From Contingency to Dependency: The Journey to Commercialization in the Aerospace Industry

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Throughout the history of the United States, many technologies have been researched and developed using government funding before their maturation in the private sector, from airplanes and automotives to nuclear energy. Rocketry is not unique in this respect, but unlike many other technologies, it has lagged in commercialization, even fifty years after the monumental success of the Apollo missions. The continued reliance on government for all aspects of spaceflight has contributed to the delay in lowering the staggering cost of transportation to space, as well as the development of practical applications of space technology to benefit humanity. It was only during the Reagan Administration in the 1980s that the United States government made its first efforts to spur a shift from an inefficient, uninnovative, government-centric space industry to one driven by private investment and private demand where the government was a customer, rather than its own supplier.

The first rockets were built by individuals in the 1920s and 30s, both in the United States and Germany.[1] The milestone of the first successful liquid-fueled rocket was reached by Robert Goddard in Auburn, Massachusetts in 1926, but these early prototypes were fairly primitive and useful only for research.[2] It was only with the support of the Nazi German military in the 1940s that rocketry really began to take off (figuratively *and* literally). During World War II, many early German researchers, including the well-known Werner Von Braun, collaborated with Hilter's military to develop the V-2 rocket, which had a 200 mile range and was used in the London Blitz.[3] Despite the tragic uses of the V-2, Von Braun and his colleagues had originally come up with the V-2 under a different name, the A-4,

[1] Ted Spitzmiller, *The History of Human Space Flight* (Gainesville, Florida: University Press of Florida, 2017), 33-37.
[2] Rudimentary solid-fuel rockets had technically been invented in Ancient China over one thousand years prior, due to their simple design, but had never been used for much more than "fire arrows" or rocket-propelled cannonballs up through the 19th century (Spitzmiller, *The History of Human Space Flight*, 24).
[3] Spitzmiller, *The History of Human Space Flight*, 43-46.

and had hoped to use it for the first manned spaceflight.[4] The development of the V-2 had a mix of military and civil objectives which established a dominant paradigm of military sponsorship for rocketry research as a whole that would continue into the 1960s—across the globe.

The impetus to develop Intercontinental Ballistic Missiles (ICBMs) in the 1950s and 60s was one of the main drivers of the development of rocket technology in the era: the reality is that the first human space capsules were not much larger than the nuclear weapons that the US and Russia had developed for national defense in the late 1950s.[5] This framework of military sponsorship was highly beneficial for fledgling space programs in both countries, because it meant that development costs of many early rockets like the Soviet R-7 and American Redstone missiles—and particularly the burden of proving the technology—were borne by the respective militaries of each country, relying on existing bureaucracy rather than requiring the justification of new civil agencies.[6] This paved the way for launching the world's first satellite, the Russian Sputnik in 1957, and allowed the United States to launch its first satellite, Explorer 1, in February 1958. This achievement was reached before NASA had even been formed, when rocket development was split between modestly-funded research organizations like JPL and the Army Ballistic Missile Agency (ABMA).[7]

The development of space technology in the 1950s and 60s was understood to be completely under the purview of the government, and any involvement from private companies would be in the form of contracts for public money, generally from the federal government and the military. The NASA Act of 1958, which established the agency primarily to consolidate government resources spent on space research,[8] stated that "aeronautical and space activities...shall be directed by, a civilian agency exercising control over aeronautical and space activities sponsored by the United States, except that

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[4] Spitzmiller, *The History of Human Space Flight*, 45.
[5] Spitzmiller, *The History of Human Space Flight*, 143-146.
[6] Soviet R-7: Spitzmiller, *The History of Human Space Flight*, 124; Redstone: Spitzmiller, *The History of Human Space Flight*, 120.
[7] Spitzmiller, *The History of Human Space Flight*, 120-123.
[8] Spitzmiller, *The History of Human Space Flight*, 133.

activities peculiar to or primarily associated with the development of weapons systems…"[9] While the act technically allowed for the existence of non-government activity in outer space, the word "commercial" didn't appear once in the entire law; nor did "private" appear once in reference to aerospace companies (I counted myself).[10] The act further discussed the priorities for the "aeronautical and space activities of the United States," which boiled down to furthering scientific knowledge and gaining military advantage,[11] and contrasted military interests as a whole with "the civilian agency established to direct and control nonmilitary aeronautical and space activities."[12] The binary view that all activities in space are either the purview of the civil side of government or the military was clearly expressed in this act and demonstrates that all "aeronautical and space activities" *within* the US and those conducted by the US *government* were seen as one and the same in the early years of the Space Race.

In the 1960s, the industry providing both manufacturing capabilities and research and development in the aerospace industry was totally centered around the close alliance between a choice selection of giant corporations and the federal government termed the "Military-Industrial Complex" by President Eisenhower in 1954. This close relationship gave huge levels of economic and political power to aerospace contractors, which were detrimental to the American space program in a number of ways. In a 1968 paper, distinguished economist Walter Adams characterized the relationship between the government and its aerospace/defense contractors: "[The government] buys at prices for which there is little precedent and hardly any yardsticks. It deals with contractors, a large percentage of whose business is locked into supplying defense, space, or atomic energy needs. It confronts powerful oligopolists in a market where technical capability rather than price is the controlling variable…In the process, government becomes—in the extreme—subservient to the private and special interests whose

[9] National Aeronautics and Space Act of 1958. Pub. L. No. 85–568, § 102.
[10] See the NASA Act of 1958 at https://www.nasa.gov/history/national-aeronautics-and-space-act-of-1958-unamended/
[11] National Aeronautics and Space Act of 1958. Pub. L. No. 85–568, § 102 (c).
[12] National Aeronautics and Space Act of 1958. Pub. L. No. 85–568, § 102 (c).

entrenched power bears the governmental seal…"[13] Aside from the fact that the government had limited opportunity to support competitive bidding due to the simply monopolistic market control of these big corporations,[14] the aerospace giants of the Military-Industrial Complex (including Lockheed, Boeing, General Dynamics, and Martin, among others[15]) benefitted from generous "cost-plus" R&D contracts, in which the procuring agency, either NASA or DOD, compensated the contractor for their costs entirely, no matter how high they grew, while guaranteeing a percentage of the costs on top as a "fee" ensuring profit without risk for the contractor.[16] Adams further explained that the incredibly lucrative terms of these contracts "convert the private contractor into a quasi-governmental, mercantilist corporation, maintained in a privileged position by 'royal' franchise,"[17] analogous to the Victorian corporations of imperial Britain criticized a century earlier by Adam Smith.[18] Cost-plus made the suppliers of the aerospace industry inefficient, yet also conservative and risk-averse due to their close connection with their single customer, which stifled innovation in the industry and kept launch costs high for both the military and civil sides of the government.[19] The "cost-plus" contract structure and the high level of centralization effected by the power of the Military-Industrial Complex and the political, rather than economic, motivations for the American space program[20] would define the aerospace and defense industries for decades to come.[21]

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[13] Walter Adams, "The Military-Industrial Complex and the New Industrial State," *The American Economic Review* 58, no. 2 (1968), 655.
[14] Adams, "The Military-Industrial Complex and the New Industrial State," 656-659.
[15] Paul Stevenson, "The Military-Industrial Complex: An Examination of the Nature of Corporate Capitalism in America," *Journal of Political & Military Sociology* 1, no. 2 (1973), 251.
[16] Adams, "The Military-Industrial Complex and the New Industrial State," 658; Craig R. Reed, "Factors Affecting U.S. Commercial Space Launch Industry Competitiveness," *Business and Economic History* 27, no. 1 (1998), 225.
[17] Adams, "The Military-Industrial Complex and the New Industrial State," 656.
[18] Adams, "The Military-Industrial Complex and the New Industrial State," 656.
[19] Reed, "Factors Affecting U.S. Commercial Space Launch Industry Competitiveness," 225; Adams, "The Military-Industrial Complex and the New Industrial State," 656-659; Matthew Weinzierl, "Space, the Final Economic Frontier," *The Journal of Economic Perspectives* 32, no. 2 (2018), 176.
[20] Spitzmiller, *The History of Human Space Flight*, 228, 231-232; W.D. Kay, "Space Policy Redefined: The Reagan Administration and the Commercialization of Space," *Business and Economic History* 27, no. 1 (1998), 238-239. See also the 2025 paper "The Sputnik Explosion onto American Politics" by Brian Li '26 on this topic.
[21] Weinzierl, "Space, the Final Economic Frontier," 175-176; Reed, "Factors Affecting U.S. Commercial Space Launch Industry Competitiveness," 224-226.

Many in the spaceflight industry had been hopeful for commercial applications and commercialization since at least the 1960s,[22] but it wasn't until the Reagan administration that the federal government would make the first attempts at soliciting private investment in spaceflight and creating a competitive commercial environment in the launch services industry. Reagan's early Space Policy directive, signed in 1982, required that the national space program not only seek "scientific benefits" but also "obtain economic... benefits through the exploitation of space."[23] It included the first mention of development of a privatized space industry ever in a presidential space policy directive,[24] with the object of "commercial exploration of space capabilities, technology, and systems for national *economic* benefit" (emphasis added).[25] Rather than kindling innovation through government projects as had been done in the past, Reagan for the first time sought to use government funds to encourage the development of private, self-sufficient firms engaging in their own research, theoretically in hope of advancing space technology "without direct Federal subsidy."[26]

Reagan included two major priorities in his space policy: increased government defense spending in the form of the Strategic Defense Initiative (mockingly dubbed "Star Wars" by its critics) and the establishment of a commercial space-launch industry.[27] Reagan's early executive statement called for "a climate conducive to expanded private sector investment and involvement in space activities"[28]—but this vague goal yielded only vaguely positive results for a sector which had previously not existed. The *Conestoga I*, the first privately-developed rocket and a subtle reference to the horse-drawn carriage used by west-moving settlers in the 19th century, technically enjoyed a successful

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[22] Kay, "Space Policy Redefined," 240.
[23] U.S. Executive Office of the President, "National Security Decision Directive 42: National Space Policy" (Washington, DC, 1982), I, https://www.nasa.gov/history/national-security-decision-directive-number-42/.
[24] Jane Gibson et al., "Current Space Law And Policy," AU-18 Space Primer (Air University Press, 2009), 49, https://www.jstor.org/stable/resrep13939.10.
[25] U.S. Executive Office of the President, "National Security Decision Directive 42: National Space Policy," I.(d).
[26] U.S. Executive Office of the President, "National Security Decision Directive 30: National Space Policy" (Washington, DC, 1989), https://www.nasa.gov/history/presidential-directive-on-national-space-policy-february-11-1988/.
[27] Kay, "Space Policy Redefined," 239-240.
[28] U.S. Executive Office of the President, "National Security Decision Directive 42: National Space Policy," III.(b).

launch in September 1982,[29] but it merely contained a dummy payload of water and was described in hindsight as a "modest Wright Brothers sort of proof-of-concept outing."[30] Thus, until 1989, all satellites launched in the United States were brought to space by the federal government using rockets obtained under federal contract.[31] The Reagan administration did make a solid advancement in its goal to foster private rocket development in the mid-1980s with its efforts to ease regulation on non-government space launches. The administration made the process of obtaining launch approval easier for private companies, establishing a legal framework that had not needed to exist before.[32]

Early commercial ventures inspired by the Administration's new emphasis on privately-funded spaceflight struggled to get off the ground for multiple reasons: not only was investment slow to come due to the high risk of ventures in the unproven industry, but opportunities for commercialization and profit were not clearly visible. For example, the Industrial Space Facility was a proposed "industrial park in space"[33] which stagnated when its parent start-up could not find private investors who were interested in using the station.[34] Motivation for private investment in the launch services industry was thwarted by competition for launch demand from the government-sponsored Space Shuttle. Those hoping for growth of self-sustaining, private launch companies at the time warned, and in hindsight observed, that launch services from the government being priced unfairly low, or "subsidized" to support customer satellite-making firms would make it incredibly difficult for private firms with more realistic launch costs to get a foothold in the market. The Shuttle was made available for commercial payloads in 1982 through private-customer-friendly fixed-price launch contracts[35] at a price per launch

[29] Kay, "Space Policy Redefined," 241.
[30] John C. Abell, "Sept. 9, 1982: 3-2-1 ... Liftoff! The First Private Rocket Launch," *Wired*, September 21, 2009, https://www.wired.com/2009/09/dayintech0909privaterocket/.
[31] Reed, "Factors Affecting U.S. Commercial Space Launch Industry Competitiveness," 224.
[32] Kay, "Space Policy Redefined," 241.
[33] Kay, "Space Policy Redefined," 242.
[34] Kay, "Space Policy Redefined," 242.
[35] Reed, "Factors Affecting U.S. Commercial Space Launch Industry Competitiveness," 224.

that was viewed to be "too far below market price"[36] by the DOT and private launch companies alike.[37] With no way to compete with NASA's subsidized shuttle, privately-funded launch supply could not grow during this period.[38]

One might think that the situation would change after the Space Shuttle *Challenger* tragically exploded on January 26, 1986, when the decision was made to terminate all future launches by commercial customers on the Space Shuttle.[39] After Reagan's false start to commercialization in the early 80s, private interest in spaceflight might have begun to pick up once competition from the Shuttle was removed: *Challenger* had removed a significant amount of supply from the space launch market, without culling demand from commercial customers, which had led to a gap in supply.[40] The new provisions in Reagan's Commercial Space Launch Act of 1984 allowed for this gap to be filled by launch services offered directly to satellite companies by three big, government-subsidized aerospace corporations (General Dynamics, Martin Marietta, and McDonnell Douglas) starting in 1989.[41] On the whole, this was not considered to be a major step forward in commercialization, however, since these descendants of the Military-Industrial Complex were neither new entrants to the industry, nor were they using new vehicles. Commercial customers only made up between fifteen and thirty percent of payloads launched in the early 90s, while the bulk of launch demand continued to come from DOD and NASA.[42] The government in this period continued to own and operate the launch pads used by these familiar aerospace giants, and the significance of government demand continued to dictate supply.

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[36] Kay, "Space Policy Redefined," 244.
[37] Kay, "Space Policy Redefined," 244; Weinzierl, "Space, the Final Economic Frontier," 176; Reed, "Factors Affecting U.S. Commercial Space Launch Industry Competitiveness," 224.
[38] Reed, "Factors Affecting U.S. Commercial Space Launch Industry Competitiveness," 224, 227.
[39] Kay, "Space Policy Redefined," 244; Reed, "Factors Affecting U.S. Commercial Space Launch Industry Competitiveness," 224.
[40] In the days after the disaster, the press regularly referred to the huge launch backlog that the grounding of the shuttle would cause in the years ahead. See for instance John Noble Wilford, "The Challenger's Fate, the Shuttles' Future," *New York Times* (New York, NY), February 2, 1986.
[41] Reed, "Factors Affecting U.S. Commercial Space Launch Industry Competitiveness," 224; Kay, "Space Policy Redefined," 245.
[42] Reed, "Factors Affecting U.S. Commercial Space Launch Industry Competitiveness," 226.

The big aerospace companies were so reliant on government funding that without launch vehicle procurements from DOD, these companies would not have been able to keep their expendable launch vehicle production lines alive as NASA had shifted to using the reusable Space Shuttle in the late 80s and early 90s.[43] In short, the type of government dependence exhibited by the space-launch divisions of General Dynamics, Martin Marietta, and McDonnell Douglas in the early 90s aligns more closely with government programs than self-sustaining private ventures, showing little departure from the system of the Military-Industrial Complex of decades past.

While Reagan and *Challenger* failed to bring changes to the industry as a whole, the development of a commercial space launch industry survived, at least on paper, as a permanent priority of the space policy of George H. W. Bush, Clinton, and all future presidents.[44] The continued hope for commercialization was reflected throughout the 1990s by DOD and NASA experimentation with new "commercialized" contracts. One key program that reflected the government's increased commitment to commercialization was the Air Force's Evolved Expendable Launch Vehicle program (EELV). Started in 1995, EELV sought to modernize the military's launch capability via the development of two new launch vehicles, Boeing's Delta IV and Lockeed Martin's Atlas V. Indeed, one of the central priorities of the EELV program was to reduce launch costs by twenty five percent over existing systems, both for the military and NASA,[45] which the military hoped to achieve by giving their contractors more freedom in development. While previous programs, both military and civil, were structured so that the purchasing government organization retained ownership of the launch vehicle, the EELV program left the contractor to own and operate the vehicle, giving them more flexibility to use the product for other, non-government customers. In return, the Air Force did not reimburse all the costs required for the development of the vehicles and had the contractors themselves bear some of the expense, effectively

[43] Reed, "Factors Affecting U.S. Commercial Space Launch Industry Competitiveness," 226.
[44] Gibson et al., "Current Space Law And Policy," 48-53; Kay, "Space Policy Redefined," 240.
[45] David N. Spires, "Evolved Expendable Launch Vehicles: 1995–2019," Assured Access (Air University Press, 2022), 277-78, https://www.jstor.org/stable/resrep41950.12.

sharing the cost of development and operation, rather than the cost-plus route where the purchasing agency completely compensated the contractors for development costs.[46] EELV also restructured the role of the Air Force in supervising their contractors: rather than the traditional "oversight" role of the government customer, the Air Force called the type of supervision they exercised during EELV "insight," which focused more on making sure the contractors were keeping up with program deadlines rather than actively steering the direction of development. This let Boeing and Lockeed Martin be more innovative in their designs, relying more on new technology and materials, and less on legacy systems.[47]

On the civil side, NASA did engage in several spaceplane-related public-private partnerships at this time, most notably the X-33/VentureStar program in collaboration with Lockheed Martin. Initially, NASA would work with the company to collaborate on a prototype spaceplane vehicle, prioritizing the research and development side of the project, but once the technology was proven and determined feasible, Lockheed Martin was planning to turn the experimental craft into a commercial product named VentureStar, selling launches to customers from space tourists to satellite companies, by 2003. However, this program and others encountered technical issues and delays and never got to the commercialization phase.[48]

The nineties saw the first signs of the massive shift that was underway in government-contractor relationships in the aerospace industry, but significant parts of the traditional system remained. On the one hand, the Evolved Expendable Launch Vehicle program was the first major program to loosen the leash on government contractors, letting the Air Force behave more like a commercial customer, and the X-33 program showed NASA's growing interest in supporting private space ventures, particularly new and innovative concepts like VentureStar. Despite this growth of substantive government-driven initiatives for the commercial launch market, the players in said market

[46] Spires, "Evolved Expendable Launch Vehicles," 278.
[47] Spires, "Evolved Expendable Launch Vehicles," 278-279.
[48] Spitzmiller, *The History of Human Space Flight*, 590-591.

were old and familiar faces: the most important goal of supporting the commercial launch market, increased innovation and lowered launch costs through the competition of a diverse set of suppliers, had not yet been achieved. The launch market was still dominated by the oligopoly of giant firms (exacerbated by a series of mergers including but not limited to Lockheed with Martin Marietta and Boeing with McDonnell Douglas in the late 90s[49]) still reliant on the government for R&D funds, as well as launch demand. While EELV did begin the Air Force's transition towards being a customer of its contractors less involved with production itself, NASA continued to rely on the Space Shuttle as its primary launch vehicle for constructing the International Space Station and launching its larger telescopes and satellites, both because of the Shuttle's superior payload capacity and the continuing need to justify the development of the Space Shuttle in the first place.[50]

The Space Shuttle *Columbia* accident in February 2003 prompted another shaking up of the United States space establishment that finally resulted in the real kickstarting of the American commercial space industry. Unlike the *Challenger* accident, *Columbia* put mistrust of NASA bureaucracy and the traditional system of government-dependent rocketry R&D the minds of President Bush and the public, leading to the expedited retirement of the Space Shuttle and christening of a new era of space commercialization, driven by a new generation of government initiatives run by a restructured NASA.

Unlike President Reagan, who stated in a public address soon after *Challenger* "I've always had great faith in and respect for our space program, and what happened today does nothing to diminish it,"[51] President George W. Bush's address following *Columbia* included the statement, "In an age when space flight has come to seem almost routine, it is easy to overlook the dangers of travel by rocket"[52] and

[49] Spitzmiller, *The History of Human Space Flight*, 581.
[50] Spitzmiller, *The History of Human Space Flight*, 497, 527-528.
[51] President Ronald Reagan, "Address to the Nation on the Explosion of the Space Shuttle Challenger" (Washington, DC, January 28, 1986), https://www.reaganlibrary.gov/archives/speech/address-nation-explosion-space-shuttle-challenger.
[52] President George W. Bush, "President Addresses Nation on Space Shuttle Columbia Tragedy" (Washington, DC, February 1, 2003), https://georgewbush-whitehouse.archives.gov/news/releases/2003/02/20030201-2.html.

merely included the terse "Our journey into space will go on"[53] in lieu of a more encouraging message for the existing Shuttle program. NASA's post-*Columbia* investigation board would go on to say "bureaucracy and process trumped thoroughness and reason"[54] and the *New York Times* said in the aftermath that "NASA is 'rapidly losing credibility'" because of its poor handling of the post-accident investigation.[55]

The *Columbia* accident prompted the swift grounding of all space shuttles for two years,[56] and during this time, in the midst of deep investigations into NASA, President Bush endeavored to bring a new direction to the American space program with a key address known as his Vision for Space Exploration (VSE) in 2004.[57] Bush's VSE confined the now aging Shuttle to the completion of the ISS before completely retiring it by 2010, as well as calling for a return to the moon by 2020 using a new Apollo-class spacecraft (which would be the earliest ancestor of Trump's modern Artemis program).[58] The VSE called for the appointment of "a commission of private and public sector experts to advise on implementing the vision,"[59] which would come to be known as the Aldridge Commission after its chair, the former Air Force Secretary Pete Aldridge.[60]

When compared to the space policy of previous administrations, the Vision for Space Exploration was not particularly novel in its commitments to a return to the Moon by such-and-such

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[53] President George W. Bush, "President Addresses Nation on Space Shuttle Columbia Tragedy."
[54] Report of the NASA post-*Columbia* accident investigation board via Adam Keiper, "A New Vision for NASA," *The New Atlantis*, no. 3 (2003), 5. See also Spitzmiller, *The History of Human Space Flight*, 534-538.
[55] Richard A. Oppel, Jr., "Lawmakers Favor Panel Under Bush On Columbia," *New York Times* (New York, NY), February 14, 2003.
[56] Spitzmiller, *The History of Human Space Flight*, 540.
[57] Lewis D. Solomon, *The Privatization of Space Exploration: Business, Technology, Law and Policy* (New Brunswick, N.J: Transaction Publishers, 2008), 23-24.
[58] President George W. Bush, "Vision for Space Exploration" (Washington, DC, January 14, 2004), https://www.nasa.gov/history/vision-for-space-exploration/. Bush referred to this vehicle as the "Crew Exploration Vehicle" which was later renamed Ares under the Constellation program. Cancelled by Obama in 2009 and subsequently revived as Artemis under the Trump administration in 2017, Artemis had one successful unmanned flight to lunar orbit in 2022 and its first manned, Apollo-8-style lunar flyby is currently scheduled for early 2026.
[59] Bush, "Vision for Space Exploration."
[60] Solomon, *The Privatization of Space Exploration*, 26.

date and its optimism for subsequent efforts to reach Mars,[61] but what was different this time was the nature of the impact the Aldridge Commission would have on NASA. One of the key suggestions of the commission in their June 2004 report was for NASA to step up its efforts to incentivize the development of small startups and other new players in the aerospace industry, relying on competition between firms for contracts to increase the financial efficiency and drive down the cost of spaceflight, within NASA's programs,[62] an echo of Reagan's 1980s policy statements. The report of the Aldridge Commission led to NASA's formation of a new Commercial Crew/Cargo Project Office (known as C3PO), tasked with incentivizing growth in a new private aerospace sector consisting of small startups with innovative new ideas.[63]

The Aldridge Commission and C3PO had set out with a clear mission, incentivizing growth of small startups in the industry, but there was no sudden increase in demand from satellite companies or other private customers to sustain these startups.[64] If C3PO wanted to make these firms successful, demand would have to come from NASA itself, and this is exactly what the office did with the Commercial Orbital Transportation Services (COTS) program in 2005. COTS would be the first program in a successful series of initiatives by C3PO to use the International Space Station as a platform by which NASA could supply startups with a source of revenue that they could put towards research and development, without NASA directly subsidizing private R&D as under the cost-plus model. The COTS contracts consisted of a fixed sum of money given to the contractor in spread out, sequential payments contingent on meeting certain demonstrations of progress by certain deadlines.[65] NASA permitted their COTS contractors total freedom in development, a step further than EELV before them, but required demonstrations of generic capabilities, such as a successful flight to orbit, or

[61] Bush, "Vision for Space Exploration;" Gibson et al., "Current Space Law And Policy," p.48-53; Solomon, *The Privatization of Space Exploration*, 24.
[62] Solomon, *The Privatization of Space Exploration*, 28-30.
[63] Solomon, *The Privatization of Space Exploration*, 29.
[64] See pre-COTS launch demand, Weinzierl, "Space, the Final Economic Frontier," 182, Figure 3.
[65] Solomon, *The Privatization of Space Exploration*, 30.

successful docking of the craft to the ISS, before awarding each payout. In this way, NASA became, for the first time, a true customer rather than a supervisor of their private contractors.[66] Analysis of the program after its completion in 2014, which ended with the development of SpaceX's new Falcon 9 rocket, showed that COTS had brought the cost to launch a kilogram to Low-Earth Orbit down from $272,000 on the Space Shuttle to $89,000 through SpaceX, a three-fold reduction.[67] And all of this was achieved on a budget of $500 million, split between Rocketplane-Kistler and SpaceX: less than one percent of NASA's five-year budget.[68]

The new activity generated by COTS, particularly its symbolism as a proxy for NASA's renewed commitment to the commercial space industry, generated a huge amount of optimism for a renaissance of startups and decentralized innovation in the aerospace industry dubbed "NewSpace" in the early 2000s.[69] In addition, the full retirement of the Space Shuttle in 2011[70] without a clear replacement lined up encouraged a huge bump in private investment by startups looking to seize the existing launch demand.[71] A fall 2006 article in *The New Atlantis* said "2006 may be viewed in the future as a critical inflection point...and the beginning of a new space age for the rest of us."[72] In his 2008 book, Lewis D. Solomon described a budding space industry with "innovative and risk-taking" entrepreneurs. "Firms are sprouting up," Solomon said, "what start as billionaires' pet projects soon morph into market contenders for space exploration vehicles and even payload launch services."[73] A 2009 report on the inventory of space-lift vehicles available to the Air Force said "Historically, access to

[66] Solomon, *The Privatization of Space Exploration*, 30; Weinzierl, "Space, the Final Economic Frontier," 180.
[67] Weinzierl, "Space, the Final Economic Frontier," 181.
[68] Weinzierl, "Space, the Final Economic Frontier," 180.
[69] Weinzierl, "Space, the Final Economic Frontier," 177.
[70] The author witnessed the last two Shuttle launches, STS-134 and STS-135, in person at Cape Canaveral on May 16th and July 8th, 2011.
[71] Weinzierl, "Space, the Final Economic Frontier," 177.
[72] Rand Simberg, "Space Deals: The Coming of the New Space Industry," *The New Atlantis*, no. 14 (2006), 194.
[73] Solomon, *The Privatization of Space Exploration*, p.9.

space was primarily a function of national governments. Today, space launch is primarily a commercial enterprise."[74]

The triumphant success of COTS led to successor programs, including the Commercial Resupply Services program in the mid-2010s and the Commercial Crew Development program (for commercial transportation of crew to the ISS)[75] in a shift "From Contingency to Dependency"[76] on private contractors. C3PO's Commercial Crew Development program, started in 2014, allowed for the first successful manned flight of a commercial spacecraft in history on SpaceX's Crew Dragon spacecraft, which brought domestic manned space-launch capacity back to the United States in 2020 for the first time since the retirement of the Shuttle almost a decade prior.[77] Throughout the 2010s, the United States was forced to rely on Russian Soyuz spacecraft for all of its crew transportation needs, including ISS personnel, in a situation felt at the time to be embarrassing and strategically tenuous for the country.[78] While the aerospace industry relies heavily on government money to this day for the research and development of its largest heavy-lift vehicles and most manned vehicles, the R&D subsidies delivered by NASA's Commercial Crew/Cargo Project Office have led to the successfully commercialized Falcon 9 rocket, which has contributed to a newly self-sustaining and diversified space economy that is finally beginning to forge a path to true commercialization of space, through novel products like SpaceX's Starlink Internet system. However, COTS would not have been possible without the pioneering of the public-private experimentation of the 1990s and the commercial spark lit by Reagan before them still.

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[74] Christopher J. King et al., "Space-Lift Systems," AU-18 Space Primer (Air University Press, 2009), 259, https://www.jstor.org/stable/resrep13939.27.
[75] Weinzierl, "Space, the Final Economic Frontier," 177.
[76] NASA, "Commercial Orbital Transportation Services: a new era in spaceflight" (2014) via Weinzierl, "Space, the Final Economic Frontier," 177.
[77] Azi Paybarah, "SpaceX Crew Docks at the International Space Station," *New York Times* (New York, NY), Nov. 17, 2020, https://www.nytimes.com/2020/11/17/science/space/spacex-docks-international-space-station.html.
[78] Spitzmiller, *The History of Human Space Flight*, 567.

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