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The 4C1000 Seven Tenets for the 21st Century—The Innovation Secret at the National Reconnaissance Office and Silicon Valley

By Robert A. McDonald, Ph.D., M. Sam Araki, & Patrick Widlake

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The 4C1000 Seven Tenets for the 21st Century—The Innovation Secret at the National Reconnaissance Office and Silicon Valley[1]

Robert A. McDonald, Ph.D., M. Sam Araki, & Patrick Widlake[2]

Abstract: The NRO management philosophy of the "4C1000 Seven Tenets" (7 Tenets) shaped an environment for creativity and innovation that resulted in revolutionary changes in overhead reconnaissance during the Cold War—a remarkable paradigm that played a critical role in bringing the Cold War to a peaceful end. In this article we selected four imagery reconnaissance programs as examples to illustrate this point. In Figure 5 of the article you will find a summary timeline graphic that illustrates the short time period for development, the innovative accomplishments, and the revolutionary impact of these four imagery reconnaissance programs that benefited from the principles in the 7 Tenets. "Silicon Valley companies" subsequently applied these same principles, and that resulted in a 21st century technological revolution. This revolution created innovative products and services that rapidly became interwoven into the daily lives of billions of people worldwide. The findings from independent analyses of the principles inherent in the 7 Tenets have validated their contributions to innovation and revolution changes.

Innovation has been the hallmark of the National Reconnaissance Office (NRO) and Silicon Valley. Their successes have been revolutionary, and have changed the world. What is the secret of their successes? Is their secret applicable to 21st century challenges? The answers: to the first question, their secret was that they embraced the "4C1000 Seven Tenets" (7 Tenets), and to the second question, definitely yes, the 7 Tenets are applicable for the 21st century.

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These tenets are foundational principles that grew out of a competitive, decentralized structure for development of Cold War national reconnaissance systems—principles that evolved out of practices by the Central Intelligence Agency (CIA) in its development of the U-2, the practices by the Naval Research Laboratory in its development of the first signals intelligence satellites, Grab, and the practices by the CIA and US Air Force in their joint development of the first photoreconnaissance satellite, Corona. During these early days of the Cold War the principles became focused and refined in the program offices of the National Reconnaissance Office, and the NRO came to symbolize those practices.[3]

We have called these principles the "4C1000 Tenets" because they reflect the management philosophy of this national reconnaissance intelligence organization—an organization that was so highly classified during the Cold War, that its name and acronym, National Reconnaissance Office and NRO, infrequently were spoken. The NRO typically was referred to by the room number of its Director's office, Pentagon Room 4C1000. Hence, the "4C1000 Tenets."

The 7 Tenets are an overarching management philosophy and practice that generates an environment for creativity and innovation with an appropriate infrastructure to maintain a rapid pace. During the Cold War the National Reconnaissance Office (NRO) became a focus for evolving these principles during its ground-breaking development of America's space-based reconnaissance, along with the associated data processing, dissemination, and information capabilities. In more-recent times, Silicon Valley has become a new focus for innovation, and it has been, perhaps unknowingly, applying these same principles with its explosion of 21st century technological breakthrough companies. These companies have been achieving remarkable innovations in the world of computer technology, artificial intelligence, data processing, and communications resulting in the Internet revolution. The 7 Tenets are principles that we see continuing to be relevant well into the 21st century providing innovative solutions that can contribute to future acquisitions for the national security community.

4C1000 Seven Tenets

1. Focus on threat-based need
2. Adhere to short timelines
3. Maintain resource stability in funding and staffing
4. Rely on small, streamlined, breakaway, collaborative team
5. Employ strong systems engineering & program management
6. Adapt and draw from the latest advances in technology and concepts of operation.
7. Establish a short chain of command & avoid bureaucracy.

3 The Cold War NRO reconnaissance programs were organized into three collaborative, yet competitive overarching program offices formed by three separate organizations, the Air Force for Program A, the CIA for Program B, and the Navy for Program C.

To demonstrate that relevance we need only briefly review some of the innovative successes. (While there could be numerous examples from across the intelligence disciplines of national reconnaissance, we have limited our discussion to four imagery examples from the early years, in part to keep our discussion unclassified.)[4] The principles inherent in the 7 Tenets played essential roles in ensuring the Intelligence Community's dramatic successes during the Cold War successes that resulted in the development of the U-2 reconnaissance aircraft, the Corona photoreconnaissance satellite, the succeeding Gambit and Hexagon photoreconnaissance satellites, and the subsequent Kennen near-real-time imagery reconnaissance satellite. During the turn of the century, the same principles were crucial factors at innovative Silicon Valley companies that created a revolution in technology.

The U-2 Reconnaissance Aircraft.

It was a joint CIA and Air Force program team that produced the U-2—an aircraft that was technologically innovative, operated at a high altitude, and penetrated Soviet airspace to collect vital intelligence. In the course of its development, the program team created an organizational structure and managerial model that influenced the subsequent NRO successes in developing the Corona, Gambit, Hexagon and Kennen reconnaissance satellites. The lessons of the U-2 experience were the foundation for the NRO to develop and apply its 7 Tenets (Lewis, 1997, p. 13).

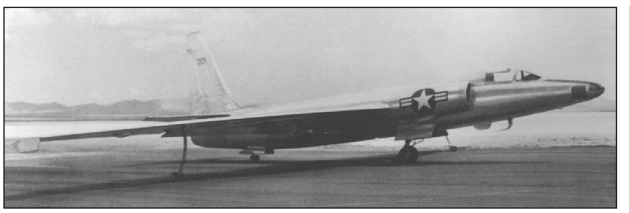
The CIA project leader for the U-2 program was Richard Bissell. He created a small break- away team that worked in partnership with Col Osmund Ritland's Air Force team and Clarence "Kelly" Johnson's streamlined Lockheed Skunk Works®.[5] The government and contractor collaboration integrated the two operating paradigms, and with their short chains-of-command, they cut through the red tape of procurement and made swift decisions. This rapid and efficient decision process translated into exceptional project execution by both the government and contractor. During program execution, much of the decision making actually transferred from government to contractor. The two teams were motivated by a sense of national emergency to respond to the nuclear threat of the Soviet Union. Bissell and Johnson liberated their team's talent with an informal environment

4 One signals intelligence (sigint) example was the application of the 7 Tenets to the Agena Aftrack Project, which was initiated in 1959. It was a joint Air Force-CIA series of "experimental systems" where a small, self-contained electronic payload was attached to the aft rack of the Agena vehicle that carried the Corona photo-satellite reconnaissance system. The payload was capable of detecting electronic signals. Consistent with the 7 Tenets, the project relied on a small, streamlined breakaway, collaborative team that did not necessarily conform to all military standards and practices and would develop a system in a short timeline of less than nine months. The Aftrack multiple mission project, including a series subsats, extended to the end of the Corona missions. The project made major contributions to national security, such as identifying a high density of Soviet early-warning radars, identifying the locations of Soviet communications transmitters, and monitoring Soviet radar tracking of US reconnaissance satellites (NRO, 1973).

5 The Skunk Works® came into being during World War II when Kelly Johnson established a small break-away Lockheed team that was organized unconventionally and typically broke the rules by challenging the bureaucratic system that stifled innovation. The name was adapted from Al Capp's popular newspaper comic strip at the time, Li'l Abner. The strip's "Skonk Works" was a "mysterious and malodorous place deep in the forest." Lockheed's adaptation, (i.e., Skunk Works®) is a registered trademark of the company (Lockheed, 2019).

that encouraged risk-taking, innovation, quick decision making, and maintaining a fast pace (Lewis, 1997, pp. 15ff; Pedlow & Welzenbach, 1998, p. 61).

The result was the timely delivery of a reconnaissance system that made critical contributions to national security. (See Figure 1.) In less than eight months after Presidential approval, Lockheed delivered, on 25 July 1955, the first U-2 at a cost that actually was under budget.[6] The aircraft had a range of 2,950 miles at an altitude of 72,000 ft., beyond the reach of known anti-aircraft weapons and interceptor aircraft. The first official flight was on 8 August 1955, with final testing completed in 1956 and the first operational mission on 20 June 1956. The U-2's reconnaissance exposed the US "bomber gap" with the USSR as a myth, and it increased the capabilities of America's deterrent force by providing timely and precise targeting data (Lewis, 1997, pp. 15ff; Pedlow & Welzenbach, 1998, pp. 66, 70, 76, 93, 100, 316-317;).



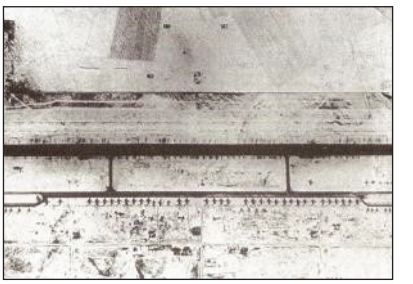


Figure 1a (left). U-2 Reconnaissance Aircraft (Courtesy, CSNR Reference Collection). Figure 1b (right). U-2 Photograph of Saratov-Engels Air Field at Ramenskoye, USSR, 1956. (Courtesy, CSNR Reference Collection, via Defense Intelligence Journal, Vol. 8 No. 1, Summer 1999.)[7]

The Corona Reconnaissance Satellite.

The spectacular success of the U-2 project resulted in replicating, for the development of Corona, the same kind of break-away, collaborative team approach. After President Eisenhower formally endorsed the Corona project in February 1958, CIA's Bissell became the CIA project manager with responsibility for the payload, mission, and photo exploitation. The Air Force's Ritland took charge of the Air Force support, with Col Lee Battle guiding the day-to-day Air Force management. Lockheed was the prime contractor, with James Plummer the Lockheed program manager who became responsible for the engineering and development of the payload, spacecraft, recovery vehicle. As the

6 President Eisenhower approved the U-2 project in early November 1954, and on 24 November Eisenhower orally approved the CIA managing the project with assistance from the USAF. The initial planning document called for deploying the aircraft within a period of 20 months at a cost of $22 million (Pedlow & Welzenbach, p. iii, 33, 36-37).

7 The U-2 acquired coverage that demonstrated the Soviet threat was not as great as initial intelligence assessments had suggested. During the U-2's first months of operations it identified less than three dozen Bison bombers at this airfield near Ramenskoye. (McDonald, 1999).

prime contractor, Lockheed was responsible for integrating the components from the various subcontractors. The break-away teams operated in a very informal manner with a high degree of collaboration among the various government and industry components (McDonald, 1997a, p 63-64; McDonald, 1997d, p. 148).

The 7 Tenets were emerging during development of Corona, as evidenced in Bissell and Battle's management style, which included an approach that focused on selecting a small group of good people, demanding quality performance, focusing on mission accomplishments, avoiding busywork, and relying on contractor's technical recommendations. Battle summarized his principles in what he called "Battle's Laws."[8] Those laws, along with Bissell's philosophy, Kelly Johnson's Skunk Works® concept, and NRO's early management style, subsequently evolved into the 7 Tenets (Battle, 2002).

The result was that, 30 months after approval, the Corona program was conducting operational missions, and did so for 12 years from August 1960 to May 1972.[9] (See Figure 2.) With Corona, the U.S. had launched the first camera into space, taking pictures from 100 nautical miles, ejecting the film back toward earth, snatching the film capsule by an aircraft in midair, and acquiring photographs that ultimately had a resolution of 6 ½ feet. During its operational life, Corona collected over 800,000 images. This kind of imagery provided US policy makers with intelligence not previously available. Additionally, the technology enabled the intelligence analysts to demonstrate that the USSR did not have an overwhelming number of intercontinental ballistic missile, thereby disproving the myth of a "missile gap" between US and Soviet capabilities. More basically, there grew a consensus that Corona was instrumental in keeping America from overestimating the Soviet nuclear capability, thereby avoiding the US overreacting with an unnecessary nuclear buildup (McDonald, 1997b, p. 8; McDonald, 1997c, p. 213; 1997b, p. 8).

8 Col Battle issued his management principles in the form of "Battle's Laws" (McDonald 1997b).

9 President Eisenhower formally endorsed the Corona project in February 1958. On 18 August Corona was conducting an operational mission (McDonald, 1997a, p. 63; McDonald, 1997b, p. 301).

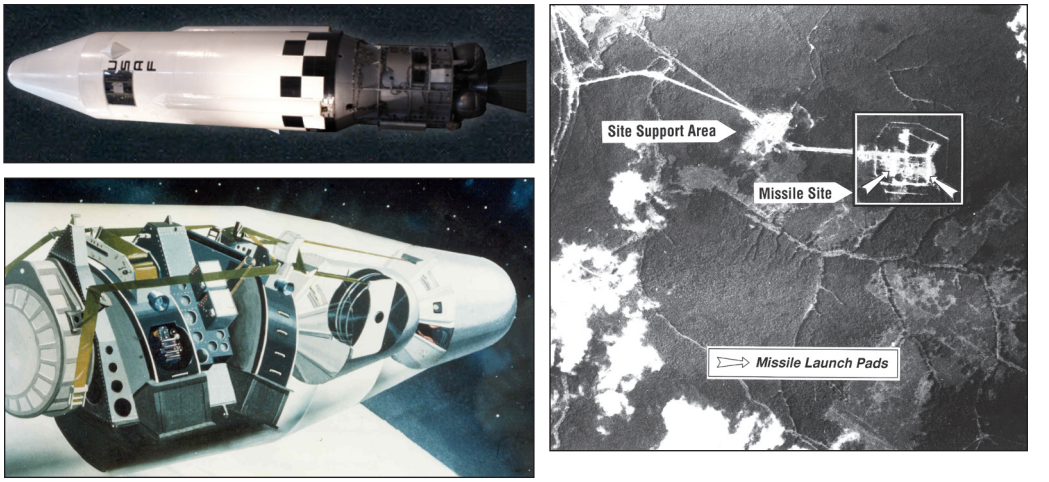


Figure 2a (left top) Agena-B that served as a spacecraft for Corona (Photo courtesy of Smithsonian, NASM, 2019). Figure 2b (left bottom). Artist concept of cut-away view of Corona KH-4B camera in flight (Photo courtesy of CSNR Reference Collection). Figure 2c (right). Corona photograph showing construction of an SS-7 launch site at the Soviet Yurya ICMB Complex, 28 June 1962, Mission 9038.[10] (Photos courtesy of CSNR Reference Collection, via Photogrammetric Engineering & Remote Sensing, Vol LCL, No. 6, 1995.)

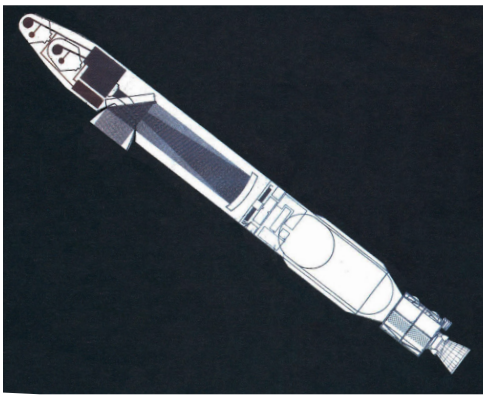
The Gambit and Hexagon Reconnaissance Satellites

The NRO continued to apply the 7 Tenets as it went on to develop two additional photoreconnaissance satellites, the Gambit as a companion to Corona, and Hexagon as a follow- on for a search mission. These multifaceted programs were highly complex, and—through application of the principles of the 7 Tenets—the program teams developed, what was a novel "systems engineering" approach. This approach uniquely conceptualized and integrated all program elements, including distinct spacecraft subsystems, camera optics, film, and ground control components, and utilized a "factory-to-launchpad" scheme that entailed a strategy to fully test and ensure reliance of all system components (Ragusa, 2012, p. 81; Araki & Treat, 2012, p. 91, 93).

Some three years after the first Corona successes, the NRO, under the auspices of its Air Force Program A, deployed the first of its two high-resolution Gambit photoreconnaissance satellites. This first Gambit series of satellites operated for four years from July 1963 to June 1967, and provided average resolutions of about 2 to 3 feet. At the same time, the NRO, also under the auspices of its Air Force Program A, was developing its second, even higher- resolution series of Gambit satellites, which took only 24 months to develop

10 Corona monitored Soviet activity at this complex, and analysts determined that the Soviets were constructing an SS-7 ICBM launch site. As a result of the subsequent 1972 SALT I Interim Agreement on Strategic Missiles, the Soviet Union deactivated the site and destroyed its launch facilities. Figures 2a (spacecraft) and 2b (payload) are an example of the close teamwork between the CIA, which was responsible for the payload, and the Air Force, which was responsible for the spacecraft, as well as the

and then operated for 18 years from July 1966 to April 1984 with a best resolution better than 2 feet.[11] Together these high resolution Gambit systems gave the U.S. Intelligence community a reliable collector of high-resolution technical intelligence for 21 years. They provided such significant spatial resolution that photo interpreters were able to conduct detailed scientific and technical analyses of Soviet air, naval, and ground equipment, including the identification of Soviet armor and artillery down to model. (See Figure 3.) A four-month Gambit-3 mission would image 27,652 frames of film and capture 48,372 intelligence targets (Ragusa, 2012, pp. 78, 82, 83).[12]



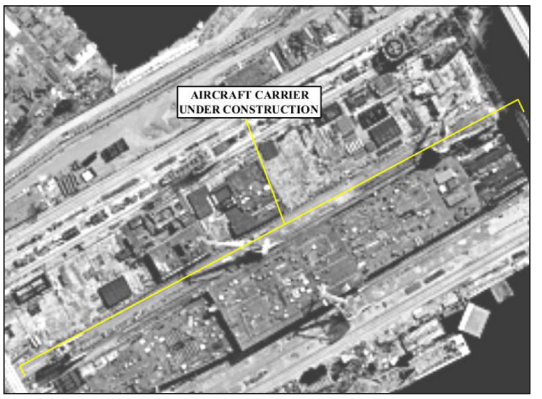


Figure 3a (left). Schematic of Gambit-3 spacecraft (28.6 ft long, 5 feet diameter). Figure 3b (right). Gambit image of a Soviet aircraft carrier under construction at Mykolayiv, 4 July 1984. (Photos courtesy of CSNR Reference Collection.)

The continuity of personnel, both within the government and within industry, resulted in a cadre of experienced engineers and managers who could apply what they learned to the new problems and challenges. By the time the NRO began developing Hexagon (first under the auspices of the its CIA Program B and then its Air Force Program A), the 7 tenets philosophy was so engrained into the program offices that even though Hexagon represented a technological leap with an extensive advancement in capability and performance, the NRO completed its development in only 36 months. (See Figure 4.) The Hexagon Program had learned from the Corona and Gambit experiences how to refine its systems engineering approach thereby creating a "factory-to-pad" concept that integrated spacecraft, launch vehicle, and ground station operations into a sophisticated systems engineering approach that enabled the development and operation of a highly reliable system free of on-orbit anomalies. The film load went from 100 pounds to two thousand pounds; the satellite diameter from 5 feet to 10 feet; the weight from 6,000 pounds to 30,000 pounds. Its twin panoramic cameras could photograph, in a single

11 The specific resolution was so good that in 2019, 35 years later, the exact number remains classified, and we cannot reveal it.

12 The second Gambit system actually was called "Gambit-3" or "Gambit Cubed" because of how the NRO selected the best proposed option for this second, improved Gambit (McDonald & Widlake, 2012, p. 5).

frame, an area of the earth's surface that was 300 nautical miles by 16.8 nautical miles area, meaning that in one frame it could scan 370 nautical miles covering approximately the distance between Washington, DC and Cincinnati, OH. Hexagon satellites operated for 13 years (June 1971-April 1984) and provided complete stereo coverage of the denied areas in the Sino-Soviet bloc with a ground resolution of 2.7 feet (Araki & Treat, 2012, pp. 90, 97; McDonald & Widlake, 2012, pp. 40-41).[13]

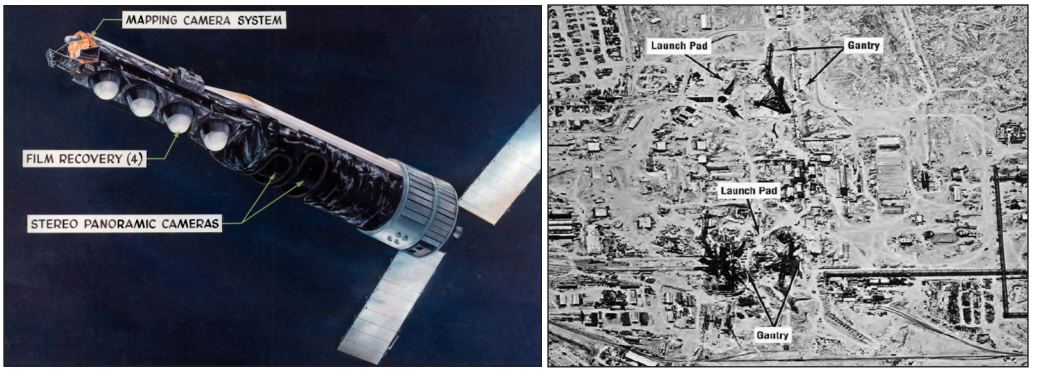


Figure 4a (left). Artist Concept of Hexagon Vehicle (60 ft long, diameter 10 ft). Figure 4b (right). Hexagon Panoramic photograph of Tyuratam Missile Test Range in Former USSR, August 1984.[14] (Photos courtesy, CSNR Reference Collection.)

Together Gambit and Hexagon played a significant role in giving the Nixon Administration confidence to begin arms control negotiations. Gambit's high-resolution cameras provided the US with it first-ever close-in satellite surveillance capabilities, which enabled analysts to assess U.S. adversaries' scientific and technical capabilities; Hexagon's camera's photographed and accurately charted virtually all of the world's inhabited regions. These two NRO reconnaissance systems gave Presidents enough confidence in their knowledge of the strategic threat that they were willing to enter into arms control agreements with the Soviet Union (McDonald & Widlake, 2012, pp. 39, 42, 48).

13 The Hexagon program actually closed in 1986. However, we used the year 1984 because it reflects the year of final Hexagon collection when its operational missions ended. The NRO had launched what was to be one final Hexagon mission in April 1986; however, that mission terminated immediately after launch when the titan booster exploded shortly after launch. With that final launch in 1986, the Hexagon program closed.

14 Hexagon provided the US with a broad-area search capability that monitored Soviet and other adversaries activities in denied areas, giving the US decision makers the confidence to enter into arms control agreements. (McDonald & Widlake, 2012).

Kennen Near-Real-Time Space Imaging[15]

The NRO's application of the 7 Tenets enabled the NRO, under the auspices of its CIA Program B, to develop the Kennen near-real-time imaging reconnaissance satellite in the 1970s. This satellite system represented a revolutionary transformation in space-based imagery reconnaissance, moving from a delayed-recovery, film-based photo reconnaissance capability to a near-real-time, electro-optical-based digital imaging system (Outzen, 2019).

In the early 1970s President Nixon assigned a high priority to the NRO for development of a near-real-time imaging capability. The United States Intelligence Board had endorsed the near-real-time imaging requirement in 1971, and on 23 September 1971 President Nixon approved a plan for Kennen development. Presidential advisor, Edwin Land, had told Nixon that this system would be a "quantum jump that would give the U.S. an unquestioned technological lead in the field."[16] The President set the challenging target date of 1976 for initial operations. Some sixty months after Nixon's approval, the NRO met the target date, and on 19 Dec 1976 the NRO successfully launched the Kennen electro-optical satellite. On 19 January 1977 former DCI George H. W. Bush signed a cable declaring this innovative electro-optical system as operational. This fourth NRO satellite imaging system satisfied Land's straightforward statement of requirements for satellite imagery, "See it All, See it Well, and See it Now." Hexagon saw it all; Gambit saw it well; and Kennen saw it now (Outzen, 2012, pp. 117, 130; Perry, 1974, p.20, 132; NRO, 2011; McDonald, 2002a, pp. 35, 38).

The NRO's development and deployment of this revolutionary system created a demonstrated need to innovate processing of the image data. The application of the 7 Tenets led to further innovation during this period, eventually resulting in enhanced capabilities in imagery collection, storage, retrieval, and dissemination, as well as the development of new signals intelligence collection systems and programs to support military operations. America's fighting forces now had near-real-time access to national reconnaissance, and when the first Gulf War (Operation Desert Storm) broke out, NRO imagery and signals intelligence systems played critical roles in supporting the decisive U.S.-led victory (Teets, 2004; Berkowitz, 2011, p. 23).

15 Former DDNRO Bob Naka selected the Middle English word, "kennen," to be the program name. In Middle English the word meant "to perceive;" the same word in German means "to know" (Hofman, 1971).

16 Edwin Land, among other appointments, chaired the National Reconnaissance Panel of the President's Science Advisor Committee and served as a member of the President's Foreign Intelligence Advisory Board (McDonald, 2002a, p. 27.

The National Reconnaissance Imaging Programs and the 7 Tenets

The NRO's experiences in developing Cold War imaging reconnaissance satellites is a model that demonstrates the impact and value of the 7 Tenets. This becomes evident when we review those experiences within the context of the specific tenets.

For example, for Kennen, one Tenet is especially relevant, Tenet 6 ("Adapt and draw from the latest advances in technology"). During Kennen's development, the program office aggressively took advantage of the advancing technology implied in Moore's Law. In 1965 the number of components on a microchip had doubled, and Gordon Moore predicted at the time that over the short term that rate could be expected to continue, which it did.[17] Moore told us that this phenomenon would bring about a proliferation of electronics and push science into many new areas. And drawing on that proliferation, the NRO was developing its reconnaissance satellites and produced Kennen, the beginning of the digital age (Moore, 1965; Smil, 2015).

More broadly, the success of all the NRO programs in our examples can, in large part, be attributed to the impact of Tenet 4 ("Rely on small, streamlined breakaway collaborative team"), and Tenet 7 ("Avoid bureaucracy and establish short chain of command"). The reality is that the NRO and its programs essentially were exempt from most of the review and approval processes that were imposed on other intelligence and defense organizations. The NRO structure offered a conduit to essentially "bypass" the numerous bureaucratic layers of review, approval, and oversight that was imposed on other agencies.

Fundamentally, however, the driving force for the NRO successes was derived from Tenet 1 ("Focus on threat-based need"). During the Cold War there was a very real, immediate, and overwhelming threat that was clearly ominous--that of a nuclear attack. A Soviet nuclear attack could destroy the US. Both the American leadership and population knew this. On 7 September 7, 1961, President John Kennedy sent a message to all Americans in which he warned, "Nuclear weapons and the possibility of nuclear war are facts of life we cannot ignore today . . . The ability to survive coupled with the will to do so therefore are essential to our country." In response, the government was identifying public buildings where there could be fallout shelters; individuals were building their own private fallout shelters, and the Intelligence Community was developing innovative ways—through national reconnaissance—to collect intelligence about this threat. By focusing on the threat-based need, the NRO found itself, by necessity, adhering to the principle of Tenet 2 ("Short timelines"), which is highlighted on the summary timeline in Figure 5 (Kennedy, 1961).

17 In the 48 years from 1971 to 2019, "the number of electronic components that can be crammed onto a given area on a chip has increased seven orders of magnitude. That corresponds to a doubling about every two years," which is consistent with Moore's prediction (Smil, 2019).

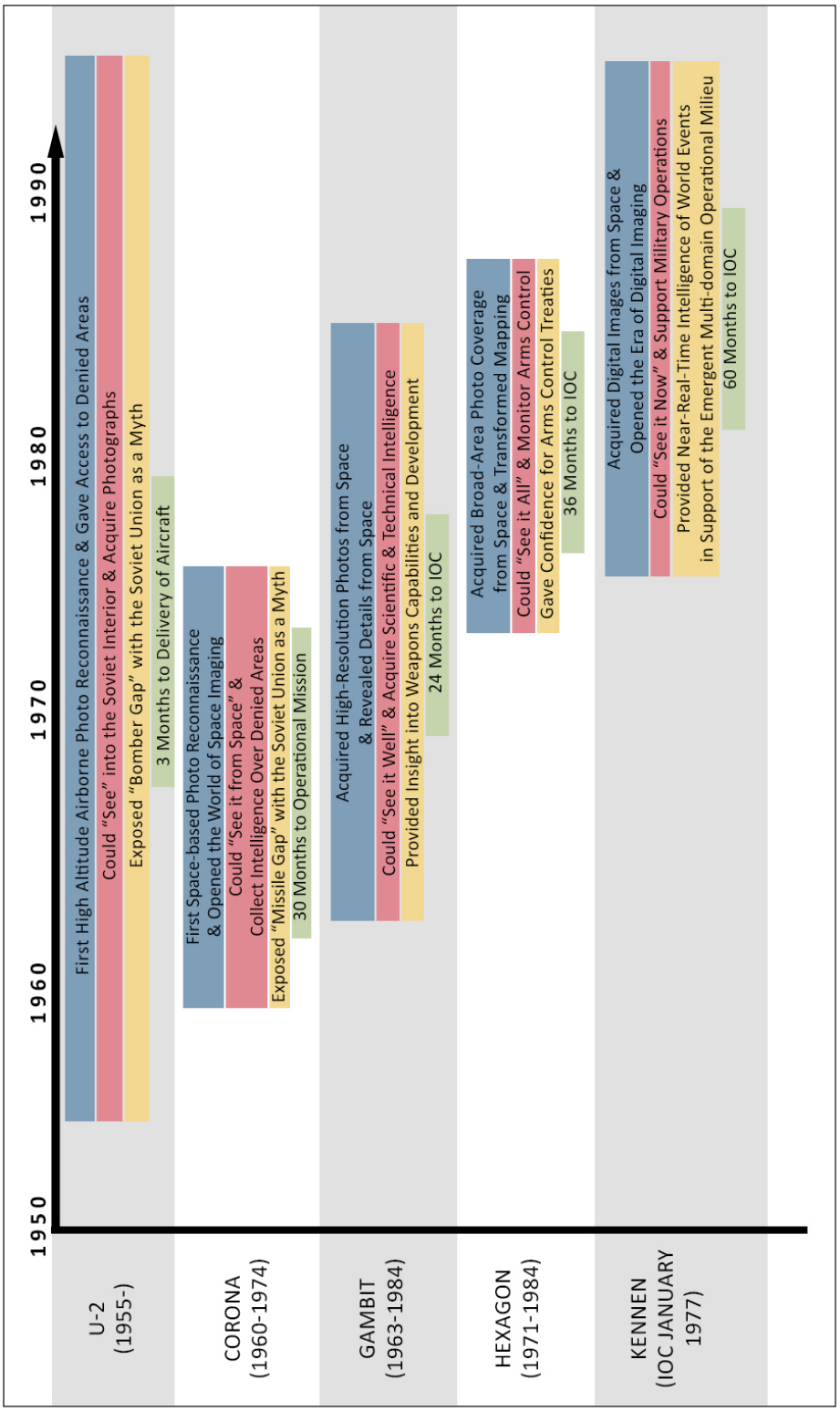


Figure 5. Results From Applying the Seven Tenets to the Development of Five National Reconnaissance Systems~ Summary Timeline Showing the Impact of the Programs' Innovations and the Comparative Time for Development.

But the underpinning of the success came out of applying Tenets 3 and 5 ("Stability in funding and staffing with a focus on strong systems engineering and program management"). In the first instance, these NRO programs were highly classified and compartmented, which afforded them a sustained and protected fiscal commitment.

Perhaps equally, or even more important than the sustained funding was the people, where two of the Tenets came into play, Tenet 4 ("Streamlined collaborative team") and Tenet 5 ("Strong system engineering & program management).

The NRO and its industry partners recruited a strong cadre of long-term, highly-skilled people who were experts—drawn from across government, industry, and academia. The people became a cadre that government and industry were able to retain. Each individual was committed to both the challenge of the problem and the task dealing with the threat. At the same time, the leadership was committed to protecting and rewarding them throughout their NRO career for their contributions.

This resulted in the creation of a series of collaborative government-industry-academia teams where each component put forward its best people.[18] These collaborative teams had a short command chain and almost nonexistent bureaucratic constraints. The teams had end-to- end responsibility for the development, production, and operation of the system they were developing. As a collaborative group these teams of highly proficient engineers and program managers did not merely take on a temporary job, they typically made a career commitment to apply their skills not only to the challenge of the initial program, but also to draw on their experiences and insights to address the new challenges of future national reconnaissance programs. (McDonald, 2002b, pp xxiii-xxxviii)

Silicon Valley Innovations

The NRO has not been alone in creating revolutionary innovations. Like the NRO's innovative successes in foreign intelligence collection, Silicon Valley companies have created technology and business successes. Silicon Valley, as a group of high-tech companies, has become a global leader in technological innovation and a dominant player in the world of information and cyberspace. The "Big Four Tech Companies"– Google, Facebook, Apple, and Amazon—have created products and services that are interwoven into the daily lives of billions of people worldwide, have created hundreds of thousands of high-paying jobs, and have generated over $2.3 trillion in wealth. They have become centers of innovation. How were both the NRO and Silicon Valley able to become successful innovators that had revolutionary effects (Chander, 2014; Galloway, 2018, p. 1)?

The answer is a common explanation, the principles of the 7 Tenets. An analysis of the Silicon Valley companies suggests they intuitively applied those principles. This becomes clearer by examining more closely, within the context of the 7 Tenets, one of the "Big Four," namely Google.

18 Companies consistently placed and retained their best people so as to be most competitive to win contract competitions, and then ensured these best people were maintained on the team for the duration.

Google co-founders, Larry Page and Sergey Brin set up their company in a garage and hired one employee (consistent with Tenet #4, small breakaway collaborative team); they did not have a formal business plan or strategy and maintained an informal work environment (consistent with Tenet #7, avoid bureaucracy and maintain short chain of command); they obtained a stream of funding from venture capitalists and recruited bright engineers from the region (consistent with Tenets # 3 and # 7, stable funding/ staffing and strong engineers); they stayed focused on the end users and getting the world's information online, where in the commercial world the market and its threats drive the need (consistent with Tenet #1, focus on threat-based need) (Vise & Malseed, 2008).

The result of employing these principles was to create a revolution in the way information is made available to the masses and creating a company that became indispensable to millions of people. Google became a magical capability that produced speedy, relevant answers to queries hundreds of millions of times daily. The company also proved to be a remarkable financial success. In its first year as a public company, employees and major shareholders sold $3 billion worth of Google shares. In 2016 Google earned $20 billion in profits (Vise & Malseed, 2008; Galloway, 2018).

In 1995 the US Government began a program of declassifying imagery and technology associated with NRO's Cold War space reconnaissance programs. This resulted in the commercial sector and Silicon Valley taking advantage of the newly-available technology and commercializing the realm of acquiring and marketing space imagery. For example, Ikonos-2 is a commercial high- resolution imaging satellite that can acquire 1-meter spatial resolution imagery.[19] The declassification policies and the transfer of previously restricted technical information about space imaging shaped a new world in this discipline. There was a merging of innovations that had taken place at the NRO and Silicon Valley, and this created a pathway that resulted in a 21st century information transformation exemplified by Google in its launching Google Earth in 2006. This resulted in what some have called the "democratizing access to satellite imagery"—a world where anyone with access to a computer or smart phone also has access to overhead imagery of almost any place in the world (Denis, Claveri, Pasco, et. al., 2017; ESA, 2019; McDonald, 1997e).

Application of 7 Tenets to 21st Century national security

The 21st century applicability of, and need for, the 7 Tenets is apparent not only from examining the successes created by the NRO and Silicon Valley, but also apparent in the independent analyses of management practices that echo the principles. Two examples are most relevant, the Packard Commission and the Jeremiah Panel.

19 Drawing on its experiences with NRO Cold War project, the Ikonos project was initiated by Lockheed Martin Missiles & Space, the same company that was the prime contractor for Corona. (ESA, 2019; McDonald, 1997)

First, the Packard Commission observed that efficient Defense acquisition in the 1980s was frustrated by rigid bureaucratic procedures. It concluded that more successful management would be in the implementation of short, unambiguous lines of authority that could cut through bureaucratic red tape, along with small staffs of highly competent professional personnel where there would be an emphasis on innovation, and results (White House, 1986, pp. xxii, xxiv, xxv)

Second, and more relevant to the NRO and Intelligence Community are the 1990s findings of the Jeremiah Panel. The Panel observed that ever since the NRO's inception it used business practices that increased the likelihood and speed of success. These practices included adequate and stable funding, streamlined management, top-quality personnel, empowered managers, "cradle-to-grave" management, and acceptance of failure—all of which are reflected in the 7 Tenets. The Panel went on to point out that these practices have not been unique to the NRO. The Panel saw them reflected in the successes of other programs that had extreme national security importance and urgency, such as the Manhattan Project's atom bomb, the Polaris Project's submarine-launched nuclear missile, and the Air Force's F-117 Stealth Fighter. The success of these programs further endorses the validity and justify the continued application of the 7 Tenets (NRO, 1996, p 16).

The NRO and Silicon Valley experiences with the principles of the 7 Tenets created environments that encouraged risk-taking and innovation. In both cases, this resulted in transformative 21st century changes that are comparable to revolutionary changes of the past. In the case of the NRO, its 20th century innovative use of space reconnaissance to collect information about the earth's surface was transformative for the acquisition and presentation of spatial information, just as the 6th century B.C. innovative Greek use of mathematics in mapmaking was transformative for the representation of the earth's surface at that time (McDonald, 1997b).

In the case of Silicon Valley, its 20th and 21st century technological innovative ways of collecting, processing, and transmitting information was transformative for how information is made available and transmitted, just as how the 15th century Guttenberg printing press created a revolution in making books and scientific tomes affordable and widely available to the masses for the first time (Vise & Malseed, 2008).

The 7 Tenets have been and continue to be fundamental to successful, innovative, and timely revolutionary advancements that have been transformative. It is out of the NRO Cold War projects we discussed in this article that a technological infrastructure grew in places like the Boston Route 128 corridor and the Stanford Industrial park-- an industrial base that has come to serve as a source of innovation for Silicon Valley and the Intelligence Community. Over the years, the NRO has drawn on these tenets to consistently make enhancements that have increased its capabilities to expand its mission and respond to an ever-growing user base.

References

Araki, S. & Treat, S. (2012). "Hexagon—'No Single Failure Shall Abort the Mission'—Managing System Integration for the NRO's Wide-Area Search Satellite from the Lockheed Missile and Space Company's Perspective." *In National Reconnaissance–Journal of the Discipline and Practice,* Issue 2012-U1, Spring 2012, pp. 85-102.

Battle, C. L. (2002). "The Laws and Principles of Program Management." In R. A. McDonald (Ed.), *Recollections of the Pioneers and Founders of National Reconnaissance* (pp. 169-172), Bethesda, MD: American Society for Photogrammetry & Remote Sensing.

Berkowitz, B. (2011). *The National Reconnaissance Office at 50 Years: A Brief History. Chantilly, VA:* NRO Center for the Study of National Reconnaissance.

Chander, A. (2014). "How Law Made Silicon Valley." *In Emory Law Journal,* Vol 63, pp. 639-694.

Denis, G, Claverie, A., Pasco, X, et. al. (2017). "Towards disruptions in Earth observation? New Earth Observation systems and markets evolution: Possible scenarios and impacts," *In Acta Astronautica,* August 2017, pp. 415-433.

European Space Agency, ESA (2019). "Ikonos-2," Sharing Earth Observation Resources, eoPortal Directory, ESA Web page, https://earth.esa.int/web/eoportal/satellite-missions/i/ikonos-2, [Accessed 16 September 2019].

Galloway, S. (2018). *The Four: The Hidden DNA of Amazon, Apple, Facebook, and Google,* New York: Portfolio/ Penguin.

Hofmann, F. L. (1971). Memorandum for the Record from Lt Col Frederick L. Hofmann, USAF (on Department of the Air Force note paper), 24 November 1971.

Kennedy, J. F. (1961). "A Message to You From the President." Life Magazine, 15 Sep 1961, p. 95.

Lewis, J. E. (1997). "Tension & Triumph: Civilian and Military Relations and the Birth of the U-2 Program," In R. A. McDonald (Ed.), *Corona Between the Sun & The Earth–The First NRO Reconnaissance Eye in Space* (pp 13-14). Bethesda, MD: American Society for Photogrammetry & Remote Sensing.

Lockheed (2019). "Skunk Works® Origin Story," Lockheed Martin Web Page, https://www.lockheedmartin.com/en-us/who-we-are/business-areas/aeronautics/skunkworks/skunk-works-origin-story.html [Accessed 7 Sep 2019].

McDonald, R. A. (1989). *Proceedings: Space Imagery and News Gathering for the 1990s: So What?* Symposium in Lexington, KY; sponsored by The University of Kentucky Patterson School of Diplomacy & International Commerce, US State Department Foreign Service Institute Center for the Study of Foreign Affairs, and the American Society for Photogrammetry & Remote Sensing (ASPRS). Bethesda, MD: ASPRS.

McDonald, R. A. (1995). "Corona: Success for Space Reconnaissance, A Look into the Cold War, and A Revolution for Intelligence," *Photogrammetric Engineering & Remote Sensing,* Vol. LCI, No. 6, June 1995.

McDonald, R. A. (1997a). "Corona, Argon, and Lanyard: A Revolution for US Overhead Reconnaissance." In R. A. McDonald (Ed.), *Corona Between the Sun & The Earth–The First NRO Reconnaissance Eye in Space* (pp 61-74). Bethesda, MD: American Society for Photogrammetry & Remote Sensing.

McDonald, R. A. (1997b). *Corona Between the Sun & The Earth–The First NRO Reconnaissance Eye in Space,* Bethesda, MD: American Society for Photogrammetry & Remote Sensing.

McDonald, R.A. (1997c). "Corona Imagery: A Revolution in Intelligence and Buckets of Gold for National Security." In R. A. McDonald (Ed.), *Corona Between the Sun & The Earth–The First NRO Reconnaissance Eye in Space* (pp 211-220). Bethesda, MD: American Society for Photogrammetry & Remote Sensing.

McDonald, R.A. (1997d). "Corona's Pioneers." In R. A. McDonald (Ed.), Corona Between the Sun & The Earth–The First NRO Reconnaissance Eye in Space (pp 141-152). Bethesda, MD: American Society for Photogrammetry & Remote Sensing.

McDonald, R. A. (1997e). The Declassification Decision." In R. A. McDonald (Ed.), *Corona Between the Sun & The Earth–The First NRO Reconnaissance Eye in Space* (pp 169-176). Bethesda, MD: American Society for Photogrammetry & Remote Sensing.

McDonald, R. A. (1999). "NRO's Satellite Imaging Reconnaissance: Moving From the Cold War Threat to Post-Cold War Challenges, *Defense Intelligence Journal.,* Vol. 8, No. 1, Summer 1999, pp. 55-91.

McDonald, R.A. (Ed.) (2002a). *Beyond Expectations–Building an American National Reconnaissance Capability: Recollections of the Pioneers and Founders of National Reconnaissance.* Bethesda, MD: American Society for Photogrammetry & Remote Sensing.

McDonald, R.A. (2002b). "Introduction." In *Beyond Expectations–Building an American National Reconnaissance Capability:* Recollections of the Pioneers and Founders of National Reconnaissance, pp. xxiii-xxxvii. Bethesda, MD: American Society for Photogrammetry & Remote Sensing.

McDonald, R.A. & Widlake, P. (2012). "Looking Closer and Looking Broader: Gambit and Hexagon—The Peak of Film-Return Space Reconnaissance After Corona." In *National Reconnaissance–Journal of the Discipline and Practice,* Issue 2012-U1, Spring 2012, pp. 54-74.

Meyer, C. (1998). *Relentless Growth: How Silicon Valley Innovation Strategies Can Work in Your business.* New York: Free Press.

National Air & Space Museum, NASM (2019a). Agena-B Upper Stage at the Udvar-Hazy Center, NASM web page, https://airandspace.si.edu/collection-objects/upper-stage-launch-vehicle-agena-b, [accessed 4 Oct 19].

National Reconnaissance Office, NRO (1996). *Report to the Director National Reconnaissance Office: Defining the Future of the NRO for the 21st Century–Final Report Executive Summary* (Jeremiah Panel), Chantilly, VA: NRO. Washington, DC: National Reconnaissance Office.

National Reconnaissance Office, NRO (1973). "The Air Force Aftrack" Sigint Satellite Story, Chapter 5, pp. 119-305, Washington, DC: National Reconnaissance Office.

National Reconnaissance Office, NRO (2011). "History and Heritage--50 Years of Vigilance from Above" NRO Information Sheet. Chantilly, VA: NRO Office of Public Affairs.

Outzen, J. D. (Ed.) (2012). *A History of Satellite Reconnaissance–The Perry Gambit & Hexagon Histories,* Chantilly, VA: NRO Center for the Study of National Reconnaissance.

Outzen, J. D. (2019). "Historical Context of the D-21 Program," Remarks on 21 March 2019, Southern Museum of Flight, Birmingham, AL.

Pedlow, G. W. & Welzenbach, D. E. (1998). *The CIA and the U-2 Program, 1954-1974,* Langley, VA: Central Intelligence Agency.

Perry, R. (1974). *A History of Satellite Reconnaissance–Volume IIIB–Hexagon.* Westover Air Force Base, MA: HQ Air Force Special Projects Production Facility.

Ragusa, P. (2012. "Gambit-3: Engineering an Innovative High-Resolution Reconnaissance Satellite—Program Management from the Lockheed Missile and Space Company's Perspective." In National Reconnaissance—Journal of the Discipline and Practice, Issue 2012-U1, Spring 2012, pp. 75.

Simmie, J. (1998). "Reasons for the Development of 'Islands of Innovation': Evidence from Hertfordshire," *Urban Studies,* Vol 35, No 8, pp. 1261-1289.

Smil, V. (2015). "Moore's Curse—There is a dark side to the revolution in electronics--unjustified technological expectations," *IEEE Spectrum,* 19 Mar 2015. (https://spectrum.ieee.org/energy/renewables/moores-curse, accessed 4 October 2019).

Smil, V. (2019). "During the 20th Century, Vacuum Tubes Improved in a Moore's Law-Like Way," *IEEE Spectrum,* 24 Jan 2019. (https://spectrum.ieee.org/semiconductors/design/during-the-20th-century-vacuum-tubes-improved-in-a-moores-lawlike-way, accessed 4 Oct 2019).

Teets, P. (2004). House Armed Services Subcommittee on Strategic Forces—Hearing on FY2005 Budget: Defense Strategic Forces Programs, 25 February 2004 (transcript).

Trainor, B. (2009). "Gulf War I," *Foreign Policy Research Institute Footnotes,* Vol. 14, No. 18, June 2009. [Accessed 25 Oct 19, https://www.fpri.org/article/2009/05/gulf-war-i/].

US Congress, Armed Services Committee, HASC (1993). "Intelligence Successes & Failures in Operations Desert Shield/Storm—Report of the Oversight and Investigations Subcommittee of the Committee on Armed Services House of Representatives," 16 Aug 1993 [Accessed 25 Oct 19, https://apps.dtic.mil/dtic/tr/fulltext/u2/a338886.pdf].

Vise, D. & Malseed, M. (c2008). *The Google Story–Inside the Hottest Business, Media and Technology Success of Our Time,* New York: Delacorte Press.

White House (1986). *A Quest for Excellence: Final Report to the President by the President's Blue Ribbon Commission on Defense Management* (Packard Commission). Washington, DC: White House.

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