images of the conflagration on th evening news on December 6, 1957.

Few people watching that night would have believed that, within a decade, the same scientist who designed that first tiny U.S. satellite would conceive a multi-satellite system for determining the precise location and exact time anywhere on the planet or in the air. By the time the forerunners of GI were hitting the drawing boards, the public had shifted its attention to the race to put men on the moon. Plans for a global satellite-based navigation system, largely classified and visionary beyond what most of the military brass saw as practical, would have to wait years for technical advances and conventional thinking to catch up. However, any discussion of GPS must begin with the launching of the first man-made satellites at the dawn of the space age. The system’s DNA traces directly back to the technologies, the scientists, and the military institutions that participated in what sometimes has been called “the first space race. ”[3]

After crews extinguished the fire and began cleaning up the Vanguard launch site, they found the satellite lying on the ground. It survived a seven-story fall, a 3,500-degree inferno, and being doused with tons of water. Its antennas were bent but the sphere was intact, and ground receivers set up to monitor its orbits confirmed that it was transmitting two radio signals, as designed.[4] Martin Votaw, who built the small transmitters (using early transistors in place of vacuum tubes), was listening as th satellite made its short journey to the ground. Votaw went to the launch pad to retrieve it. “There it was, clean as a whistle ,” he recalled clearly in an interview fifty-two years later.[5] He placed the battered satellite in a brown cardboard box and took it to the man who led its design team, thirty-six-year-old Roger Easton, future head of the Space Applications Branch at the Naval Research Laboratory (NRL).

“What should we do with it? ” Votaw asked.

“Take it home, I guess ,” Easton replied.[6]

In a move that today would provoke intense questioning, if not an airport lockdown, Easton nonchalantly carried the box with the satellite aboard a commercial flight back to Washington DC.[7] "I sat ~~on our kitchen table overnight ," his daughter, Ruth, recalled.~~[8] ~~Easton delivered the satellite~~ to John P. Hagen, director of Project Vanguard, who later donated it to the Smithsonian's National Air and Space Museum, where it remains today.[9]

Fig. 1.1. Roger Easton (*upper right*) and Martin Votaw (*below, seated*) look on as the National Air and Space Museum's David Devorkin opens the Vanguard TV-3 satellite in 2008, during a fiftieth anniversary gathering. Chris Hagen, son of Vanguard Project director John P. Hagen, points at the artifact. (Courtesy Roger Easton Jr.)

Bad Press

While Vanguard personnel busied themselves repairing the launch facility and readying a backup rocket, the public reacted with panic. The incident plunged the nation, already in a state of high anxiety following the Soviet Union's two successful Sputnik launches, on October 4 and November 3, into a period of humiliation, second guessing, finger pointing, and political jockeying. "Vanguard Rocket Burns on Beach; Failure to Launch Test Satellite Assailed as Blow to U.S. Prestige ," read the headline in the *New York Times* the next morning.[10] "Oh What a Flopnik! " chided the *London Daily Herald*.[11] "How about some relentless looking around for possible sabotage? " the *New York Daily News* asked.[12] The Baltimore-based Glenn L. Martin Company, the prime contractor for the Vanguard rockets, and General Electric, the subcontractor for the engines, blamed each other for the problem.[13] Sell orders forced New York Stock Exchange officials to halt trading in Martin's stock the day after the explosion.[14] The launch pad fiasco came just eleven days after a brash Texas senator with presidential ambitions, Lyndon Baines Johnson, began hearings on Sputnik in the Senate Preparedness Subcommittee. That same day, November 25, President Dwight D. Eisenhower suffered a mild stroke. Many wondered if he was healthy enough to continue as president, and there were some calls for him to step down.[15] American preeminence in world affairs and military and technological prowess, taken for granted since the end of World War II, was being openly questioned, as evidenced by Johnson remarking after the Vanguard failure, "How long, how long, oh God, how long will it take us to catch up with the Russians' two satellites? "[16]

From a modern perspective, with partisan bickering over foreign affairs routine and lack of faith in government pervasive, the reaction to the Sputnik launches and Vanguard failure may not seem unusual, but Americans viewed the federal government differently then. A 2013 Pew Research Center survey found only 26 percent of Americans trusted the government to do what is right "just about always ” or “most of the time. ” That is slightly better than 2010, when the figure was 22 percent, but the ~~trend has been mostly downward for decades. When Pew first polled the question of trust in~~ government in 1958, as part of the National Election Study, 73 percent said they trusted the government to do what is right most of the time.[17]

The satellite woes came at a time when American idealism was being shattered in popular culture as well. Over the preceding decade, television had transformed American home life. About 3.9 million U.S. households, less than one in ten, had a television in 1950.[18] By 1957, the figure had grown to 38.9 million of the nation’s 49.5 million households, nearly four in five.[19] TV advertising expenditures reflected the growing power of the industry. Between 1950 and 1960, ad spending on television grew ninefold, from $170 million to $1.53 billion, propelling the medium past radio and magazines and fueling a trend toward newspaper consolidation.[20] But the TV business was rocked by scandal when it became public in 1957 that quiz shows—so popular they represented five of the top eight shows—were rigged.[21] Later in the year, the public also learned that record companies were giving kickbacks—“payola ”— to radio disc jockeys.[22] With or without in-home television, every American could witness the Vanguard explosion via grainy, black-and-white Defense Department footage in a Universal-International newsreel titled “Satellite a Bust: Rocket Blows Up in First U.S. Try. ” Narrator Ed Herlihy, whose distinctive broadcast voice most people would recognize even if they don’t know his name, laments, “What happened is already unhappy history—another setback for the United States in the race into outer space. ”[23]

But what popular media recorded as a disastrous, dispiriting launch failure was also a failure to manage public expectations, to appreciate the risks involved in live coverage of scientific experiments, and to keep political aspirations in line with technical progress. The launch was scheduled two months to the day after the Sputnik shocker. When the December 4 rocket firing was delayed multiple times—not uncommon in launch countdowns—and finally “scrubbed ” for that day, many newspapers ran large, bold headlines across the entire front page announcing the postponement. American readers began to comprehend the complexities of modern rocketry in stories that described the launch vehicle’s various components and blamed the delays on problems ranging from frayed wires to defective parts to gusty winds. “As Impatience Mounts, Fidgety Scientists Fuss with Bride-Like Missile ,” read a headline in the *St. Petersburg (FL) Times*.[24] While such stories helped educate the public about this new technology, the focus on problems and delays only reinforced the fact that the Soviets had already overcome these complexities. During the wait, the press corps scrambled for whatever story angles they could find—filing reports about how Cape Canaveral was chosen as the launch site, what the locals thought about the commotion surrounding the event, the odds of satellites colliding in space, and even interviews with each other. NBC cameraman Gene Barnes fretted to a print reporter that the longer the delay, the less likely he could get his film to a nearby affiliate and processed for airing on the evening news.[25] Camped on the beach miles from the launch pad, others complained there were too few updates from program administrators. “They keep referring to this as a test firing, but the public looks on this as THE satellite and deserves more information about it ,” said the *New York Times*’s Milton Bracker.[26]

This buildup to the launch contributed to an exaggerated letdown, made worse by the timing—the December 7 anniversary of Pearl Harbor. The *San Francisco News* even used the headline “Cold War Pearl Harbor. ”[27] *Time* magazine, in its December 23 issue, chastised the 127 members of the U.S. and foreign press corps who covered the launch, pointing out that few “gave any strong warning to editors and readers—as briefing officers warned them—that they were there for a test shoot, and that one of three missile tests turn out to be a flop-nik. ”[28] Scientists working on the Vanguard project had warned that the odds were against successfully placing a satellite into orbit on the first try. One told reporters it would be “a real miracle. ”[29] J. Paul Walsh, deputy director of Project Vanguard, said in a press conference before the launch, “We will be pleased people if it establishes an orbit, but we will not be ~~despondent if it doesn’t. ”[30] Those cautionary words did not cut through the swirl of anxiety and~~ wishful thinking.

Lost in the coverage, in the hand wringing that followed, and in some historical accounts of the er is the fact that the original plans did not call for the rocket that burned to carry a satellite. Dubbed TV for its status as a “test vehicle ,” it was a new rocket design, and the launch was the first attempt usin three “live ” stages, meaning all three contained fuel and would undergo a “burn ” during flight.[31] Its predecessor, TV-2, used a live first stage but dummy second and third stages.[32] TV-2 was launched successfully October 23, but only after months of delays due to manufacturing problems and seven “static ” (bolted down to prevent liftoff) test firings.[33] That the United States attempted to put its firs satellite into orbit by placing it atop an unproven launch vehicle, with the eyes of the world watching is a historical oddity that appears different in hindsight than it must have seemed at the time. Although the TV-3 explosion dominated public perceptions, the Vanguard program was an unqualifie success; in a record thirty months it developed an entirely new space launch vehicle and successfully placed three satellites into orbit.[34]

Competing Programs

Project Vanguard began as a scientific initiative to launch a satellite as part of the International Geophysical Year (IGY). Proposed in 1950 and sponsored by the International Council of Scientific Unions, the IGY program was modeled after the International Polar Years, held in 1882–83 and 1932–33.[35] Astronomers were forecasting a period of increased solar activity from mid-1957 to the end of 1958, so the “year ” of research actually spanned those eighteen months.[36] In addition to studying sol activity, scientists in sixty-seven countries participated in coordinated research in such fields as geodesy, geomagnetism, gravity, meteorology, oceanography, rocketry, and seismology.[37]

In the years leading up to its start, the United States and the Soviet Union proposed launching satellites during IGY, and by agreement, these “man-made moons ” were to transmit radio signals on predetermined frequency, allowing scientists around the world to track those achieving orbit. Calling orbiting satellites man-made moons seems quaint now, but in those days, headline writers needed a description that average newspaper readers could grasp, as shown in a United Press headline from February 15, 1956, in the *Sarasota (FL) Herald-Tribune*: “First Man-Made Moon May Be Visible in 1957. ”[38] The story introduces the term “artificial earth satellite ” in the second paragraph and sticks with “satellite ” for all but one reference through the rest of the story. Project Vanguard’s director, Hagen, tells the reporter that to see the satellite, traveling from horizon to horizon in eight to twelve minutes at eighteen thousand miles per hour, “will take a little doing ,” even with binoculars.[39] According to the United Press story, the United States planned to launch ten satellites in all, the first being 30 inches in diameter and weighing twenty-one and a half pounds. That is larger than the 20-inch size that was ultimately decided upon, and much larger than the 6.44-inch “grapefruit ” placed atop TV-3.

The shortcomings of trying to track a satellite visually, even using powerful telescopes, was a major factor in the selection of Project Vanguard as the IGY satellite program. After the U.S. Nationa Committee for the International Geophysical Year decided, in early 1955, that the nation’s participation should include launching a satellite, the Army, Navy, and Air Force put forth competin proposals for this chance to make history. All three had active rocketry programs, and interservice rivalry for priority and funding of weapons systems was intense. All three proposed modifying existing rockets, but only the Naval Research Laboratory proposed using one not tied to an existing military purpose—the Viking. The Army’s Redstone and Air Force’s Atlas rocket programs were par of the country’s nascent intermediate-range ballistic missile (IRBM) and intercontinental ballistic missile ~~(ICBM) fleets, and the Air Force had already begun developing plans for a military satellite~~ to be launched using Atlas or Titan rockets.

The contrasting Army and Navy satellite proposals illustrate the trade-offs that early satellite designers faced in terms of size, weight, and functionality. A smaller, lighter satellite would be easie to put into orbit but hard to verify. If it achieved orbit, what further value could it offer to justify the effort and expense? A larger, heavier satellite could hold the instrumentation and batteries needed to transmit tracking signals and other data over a period of time, but lifting more weight high enough fo a stable orbit stretched the capabilities of existing rockets. The Army proposed launching a small, five-pound satellite called Orbiter. Although the use of the well-established Redstone rocket promise an earlier launch date, the satellite as originally proposed lacked any means to transmit tracking signals and could perform no scientific experiments.[40] The Naval Research Laboratory’s proposal, *A Scientific Satellite Program*, dated April 13, 1955, notes that such a satellite would be visible only at dawn or sunset, in favorable weather, and would be “exceedingly difficult to acquire in an optical instrument of sufficient power (and hence restricted field of view) ” unless its location were already known.[41] “Indeed, it is readily conceivable that an object could be placed in an orbit and never observed, if only optical methods are used ,” the proposal warns.[42] To address this issue, eight pages the proposal are devoted to describing in detail a tracking system called Minitrack, based on modifications to the guidance system used in the Viking rocket program. The modified Viking rocke and modified tracking system, Minitrack, together with a new, instrumented satellite design, became Project Vanguard.

Milton Rosen, chief engineer of the NRL ’S Viking rocket program, conceived Viking as a research tool to study the upper atmosphere, and at the time of the proposal, it held the altitude record for single-stage rockets—158 miles.[43] Rosen, an electrical engineer, had worked on guided missiles at th NRL as World War II ended.[44] First launched in 1946, Viking incorporated innovative “gimbaled ” motors, which could be angled for steering the rocket, intermittent gas jets for stabilizing it after the main propellant was exhausted, and radio telemetry.[45]

In his bid to win the IGY project, Rosen collaborated with Roger Easton, who had joined the NRL in 1943 and worked on radio beacons and blind aircraft landing systems, and Easton’s boss, John Mengel, who headed the laboratory’s Radio Division.[46] Mengel coined the name Minitrack from a phrase used in the title of a memo, “Proposal for Minimum Trackable Satellite ,” that he and Easton wrote to describe the system.[47] By switching to a lower radio frequency, which Rosen had suggested, and using large, five-by-fifty-foot ground antenna arrays, the system could pick up the relatively wea signal generated by a transmitter small enough to fit in the satellite. Minitrack used trigonometry to calculate the satellite’s position by comparing the different angles of the incoming radio signal at pairs of ground antennas connected to receivers capable of detecting tiny differences in the signal wavelengths. As Mengel explained in a *Scientific American* article, humans use the same the technique to locate the direction of a sound that reaches their ears at different times.[48] For a visual illustration, think of sitting on a long, straight beach. Waves arriving perpendicular to the shore breal evenly, but those that roll in at an angle break from one side to the other and arrive at two points on the shoreline at different times. Figure 1.2 shows how the tracking technique was later illustrated in *Project Vanguard Report No. 18*, dated July 26, 1957, which was devoted solely to a progress update on Minitrack.[49]

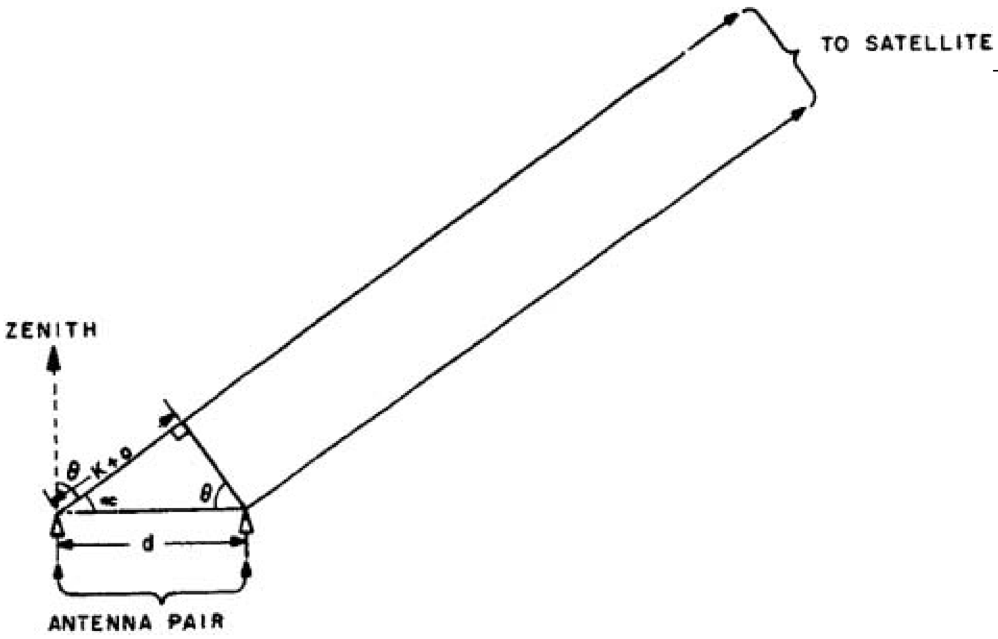

Fig. 1.2. Minitrack technique, using angles of signals. This diagram shows how the Mini-track system tracked satellites using the different angles of signals arriving at a pair of antennas. (Courtesy Naval Research Laboratory)

The NRL'S initial 1955 proposal goes into similar detail about the launch vehicle, describing modifications to the Viking rocket and the addition of two solid propellant stages. There is also a thorough discussion of orbital considerations, such as the advantages of launching eastward from a location near the equator to maximize the boost from the earth's rotation and the critical timing and precise angle needed in the final stage to achieve stable orbit. It provided fewer details regarding the satellite. The payload was to be "small in size and mass ," between ten pounds and forty pounds—the projected weight of the shell, instruments, and batteries needed to transmit data for up to four months.[50] That is all that is stated—no materials, no dimensions, no schematics—but ultimately, onc the satellite's design was fleshed out, it would join the tracking system as the winning elements of th proposal.

The NRL laid out an ambitious schedule of ten launches in thirty months, with three test flights anc seven satellites, placed on the fourth through tenth rockets.[51] It predicted sending up the first satellite two years from the start of the program. Its main scientific objective was in the field of geodesy—using a satellite to make more accurate measurements of the earth, which would help in "tying together the various continental grids and locating the many islands with respect to these grids. "[52] Geodesists relied on the moon as a reference point for making measurements in the middle of the ocean, and a satellite, by virtue of its closer proximity, would improve accuracy tenfold. In this case, satellite truly would function as a "man-made moon. " The data would yield practical and militarily significant results, the proposal notes: "Improved geodetic data is required to provide maps of sufficient accuracy for locating potential military targets and Loran navigation stations. "[53] Loran, short for long-range navigation, was a land-based system of radio beacons operated by the Coast Guard. Left unstated is the reason the proposed partner in the effort, the Army Map Service, was interested in pinpointing several Pacific islands—they were to be used in ICBM test flights.

Beyond proving that a satellite had achieved orbit, other considerations factored in selecting the IGY satellite program. Among the concerns were how to keep the time and resources required from delaying existing military programs (no civilian organization had the wherewithal); how, for strategi and public relations purposes, to portray the launching of a satellite as a scientific rather than a military exercise; and how to keep sensitive military secrets from leaking out with published scientific findings. The National Security Council weighed these concerns, established policies for th