HISTORICAL REFLECTIONS

Hey Google, What's a Moonshot?: How Silicon Valley Mocks Apollo

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Apollo 11 Lunar Module Pilot Buzz Aldrin on the Moon, with Commander Neil Armstrong reflected in his helmet's face plate.

Credit: NASA

The radio in my kitchen is tuned to a public station. One day it startled me by delivering a lecture, "The unexpected benefit of celebrating failure," by the implausibly named Astro Teller who, according to his website, enjoys an equally idiosyncratic list of accomplishments: novelist, entrepreneur, scientist, inventor, speaker, business leader, and IT expert. That talk concerned his day job: "Captain of Moonshots" at X (formerly Google X, now a separate subsidiary of its parent company Alphabet).[a] It centered on the classic Silicon Valley ideal of being prepared to fail fast and use this as a learning opportunity. Teller therefore advised teams to spend the first part of any project trying to prove it could not succeed. Good advice, but maybe not so new: even 1950s "waterfall" methodologies began with a feasibility stage intended to identify reasons the project might be doomed. Still, many of us have had the experience of putting months, or even years, into zombie projects with no path to success.[b] The HBO television series "Silicon Valley" captured that problem, in an episode where a new executive asked for the status of a troubled project.[c] Each level of management sugarcoated the predictions it passed upward and avoided asking hard questions of those below it.

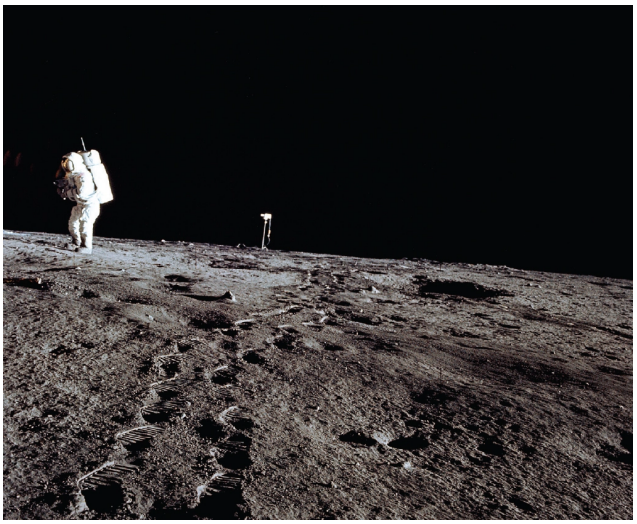

Figure. Astronaut Alan L. Bean walks from the moon-surface television camera toward the lunar module during the first extravehicular activity of the November 1969 Apollo 12 mission,

the second lunar landing in the NASA Apollo program. The mission included placing the first color television camera on the surface of the moon but transmission was lost when Bean accidentally pointed the camera at the sun, disabling the camera.

To be honest, I was more intrigued by the "moonshot captain" thing. Teller briefly paid homage to President Kennedy and the huge scope of the real moonshot achieved by the Apollo program of the 1960s. By promoting X as a "moonshot factory" he suggested plans to crank out Apollo-style triumphs regularly, at the inter-section of "huge problems, breakthrough technologies, and radical solutions."[d] X boasts of uniting "inventors, engineers, and makers" including aerospace engineers, fashion designers, military commanders, and laser experts. Teller's most dramatic example of an X moonshot that failed admirably was that staple technology of alternate worlds, an airship "with the potential to lower the cost, time, and carbon footprint of shipping." According to Teller, X achieved the "clever set of breakthroughs" needed to mass produce robust, affordable blimps, but had to give up when it estimated a cost of "$200 million to design and build the first one" which was "way too expensive." X relies on "tight feedback loops of making mistakes and learning and new designs." Spending that much "to get the first data point" was not remotely possible.

At this point, I would like you to imagine the record-scratching noise that TV shows use for dramatic interruptions. That's what played in my head, accompanied by the thought "this guy doesn't know what the moonshot was." Teller's pragmatic, iterative, product-driven approach to innovation is the exact opposite of what the U.S. did after Kennedy charged it to "commit itself to achieving the goal, before this decade is out, of landing a man on the moon and returning him safely to the earth." Letting Silicon Valley steal the term "moonshot" for projects with quite different management styles, success criteria, scales, and styles of innovation hurts our collective ability to understand just what NASA achieved 50 years ago and why nothing remotely comparable is actually under way today at Google, or anywhere else.

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The Actual Moonshot

As historians of technology Ruth Schwartz Cowan and Matthew Hersch tell the story: "Eight year later, on July 20, 1969, millions of people all over the world watched their televisions in wonder as Neil Armstrong and Edward Aldrin planted the American flag on the moon [after] the largest managed research project of all time .... The Saturn V rocket had a diameter of 33 feet (three moving vans could have been driven, side by side, into the fuel tanks for the first stage) and a height of 363 feet (about the size of a 36-story building). At liftoff, the vehicle weighed 6.1 million pounds, and when the five engines of the first stage were fired ... they generated 7.5 million points of thrust ... [burning] three tons of fuel a second ..."[3]

The moonshot was a triumph of management as much as engineering.

Those statistics tell you something important: the moonshot was about doing something absurdly expensive and difficult once (followed by a few encore performances), not doing something useful cheaply and routinely. Apollo 11 pushed a gigantic rocket though the atmosphere and into space, launching three men toward the moon at more than 24,000 miles an hour. Two of them descended in a flimsy little box wrapped in foil, took pictures, collected rocks, and flew back into lunar orbit. All three returned to Earth, or rather to sea, hurtling back through the atmosphere in a tiny capsule that splashed into the ocean.

Apollo was the capstone to a series of gigantic American technological projects, beginning with the Manhattan Project of the 1940s and continuing into the Cold War with the development of nuclear submarines, Atlas and Minuteman missiles, and hydrogen bombs. It was shaped by a vision for the U.S. space program devised by former Nazi rocket engineer Werhner von Braun, whose heavily accented lectures on space stations and manned missions to the Moon and Mars were popularized during the 1950s with the all-American aid of Walt Disney. Their elaborate agenda came with a huge price tag, but after the USSR checked off the first few items, by launching a satellite and sending a human into orbit, that suddenly looked like money worth spending. In 1961, Kennedy announced his intentions to Congress and won the first in a series of massive increases for NASA's budget. Like Kennedy's other initiatives, the moon program became more popular and politically secure after his death, thanks to Lyndon Johnson's political arm twisting and huge congressional majorities.

Apollo, like Medicare, was part of a dramatic expansion in federal government spending. A future of interplanetary exploration and colonization was already an article of faith for American science fiction writers in the "golden age" of the 1940s, but they were better at imagining rockets than economic changes. One of Robert Heinlein's most famous stories, "The Man Who Sold The Moon," described a moon landing in the 1978 by an eccentric businessman. Described as the "last of the robber barons" he funded his dream by, among other things, promising to cancel postage stamps in a temporary lunar post office, sell the naming rights to

craters, and engraving the names of supporters onto a plaque.[e] Rather than the big government approach of NASA, had Heinlein imagined a space program run like a Kickstarter project. The government's sudden and mobilization of overwhelming resources for the moonshot took science fiction writers by surprise.

The moonshot was a triumph of management as much as engineering. Meeting a fixed launch deadline meant working backward to identify the points by which thousands of sub-systems had to be ready for testing and integration, and further back to the dates by which they had to be designed and ordered. Steven Johnson's book *The Secret of Apollo* looked at the systems and techniques developed to turn the efforts of hundreds of subcontractors into a successful moonshot.[7] As he points out, NASA and its partners succeeded in doing something apparently paradoxical: bureaucratizing innovation. Rather than attempt to do lots of new things at once, an approach that had produced problems for the early U.S. space program, von Braun enforced a careful step-by-step approach. These techniques built on those developed for other Cold War projects, described by historian Thomas Hughes in his book *Rescuing Prometheus*.[6] For example, the PERT project management tool, now a crucial part of project management software, was developed in the 1950s to support the U.S. Navy's Polaris nuclear submarine project. So was MRP (Materials Requirements Planning), which evolved into the foundation for the enterprise software packages that run almost all modern corporations.

NASA management placed a series of milestones along the road to the moon landing, paralleling some aspects of the incremental approach practiced by modern technology leaders. That is why the moon landing was Apollo 11: previous flights had tested the rockets, the command module, the docking capabilities, and so on. Apollo 8, for example, flew a crew into lunar orbit and back, giving an integrated test of many of the key system components. Before those flights came a series of Gemini missions flown during the mid-1960s to test technologies and develop techniques for challenges such as orbital rendezvous and space-walks. Systematic ground tests focused on space suits, engines, and other new technologies in isolation before integrating them into larger systems.

Teller stressed the need to prototype rapidly and cheaply and to be ready to kill any "moonshot" in its early stages, but NASA agreed to non-negotiable goals for time (by the end of 1969) and scope (landing and returning a man) without building testable prototypes. When Kennedy announced those objectives in 1961, NASA had achieved just 15 minutes of manned flight in space and its managers had not even decided whether to launch a single integrated spacecraft or send up modules to assemble in Earth orbit. One cannot plan out a schedule that depends on fundamental scientific breakthroughs, since those do not occur on a fixed timescale. A project of that kind is about spending money to mitigate risk, by pushing existing technologies to levels of performance, reliability, or miniaturization that would not otherwise be economically practical. Given a choice of two technologically workable ways to do something, NASA would take the better-proven and more expensive way.

Project management tools may have improved, but human nature continues to undercut best practices.

Despite this technological conservatism, the focus on fixed deadlines still caused deadly trade-offs. After the Apollo 1 crew died when fire engulfed their capsule in a ground test in January 1967, manned flights were halted for 20 months. A review identified several management failures that had contributed to the accident, including a flawed escape system, poor wiring, and the use of pure oxygen instead of a less dangerous air-like mixture. Afterward, mission controller Gene Kranz confessed to his team that "We were too gung-ho about the schedule and we locked out all of the problems we saw every day in our work. Every element of the program was in trouble ... Not one of us stood up and said, 'Dammit, stop!'"[9] Half a century later, the same words could be applied to many of Silicon Valley's highest-profile projects, from Tesla's spectacularly hubristic attempt reinvent the assembly line to Uber's lethally ambitious self-driving car program. Project management tools may have improved, but human nature continues to undercut best practices.

Although Teller, as "Captain of Moonshots," wants to celebrate failure that is not how NASA reacted when it lost Gus Grissom, Ed White, and Robert B. Chaffee. Kranz named his memoir *Failure is Not an Option*, after "the creed we all lived by." Explaining the title, he wrote that in 1970, as his team struggled to save the crew of Apollo 13 after an explosion in space, "each of us" was haunted by "indelible memories of that awful day three years earlier" when "we had failed our crew."

In the end the Apollo 13 astronauts were fine, but the space program was not. Diminishing political returns led to Apollo's early cancellation, like a briefly buzzy TV show that lost its audience and thus its reason to exist. No human has been further than 400 miles from Earth since 1972. With the Soviets defeated in the moon race there was no need to increase spending still further to tackle the remaining items on von Braun's to-do list: moon bases, space stations, manned Mars missions, and so on. Facing shrinking budgets and

diminished political will, NASA instead delivered disconnected fragments of the plan—a space shuttle to assemble large structures in orbit and, many years later, a space station to give the shuttle something to do.

Twenty-first century America is not without enemies, but ISIS and the Taliban never developed space programs. Generations of American politicians have nevertheless tried to prove their visionary leadership by ordering new space missions. None committed anything like the funds needed for a true moonshot effort. George W. Bush dusted off von Braun's old dreams in 2004, terminating the space shuttle and directing NASA to restart manned moon missions by 2020 as a stepping-stone to Mars. This set a leisurely 16-year schedule for a moon landing, but a progress review five years later concluded that the program was already so underfunded, overbudget, and behind schedule as to be unsalvageable. In 2012, Newt Gingrich, enjoying a brief surge in support for his presidential candidacy, promised voters he could build a permanent moon base and launch a manned Mars mission by 2020 while still slashing government spending and cutting taxes. Rather than prove Gingrich's gravitas on a trip to the White House, the moon base express took him straight back to the political fringes. More recently, President Trump held a ceremony to sign a policy directive directing NASA to head back to the moon and then onward to Mars. Cynics noted the directive made no mention of new funding and set no timeline.

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A Moonshot Is Awesome and Pointless

In 1962, Kennedy campaigned for his plan by saying "We choose to go to the Moon in this decade and do the other things, not because they are easy, but because they are hard." His moonshot was about spending a $25 billion fortune to do something absurdly difficult with no direct economic return. It showed America's technological capabilities, political will, and economic might in its long struggle with the Soviet Union (or, as Kennedy put it, "to organize and measure the best of our energies and skills ..."). Nothing economically viable or practical deserves to be called a moonshot. Scaled up for the size of the U.S. economy, a similarly impressive investment today would be approximately $600 billion. Apollo was a monumental accomplishment, like the construction of the Pyramids. For Google to emulate that might mean erecting a 10-mile-high earthquake-resistant skyscraper, to literally overshadow Apple and provide an object of public marvel. Does that sound like something Google management would authorize a massive bond issue for? No, it does not—even though the project would surely spur advances in architectural engineering, improvements in materials science, and create a lot of engineering and construction jobs.

In his talk, Teller explained the true goal of his moonshot factory was "making the world a radically better place." I was a little surprised to hear that cliché used in earnest, several years after "Silicon Valley" skewered it in a montage of fake TechCrunch pitches centered on phrases like "making the world a better place though scalable fault tolerant databases with ACID transactions."[f] I suppose that is why he had to promise "radical" global betterment.

I am having a hard time imagining Kennedy's famous speech working as a TechCrunch pitch to "make the world a better place by spending billions dollars to harvest 381 kilos of rocks." Was the Apollo program's goal to make the world a radically better place? Enough people doubted that at the time to make Apollo the most obvious symbol of the failure of technology to make the world a better place. "If they can put a man on the moon," asked critics, "why can't they do [X]." Common values for X were "cure the common cold," "end urban poverty" and "fix traffic problems." The modern version of that might be "If Elon Musk can launch a Tesla at Mars, why can't his car factory come close to production metrics for quantity and quality that other carmakers hit routinely." Sometimes the rocket science is the easy part.

The Apollo program did little to directly advance scientific understanding. The decision to meet arbitrary deadlines by rushing special purpose hardware, rather than maximizing the scientific value of the missions or their contribution to longer term goals, caused tensions within NASA at the time.[g] Apollo did more to push technology and build engineering capabilities. Apollo created good jobs for scientists, mathematicians, programmers, and engineers, at NASA itself and with contractors. Political considerations spread the work out to facilities around the country, rather than concentrating it in a handful of urban areas. It is easy to decry that spending as corporate welfare or help for the already privileged but, as the recent movie *Hidden Figures* showed, the beneficiaries were not all white men with easy lives. The Apollo program also contributed to the development of software engineering techniques—the guidance code had to work reliably first time. Margaret Hamilton, who led its software team, eventually won the Presidential Medal of Freedom her work on the project.

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There were some significant technology spin-offs from Apollo, though contrary to popular belief, the powdered drink Tang was developed previously, as were Velcro and Teflon. Space technology improved freeze-dried food, microelectronics, scratch-resistant sunglass lenses, and lightweight foil blankets. Most notably, the need for reliable, miniaturized control electronics drove the emergence of a commercial market for microchips, years before they were competitive for ground-based applications. Each Apollo guidance computer used approximately 5,000 simple chips of a standard design, providing enough demand to drop the cost per chip for around $1,000 down to $20 or so.[2] The technique of using redundant control computers, now a standard approach for "fly by wire" commercial airliners, was pioneered by IBM in its work on the Saturn V control systems. One of the most popular database management packages of the early 1970s, IBM's Information Management System (IMS), had its roots in a system built with North American Rockwell in 1965 to handle the proliferation of Apollo parts.[5] Despite those accomplishments, the moonshot was not a cost-effective way to boost technology. Giving a quarter of the money on the National Science Foundation would surely have accomplished more, as would directing NASA to spend it on satellites and unmanned space probes. But would politicians ever have made those choices? Spending the money to drop more napalm on Vietnam or stockpile more nuclear weapons would have accomplished less than nothing.

If the moonshot made the world a "radically better place" it was by redirecting history in subtle ways. Like medieval jousting, the space race offered a non-lethal, and proudly phallic, substitute for real military clashes. Despite the flag waving, people across the world thrilled to the spectacle and took collective pride in the accomplishments of our species. The "Earthrise" photograph of a gibbous Earth rising over the lunar horizon, was taken in 1968 by the first humans to venture beyond low Earth orbit. It has been credited with inspiring the modern environmental movement. The similarly iconic "Blue Marble" photograph of a tiny, fragile, and complete planet floating in space, was taken by the crew of Apollo 17 in 1972 just as the short era of manned space exploration closed. That image inspired the *Whole Earth Catalog*, and hence the utopian aspirations of today's tech culture.[10] So in the end, moon rocks were not the only thing the astronauts carried back for us.

Figure. NASA astronauts Neil A. Armstrong (right), Michael Collins (center), and Edwin E. ("Buzz") Aldrin Jr. received a ticker-tape parade in New York City after returning from the Apollo 11 mission to the Moon.

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New Models of Space Flight

The master-planned monumentality of the moonshot is unfashionable today, even in space development. New space companies like Space X and Blue Origin were founded by Internet commerce pioneers (Elon Musk and Jeff Bezos respectively) to apply Silicon Valley approaches to space development. When the Bush-era Constellation moon program, which NASA had promoted as 'Apollo on Steroids' was canceled, Musk repurposed the description as an insult writing that the "new plan is to harness our nation's unparalleled system of free enterprise (as we have done in all other modes of transport), to create far more reliable and affordable rockets."[h] Rather than the moonshot approach of launching gigantic rockets as political performance art, these companies have focused on bringing down the cost of launches to make spaceflight viable for more purposes. Instead of tech firms becoming more like NASA, space exploration has become more like information system development. They have exploited developments in computer hardware and software to build reusable rockets able to guide themselves stably back to earth. The same advancements have greatly decreased the minimum size of useful satellites, reducing the mass that needs to be launched into space. (NASA itself anticipated some of this in the "faster, better, cheaper" push of the 1990s that produced the Mars Pathfinder rover). Starting with the smallest useful rockets and a modular architecture, they have

been working incrementally to larger and more powerful models. Since the Obama administration, U.S. policy has shifted toward contracting with space companies to purchase the use of privately developed rockets, rather than the traditional government procurement model where companies are given up-front development contracts to supply equipment to government specifications.

The master-planned monumentality of the moonshot is unfashionable today, even in space development.

Musk and Bezos hope that incrementally developing efficient and economically viable space systems will eventually lead to moon colonies, asteroid mining, and Mars missions. Like Delos D. Harriman, Heinlein's space fairing businessman, Musk dreams of dying on another world. Yet the new approach has its limits. The $30 million Google Lunar XPRIZE, for the first private landing of a robot on the moon, recently expired unclaimed 11 years after its announcement. The documentary commissioned to celebrate the competition was, of course, called "Moon Shot." Private-sector ingenuity proved unable to deliver new Apollo on a shoestring budget, despite the considerable advantages of a longer timescale, 50 years of technological improvement, and an easier task (one way robot transport vs. round trip travel for humans).

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Apollo vs. ARPANET

A few months after Neil Armstrong's short step down to the lunar service, data packets started making longer hops up and down the West Coast. ARPANET's first four nodes had gone live. Both were government projects, funded as part of the broader Cold War effort but not directly military. Apollo landed a total of 12 men on the moon, the last in 1972. By then ARPA had interconnected around 30 sites. By the time Apollo was officially shut down, after flying a final joint USA-USSR mission with spare hardware, the ARPANET had received less than one-thousandth of its funding.

The ARPANET was immediately useful and soon became more useful when network email, rather than the remote logins used to justify its construction, provided an unexpected "killer application." It evolved continually, in response to the needs of its users. The Apollo program, in contrast, had accomplished its objective by the time the Apollo 11 astronauts rode in their tickertape parade down Broadway in New York City.

Since then the divergence of the moonshot and ARPANET approaches has been rather dramatic. As of this writing, only four of the planet's seven billion human inhabitants have walked on the moon. The youngest of them is now 83 years old, so that number seems more likely to fall than rise. In contrast, approximately half of the world's population uses the Internet, the direct descendent of ARPANET, and millions more connect to it every day. The incremental, exploratory development of the ARPANET provided the modern tech firms with their model of innovation as well as the Internet infrastructure they rely on.

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The End of Innovation?

I am glad Google still spends some money exploring new product opportunities outside its core businesses, unlike many other modern firms, but do not forget that is something big companies used to do routinely without blathering about "moonshots." Fifty years ago Ford, General Electric, Kodak, Xerox, RCA, AT&T, Kodak, Dow Chemical, 3M, and a host of aerospace firms were investing heavily in such projects. Consulting firm Arthur D. Little specialized in helping companies apply newly developed materials, with stunts like turning a sow's ear into a silk purse.[8] Many of those firms also supported labs doing basic research in relevant areas of science, which Google and its peers do not attempt. Today's leading tech companies are not short of cash, but their focus is on minor improvements and the development of new features and applications within their existing platforms.

Tech companies have not always been so wary of moonshot-scale projects.

Tech companies have not always been so wary of moonshot-scale projects. In my January 2018 column I mentioned IBM's System/360 development project in the 1960s, which reportedly required a commitment of twice the firm's annual revenues when the project was launched. For Alphabet today, two years of revenue would be over $200 billion. Yet its "moonshot captain" had to kill what he claims was a highly promising

project, just because an initial investment of $200 *million* was unworkable. Poor Astro was three zeros and one comma away from being able to live up to that ridiculous job title. (Talking of absurd job titles, X recently lost its 'Head of Mad Science' to a sexual harassment scandal.)

Perhaps that is a good thing. Apollo's politically driven, money-no-object pushing of technology toward a fixed goal made for great television but did not bring us closer to routine space flight. Like the Concorde supersonic jetliner, sponsored by the French and British governments, it was a technological marvel but an economic dead end. On the other hand, the Silicon Valley model has not delivered nearly as much economic growth as all the talk about innovation and disruption might lead to you believe. Notwithstanding all the amazing things your cellphone does, technological change in the developed world has slowed to a fraction of its former rate. The 1960s were a highwater mark for confidence in the effectiveness of investment in bold technological projects like Apollo, System/360, or ARPANET. In *The Rise and Fall of American Growth*, economist Robert Gordon suggested a century of spectacular growth in living standards, life expectancy, and economic productivity began to stall around 1970, just as the focus of technological innovation shifted toward computers and networks.[4] These have not produced anything like the broad and sustained productivity gains created by electricity or assembly lines. Widespread adoption of the Internet gave productivity growth a significant jolt a decade ago, but that has already faded away.

It is inaccurate to blame this slow-down on public reluctance to fund moonshot-sized projects without direct economic returns. More likely, the end of rapid American growth and the end of moonshot projects are two consequences of a political and ideological shift away from long-term public and corporate investment in a range of areas, from infrastructure to education. At the height of the Apollo project, federal spending on research and development was more than twice its level in recent decades. A decades-long push for tax cuts, combined with rising government spending on healthcare and social security, has hollowed out investment in research and infrastructure and left massive deficit.

Companies are likewise more focused than ever on quarterly earnings and shareholder value. Alphabet has the money to fund something close to a real moonshot, if its investors allowed it. In 2015 its total spending on non-core business, not just the "moonshot factory" but potentially vast emerging business areas like fiber-optic Internet service, life sciences, home automation, venture capital, and self-driving cars, accounted for only approximately 5% of its revenues. Even that was viewed by investors as irresponsible, given that they generated less than 1% of its income, and in early 2017 Alphabet reportedly launched an "apparent bloodbath," killing ambitious plans for delivery drones, modular cellphones, and the rollout of fiberoptic Internet access to more cities.[i] Subsequent reports tied a transition in which "futurism has taken a back seat to more pressing concerns" to the withdrawal of Google co-founder Larry Page from hands-on management.[1]

What would modern tech companies do with a windfall big enough to fund an actual moonshot? Thanks to the recent corporate tax-cut bonanza this is not a hypothetical question. Rather than investing in new projects they purchased their own stock, to return surplus money to shareholders. In the first quarter of 2018, Alphabet announced a $8 billion buyback. Cisco spent $25 billion. Apple more recently launched a $100 billion stock purchase program. Moves of this kind reflect a belief by management that they have no untapped opportunities, including new product development, to make better use of the money. (Thanks in part to those same tax cuts, the U.S. government deficit is expected to balloon to approximately $1 trillion dollars this year, forestalling any possibility of new public investment).

If you expect to live to see anything as intoxicatingly implausible as a moon landing was in 1969, you will have to pay for it too.

The Internet approach of scaling up incrementally from a working prototype based on the needs of users has beaten out the centrally planned, all-or-nothing moonshot approach. Investment funds flow to companies with already viable prototypes in hot fields, as evidenced by the vivid but potentially baffling news headline "Bird races to become first scooter unicorn."[j] (Translation: urban scooter rental company Bird was about to pin down a new round of venture capital funding valuing it at more than a billion dollars, making it a "unicorn.") Silicon Valley is trying to stop us from noticing the difference between the Apollo program and scooter unicorns by draping the heroic rhetoric of "moonshots" over a far less-inspiring reality. You have probably heard the comment, "we were promised flying cars, but we got 140 characters" (a dismissive reference to Twitter). That is true, but let's not forget that anyone old enough to have been promised a flying car, back in the 1950s when Ford promoted the idea heavily, was also promised a moon rocket by Disney. They got one too, but only because they were collectively willing to pay for it.

Many people now believe the moonshots were faked. Manned lunar flight remains prohibitively challenging today. Was it really achieved 50 years ago, before microprocessors and Twitter were invented? Yes, but if you

hope to live to see anything as intoxicatingly implausible as a moon landing was in 1969, perhaps something to address the challenge posed by climate change, you will have to pay for it too. Otherwise—and I'm looking at you Google—please show some respect for the inspiringly unprofitable lunacy of the real moonshot by finding a different name for whatever Astro Teller and his colleagues are up to. "Research and development" has a nice ring to it.

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Footnotes

a. See https://bit.ly/1TTLG9n

b. Ed Yourden wrote an interesting book about the tenacity of doomed projects: E. Yourdon, *Death March: The Complete Sofware Developer's Guide to Surviving "Mission Impossible" Projects*. Prentice Hall, 1997.

c. This incident occurs in "Server Space" (season 2, episode 5) and, ironically, is set in the Hooli XYZ "moonshot factory"—a rather crude parody of Google X.

d. X grew out of the lab that "graduated" to become Waymo, now a separate company successfully selling technology for self-driving cars. It was also the group responsible for Google Glass, whose camera/screen eyeglasses went abruptly from next big thing to epic flop in 2014, for the Loon project to deliver Internet access via high-altitude balloons, and for a fleet of experimental delivery drones. The most balanced portrait of its workings was given in https://bit.ly/2gqMi8s.

e. This short story was written in 1949 and appeared as the title story in Robert A. Heinlein, *The Man Who Sold the Moon* (Shasta, 1950).

f. "Silicon Valley"'s relationship to real Silicon Valley culture is discussed in A. Marantz, "How 'Silicon Valley' nails Silicon Valley" *The New Yorker* (June 9, 2016) which reports that Teller was not amused when the show parodied his "moonshot factory."

g. The scientific side of the Apollo program is the focus of W.D. Compton, *Where No Man Has Gone Before: A History of the Apollo Lunar Exploration Missions*. U.S. Government Printing Office, Washington, D.C., 1989.

h. https://bit.ly/2qCT9QY

i. https://bit.ly/2PLDigV

j. The headline, originally attached to a story posted by Bloomberg.com on May 29, 2018, has since been replaced with the less-evocative title "Sequoia Said to Value Scooter Company Bird at $1 Billion."

Thanks to Paul Ceruzzi of the National Air and Space Museum and Matthew Hersch of Harvard University for checking the discussion of the Apollo program for historical accuracy and making valuable suggestions.

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