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## Analytical Article

# (U) The Second Great Divide

*By L. Parker Temple, Ph.D.*

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# The Second Great Divide

*L. Parker Temple, Ph.D.*

*Change in the nation's space programs is common and probably the norm. However, changes affecting the space programs in a fundamental way, such that the direction before the change is radically different thereafter, are few. The times when multiple fundamental changes come together in a four- or five-year period are very rare indeed. These are the "great divides," and there have been three in the history of the U.S. space programs.*

*The first great divide, from 1958–1962, has been extensively documented. The nation went from not having achieved spaceflight to the beginnings of the use of space with the first U.S. satellites, the shifting of the Army's space programs largely to the newly created National Aeronautics and Space Administration (NASA), the first human spaceflight, numerous "firsts" in space capabilities, and the differentiation of national security, national defense and national prestige space programs (explained below). And of course, formalization of the National Reconnaissance Office (NRO) goes without saying; or it did until 18 September 1992.*[1]

*The third major divide occurred in the mid-1990s, impelled in large part by Acquisition Reform. That story remains for a different time.*

*This article concerns the second great divide which occurred from 1969–1973. These years marked transitions such as the end of military human spaceflight and the beginning of near-real-time reconnaissance imagery. During the same time, significant changes were introduced in parts and processes to address concerns of overreliance on what were perceived to be fragile and unreliable space systems. Overriding previously strong lines dividing the national prestige space program's immensely successful human missions to the moon and return from the national security and national defense space programs, the follow-on to the Apollo program was fundamentally altered by these latter programs during this period Embedded in all of these changes was some element of the changing national mood about making space relevant and in some sense "operational." The remainder of this history consequently follows these radical changes in six sections: Military Human Spaceflight; See It Now; Unreliable or Operational?; Everything Starts With Parts; Following Apollo; and, Towards Tactical Relevance.*

*In each of these topic areas, this article examines changes that made the time before 1969 distinctly and radically different from the time after 1973.*

*National security space has been a blanket term thrown broadly over multiple agencies and organizations dealing with a variety of critical national space programs. However, the terms used here differentiate three U.S. space sectors. The first, referred to here as the national security space program, was the unmentionable, unacknowledged and highly classified national reconnaissance*

1 The date, of course, was the date of the official acknowledgement of the NRO's existence.

*satellite programs acquired and operated by the NRO. In the late 1960s, their focus was essentially strategic: support to the National Command Authority, providing indications-and-warning intelligence to remove the possibility of a surprise nuclear attack on the U.S., and contributing to treaty verification. The second was the national defense space program, mainly acquired and operated by the Air Force. National defense space responsibilities covered a mix of mainly strategic and some tactical applications of space in support of military operations. Its responsibilities included early warning of an actual attack underway against the U.S., as well as providing secure communications, weather, and environmental information. The third was national prestige space programs within the civil space program. The National Aeronautics and Space Administration (NASA) administered the civil space program, which also supported other government agencies such as the National Oceanic and Atmospheric Administration. This third space program was responsible for human spaceflight, space exploration, and dissemination of technology and information derived from space. The three programs were largely independent, but at times influenced each of the others. The distinctions among these three are important to understand because some of the activities from 1969–1973 began to blur previously clear lines.*

*The first episode marks the end of military human spaceflight within the national security and national defense space programs at the apex of the national prestige program's civil human spaceflight effort.*

## Military Human Spaceflight

One part of the government's reaction to the Soviet satellite Sputnik in 1957 involved creation of the civil space program under NASA, which quickly came to include responsibility for human spaceflight. Almost immediately, the glamour and excitement of sending people into space captured human imagination worldwide, contributing to national prestige. Throughout the 1960s, while much of the world watched with anticipation the race to send people to the moon and return them safely, military interest in human spaceflight continued in parallel but for reasons far different than national prestige. In this section, we look back at the reasons for that continued military interest and how it changed fundamentally. In particular, we will see how this first topic affected some critically important programs for the NRO.

At the outset of the U.S. in space, military thinking held that space was the medium extending the air operations' domain. General Thomas Dresser White, Air Force Chief of Staff at the dawn of the space age, coined the term "aerospace" for this indivisible operating medium. Military human presence was essential to all aspects of Air Force operations. Addressing Air Force Academy cadets on the 54th anniversary of the Wright Brothers' first flight, White recalled their aircraft was in a museum alongside Lindbergh's *Spirit of St. Louis.* Then, he claimed:

> ...the day you stroll into a museum to see a B-52 or one of the Century Series fighters, it will not be because man has been eliminated as a direct participant. It will be because new equipment has been perfected to propel him higher, drive him faster, keep him in motion longer, and so enable him to perform more tasks

> better. The missiles that are getting the headlines today are but one step in the evolution from aircraft to piloted spacecraft. (White, 1957)

The Air Force experience with robotic aircraft, beginning during World War II right up to the time of *Sputnik's* 1957 launch, was highly unsatisfactory. The first robotic aircraft, essentially early cruise missiles, were airplanes without pilots. Many versions (Matador, Mace, Snark, Regulus, to name a few) were tried, but with very mixed results, which did not engender trust in the robotic aircraft's mission success. Tarred with that legacy, robotic spacecraft seemed even more rudimentary, fragile, and remote.[2] Air Force leaders considered the potential of robotic spacecraft so extremely limited that only human presence could make space militarily useful. The premier spaceflight program of the day was the DYNA-SOAR, a hot-skinned reconnaissance-bomber.

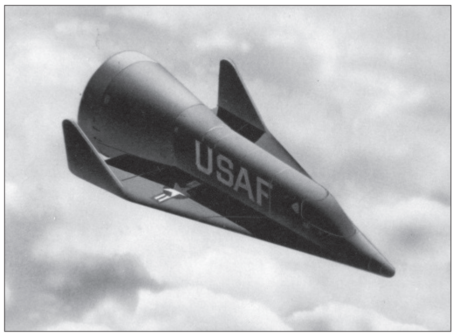


**Figure 1. The X-20A DYNA-SOAR**
**(Photo courtesy of the National Museum of the Air Force)**

Clearly, that was in White's mind when he extrapolated "higher, faster, longer" to say:

> The next step is the Air Force program to fly at hypersonic speeds, circumnavigating the globe many times before re-entry into the earth's atmosphere. As a weapon system, this program will represent the first major breakthrough in sustained piloted space flight. (White, 1957)

Disappointment followed quickly. The only things that soared in the technologically challenged DYNA-SOAR were cost and schedule. Thus, it ran afoul of Defense Secretary Robert S. McNamara who, on 10 December 1963, cancelled it in favor of what he considered a more modest and realistic program. The successor, bearing the slightly misleading title of Manned Orbiting Laboratory (MOL), became the largest national defense and national security space program to that time.

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2 Machines intended to accomplish some mission on their own, without humans on board, are considered "robotic" in this paper. Hence, the cruise missiles of the post-World War II era were like airplanes, but without pilots, and were required to navigate to their targets without outside control. In the same sense, spacecraft, once in orbit, were considered essentially "hands-off" systems, despite the intensive ground support they required. Robotic in this sense has to do with the mission accomplishment, and the humans providing the ground support were mainly working to keep the satellites functioning. The mission being accomplished was accomplished robotically and involved the mission data stream; the health and status monitoring were handled via the telemetry stream. Many senior military leaders did not understand or appreciate the distinction between the mission data stream and the tracking, telemetry and control data streams, certainly until well past the 1969–1973 timeframe.

Military human presence was a "given" for DYNA-SOAR. Yet, when it ran into trouble, justifying human presence became increasingly necessary to sustain funding and Congressional support. By the time of its cancellation, robotic spacecraft were already eroding assumptions of how essential human presence was. So, MOL faced a different sustainment challenge, and set out to define missions that only humans could perform. These missions accentuated human synoptic vision, flexibility, and reasoning.

Before long, though, advanced aircraft and robotic spacecraft systems began eroding these. Advanced aircraft (such as the Lockheed U-2, A-12 and SR-71) fielded new and highly advanced sensors, causing the intended MOL missions to become moving targets. Further, the wisdom of having people on-board a spacecraft whose primary mission involved highly sensitive sensors became questionable, because humans were a source of random noise and disturbances (Newman, et al., 2001, p. 578).[3] Also, the rapid growth of robotic spacecraft's capability per dollar invested and per pound in orbit had improved exponentially during the interim (Space Systems Division, 1967). For instance, the satellite photoreconnaissance program, Corona, and its successors took advantage of available worldwide cloud cover information to increase the percentage of cloud-free images being returned, which meant that robotic spacecraft could perform such a mission nearly as well as if a human were present. Another system, to be discussed shortly, was a see-it-now system that would drastically shorten the delivery timelines for reconnaissance information, undermining the claimed advantages of a human-in-the-loop aboard the MOL.

On 19 April 1969, as the national security advisors weighed MOL cancellation, Presidential Science Advisor Dr. Lee A. DuBridge told President Richard M. Nixon:

> There are advantages to having all the manned spaceflight operations of the U.S. open and unclassified and therefore under the sponsorship of NASA. Any classified manned operation presents public relations and international difficulties. It is an attractive option therefore to let such manned spacecraft operations as contribute to our national objectives be carried out in unclassified NASA projects until a requirement, not immediately foreseen, for military manned flights becomes evident. (DuBridge, 1969a)

The military need for human presence evaporated. Thus, MOL had moved inexorably towards irrelevance when Defense Secretary Melvin R. Laird abruptly cancelled it on 10 June 1969, leaving no military human spaceflight follow-on. Certainly, the need for operational space capabilities had not diminished, but in-situ humans were unnecessary (Secretary of the Air Force, 1969; Packard, 1969). In fact, robotic spacecraft had proved themselves capable of doing critical jobs for which humans were unsuited. The Defense Support Program (DSP), for instance, was providing early warning of ballistic missile attacks on the United States. This required continuous, unblinking staring at the Soviet Union and the periphery of the U.S.—something humans could not do as well. Satellite communications were becoming an essential element of positive control of the strategic nuclear forces and other critical functions worldwide. Military weather satellites and

3 The *Mir*, by virtue of its larger size, was not as affected as DYNA-SOAR or MOL would have been.

national reconnaissance satellites quietly and competently performed their essential missions. All of these were done without the distraction of human presence.

Human spaceflight seemed to retain some relevance to the nation as the race to the moon reached a climax. The month following MOL's cancellation, Apollo 11 astronauts Neil A. Armstrong and Edwin E. Aldrin landed on the moon and successfully returned to earth. Human spaceflight was front-page news, gaining considerable national prestige though irrelevant to national security or national defense space. Emphasis in these latter areas was shifting to operational relevance—performing functions that contributed to some intelligence or defense missions.

Before 1969, human spaceflight captured the imagination of the country and the world. It had been considered essential to the exploration and practical use of space. For national security and national defense, all that changed in 1969 when MOL was cancelled, abruptly ending military human spaceflight. In any event, MOL had already lost much of its timely reconnaissance mission to airborne sensors and robotic space systems. Its cancellation freed up resources for important new NRO missions. In the next section, I will discuss one of the new robotic spacecraft technologies that obviated MOL and benefitted from its cancellation.

## See It Now

By 1969, the nation was involved in a highly unpopular war in Southeast Asia (SEA). Instead of fighting a strategic war against a peer adversary, the U.S. had gotten involved in a war of fluidly shifting conditions and highly mobile targets. The timelines of warfare drastically shortened during the 1960s, such that by 1969 NRO space systems were of limited value to those fighting the war. Pressure began to mount for new, more responsive reconnaissance technologies in aircraft and in space. With funds freed from the cancellation of MOL, advocates for a new system had to make the case that a technological opportunity existed. In this section, we will see what was at stake for the military in shortening the timelines of war, increasing the operations tempo, and how these affected a major new NRO program.

During the MOL's entire lifetime, the U.S. was involved in an increasingly large war in SEA. The war's operational tempo vastly accelerated over those years. Lessons were quickly being learned about how to respond to a small, dispersed, tactically mobile enemy force—a force that the U.S. was initially ill-prepared to meet. The timeline from the collection of potentially useful reconnaissance intelligence to military forces' response had to be drastically shortened.


**Figure 2. The film arrives at the end of a reconnaissance mission, to be rushed to the base film processing unit. (Photo courtesy of the National Museum of the Air Force)**

By the mid-1960s, using fighter aircraft adapted for photoreconnaissance, the timeline from discovery to delivery of film canisters was about as short as it could be. Processing the film was done in fixed, centralized facilities for economy. However, the timeliness of centralized film processing was unresponsive to bringing weapons to bear on recently discovered targets. One important advance was the forward deployment of mobile film processing facilities.

The response time improved to minutes instead of hours after the film's receipt. As important as this increased responsiveness was, it fell short of the needed timeliness. An alternative had been slowly evolving from its earliest roots.[4]

Since the 1951 Korean Conflict, the U.S. had flown both unobtrusive peripheral and dangerous intrusive overflights of denied areas in Korea, Manchuria, China, and Russia (Pedlow and Welzenbach, 1998, p. 3). These flights were collectively known as Sensitive Intelligence (sensint). In the 1950s, these constituted the most highly classified and protected aerial intelligence collection efforts conducted by the Air Force and the Navy. The beginning of Corona film-return photoreconnaissance missions and Grab electronic intelligence missions supplanted the sensint missions and removed the flight crews from harm's way.[5]

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4 One might argue the earliest roots of near-real-time reconnaissance go back to the balloon Intrepid at the Battle of Fair Oaks in the Civil War, or some similar earlier occurrence. Using signals to indicate what was being observed of the enemy, reconnaissance moved at the speed of light. But that only reflects an alteration to the time honored sacred functions of the horse cavalry. The topic here has to do with reconnaissance of otherwise denied territory.

5 As will be discussed shortly, several problems existed with film-return photoreconnaissance programs, but the time delays made them the least responsive to the situation in SEA. Corona film products might not reach the theater for days to weeks after being taken, and in the dynamic guerilla warfare of the period, this lessened their importance.

But Corona's film-return imagery had an Achilles Heel. From the time an image was taken, it might be several days before the recovery capsule (the "bucket") could be de-orbited and recovered, and, beyond that, several more days for the imagery to be processed and analyzed. National Reconnaissance Office studies at the time investigated the means to improve the timeliness of imagery delivery, but more work was needed.

Meanwhile, sensint programs provided another benefit as they pioneered infrared cameras for airborne reconnaissance. This became especially relevant because the nighttime movement of troops and equipment in SEA defied traditional photoreconnaissance. Consequently, the Air Force ordered General Dynamics to modify a Martin B-57 Canberra with an experimental infrared T-100 camera system to "see" at night (Greenhalgh, 1977, p. 84). Two such aircraft, designated RB-57E and given the secret mission name of Patricia Lynn, arrived at Tan Son Nhut Air Base in Vietnam in February 1963 (Greenhalgh, 1977, p. 85).[6] The infrared sensors lacked sufficient tools, parts, manuals, and people to keep them operating and, consequently, for the time being, fell far short of expectations (Greenhalgh, 1977, pp. 86-87). Furthermore, the film-return process prevented the aircrew from knowing whether the sensor was getting the required information. Consequently, the headquarters of 2nd Air Division asked for two more RB-57s modified so that the aircrew could directly readout the infrared sensor. Such real-time exploitation would allow the aircrew to react and adapt what they were doing to improve the responsiveness of the operation. The same kind of instantaneous feedback was a key claimed advantage for human presence aboard the MOL, but RB-57s could fly under cloud coverage and provide persistence over a discovered area of interest. This provided an important lesson for the Intelligence Community (IC), because responsive imagery entailed more than simply returning the imagery quickly. Short timelines in fluid situations necessitated frequent revisits if not constant and persistent coverage.


**Figure 3. General Dynamics RB-57F.**
**(Photo courtesy of the National Museum of the Air Force)**

6 During the course of Patricia Lynn, the T-100 camera was replaced with several other versions. The evaluation of the infrared camera was conducted under the project title Tropic Moon II. Eventually, 16 B-57s were modified to Tropic Moon III standards, housing low light level television, laser range finders, forward looking infrared and a multifunction radar. This allowed a single aircraft to detect, designate and strike its target with precision, laser-guided munitions.

Work continued on sensors and exploitation capabilities. The direct readout matured in April 1967 when the first General Dynamics-modified RB-57F arrived at Ton Son Nhut (Greenhalgh, 1977, p. 92). Its arrival presaged an even shorter timeline for imagery intelligence than the mobile film-processing laboratories could provide.

The results of a direct readout system could be available immediately, either from the on-board sensor operators, or so long as line-of-sight could be maintained. The RB-57s provided their data directly to in-theater centers, without resort to "store and forward" recording systems or other kinds of relays for the most part. Occasionally, Lockheed EC-121 Constellation aircraft acted as relays when line-of-sight was not available. At the same time, though, communications satellites had come of age, and this was part of the necessary key to the next step in direct readout.

Communication satellites allowing instantaneous communications far beyond the horizon proved a mixed blessing to the commanders in SEA. While such unprecedented communications abilities had advantages, they also provided opportunities for armchair quarterbacking from the Pentagon and even, at times, from the Oval Office. Yet the same capability that would allow such long distance global communication also made possible the development of a relay satellite that could make intelligence collected anywhere in the world immediately available anywhere else.

Far from SEA, on 5 January 1968, the democratic reformer Alexander Dubcek was elected as the head of the Communist Party and leader of Czechoslovakia. His anti-Stalinist democratic reforms—known as the Prague Spring—greatly concerned Soviet leadership. President Lyndon Johnson's only intelligence information said to expect a strong warning from the Soviets to the Czechs. Instead, starting the evening of 20 August 1968, the Soviet Union invaded and crushed the nascent Czech democracy movement. The crisis moved too swiftly for the U.S. to keep aware. By the time Corona imagery was obtained and processed, the crisis was over. Such lack of situational awareness was unacceptable to the President and his advisors.

Thus, by 1967, all of the technological pieces seemed nearly ready for a space capability to once again allow removing aircraft and aircrews from harm's way. The MOL's problems and the convergence of other new technologies became the focus of Dr. Edwin Land, inventor of the Polaroid camera. One of the most important and enduring shepherds of the national security space program, Land chaired a key Presidential Science Advisory Committee (PSAC) panel. The Land Panel had been specifically constituted by the Special Assistant to the President for Science and Technology, Dr. Donald F. Hornig, in July 1965, and met at irregular intervals as needed until President Nixon abolished the office of science advisor in 1973 (Perry, 1973b, p. 8). Just as the 1954 Technological Capabilities Panel (on which Land was a member) had spawned the U-2, Corona and other crucial Cold War intelligence capabilities, Land's panel again prepared to review and advise on critical national security programs. Dr. Richard Garwin, another panel member, noted that their function was "as quickly and surely as possible to separate the wheat from the chaff, and to encourage (even selectively breed) the wheat" (McElheny, 1998, p. 339).

As they were doing their analysis, they were constantly reminded that the world was a dangerous place, and that the U.S. could not stand for loss of situational awareness in volatile regions of the world. Since the Arab-Israeli Six Day War in 1967, the Egyptian government under Gamel Abdel Nasser proved unable to push the Israelis back to their former borders. So, in March 1969, Egypt began a campaign known as the War of Attrition in an attempt to wear down the Israelis and make the cost of holding their territories too high.

Presidents had come to depend on imagery from NRO systems so heavily that they usually took a personal interest in each new system and the improvements. Improved responsiveness of imagery was hardly a new idea in the late 1960s. In various forms it had cropped up before.

The genesis of the interest in a crisis-response, rapid-response imagery intelligence system can be traced back to the early 1960s. The Cuban Missile Crisis of October 1962 taught the American national security establishment some serious lessons about the adequacy and timeliness of its intelligence. Corona's long delays between film-return missions and Gambit's planned launches every 40 days on average were incompatible with the 13-day international missile crisis. Consensus grew among national policymakers and the IC that imagery intelligence proved such plans were unsuitable for real world needs and had to be more responsive. This led to a decision in the Gambit program to acquire multiple vehicles. Essentially, each Gambit launched would need to have a backup ready to go should the first fail at launch or shortly thereafter (Perry, 1974, p. 76). A second satellite effectively remained in standby, so that, in the case of such a failure, another was ready to be stacked on another booster and launched in minimum time. This kind of responsiveness was all that was available, but such brute force methods did not solve the need for persistent intelligence.

The problem of responsiveness proved to be more than an issue with the availability of satellites. More pressure for a responsive system came from the Committee for Overhead Reconnaissance (COMOR), responsible for collection target prioritization. The COMOR, attempting to collect an image of some "random" target that required immediate attention, wanted to insert ad hoc collection requests into the program for the Gambit satellites. The analysis required to get the most out of each imaging opportunity for Gambit required a great deal of computer time, so inserting a "random" target simply was not practical as the systems stood at the time (Perry, 1974, pp. 139-140).

Such was the state of things at the time the Land Panel took up the issues of the MOL program. Land and Garwin were aware of these and other expressions of need for responsiveness. Furthermore, the evidence from the fielded airborne tactical reconnaissance systems in SEA and from within the electronics industry was that a near-real-time readout system was technologically feasible for aircraft.

By October 1968, Land's panel concluded that MOL's situation was not hopeful. But that was not the end of their conclusions. Land was well aware of the increasing interest for some kind of rapid readout, electro-optical imagery space reconnaissance system. Studies in both NRO Program A (Air Force) and Program B (Central Intelligence Agency) had been underway for some time. Both were on essentially equal footing for proposing solutions to the need for rapid readout systems. Program A had been building the highest resolution film-return systems, the KH-8 Gambit satellites, and had been cooperating with Program B on the KH-9 Hexagon satellites. While Program A was to build the latter's satellite bus, Program B was responsible for the sensor.

Two competing readout concepts emerged. Program A's was evolutionary, essentially modifying existing Gambit satellites to include a form of electronic readout. This was an incremental step up from the Samos E-1 electrostatic readout systems attempted about a decade earlier (Perry, n.d., p. 117). Program B chose to push technology hard instead of following such an evolutionary path. Program B's approach would do away with film altogether, going directly to digital imagery stored on board. The latter approach had a significant advantage because its imagery did not degrade during processing as would the electrostatic imaging idea left over from Samos. The Program B approach was considerably more risky. Their concept called for a variety of undeveloped technologies to mature and come together in a short period of time for the imaging satellite. The concept included a relay system that had its own challenges. Technology for the frequencies needed, data rates, antenna gain, buffering, and broadcasting of the data were not in hand.

These more advanced space-related technologies were what Land and Garwin were investigating. They suspected the key technologies were not in hand, but wondered if they could be brought in on a reasonable timeline. Although they were technological realists, their investigations convinced them that a narrow range of solutions was available. Both concluded the technologies for downlinking from satellites at high data rates, linking from satellite-to-satellite, and electro-optical imaging using charge coupled devices were ready for a system development. Both recognized any such development had risk, but that risk expressed itself in estimates of when the resulting system would be operational, not whether it was feasible. Land was orchestrating "a national commitment to a radically new reconnaissance technology" by December 1969. President Nixon, like Johnson before him, was interested in a near-real-time system that would be more responsive to crisis situations than film-return or other methods (Perry, 1969, pp. 45-46, 55-56, 95-96). Endorsing that goal seemed to spur Land even further.

One immediate question for such a large new national security space program was funding. On several major fronts, the President faced major funding decisions. The year of peak funding for the SEA War coincided with the peak funding required by MOL. The MOL's mushrooming costs and loss of its mission to the new "see-it-now" system evaporated its support. Its cancellation partially offset the war's funding, but NASA faced the need for a major new post-Apollo program. At the same time, Hexagon, the largest and most sophisticated of the NRO's satellites was reaching its peak funding. The Administration, then, was about to contend with funding three major space programs. The budget pressure was enormous. Robert P. Mayo, director of the Bureau of the Budget (BoB), did an end-run of the NRO and got Nixon's approval to cancel Hexagon on 9 April 1969. Director of Central Intelligence (DCI) Richard Helms just as quickly got to Nixon, urging a delay for two weeks, during which time the BoB-proposed alternative was effectively shown to be even more expensive. Mayo reversed his position on 21 April 1969.

This serves to illustrate, however, the budget competition for space investment and the pressure to contain budget increases (Perry, 1973b, p. 73).

Nixon continued supporting the see-it-now program, delaying his response to recommendations affecting NASA's costly post-Apollo program. As a delaying tactic, he asked DuBridge and the PSAC for an independent assessment of other alternatives (Perry, 1969, p. 22).

The contention of these issues delayed any presidential commitments. Discussions began with Land, David Packard (Deputy Secretary of Defense), Lee DuBridge, Dr. John L.McLucas (DNRO and Under Secretary of the Air Force), and Richard Helms, (DCI) (Perry, 1969, p. 57). Others within the Office of the Secretary of the Defense held strong opinions counter to Land's, such as Gardner Tucker, Assistant Secretary of Defense (Systems Analysis) and Eugene G. Fubini, a senior scientific advisor to the Secretary of Defense. They viewed the necessary technologies skeptically, wanting several years of study and technology maturation before committing to such a large development (Perry, n.d., pp. 65-66). Land pushed hard for a commitment, which was not immediately forthcoming, but he was unrelenting.

Land signed out the final results of his panel's efforts on 14 July 1971 (Land, 1971, p. 134).

By 27 July 1970, Land's efforts paid off, as McLucas had obtained enough agreement to authorize the NRO's Program B to proceed with Phase I of a near-real-time electro-optical imagery system (Perry, n.d., p. 78). The January 1971 National Reconnaissance Program Executive Committee (ExCom) heard the results of Phase I, which finished the month before (Perry, n.d., pp. 95-96).

At the ExCom, Dr. James R. Schlesinger of the Office of Management and Budget (OMB), talked about Nixon's positive interest in a near-term readout system. Office of Management and Budget (OMB) Director George P. Shultz was interested in being responsive to the President (Perry, n.d., pp. 95-96). Packard understood the near-real-time electro-optical system was the solution of choice, but also considered the technologies riskier than had Land or Garwin. A risk reduction program was necessary, and that pushed the launch date into 1976 (Perry, n.d., p. 98). On 23 September 1971, Nixon (through his National Security Advisor, Henry Kissinger) accepted the recommendation to push ahead with the Program B approach (Perry, 1973b, p. 132; n.d., p. 127).[7]

National imagery reconnaissance before 1969 was not responsive in crisis situations and lacking in tactical military relevance. Aircraft and aircrews were going in harm's way to get the intelligence necessary to prosecute a near-real-time war. They were attempting to develop the means to acquire that intelligence whose relevance remained high even

7 The sources point to a memorandum from Kissinger to the Director of OMB, Director of Central Intelligence, President's Science Advisor and the Chairman of the President's Foreign Intelligence Advisory Board, indicating the major stakeholders in the new system. A separate report was sent to Senator A.J. Ellender, Chairman of the Committee on Appropriations, but that was not sent until 4 October.

under the fast pace of a fluid war, or in a national crisis. The new near-real-time system enabled a revolution in these and other areas. We will shortly see how this new space program, and the last of the major film-return systems, dramatically affected the future of the civil space program and the nation. Meanwhile, behind the scenes as these major issues churned, another was brewing within national defense space and civil space: the military's reluctance to rely on space systems in times of crisis.

## Space: Unreliable or Operational?

National defense space had matured to the point that it introduced new capabilities with great potential to affect the tactical battlefield, moving beyond the prior emphasis on strategic use of space. Reliance on space was a huge concern, however. For tactical commanders whose experience taught them that any non-organic asset was not to be considered dependable, since it could be taken away at any moment, reliance on space capabilities was anathema. One of the reasons the MOL lasted as long as it did was the persistent residual belief that only human presence could make a space system militarily useful. As military parlance evolved, that came to be synonymous with "operational," but it carried other baggage with it, implying something about availability and reliability. National defense and national security space systems concurrently had to become reliable enough to be depended on in a crisis. This was more than simply a question of timelines. This section discusses the first of two complementary efforts to address dependability and reliability, and describes how quality processes were improved. In a subsequent section, I will discuss the other thrust: improving the reliability of the parts themselves. In both cases, the changes during this period marked a radical shift from what went before.

By the late 1960s, tactical commanders viewed military space capabilities at best as irrelevant playthings of engineers and scientists and, at worst, allowing intrusion from the highest echelons of command. Weapon systems were supposed to be robust, ruggedized, with long intervals between swap-out of repairable units with minimum down-time. They could be operated by properly trained officers and enlisted personnel. From the military viewpoint, scientists only needed to be involved in the early stages of a weapon system's development to get the science right, and, after that, the emphasis needed to be on the operational user. Space systems, conversely, demanded close attention to fulfill their missions because they were (and remain) intensely technological. Operating the state-of-the-art in communications, ground- and space-based computation required engineers and scientists to command, control, and troubleshoot them.

All this implied the systems were fragile, undependable, immature, and unsuitable to support real military operations.[8]

8 For clarity, here the term fragility refers only to the tenuous ties to a satellite in orbit. If anything happens to such a machine, only the on-board capabilities, exercised through telemetry, are available to figure out the problem and correct or compensate for it. The term does not have anything to do with the ability of a satellite and its components to survive accelerations or the vibro-acoustic environment during the launch phase. Neither does it have anything to do with the health of the satellite or constellation due to long-term operation and aging effects.

As space program capabilities potentially touched every aspect of military operations, this became a problem for some Air Force leaders. Their problem was not always a lack of appreciation for the space systems' capabilities. Satellites had the potential to radically alter the American way of war and peace. However, some senior military and DoD civilian officials became concerned about over-reliance on space systems. The Soviet Union's new co-orbital anti-satellite program concerned some of them, but there was more to it than this threat.

*The United States Air Force Basic Doctrine* illustrated how the Air Force leaders in the late 1960s viewed their Air Force. Although superficially retaining General White's 1957 definition of "aerospace forces," all the descriptors of aerospace forces applied only to aircraft. Space received lip service because "Aerospace systems which perform these missions provide a natural and evolutionary extension of U.S. Air Force mission responsibilities and operational capabilities from the atmosphere into space" (USAF, 1971).[9] White's "higher, faster and longer" clearly had not completely gone away, but it was not something the Air Force considered it had made much progress on since 1957.

The fact of the matter was that military space was strategically "operational," but simply not in the same way as routine military aircraft operations were. National security space uses were of great benefit to strategic military users, the National Command Authority, and the Intelligence Community. Strategic Air Command (SAC), North American Aerospace Defense Command, and others were routinely receiving critical information from national defense and national security programs.

Communications satellites exploiting a number of frequencies had differentiated into many specialized systems supporting a variety of military users: The Navy Fleet Satellite Communications System, Air Force Satellite Communications System, Initial Defense Communication Satellite Program, and satellites for the North Atlantic Treaty Organization provided multiple global coverage capabilities. The DSP kept an ever vigilant eye for early warning of missile attacks. The Defense Meteorological Satellite Program was enhancing national security and military operations planning and execution. Navigation was emerging as the next great capability, advancing from the Navy's Timation program to what would become the Global Positioning System. National security systems were providing crucial imagery and signals intelligence in support of indications and warning, strategic targeting, early warning and other critical missions.

All of these capabilities had largely unrealized tactical potential. As I have stated, the SEA experience was mixed with respect to space. The long reach of satellite communications allowing intrusion into theater operations had become a sore spot. Weather and classification restrictions, and lack of timeliness, limited the impact of space reconnaissance, and imaging reconnaissance missions reverted to the use of high- and low-flying aircraft. The regular and routine military use of space needed to focus on the challenge of making space practical for the majority of potential users: tactical forces. The mood at the time was similar to the Pentagon adage that "If you ain't in the budget – you

9 Each issue of doctrine took several years to write, coordinate and obtain approval by the Air Force leadership. The 1971 doctrine reflected their views from 1968–1970.

ain't." It seemed that "If you ain't helping tactical forces, you ain't." If space systems did not affect tactical combat, they were irrelevant, and full acceptance of space-based capabilities would be a hard sell.

The real concern was such systems would not last long in a real stressing war. Since they could not be counted on to survive under the expected rigorous conditions of combat with the Soviets, they were not to be relied upon in peace. Training in peacetime had to closely parallel expected operations in wartime. If peacetime operations counted too heavily on some capability that would not be present in wartime, then chaos would result at the onset of hostilities. Military leaders' views on satellite fragility and tactical irrelevance manifested itself as a lack of confidence. To overcome such biases, space systems had to possess long, reliable lives.

On 1 July 1967, Air Force Systems Command (AFSC) combined two product divisions, the former Space Systems Division and Ballistic Systems Division, forming a new three star command: Space and Missile Systems Organization (SAMSO). LtGen Sam C. Phillips assumed command in 1969, at a time when quality assurance activities at SAMSO "were at their lowest ebb since the formation of AFSC" (SAMSO/CC, 1971).

Philips knew senior ranks were divided into two divergent world views. Either spacecraft were fragile scientific curiosities of little real use to the operational military, or they were something that served the nation's strategic needs and held great potential for revolutionizing national security and national defense. Phillips recognized it was unlikely that the tactical military conception of operational systems would shift to include space systems as they stood in 1969. Changing the limited views about space programs meant he had to confront quality assurance head-on to make space systems more dependable, longer lived, with fewer outages.

The combination of the two product divisions gave Phillips a much broader view of systems acquisition than his immediate predecessors. He could apply the lessons learned by the strategic Minuteman intercontinental ballistic missile program to space systems. Minuteman was the most reliable system acquired to that time. To fully appreciate the opportunity he recognized, we must step back to the start of Minuteman.

At any given moment, the number of missiles that could be relied upon to launch on command formed the basis for strategic planning, targeting, and deterrence. The SAC demanded the highest possible "in-service" rates. Reliability of the large missiles translated directly into the number of weapons that could be counted on bringing to bear against the Soviet Union, and those that would have to be held back for subsequent strikes. Together, these affected the number of missiles acquired.

Investment in reliability and quality positively impacted Minuteman costs. By 1964, Minuteman I's five-year cost of ownership was two-thirds lower than any other U.S. strategic delivery system (Wuerth, 1975, p. 10). Achieving such reliability had not been easy.

Minuteman I reliability emphasized the best thinking of the time on life testing, process controls, and failure analysis. Testing, re-testing, and re-re-testing identified and eliminated the weakest components. But more than testing was needed to achieve the reliability requirements imposed by the rigors of strategic nuclear warfare.

Minuteman II's electronics were considerably more complex and its reliability requirements even greater than those of Minuteman I. That meant greater difficulty and time in testing the parts. Consequently, Minuteman II developed a new approach to life testing known as the Component Quality Assurance Program (CQAP) (Wiesner, 1966, p. 423). Under CQAP, component manufacturers were asked to perform various stressing tests, "such as temperature, voltage, heat, vibration, etc." Such tests discriminated for problems in workmanship and fabrication. By analyzing all the test results and problems, they identified design, materials, and process improvements. These improvements were rapidly fed back into succeeding missiles and retrofitted to others.

Figure 4 illustrates the effectiveness of the CQAP across all the Minuteman blocks. In each case, significant improvements were made, despite increasing complexity and technology advancement. Each successive Minuteman version specified performance and reliability surpassing the capability of manufacturers, pushing innovation and advanced processes (Levin, 1982, p. 64). The CQAP program forced manufacturers to do intense internal process analysis and understanding. Rigor, process discipline, and continuous improvement achieved and then surpassed the reliability goals.

Minuteman III's reliability requirements were the most stringent yet. In 1969, Phillips took over SAMSO as the Minuteman III was in development (Lecuyer, 2000, p. 179).[10]

Cross-fertilizing the strengths of the Minuteman reliability improvements could increase the lifetime of satellites, reducing the number of satellites and launches. The need for fewer satellites and launches meant savings, which more than offset the cost of better parts, and would have a huge impact on defense and security program budget requirements (SAMSO/CC, 1971).

Such a payoff depended on the details of what changes were needed, how they were to be administered, and the resource impacts of the changes. In early 1970, Phillips asked for a study concentrating on the appropriate alternatives to improve quality in satellites and missiles. Drawing on the results, he established the Permanent Review Board in December 1971, shortly to be renamed the Program Review Board (PRB) (SAMSO/CC, 1971). The original name signaled Phillips' intent about this being a long-term way of doing business. The PRB had wide-ranging scope:

> In the interest of assuring maximum confidence in mission success involving SAMSO systems…a Permanent Review Board [will] assess our program status from the conceptual stages through system launch readiness…The initial phase

10 In Figure 4, that is equivalent to the 0.00009 percent failures in 1,000 hours. Over a decade after the last Minuteman III was deployed in 1975, transistor and diode manufacturers that had been part of the program's acquisition still advertised their products had "MINUTEMAN reliability" with great pride at the accomplishment.

> will consist of a comprehensive review and analysis of SAMSO system failures and anomalies as presented by major system program offices. In addition to identifying specific failures/anomalies, causes and corrective actions taken, an objective of the board will be to analyze events for indication of trends or similarities. Correlation of success/failure experience with management of functional elements impacting system development and checkout should provide useful lessons learned and aid in the avoidance of repetitive failures. (SAMSO/CC, 1971)

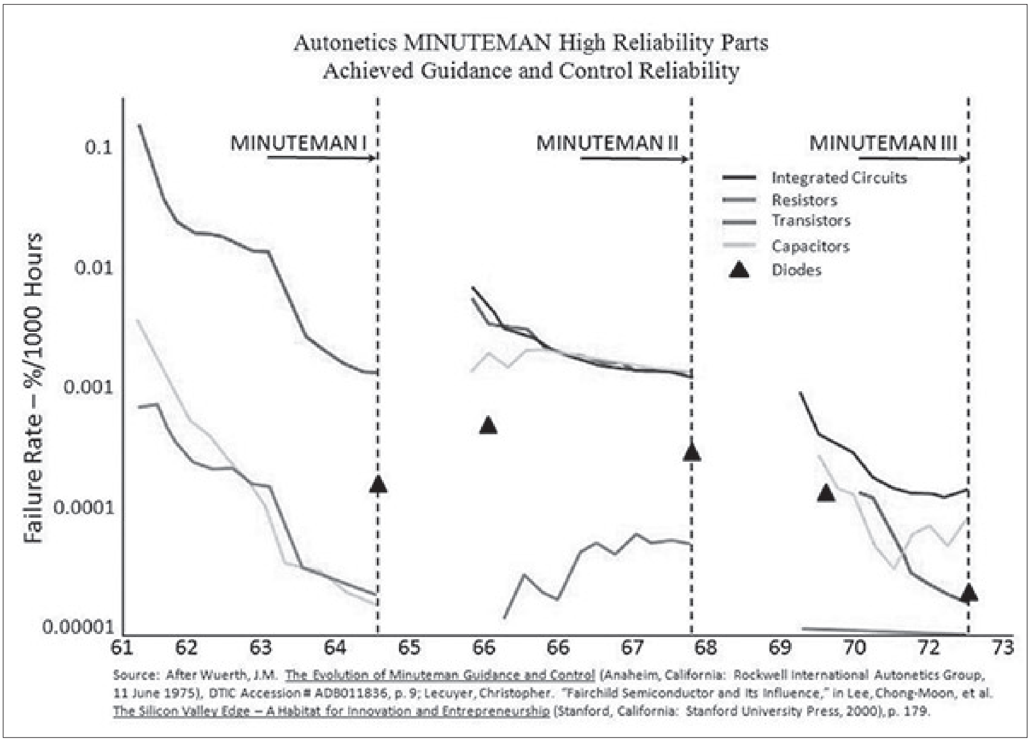


**Figure 4. MINUTEMAN Program Reliability Improvement Effectiveness. (Source: After Wuerth, J.M. The Evolution of Minuteman Guidance and Control (Anaheim, California: Rockwell International Autonetics Group, 11 June 1975), DTIC Accession # ADB011836, p. 9; Lecuyer, Christopher. "Fairchild Semiconductor and Its Influence," in Lee, Chong-Moon, et al. The Silicon Valley Edge—A Habitat for Innovation and Entrepreneurship (Stanford, California: Stanford University Press, 2000), p. 179.)**

This sweeping review struck at the heart of the most important reliability problems.

A major emphasis was improving current processes, which were mainly about testing. Testing was a critical element of spacecraft reliability, and the earlier it was performed, the fewer problems were found as parts were assembled into boxes, then subsystems, systems, and finally spacecraft. Testing at each assembly level was expensive. However, the early testing cost paled in comparison to the expense of tearing apart a unit or subsystem, reworking and then retesting it, as well as the consequent costs in schedule delays or loss of needed capabilities in orbit.

The PRB comprised the key individuals who matured the space programs in the early 1970s. Phillips was the chair, and others included: BGen Thomas W. Morgan (SAMSO Vice Commander, but eventually Commander); BGen Lew Allen (later to be AFSC commander and Air Force Chief of Staff, but then commander of the Office of the Secretary of the Air Force Special Projects, part of the NRO); and Dr. Ivan Getting (President of The Aerospace Corporation); AFSC Deputy Chief of Staff MGen Kenneth W. Schultz (shortly to follow Phillips as SAMSO commander), and the commanders of Arnold Engineering Development Center (an AFSC test and development center), and the AFSC Electronic Systems Division. The first PRB, on 6 January 1972, ran all day concentrating on launch vehicle failures over the previous two years. Its results were a watershed event in the history of national defense and national security space by setting the prioritized agenda for the improvement of space system quality and reliability. In the months that followed, a broad range of process improvements were settled on and changes made to appropriate military standards, with near immediate effect.

Although the first of a new series of early warning satellites was launched on 6 November 1970, the PRB's process improvements would produce dramatic improvements in later vehicles. The DSP was the geosynchronous orbit successor to the earlier space-based Missile Defense Alarm System (MIDAS) program of the 1960s. The DSP surveilled nearly the entire globe with infrared sensors to detect missile exhaust heat and other sensors to detect nuclear detonations. Whereas MIDAS required more than a dozen satellites each lasting about a year to 18 months apiece, DSP did the same job better with only three satellites. The MIDAS might miss some of the lower radiance ICBMs, whereas DSP could even detect the smaller tactical ballistic missiles. As the process improvements were applied, DSP satellites would last five years and more. The DSP's experience was indicative of the greater capability of satellites and the drastic reduction in military space launches across the board.

Process improvements made a critical difference in spacecraft reliability. For the NRO, it meant fewer on-orbit anomalies and fewer factory problems. But as critical as processes are, they did not accomplish all Phillips set out to do. Improved quality processes were necessary but insufficient to turn back concerns about over-reliance on national defense satellites. That required the PRB's most important emphasis on electronic parts, which are the subject of the next section.

## Everything Starts With Parts

The improved processes addressed the workmanship and testing of spacecraft. They did not, however, deal with the fundamental starting point of any complex machine—the piece parts. The earlier development of intercontinental ballistic missiles pointed the way to improving part reliability, because these missile programs had to provide weapons with the highest possible in-service rates. Every effort had been made to eliminate any source of failure, and that led to working with the electronics industry to find new ways to reduce failure rates. But, at the start of the second great divide, the highest reliability parts then available were about to go off the market for an unexpected reason. These circumstances resulted in the development of a new, separate class of parts specifically for use in space. With these new, extremely reliable parts, the way was clear for spacecraft to break all prior barriers to longevity, which led ultimately to dramatic reductions in the numbers of satellites needed. As fewer satellites failed, satellites were needed less often, and for the next decade the lower launch rate and lower space expenditures far exceeded expectations and paid for the more expensive parts many times over. But before that could be realized, serious attention had to be paid to the highest reliability parts.

By the early 1960s, testing, re-testing and testing yet again until boxes worked as desired was the normal approach, and was referred to as "testing in" quality. The problem, though, was starting with bad parts, because no matter how much testing is done, quality cannot be achieved in any program. The best specialty engineering processes cannot make a purse out of a sow's poor parts. The key to reliability was not how things were assembled – though that was crucially important. The most that could be achieved was to catch defective parts in unit through system test when the impacts to cost and schedule were highest. Phillips' emphasis on improving processes took these to a high level, but he and Morgan knew full well from the Minuteman CQAP program that only the best quality parts would provide what space systems needed.

With the realization that reliability started from the outset with the best available parts, truly reliable space systems could be built. The NASA Apollo program provided some of the right stuff, but not enough. A great deal depended on the unprecedented level of reliability pioneered in Minuteman. The result would be the ultimate in reliable parts.

So, it is not surprising that the PRB's first major action was an emphasis on parts. Right after the first PRB, Morgan, chair of the PRB Executive Committee, started the Electronic Piece Parts Working Group. Quickly renamed, it became the Working Group for Electronic Piece Parts (WGEPP). Their objective was to "Determine the impact of electronic component and subsystem failures on selected SAMSO programs and recommend future courses of action to reduce or eliminate identified problems." Dr. William F. Leverton of The Aerospace Corporation chaired the WGEPP, comprising three other Aerospace members and three government members, working from February through December 1972 (PRB, 1972b).

The WGEPP's first meeting articulated a new policy for developing integrated circuits:

> Because of the problems brought out to the PRB concerning Integrated Circuits (IC's) we need to develop a listing of highly reliable (Hi Rel) IC's for use by all Programs. Where Hi Rel IC's are included in the list, their use would be required or a waiver granted. The IC's would be purchased in lots and provided for program use. (PRB, 1972a)

The group examined in detail programs of SAMSO and other government agencies. "Specifically, the group sought to assess the impact of normal versus unique procurement, design, and quality assurance procedures on the ultimate reliability of electronic components" (SAMSO, 1973).

The WGEPP observed "solid state devices as purchased from vendors do not have consistently adequate reliability for space systems" (PRB, 1972b). In addition to flight failures, the cost of rework and retest in dollars and schedule was very high. The factors contributing to the solid state device problems were identified as:

- Fragmentation of purchasing (small lots)
- Inadequate standardization of devices, specifications, or screening
- Lack of close vendor-contractor relationship
- Lack of control of subcontractors
- Government source inspection of limited value in achieving high piece part reliability (PRB, 1972b)

Each of these would be addressed by the group.

The fact that the WGEPP quickly found so many fundamental and far-reaching items is important. It implies these items had been known, to some degree, prior to Phillips' emphasis on reliability, but had never gained sufficient support for implementation. That was now changing.

During the U.S. strategic buildup through about 1965, the military demand for high reliability and large volumes meant the government was effective in influencing the course of the electronics industry. That time was long gone except in certain niches. The WGEPP found "SAMSO's ability to make its high reliability requirements known and to exert meaningful impact on the piece part vendors...[was] negligible." Parts "as purchased from vendors did not have consistently adequate reliability for space and missile systems" (SAMSO, 1973, p. 453).

The Navy's Poseidon missile, NASA's Apollo and the Air Force's Minuteman programs had "techniques that focused management, engineering and fiscal attention on electronic reliability" (SAMSO, 1973, p. 453). Their solutions, no two of which were the same, had individual strengths and weaknesses, which could be cherry-picked.

One idea that had worked was captive or controlled manufacturing lines. Such lines had worked when military requirements far exceeded those of commercial industry. They had been attractive because the military could advance a manufacturer's business by taking control of an advanced technology line, getting it proved, then reaping the benefit in support of a critical national program. Eventually, the line would be turned back to the manufacturer for commercial or other military use. Captive lines had been used to ensure an adequate quality supply for Minuteman and Apollo.

Influencing industry by such methods had become less viable.[11] By Phillips' time, the rate of electronics technological change was accelerating. That meant captive lines occupied factory floor space that could be devoted to newer, higher profit purposes. By the time the military production was over, the line's technology was no longer going to be competitive, and would potentially have to be recapitalized. Captive lines worked for programs when buying hundreds of missiles, but not for small buys for a single satellite. The electronics industry was moving in a direction that made captive lines unattractive.

That meant that parts for space systems had to be obtained by some other approach. The reliability demanded by space systems could not be attained without parts intended for use in space, and made for that use from their inception (SAMSO, 1973, pp. 453-454). Space-qualified, high reliability electronic piece parts became the Holy Grail of reliability improvements.

Much was at stake because failures were indeed costly. Using 1972 dollars, the impact of actual failures puts the importance of reliability into perspective:

- IC in-flight control electronics failed in thermal vacuum incurring a retrofit cost of $150,000
- 6 failures in system test required rerun of tests at cost of $350,000
- Transistor failure caused 10-day impact on flight vehicle
- Several parts failures in flight not catastrophic due to redundancy and operational changes, but failures in test cost $ 6,000 each to correct
- UHF transistor failure retrofit cost $150,000 (PRB, 1972b)

The WGEPP also pointed out that the large number of anomalies (48) from 1969–1972 were due to electronic parts problems.

The WGEPP categorized the cost of various grades of parts to their failure rates:

| Part Class | Fail/$10^9$ Hrs | Cost of Part |
|---|---|---|
| Standard Grade | 300 | $3.60 |
| High Reliability | 6 | $6.30 |
| Minuteman | 2 | $30.00 |

**Source:** Program Review Board Meeting Minutes, 27 April 1972, Attachment 4

Clearly, some very high reliability parts were available and had significantly lower failure rates. They might cost nearly 10 times as much as a commercial part, but they were more than 100 times more reliable. Avoiding costly late development cycle problems and even more costly problems in orbit was within reach if the highest quality parts were available.

11 Captive lines still existed for NASA's Viking space exploration program, Sandia's (nuclear weapons) devices, and about 25 percent of SAMSO's IC requirements (many of which were actually bound for national security space systems).

This meant changing a program's budgeting profile, since it forced higher cost early in a program when the more expensive parts were bought. But since parts constituted only about 5 percent of the total program cost, a minor budget profile shift enabled a program manager to more nearly hit planned later expenditure profiles because they would have fewer late development problems. If the parts provided to all missile and space systems were of uniformly high quality, the initial cost of acquisition might go up slightly, but so would reliability. In systems acquisition, as Phillips' process improvements showed, this reduced overall costs by avoiding late assembly problems. In missiles, this translated to higher in-service availability and shorter maintenance downtimes. In spacecraft, it meant longer, more reliable lifetimes.

On 14 June 1972, the PRB and WGEPP worked on a policy for using NASA high reliability piece parts. The Apollo program established a special category of parts to get first class or Class A treatment. The Class A parts had added specifications over and above military avionics-grade parts. Whereas Class A parts were for the highest reliability applications, Class B parts were for use in conventional avionics environments, and Class C were used in ground systems. The new policy met resistance from program offices. While program offices would often balk even at measures designed to enhance reliability and mission accomplishment, in this instance that was not the problem. The Class A parts policy was not made mandatory because NASA's Class A parts program had a problem.

As 1972 approached, NASA's space program was deeply into its post-Apollo drawdown without an approved follow-on. The NASA Class A captive production lines were becoming less available because NASA had little need in this interim. By 1972, almost no Class A parts were available. Something akin to the NASA Class A parts was going to be needed but did not exist (SAMSO/DR, 1973).

LtGen Schultz, SAMSO's new commander, issued a 12 December 1972 directive that microelectronic parts would be "procured and tested (screened) to the most stringent requirements commensurate with the intended applications" (SAMSO, 1973, p. 460). Because Class A availability was so limited, the policy allowed use of "Class B [devices] ... or, when they can be procured, microelectronic devices that meet Class A screening requirements," for all SAMSO systems with long design lives (SAMSO, 1972). Schultz's hands were tied, for the moment, by declining Class A parts availability.

The Class A problems did not end there. Most manufacturers were unwilling to offer Class A parts as standard offerings. Surprisingly, this unwillingness was not about the small market; it had to do with inadequacies in the specifications. Manufacturers considered the Class A requirements "inadequate to meet their processing needs." Many available parts exceeded the Class B requirements, but were inadequate to meet Class A, resulting in a hodge-podge of screening processes by various manufacturers' own interpretations of the Class A requirements. A clearer, more stringent and comprehensive specification was needed (SAMSO, 1973, p. 456).

Thus, SAMSO undertook the task through The Aerospace Corporation, starting with investigations of high reliability assembly lines, and then other government agency specifications (SAMSO, 1973, p. 457).[12] Beginning with meetings at The Aerospace Corporation on 5 December 1972, continuing through 1973, they examined how to obtain the highest reliability electronic parts for space programs. It was clear the highest reliability parts came into existence differently than parts of lower reliability. At a minimum, then, reliability in parts had to begin at the starting point--that is, when they were materials as they became parts. Experience demonstrated a lower grade part could not become a higher quality part simply by testing. Such screening only identified the lucky ones that might be suitable for space use.

Achieving the highest obtainable reliability meant a new class of parts, which could not simply be upgraded from military avionics-grade. The new class would in effect be "totally unique, and…be handled and processed differently from wafer fabrication onward" (National Semiconductor Corp., 1979, p. 35).

The SAMSO group developed MIL-M-0038510B (USAF), "Microcircuits, General Specification For." Published on 1 October 1973, it established the requirements for a new kind of high reliability device, known as Class S (SAMSO, 1973, p. 458;, National Semiconductor Corp., 1979, p. 35). On 15 October 1973, Texas Instruments became the first producer of Class S parts when they registered 35 different products (DRUE History, 1973).

Class S was distinctly new and different from Class A. Class S added some requirements based on Minuteman quality measures, and rectified other problems with the Class A specification's clarity. Class S paved the way for a major increase in spacecraft reliability.

The WGEPP's timely action meant parts quality would not decrease with the loss of Class A. Their actions also showed the value of tying together independent technical experts, industry manufacturers, and government administrators. In ten months, they had created the standard for the highest reliability parts ever, and had a manufacturer to produce them.

Meanwhile, improved space capabilities and increased reliability eventually broke down leadership resistance to the acceptability of spacecraft for military operations, overturning concerns about their availability when needed in times of crisis. A decade and a half later, when the loss of the space shuttle Challenger created a national crisis, NRO and Space and Missile Systems Center (SMC) space satellites built with the improved processes and Class S parts showed that they could greatly exceed life expectations, survive, and maintain critical national capabilities. The changes–from Phillips' attention to processes and parts and Schultz's policies—made space programs last many times longer than they had just a few years before. Longer satellite lifetimes led to much lower demand for space launch, just as NASA started a program to solve the problem of the high cost of launch, which is the next topic.

12 The NASA 85MO specification in particular was studied but also found inadequate.

## Following Apollo

One of the key events in U.S. human spaceflight was its end in the demise of the MOL. The civil space program's crowning achievement occurred at about the same time, and the future lay open for NASA. The nation needed to chart the appropriate course for NASA in the wake of the moon landing success. The future seemed very rosy indeed, but appearances are rarely what they seem, and the circumstances were far from trivial. Two key NRO programs, the accumulation of quality processes, highly reliable piece parts, and a vastly unpopular war made the course ahead much more complicated.

Although military human spaceflight reached an overdue end with MOL's 1969 cancellation, human spaceflight for national prestige continued. Apollo 11's success raised the troubling question of what should come next. The U.S. won the race to the moon with a technological feat, providing some scientific benefits. The problem was it had been a success. Beating the Soviets and accomplishing the landing was a daunting, challenging task within a decade from a nearly standing start. The feat was undeniably successful, but a changing national mood due to a complex mixture of the turbulent 1960s and growing public disillusionment with all things in the government caused subsequent Apollo missions to lose some of their luster. Although NASA appeared to be ascendant with a future constrained only by the imagination, there had to be realistic funding limits. The NASA needed a sustainable program of some sort. The outcome affected all U.S. space programs for the next decade and a half (Temple, 2005a).

Nixon chartered the 1969 Space Task Group (STG) to report to Vice President Spiro T. Agnew, with the task of determining the future of NASA's space program (Nixon, 1969; DuBridge, 1969b). This comprehensive rethinking of the civil space program left everything on the table: moon colonization, Mars exploration, a major space station, and more. While the STG worked through the civil options, a parallel effort within the national defense and national security space programs examined their options and requirements.

By 22 March 1969, one major STG recommendation became clear: a new launch vehicle. The NASA and DoD would jointly study the future of space launch. On 4 April 1969, NASA forwarded the *Terms of Reference for Joint DoD/NASA Study of Space Transportation Systems* to Secretary of the Air Force Robert C. Seamans, formerly a Deputy Administrator of NASA. The study had two parts: each examining future needs independently, and then jointly (Paine 1969a).

The NASA Manned Spaceflight Center and the Air Force had been studying reusable launch vehicles for years. The outcome this time would have to reflect several new considerations, all of them tied to making space "operational," whatever that meant.[13] To some extent, it meant national defense and security space programs had to make space *routine* and *dependable*, and that tied to access to space (Temple, 2005a, p. 469; *Industry Observer,* 1969a, p. 13 and 1969b, p. 13).

13 The term "operational" is in quotes because the word was so overused by so many people in so many different ways, it was essentially meaningless. Though beyond the scope here, its lack of clear meaning caused NASA, Congress, and the Air Force all to agree the shuttle was to be operational, while all meant something different and partially mutually exclusive.

Picking up on the Air Force emphasis on making space systems operational, NASA insisted its reusable space plane would be an "operational" system. The Space Shuttle was one element of the Space Transportation System (STS), the others being a space station, upper stages, and launch facilities. Had NASA been alone in the STS's development (notwithstanding the low probability it would have been able to proceed by itself), the Air Force might not have taken as much notice. However, the idea that space programs could in some sense be made "operational" emphasized that military space capabilities might be ready for the transition out of research and development.

The Air Force's review of its future space program ended over the summer of 1969, and took into account the rough ideas of what a near-real-time reconnaissance program would entail. Seamans sent his personal views and the DoD's independent report entitled "DoD Space Programs, Options, Recommendations" to Agnew on 4 August 1969. Reflecting DoD's support for the recommended civil option in the STG report, Seamans explained that more money was needed for military space. The current military space effort had to place greater emphasis on sensor sensitivity, survivability from enemy anti-satellite attack, and longer on-orbit life times. Wary of over-reliance on space, he underscored "Each military space mission must be approved on a case-by-case basis and weighed carefully against other means for doing the same job." In 1969, any intimation of greater reliance on national defense space systems was hotly debated in DoD (Seamans, 1969a and 1969b).

Seamans was concerned about the high cost of space launch. Although he supported the idea that expending space launch hardware made expendable launch vehicles (ELVs) more expensive than reusable systems, he was reluctant to accept a radical concept like the shuttle without greater evidence it would work. He recommended "...we embark on a program to study by experimental means including orbital tests the possibility of a Space Transportation System that would permit the cost per pound in orbit to be reduced by a substantial factor (ten times or more)." Although the DoD and NASA studies were preliminary, it was "... not yet clear that we have the technology to make such a major improvement." Commitment to any such launch program could not occur until risk reduction provided schedule and cost confidence.

The STG report, however, concluded that development of a cost-effective space transportation system was necessary for both the DoD and NASA under all possible futures. Such appearance of consensus was misleading.

Seamans had already written to Lee A. DuBridge, the President's Science Advisor, differing with the STG's recommendations. Defense Secretary Laird, Deputy Defense Secretary Packard, and Seamans considered NASA's future directions as the purview of NASA Administrator Thomas Paine and the President. The STG in their view could only recommend the direction for the national prestige civil space program, not national defense space.

Agnew forwarded the STG and DoD reports to Nixon on 5 September 1969. The reports detailed the technical programs and costs for their respective programs. The development of a reusable space booster functioning like an airline to orbit, achieving commensurate cost savings, sounded like space was coming of operational age. If NASA could get people to the moon and return safely in less than a decade, surely this was not too difficult for them to accomplish. But Presidential approval was not forthcoming. Nixon was considering a new near-real-time national security space mission, so a major civil space program might be unaffordable.

Bureau of the Budget Director Robert P. Mayo did not support the STG's report. Its conclusions assumed that the large historical number of space launches would not only continue but actually increase as the shuttle made space launch more affordable. This was justified on the basis that, having gone to the moon and returned, the U.S. was now a truly space-faring nation, which necessitated launching things into space more often and more routinely.

The assumptions underlying the STG's cost numbers were largely unappreciated at the time. Most U.S. space launches were for the national defense and national security space programs. Shuttle economics projected significant increases to historically experienced launch rates. But the DoD space programs responded to an external threat. The DoD launch rates were neither artificial nor discretionary. As reliability improved, the number of payloads was declining from its peak in the mid-1960s. The economics would not work without DoD's complete commitment of every payload to the STS, and this became NASA's agenda.

On 25 September 1969, Mayo presented his independent views to Nixon. He explained that the STG did not differentiate the value of human spaceflight versus less costly robots with their "greater emphasis on scientific achievement and potential economic returns."

Having evaluated the separate DoD recommendations, Mayo (1969) said that the STG "could not, nor did it try to, assess the relative standing of the space program in our full range of national priorities." In plain terms, the 1971 budget could not support the expansion of the civil space program due to budget pressures from inflation, the Vietnam conflict, and the national security need for a near-real-time imagery reconnaissance system. The priority of the latter two significantly trumped the STG recommendations. He recommended a sequential development of the Space Shuttle followed by the Space Station. Mayo also suggested an official response on the STG report until the spring of 1970 to allow Cabinet and National Security Council consideration work through the priorities for major new programs affecting national security space, national defense space, and the national prestige space program (Mayo, 1969).

Nixon wanted his Administration to provide the operational near-real-time imagery reconnaissance capability. However, he did not want his Administration to be seen as rewarding the success of NASA by failing to support its new initiatives. Could the nation afford both, and support an on-going war? If not, what would NASA do post-Apollo?

It is not clear Paine ever knew what the Presidential approval delay was. During the noticeable delay, Paine brought George M. Low of the Houston Manned Spacecraft Center to NASA headquarters. Low's task was selling the Space Shuttle. Low understood enough of the political environment to recognize this was impossible without DoD contributing people and budget (Low, 1970a, p. 9).

Seamans and Low had been friends during their mutual time in NASA. On initially meeting in their new capacities, Seamans supported the shuttle for technology development at a slow and cautious pace. Seamans' was primarily interested in low-cost space transportation. Seamans explained the Air Force had no money for a major development, but Low felt encouraged.

As Low continued the DoD rounds, he was warmly received but obtained no serious commitments.

The civilians professed interest in shuttle technologies. Low had come expecting resistance but found positive and supportive responses, even as definitive DoD commitment eluded him at every turn. He was repeatedly told the DoD did not want a major new development program. Laird, in fact, insisted Low could count on DoD encouraging NASA's program, but that NASA would have to "pay its own way" (Low, 1970b). After all, DoD was still smarting from MOL's cancellation.

Dr. John S. Foster, Jr., Director of Defense Research and Engineering (DDR&E), was known for stirring various technology pots and pushing for new ideas. He believed strongly that technology held the key to preventing surprises from the Soviet Union (Foster, 1969). Foster's penchant for technology and complete programs heavily influenced his advice, as he explained to Low (Low, 1971). He wanted to pursue the technology, and explained how Low needed to orchestrate internal DoD politics to get a positive statement of support and favorable direction from the President (Fletcher, 1971, 1972a, 1972c; Low, 1972a, pp. 3-4).

Low worked the uniformed Air Force and was pleased when money for low level, though official, study participation was forthcoming due to the intervention of some key general officers (Low, 1970a, 1970b). General James Ferguson, AFSC Commander, and his Vice Commander, LtGen John W. O'Neill, were the executive agents for all DoD launches. In early March 1970, they met with Seamans and Assistant Secretary for Research and Development Grant L. Hansen to establish an Air Force policy on the shuttle. They all supported Secretary Laird's insistence on NASA's paying its own way (Low, 1970b).

Seamans and Low agreed to keep the shuttle program unclassified. It is likely that Seamans considered his recommendation for a shuttle technology demonstrator risk-reduction program as the direction the President would probably take. Perhaps he considered the shuttle more like a truck than a launch vehicle, so that there would be minimal interaction with its payloads. Seamans knew about the NRO and the secrecy involved in the national security space program, and how the national defense space program covered it at the time. Perhaps he meant to exclude the national security space program altogether, allowing the NRO to continue to operate using the large expendable boosters on which it and most of the military programs relied. Perhaps Seamans and Low were thinking the Air Force would own one or more shuttles, but that certainly was not the level of commitment that Seamans had indicated. Maybe Seamans did not think about the interaction at all. It is certain that neither anticipated the problems of shifting very sensitive national security and national defense satellites to a civilian launch vehicle.

They based their initial agreement on security arrangements modeled on the mainly civilian Apollo program. However, that was a unique exploratory program, and they were considering a joint DoD/NASA operational vehicle. The Apollo agreement was the best extant and most logical starting point if one ignored the operational considerations. It was an innocent and simple mistake. While lack of classification simplified the initial planning, this choice was inappropriate and shortsighted, made without a clear definition of the content of the shuttle program. At the time of the agreement (February 1970), and for more than two years afterwards, no one understood which DoD payloads might fly on the shuttle (Paine and Seamans, 1970).

Both agreed "…to insure that the proposed National Space Transportation System will be of maximum utility to both NASA and the DoD" (Paine and Seamans, 1970). The program's goal was reducing operating costs an order of magnitude below existing launch systems. They formalized the Seamans-Low agreement making the program generally unclassified. This cleared NASA's way to actively seek international participation (Paine 1969b, 1970; Low, 1970b; Paine and Seamans, 1970).

Following Nixon's request that DuBridge examine alternatives, the PSAC met in Boulder, Colorado, to hear what NASA had to say regarding the shuttle. The NASA briefers waxed eloquent, full of enthusiasm for their single-stage-to-orbit, fully reusable, airline-like shuttle. Garwin picked their presentation apart, finding no credible approach to the program. Undaunted by the lack of technological feasibility, the NASA planners expected the shuttle to be so economical that, by the year 2020, it would have repaid its development costs. Garwin quickly worked out that this was not even the return from a passbook savings account. He and the other PSAC members also considered it was too much to expect that NASA could operate a space launch vehicle system safely (or otherwise) for 40 years (Garwin, 1988, p. 59).

The NASA briefers then described their alternative two-stage vehicle, both stages being piloted and reusable. Garwin found little more to recommend this approach than he had found in the single-stage-to-orbit, though the physics were better. "Eventually they agreed to drop the manning of the booster. We couldn't convince then to drop the manning of the orbiter – although that was clearly the thing to do – because the whole purpose of the shuttle was manned space flight in order to maintain public enthusiasm and support for NASA" (Garwin, 1988, p. 59).

Despite the PSAC's doubts, DuBridge reported back to Nixon, addressing Mayo's concerns about the STG. DuBridge (1969b) explained that the options of the STG were separable, and recommended pursuing the "more technologically challenging space shuttle in view of its profound impact upon our entire approach to placing payloads into orbit."

Nixon finally responded in part to the STG with a decision on 7 March 1970, announcing three general goals to guide the space program: exploration; scientific knowledge; and practical application. He set several objectives for the space program: continued moon and eventual planetary exploration; substantially reducing the cost of space launch; extending the ability to live and work in space; expanding the practical applications of space technology; and encouraging greater international cooperation in space (White House, 1970). The announcement did nothing about answering the critical issues of Presidential approval of the STS, which continued in abeyance.

Low's own views were elusive and audience-dependent. In October 1970, Low told Caspar W. Weinberger, OMB Deputy Director, the "...shuttle is clearly the key to effective and economical use of space...(and) it will provide a single improved and more economical system for unmanned and manned missions of the future" (Low, 1970c). Privately, Low recognized NASA's need for six Titan IIIs per year through the first generation of the shuttle program. Six boosters-per-year was the minimum cost-effective production rate. He apparently expected a comparable DoD expendable launch vehicle launch rate (Myers, 1971; Hansen, 1971; Low, 1971a).

One of the first consequences of the Seamans-Low agreement on security affected how DoD performance requirements were specified. Requirements were put in terms of equivalent performance (that is, different weights to different orbits but demanding similar launch vehicle performance). The military and national security requirements were combined and expressed in equivalent but unrevealing performance terms protecting actual weights, inclinations, and altitudes (Temple, 1991).

The high level agreements drove out the need for DoD requirements. One of the MOL program survivors was its former Technical Director, Michael Yarymovych. At the time, he was a Deputy Assistant Secretary working for Assistant Air Force Secretary (Research and Development) Grant Hansen. Yarymovych collected the DoD's requirements and negotiated with NASA for their inclusion in the top-level (called Level 0) STS requirements. These Level 0 requirements soon defined what the shuttle would become.

Defining the military and national security requirements for the STS proved decisive in the course of the program. These requirements projected the growth of operational payload sizes and weights into the operational shuttle time frame of 1978-1990. The results surprised the NASA officials, who found the requirements were far larger, heavier, and fewer than expected. The impact on the shuttle program was immediate, and raised NASA program office concerns about their validity. Even NASA's most speculative mission needs did not compare to the effect of the DoD parameters on the shuttle design.

One DoD performance-equivalent mission[14] required delivering 65,000 pounds to low-earth, low-inclination orbit for transfer to higher altitude (i.e., an East Coast mission). The West Coast equivalent mission required 32,000 pounds to a low-earth near-polar orbit. This enveloped the expected weight and orbital parameters for the NRO's proposed

14 To protect specifics of mission size, orbital altitude and inclination, the requirements were put in terms of equivalent performance to a standard orbit. NASA defined the standard orbit for the shuttle to be 100 nautical miles, an unstable altitude for long duration missions. The difference between this nominal orbital altitude and the satellite's final altitude required a further extrapolation of equivalent weight to orbit.

near-real-time system, but more importantly, it also encompassed nearer-term vehicles of the size the NRO planned to be launching by the end of 1971. Namely, the KH-9 Hexagon film-return photoreconnaissance satellites had a liftoff weight in the neighborhood of 30,000 pounds to polar orbit (Oder, et al., 1992, p. 80). Although the weight was lower than the East Coast mission, the necessary overall performance was more stressing on the shuttle design, ultimately driving the thrust of the Space Shuttle Main Engines.

National security considerations and this near-polar orbit mission necessitated a shuttle capability to return to a continental United States landing site after one orbit. That required altering its flight path by 1,100 miles during re-entry. This prodigious feat could only be done with the shuttle's now familiar double-delta wing shape versus NASA's preferred stub-wings.

For security reasons similar to the performance equivalence missions, the size of expected payloads was said to be an extrapolation from current missions. But the extrapolation was made with high confidence, since, in 1969, the Hexagon was only two years from its first launch. Its size was about 59 feet in length and nearly 14 feet in diameter. The "extrapolated" DoD requirements for a payload bay 60 feet long and 15 feet in diameter were not far from actual hardware sizes. Approximately the dimensions of a Greyhound bus, that remained controversial because NASA's preferred design accommodated a payload bay of only 40 feet by 12 feet (Oder, et al., 1992, pp. 80, 95). The smaller option was more technologically achievable. When Low told Weinberger the shuttle was the single vehicle for the future, he overlooked DoD's requirements for the payload bay size which were unmet in NASA's plans at the time. Of 149 DoD payloads forecast to be flown between 1981 and 1990, 71 would not fit in the smaller payload bay NASA wanted.

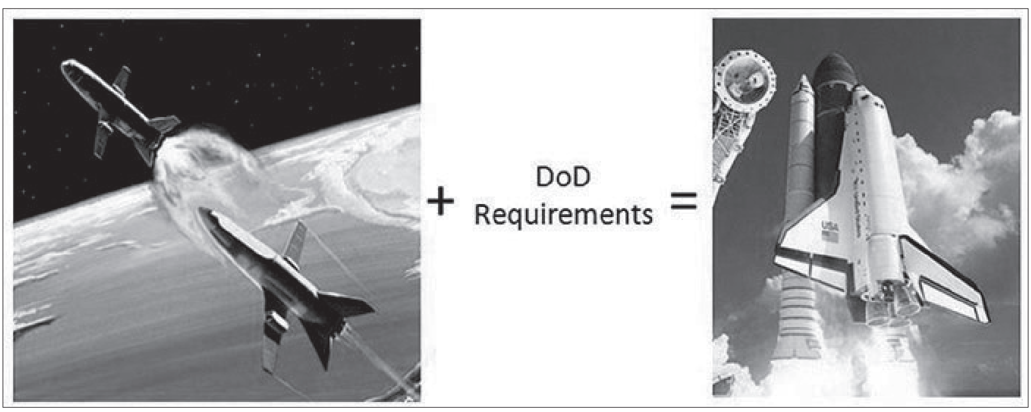


**Figure 5. The early, small payload bay, fully reusable space shuttle concepts gave way to the large payload bay, partially reusable, double-delta design after consideration of the DoD requirements. (Photo courtesy of the National Aeronautics and Space Administration)**

The minimum shuttle size accommodating DoD's requirements set the physical size of the main engines, which had to fit within the diameter of the fuselage. Altogether, then, the size of the payload bay and the cross-range requirements drove the shuttle's structural size, shape and weight, giving a maximum size for the engines, and all of that plus fuel determined the amount of thrust to be squeezed from each engine (Myers and Hansen, 1971).

In the final analysis, the military and national security missions drove the size, shape, performance, and subsystem characteristics of the shuttle. Henry Kissinger's 23 September 1971 announcement of Nixon's decision regarding the near-real-time electro-optical reconnaissance system cleared the way for the final shuttle design decision.

To pay its own way, the shuttle had to be flown 60 times per year—40 times from Kennedy Space Center and 20 times from the Air Force's West Coast launch site. The NASA clearly needed the DoD traffic to make the shuttle economically attractive (Seamans, 1971).

The available evidence was unassembled, but the space launch landscape was changing. The Phillips and Schultz initiatives discussed earlier were drastically reducing launch rates. Although the national security and national defense space programs provided the largest and most dependable data for launch predictions, long satellite lives meant a declining demand. Military and national security launches would only need, at most, 15 launches per year (Hansen, 1971; Seamans, 1971). Film-return reconnaissance missions had inflated the historical number of launches, which the 60 launches-per-year number assumed would continue. The move to near-real-time reconnaissance meant film-return missions would vanish, albeit not immediately. Solid state technologies were advancing rapidly, so many of the justifications Land used concerning the technological maturity for a new charge coupled device, electro-optical imagery system also undermined the launch numbers. With the expected number of launches falling far short of the 60 required to realize NASA's cost numbers, the shuttle could not realize its advertised savings, either.

The NASA Administrator James C. Fletcher was waiting on the President's decision, unaware that the President was weighing the start of a revolutionary system that would obviate a large segment of what NASA was expecting to launch. In the meantime, Low found a means to distribute a portion of the program costs with the Air Force. The Air Force program content would include responsibility for a western launch and landing site, and an orbit-to-orbit reusable space tug to take payloads from the shuttle's low earth orbit to higher altitudes.

Funding concerns led to a series of meetings with OMB to determine the scope and what could be obtained within fiscal guidelines. The OMB remained unconvinced about the cost-effectiveness of human spaceflight and whether any scientific grounds justified the program. On 29 December 1971, Low and Fletcher took a briefing and a letter that they hoped Caspar Weinberger would sign. The letter recommended developing a small payload bay (45-foot length), which was acknowledged to exclude many DoD and some NASA payloads. This option cut DoD's projected launches in half, since only eight per year fit in the smaller shuttle. Despite this, Low's briefing charts described the threefold purpose of the Space Shuttle program as a replacement for all launch vehicles, continued human spaceflight capability, and achievement of the lowest possible cost per flight.

Weinberger did not sign their letter. The OMB support was predicated to some degree on exclusive national use of the shuttle. Exclusive use required the design to accommodate all DoD payloads and their associated requirements. At a meeting with OMB Director George P. Shultz on 3 January 1972, Fletcher and Low were surprised at OMB's insistence on the 60-foot payload bay. This enabled the replacement of all existing launch vehicles. All subsequent shuttle studies were performed against projections of the total set of future U.S. space launches (Rice, 1970; Fletcher, 1971, 1972b, 1972c; Briefing Charts, 1971; NASC, 1972).

Everything was finally in place for the shuttle decision. On 5 January 1972, Fletcher and Low discussed the shuttle with President Richard M. Nixon and his aide, John Ehrlichman. The 10 a.m. meeting had been scheduled for only ten minutes but lasted about 40 minutes (Parker, 1971). Nixon enthusiastically supported the proposed program and its potential, particularly for low cost and quick response to observe problems such as natural disasters. These advantages that Nixon spoke about with Fletcher, and his enthusiasm for them, reflected the recent spate of discussions regarding the NRO's near-real-time imagery program for crisis response, though he did not mention this to Fletcher or Low (McLucas, 1972, p. 22).[15]

Nixon, who had seen the birth of the U.S. space program while serving as Eisenhower's Vice President, endorsed the thrust of the civil space program. He opined that the shuttle was necessary even if the economics did not work out, since human spaceflight was a lasting part of the U.S. civil space program. Nixon then publicly announced the U.S. would proceed with the development of the STS to achieve routine access to space and faster development of space capabilities, taking the place of all launch vehicles except "the very largest and very smallest" (Low, 1972b; White House, 1972; Temple, 2005b).

Apparently, some of the confusion between the smaller and larger payload bays had found its way into the White House, and got erroneously reflected in the President's announcement. The error was not corrected, and that remained the only official policy regarding what would fly on the shuttle.

Following Nixon's announcement, Fletcher added details for the press. The NASA and the DoD would build a spaceship the size of a DC-9 airliner to carry into low-earth orbit payloads of 15 x 60 feet and up to 65,000 pounds. For each of the five Orbiters, from the moment the wheels came to a stop on return from space until it lifted off again would be

15 Despite the President's announcement and the significant impact of the NRO's requirements on the shuttle, McLucas told Laird "The NRO has not yet designed or redesigned any payloads specifically for Space Transportation System launches." While remaining involved "at a low level of participation," commitment to the shuttle awaited McLucas' successor.

160 hours.[16] The costs were projected at $5.5 billion in development over six years, resulting in a $10 million cost per flight at 60 launches per year. The operational, reusable approach promised to amortize development costs over 100 flights per shuttle orbiter, minimizing the amount of material thrown away (unlike the ICBM-derivative ELVs) (Fletcher, 1972b).

The heyday for NASA came to a close a few months later. Apollo 17, the last mission to the moon, was launched on 7 December 1972. When it returned on 19 December, it closed the era of active human exploration of space. The NASA had to follow its own very hard act with something that would sustain the prestige of the U.S. in space.

The shuttle promised airline-like operations, borrowing military terminology about operational systems, misleading many about what the reality would be. Its promise was based on an assumption of its own extremely high reliability, and on the lack of reliability of spacecraft--hence, the need to launch 60 per year and to repair them in orbit. Economics of saving an order of magnitude on launch costs were based on a future that had already been altered as the shuttle approval languished between the STG and Nixon's approval.

The Space Transportation System Program included five shuttles. No continuing production line was envisioned. So, like the ELVs whose production would eventually be eliminated, the U.S. was moving towards the end of its launch vehicle industrial base, barring some future disaster.[17]

The shuttle never demonstrated most of the performance required to support the largest and most critical payloads. It did not disprove the utility of reusable space launch vehicles. Instead it taught some tough lessons about space launch, dependability, overselling capabilities, and how public statements and policies can reduce or eliminate essential flexibility in acquiring such an advanced machine. The shuttle did disprove the ability of one reusable design and architecture to reduce costs and achieve real operational status.

The second divide saw the change from ELVs to reusable launch vehicle, which would affect space programs for 30-plus years. The before and after of the second great divide could hardly have been more dramatic for NASA's future plans, and for the NRO.

The changes in quality processes and in electronic parts reliability completely undermined the economic justification for the Space Shuttle's planned launch rates and need for reusability. Satellites had begun to live significantly longer, having overcome much of the early mortality problems that had plagued earlier generations of satellites. These changes also undermined the ideas for the quick checkout and possible return of a defective satellite that was part of the justification for the 1,100-mile cross-range

16 The 160 hour figure was based on two 8-hour shifts per day, Monday through Friday, resulting in an alternative statement of the requirement as a two-week turnaround from landing to launch.

17 The actual situation was even more bizarre. The only official Presidential policy was for the shuttle to replace "all but the largest and smallest" launch vehicles. Various agencies had agendas to eliminate all ELVs, but no national policy ever committed all payloads without also retaining the option for a prudent ELV backup in case of problems. Not until Hans Mark was under secretary of the Air Force and NRO Director did the full commitment become a fait accompli, when he limited the final buy of Titan 34Ds, bringing ELVs to an end. Despite the lack of an official policy of commitment, shortly thereafter the U.S. had no alternative to the shuttle.

requirement for the shuttle, which forced the large double-delta wings. The NRO's new KH-9 and near-real-time systems drove the weights and volume for the shuttle payload bay, which in turn drove the size and power required for the engines. In short, had the shuttle been approved a few years earlier or a few years later than the second great divide, it would have been a radically different program. What happened instead meant the system moved from a technically challenging but achievable set of requirements to a set of requirements that never would be met. Trying to be the launch vehicle for all satellite programs caused delays in availability, slips in launch dates, backups of critical national security space systems built for a launch vehicle that was years behind in delivery and performance. This ultimately contributed to the imperative to launch, which contributed to the loss of Challenger on 28 January 1986. That loss returned the nation to the successful launch approach existing prior to the second great divide.

The shuttle's media storm emphasized how it would make space operations routine. The next section will explore the germ of the idea that national security space capabilities could be useful to tactical military forces.

### Towards Tactical Relevance

As unpopular as the SEA war was, the military lessons learned were redolent with changes. First was the dramatic shortening of timelines. Also, the national defense and national security space capabilities' primarily strategic emphasis had to change, despite the reluctance to become dependent on robotic spacecraft. Another thing brought sharply into focus was that national security space systems, in general, produced products that could vastly enhance U.S. tactical military forces, if they could be made available. Towards the end of the second great divide, the changes discussed earlier coalesced thinking that there must be a technological way to make the U.S. investment in national security space tactically relevant.

Trustworthy and timely intelligence has been important since ancient times. In Napoleon's time, Clausewitz used the term "fog of war" to describe the conflicting, confusing, and often disjointed information finding its way to a commander. More information was not better in such circumstances; it was just more noise. In the 1960s, some important lessons about the criticality of intelligence information were being re-learned in SEA. The timelines of modern warfare accentuated the need to move information from where it was discovered to the point of putting weapons on target with the least delay in between. Although the term "sensor-to-shooter" did not emerge for more than a decade, the necessary proofs-of-concept reducing the time from aerial photographic intelligence to the tactical commander's targeting staff were demonstrated in SEA. The changes being wrought in intelligence collection and dissemination by modern tactical aircraft were lifting the fog of war in tactical situations, saving lives and materiel.

Although the Air Force was struggling with tactical relevance and over-reliance, the situation was different in the NRO. The original NRO charter was for indications and warning and early warning – both strategic missions. To these, as capabilities improved, the charter expanded to include mapping & charting and, later, scientific & technical intelligence. The extremely high-resolution Gambit satellites supported detailed analysis of foreign weapon systems as part of scientific and technical intelligence. Each new Hexagon satellite, first launched in 1971, carried miles of film for broad area search and mapping & charting. While the objectives were strategic, mapping & charting was important to tactical operations and intelligence preparation of the battlefield. The NRO systems could contribute to estimating various performance measures of foreign weapon systems. All were highly relevant to the tactical military branches.

However, national reconnaissance film-return systems were not responsive to battlefield timelines. Before the information dominance of the 1990s could even be conceived, some important first steps had to be taken.

Tactical warfare's pace marginalized satellite images, which for film-return systems, would not be available until days or weeks later. Intelligence information from "see-it-now" systems, electronic processing delays aside, was potentially available almost immediately, making possible timely responses to fluid warfare situations. Electronically linking aircraft sensors through relay stations directly to the processing and exploitation units in the rear echelons dramatically reduced response timelines. As each delay in the chain from collection through delivery was reduced or eliminated, near-real-time became synonymous with instantaneous availability of reconnaissance information. Such capabilities in aircraft changed the pitch and pace of tactical warfare, slowly at first, but eventually to the point U.S. forces would be able to detect and react to enemy movement faster and more accurately than the enemy. And that made intelligence information not only tactically relevant – it moved towards a revolutionary and significant information advantage for the U.S. The rapid advance of solid state electronic technology, which was making a crucial difference in bringing about near-real-time national reconnaissance, also provided a technical basis for dramatically shortening the delay from sensor-to-shooter.

As NASA and Air Force space programs were jockeying for budgets in the wake of the MOL cancellation, the funding of the SEA war, and the start of the post-Apollo effort, the NRO began receiving pressure from Congress to expand its constituency. Congress wanted to ensure the nation took wider advantage of the investment in NRO capabilities such as Land's near-real-time reconnaissance system. Growth comes when a non-traditional customer demands something because it has become essential to their mission. In 1973, that is exactly what happened in terms of national reconnaissance.

The NRO was making some important strides in that regard. The NRO supported naval fleet exercises aimed at determining the tactical benefit of using satellite data. Working with the Air Force, the NRO expedited the collection of electronic order of battle in Europe. Such efforts underscored difficulties that slowed or made impractical the flow of intelligence from the sensor to the shooter (McLucas, 1972, pp. 17-18).

The hurdles to tactical relevance were not entirely about new space sensor capabilities. Classification and communications were also obstacles.

Classification of the NRO's products had been an issue for a number of years. McLucas was able to take credit for some initial success with abolishment of "Special Access Required" (SAR) caveats on several space programs (McLucas, 1972, p. 18).

Other progress in declassifying capabilities came with Program 417, known in 1972 as the non-descript Defense System Application Program (DSAP). Begun in August 1961, DSAP provided weather observations over the Soviet Union and China for use by photographic intelligence satellites and in support of strategic targeting (Hall, 2001, p. 2).[18] It had been removed from NRO's Byeman compartment controls earlier, but remained under Special Access Program controls until 1972. At that point, the DSAP was classified as secret. It remained classified because its resolution was considerably superior to that released to the public by the Department of Commerce's National Oceanic and Atmospheric Administration (NOAA). During 1972, McLucas had begun discussions with the Secretary of Commerce to provide DSAP data, declassified, to NOAA (McLucas, 1972, p. 19).

One of the reasons national imint and sigint space systems were not more relevant to tactical commanders was that dissemination of information from these systems was inconsistent, often poor, and hampered by classification. Tactical commanders generally did not have the means to receive, process and use national reconnaissance information. If communications, processing, and display systems could be built to do these things, the issues of classification could be settled on and the warfighters would benefit.

The Army may have lost its early space programs to NASA in 1958 and 1959, but it became consumers of information derived from NRO and Air Force systems. By 1973, the Army's chief of staff for intelligence came to believe the Army's future battlefield effectiveness depended on more effective use of intelligence from the NRO's satellite missions. From preparation of the battlefield to the conduct and aftermath of battle, national security systems had important capabilities with even greater promise from the near-real-time system.

The near-real-time system was conceived as a crisis reporting system, and approved as such by Nixon. The national need for this was highlighted by an Arab-Israeli crisis cited by R.S. Cline, the State Department's Director for Intelligence and Research, in a September 1970 letter to DCI Richard Helms. Corona was not timely enough, and without the U-2, the U.S. would have been severely constrained and uninformed (Perry, 1973a, pp. 207-208).

Cline shared his views with Defense Intelligence Agency Director Lt. Gen. D.V. Bennett, suggesting alternatives to cover crisis situations. Bennett immediately concurred, and contacted both McLucas and Packard to see what could be done. At the same time, the near-real-time system gained the attention of the Army's chief of intelligence (G-2) (Perry, 1973a, p. 209). The Army's G-2 got ready to take maximum advantage. Army

18 The program was eventually better known as the Defense Meteorological Satellite Program.

systems would be in place and ready to deal with the expected new near-real-time imagery when it went into operation a few years later.

Starting with a small budget, the Army began programs in 1973 to adapt national security capabilities for use in tactical military operations. The program was later entitled "Tactical Exploitation of National Capabilities," or TENCAP. Through initial exploratory work, the Army began to work with the national intelligence agencies that received and processed the NRO data. Despite a small initial budget, the Army was able to leverage the major national investments for this information to get into the hands of the strategic military customers. The Army paid for adapting these mechanisms and processes to support tactical use. Often, this entailed combining tactical communications with forward-deployed processing and exploitation vans (Mitchell, 1991, p. 72).

The Army's TENCAP programs were intended not only to take advantage of some of the electronic intelligence sources, but also to pave the way for a coming revolution in the availability of imagery (Perry, 1969, pp. 45-48). Soon, in part due to Congressional direction, all the Services began TENCAP efforts to leverage systems developed to support strategic indications and warning, early warning, nuclear detonation detection, and communications (House Committee, n.d., pp. 680-681). The TENCAP efforts aimed at taking the information that was already present and making it useful and available to the tactical warfighting community. Other efforts developed new tactically relevant payloads.

In a fascinating turn of events, as the Air Force wrestled with itself about over-reliance on its space systems, the Army began to take advantage of the most advanced capabilities and systems, transforming the way they would fight future wars. Space was more than simply operational; it was becoming tactically relevant.

## Epilogue

The years 1969-1973 divide the character and content of the U.S. space programs before and after in ways unlike any similar time span. They separated what had been from what would be in ways distinctly different from most other periods of such a few years. While the American public watched the war in Vietnam and protesters were center stage on the nightly news, important changes were taking place in the national security and national defense space programs. Humans walking on the moon belied the true state of the civil space program which was committed to unobtainable goals. Meanwhile, national defense space was transforming to provably enhance the U.S. military forces dependably and reliably. National reconnaissance, taking lessons from the timelines of modern events, was transforming national intelligence collection to become near-real-time as new dissemination processes and equipment were about to make it tactically relevant.

The changes of the second great divide had more than a local effect on the years under investigation here. The broad range of changes summarized here had a profound impact for more than two decades of the U.S. space programs. Furthermore, limiting consideration only to the space programs' impacts themselves ignores the more profound effects of space and benefits to society in general.

The mechanisms were varied. In some cases, the changes required education of target audiences, but that education would have been insufficient without demonstrating the fundamental importance of superior parts and quality or specialty engineering disciplines. In some cases, technology opportunity was recognized by entrepreneurial leaders, such as the near-real-time system. In other cases, apparent technological opportunity was oversold in the face of policy, political and classified realities, as in the case of the Space Transportation System. Classification became recognized as hampering wider utility of and return on taxpayers' investments.

Military human spaceflight, based on the perceived need for human presence to overcome the lack of dependability of robotic spacecraft, essentially ended. In the early 1980s, the creation of an operational Air Force Space Command briefly sparked a resurgence of interest in military human spaceflight. However, as the shuttle was unable to deliver on its promises and the reality of its limited utility (compared to what had been expected) emerged, interest gained in NASA's next major program, the manned space station. When asked by NASA if the DoD would be interested in participating in the space station, intense studies revealed no compelling military mission was enhanced by, or depended upon, military human presence. Aside from reserving the option to come aboard the space station occasionally to test new technologies, the DoD declined the NASA offer.

The TENCAP, overcoming the sentimental desire for military human presence in space, extreme quality processes and electronic parts reliability, and the NASA media blitz about the shuttle's "routine" space operations all contributed to the eventual political decision to create military space commands. The timelines of warfare continued to shrink, but the development of the NRO's near-real-time, electro-optical capability coupled with the start of the military TENCAP programs to take advantage of these highly capable national assets, kept pace with and even supported the continued expansion of the utility of space capabilities to military planning and operations.

The optimization of quality practices and development of highly reliable space electronic parts resulted in space systems of the 1980s up to the early 1990s being the most reliable systems ever acquired. Lack of trust in these space systems died gradually through the 1970s until the formation of operational space commands in the 1980s. These led to reliance on space capabilities in Desert Storm. As a consequence, General Donald Kutyna, Commander of U.S. Space Command, was able to claim that Operation Desert Storm was the first real "space war." The NRO's key role throughout Desert Storm, facilitated by the TENCAP programs, contributed to the decision process declassifying the existence of the NRO in 1992. Ultimately, the changes in the second great divide spawned activities enabling the conception of information dominance, revolutionizing the American way of war.

There was a downside to the changes. The creation of the highest reliability parts put spacecraft on a path headed for a "coffin corner"—an aeronautical term for a situation from which there is no recovery. Spacecraft could only get so long-lived, thus reducing launch rates, thus increasing the costs of space launch, and reducing the ability to sustain a robust and competitive industrial base as spacecraft prices rose astronomically, in part contributing to disastrous acquisition reform in the wake of the end of the Cold War.

But even those stories, for another time, do not amount to the full effect of the changes of the second great divide between 1969 and 1973.

## References

Briefing Charts. (1971, 29 December). Briefing Charts for NASA Administrator Fletcher Meeting with OMB Deputy Director.

DRUE History. (1973). *Historical Report, Engineering Support Branch (DRUE), 1 July–31 December 1973.*

DuBridge, Lee A. (1969a, 19 April). President's Science Advisor Memorandum for the President. Subject: MOL.

DuBridge, Lee A. (1969b, 3 July). President's Science Advisor Letter to President's Science Advisory Committee. Subject: Post-APOLLO Space Program Study.

Fletcher, James C. (1971, 29 December). NASA Administrator Letter to Office of Management and Budget Deputy Director Caspar W. Weinberger. Subject: Space Shuttle Course of Action.

Fletcher, James C. (1972a, 4 January). NASA Administrator Letter to OMB Deputy Director Caspar W. Weinberger. Subject: Space Shuttle Decisions.

Fletcher, James C. (1972b, 5 January). NASA Administrator "Statement on Space Shuttle."

Fletcher, James C. (1972c, 6 March). NASA Administrator Letter to Office of Management & Budget Deputy Director Caspar W. Weinberger.

Foster, John S. Jr. (1969, September ). Speech to Armed Forces Management Association Conference. Washington, D.C.

Garwin, Richard. (1988). "Science Advising: Challenges and Controversies," in Thompson, Kenneth W. (Ed.). *The Presidency and Science Advising,* Vol. V. New York, NY: University Press of America.

Greenhalgh, W.H., Jr. (1977). *U.S. Air Force Reconnaissance in Southeast Asia, 1960-1975, Study 135.* Montgomery, AL: Air Force Historical Research Agency.

Hall, R. Cargill. (2001, September). *A History of the Military Polar Orbiting Meteorological Satellite Program.* Chantilly, VA: Office of the Historian, National Reconnaissance Office.

Hansen, Grant L. (1971, 21 June). Air Force Assistant Secretary, Research and Development memorandum to NASA Associate Administrator for Manned Space Flight Dale D. Myers. Subject: Impact of Shuttle Small Payload Bay.

House Committee on Appropriations. (n.d.). *Department of Defense Appropriations for 1987.* House Committee on Appropriations, 99th Congress, 2nd Session, Part 3.

*Industry Observer.* (1969a, 15 September). *Aviation Week & Space Technology.*

*Industry Observer.* (1969b, 29 September). *Aviation Week & Space Technology.*

Land, Edwin H. (1971, 14 July). Chairman, National Reconnaissance Panel memorandum to the President's Science Advisor. Subject: "The Near-Real-Time Photo Reconnaissance [deleted]."

Lecuyer, Christopher. (2000). "Fairchild Semiconductor and Its Influence," in Lee, Chong-Moon, et al. *The Silicon Valley Edge–A Habitat for Innovation and Entrepreneurship.* Stanford, CA: Stanford University Press.

Levin, Richard C. (1982). "The Semiconductor Industry," in Nelson, Richard R. (Ed.) *Government and Technical Progress–A Cross-Industry Analysis.* New York, NY: Pergamon Press.

Low, George M. (1970a, 1 January). Personal Notes No. 1. Personal memoranda for record from papers held at Rensselaer Polytechnic Institute.

Low, George M. (1970b, 28 January). "Space Shuttle Discussions with Secretary Seamans." Personal memoranda for record from papers held at Rensselaer Polytechnic Institute.

Low, George M. (1970c, 28 October). Letter to Office of Management & Budget Deputy Director Caspar W. Weinberger.

Low, George M. (1971a, 12 October). "Space Shuttle Program." Personal memoranda for record from papers held at Rensselaer Polytechnic Institute.

Low, George M. (1971b, 2 December). Memorandum to Administrator James C. Fletcher. Subject: "Discussions with Johnny Foster."

Low, George M. (1972a, 2 January). Personal Notes No. 61. Personal memoranda for record from papers held at Rensselaer Polytechnic Institute.

Low, George M. (1972b, 12 January). "Meeting with the President on January 5, 1972." Personal memoranda for record from papers held at Rensselaer Polytechnic Institute.

Mayo, Robert P. (1969, 25 September). Bureau of the Budget Director memorandum to President Richard M. Nixon. Subject: "Space Task Group Report."

McElheny, Victor K. (1998). *Insisting on the Impossible–The Life of Edwin Land, Inventor of Instant Photography.* Cambridge, MA: Perseus Books.

McLucas, John L. (1972, 18 December). National Reconnaissance Office Director Memorandum for Secretary of Defense Melvin R. Laird. Subject: Taking Stock of the National Reconnaissance Office.

Mitchell, Eddie. (1991). *Apogee, Perigee and Recovery: Chronology of the Army Exploitation of Space.* Santa Monica, CA: RAND Corporation.

Myers, Dale D. (1971, 25 May). NASA Associate Administrator for Manned Space Flight letter to Assistant Secretary of the Air Force (Research & Development) Grant L. Hansen.

Myers, Dale D. and Hansen, Grant L. (1971, June). "Space Transportation System Committee Summary of Activities for 1970." NASA Associate Administrator for Manned Space Flight and Assistant Secretary of the Air Force for Research and Engineering, Co-chairmen.

National Aeronautics and Space Council (NASC). (1972, 3 April). National Aeronautics and Space Council Meeting Minutes.

National Semiconductor Corporation. (1979). *The Reliability Handbook–An Introduction to Military/Aerospace Semiconductor Reliability Concerns, Screening Techniques, and Standardization Programs.* Santa Clara, CA: National Semiconductor Corporation.

Newman, Dava J. et al. (2001, July-August). "Astronaut-Induced Disturbances to the Microgravity Environment of the Mir Space Station." *Journal of Spacecraft and Rockets.* Vol. 38, No. 4, p. 578.

Nixon, Richard M. (1969, 13 February). President's memorandum to Vice President Spiro T. Agnew, et al. Subject: Space Task Group Charter.

Oder, Frederic C.E.; Fitzpatrick, James C.; and Worthman, Paul E. (1992, December). *The HEXAGON Story.* Washington, D.C.: National Reconnaissance Office. [Declassified 17 September 2011].

Packard, David. (1969, 10 June). Deputy Secretary of Defense Press Statement. Subject: "Cancellation of Manned Orbiting Laboratory." Washington, D.C.: Department of Defense, Pentagon.

Paine, Thomas O. (1969a, 4 April). NASA Administrator letter to the Secretary of the Air Force. Subject: Terms of Reference for Joint DoD/NASA Study of Space Transportation Systems.

Paine, Thomas O. (1969b, 4 April). NASA Administrator letter to Secretary of the Air Force Robert C. Seamans. Subject: Invitation for Joint Study.

Paine, Thomas O. (1970, 23 June). NASA Administrator letter to President Richard M. Nixon. Subject: Future NASA Directions.

Paine, Thomas O. and Seamans, Robert C. (1970, 17 February). "Agreement Between the National Aeronautics and Space Administration and the Department of Defense Concerning the Space Transportation System." Administrator, NASA, and Secretary of the Air Force.

Parker, David N. (1971, 31 December). "White House Schedule Proposal."

Pedlow, George W., and Donald E. Welzenbach. (1998). *The CIA and the U-2 Program, 1954–1974.* Central Intelligence Agency, Center for the Study of Intelligence.

Perry, Robert. (1969, January). *A History of Satellite Reconnaissance, Volume V–Management of the National Reconnaissance Program 1960–1965.* Washington, D.C.: National Reconnaissance Office. [Declassified 2011].

Perry, Robert. (1973a). *A History of Satellite Reconnaissance, Volume I–CORONA.* Washington, D.C.: National Reconnaissance Office. [Declassified 2002].

Perry, Robert. (1973b, November). *A History of Satellite Reconnaissance, Volume IIIB – HEXAGON.* Washington, D.C.: National Reconnaissance Office. [Declassified 2011).

Perry, Robert. (1974, January). *A History of Satellite Reconnaissance, Volume IIIA–GAMBIT.* Washington, D.C.: National Reconnaissance Office. [Declassified 2011).

Perry, Robert. (n.d.). *NRO History, Volume IV.* Washington, D.C.: National Reconnaissance Office. [Declassified 2002].

Program Review Board (PRB). (1972a, 29 February). Program Review Board Meeting Minutes.

Program Review Board (PRB). (1972b, 27 April). Attachment 4.

Rice, Donald B. (1970, 20 September). Office of Management and Budget Assistant Director Letter to Office of Management and Budget Director George P. Shultz. Subject: "NASA Letter on Scientific Results of Apollo 15."

Seamans, Robert C. (1969a, 4 August). Secretary of the Air Force letter to Vice President Spiro T. Agnew. Subject: Post APOLLO Space Program Concerns.

Seamans, Robert C. (1969b, 5 September). Secretary of the Air Force Letter to Presidential Science Advisor Lee A. DuBridge. Subject: Space Task Group Report.

Seamans, Robert C. (1971, 7 July). Secretary of the Air Force Letter to NASA Administrator Dr. James C. Fletcher. Subject: DoD Requirements.

Secretary of the Air Force. (1969, 10 June). Office of Information, Press Release. Washington, D.C.: HQ U.S. Air Force, Pentagon.

Space and Missiles Systems Organization (SAMSO). (1972, 12 December). SAMSO Commander's Policy: "Microelectronics for Space and Missile Systems."

Space and Missiles Systems Organization (SAMSO). (1973). *History of The Space and Missile Systems Organization, 1 July 1972–30 June 1973,* HQ SAMSO History Office. Los Angeles, CA.

Space and Missiles Systems Organization, CC (SAMSO/CC). (1971, 27 December). Memorandum. Subject: Program Review Board.

Space and Missiles Systems Organization, DR (SAMSO/DR). (1973, 29 October). Memorandum. Subject: "Availability of High Reliability Digital Microcircuits."

Space Systems Division. (1967, 9 May). Office of Information, Responses to Press Queries.

Temple, L. P. (1991, July). Author Interview with Deputy Undersecretary of the Air Force Jimmy D. Hill.

Temple, L. P. (2005a). *Shades of Gray: National Security and the Evolution of Space Reconnaissance.* Reston, VA: American Institute of Aeronautics and Astronautics.

Temple, L. P. (2005b, Fall). "Committing to the Shuttle Without a National Policy." *Airpower Historian.*

United States Air Force (USAF). (1971, 28 September). *United States Air Force Basic Doctrine, AFM 1-1.*

White House. (1970, 7 March). Press Release, Office of the Press Secretary: Statement by the President, Space Task Group Report.

White House. (1972, 5 January). Presidential Announcement on Space Shuttle.

White, General Thomas D. (1957, 14 December). "Leadership—in the Conquest of Space." Address to the Air Force Academy.

Wiesner, Captain J.F. (1966, June). "Opening Remarks—MINUTEMAN II Physics of Failure Program." *Physics of Failure in Electronics.* Vol. 4, DTIC Accession # AD 637529.

Wuerth, J.M. (1975, 11 June). *The Evolution of Minuteman Guidance and Control.* Anaheim, CA: Rockwell International Autonetics Group, DTIC Accession # ADB011836.

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