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NOTHING FAILS LIKE SUCCESS: FROM MOON TO EARTH AT NASA

Most readers of this book will know that on the evening of July 20, 1969, Neil Armstrong hopped from the *Eagle* Lunar Excursion Module onto the moon's surface, to the cryptic misutterance, "That's one small step for [a] man, one giant leap for mankind."[1] Indeed, a significant portion of "mankind"—and a much larger proportion of the American public—was watching him. Yet many outside the United States were unimpressed with the moon landing, and even many Americans (particularly people of color) thought that the time and money spent on it exemplified the nation's misplaced priorities.[2] Americans as a whole were generally positive toward the moon landing on that day, but public opinion was (as Matthew Tribbe and Roger Launius have shown) much more ambivalent about the Apollo Program both before and after July 20, 1969.[3] The singular moments when Armstrong set foot on lunar soil and when the Apollo 8 astronauts circled the moon the previous December have left a mark on both popular culture and the discourse of public intellectuals.[4] But those singular moments stand somewhat outside the longer flow of public and elite opinion about the value of America's space program.

Nevertheless, Armstrong's hop was in preparation for a long time. The National Aeronautics and Space Administration was created in 1958, and its astonishing growth over the next decade made the moon landing possible. NASA wasn't created specifically for that purpose, of course; but it *was* created with the intent of preventing the Soviet Union from gaining a monopoly on space achievements, including human exploration of the moon. NASA's founding occurred in an atmosphere of panic over the launch of Sputnik and a series of Soviet space triumphs and humiliating American failures.[5] Even after NASA's creation, the Soviets continued to reach notable space milestones before the United States at an alarming rate. In terms of unpiloted craft, those milestones included firsts in the following: artificial satellite, animal in space, uncontrolled landing on the moon, pictures of the far side of the moon, flyby of another planet (Venus), controlled landing on the moon, and artificial satellite of the moon. In terms of piloted craft, the early 1960s saw the Soviets launch the first man and woman into space and the first two- and three-person spacecraft, as well as conduct the first spacewalk and the first simultaneous two-craft piloted space operations. As a result, the language of a "race" and of being "behind" suffused discussions of America's space objectives from the late 1950s until the return of Apollo 11 in the summer of 1969.

BUILDUP AND DRAWDOWN

In September, 1962, a month after the Soviet tandem missions (Vostok 3 and 4) mentioned in the previous paragraph President Kennedy journeyed to Houston to visit the new Manned Spacecraft Center (renamed the Johnson Space Center in 1973—I will refer to it as JSC throughout this chapter). While in Houston, he gave a since much-quoted speech at Rice University reifying the "race" with the Soviets and America's current place in it: "we are behind, and will be behind for some time in manned flight. But we do not intend to stay behind, and in this decade we shall make up and move ahead" by "putting a man on the moon" before the Union of Soviet Socialist Republics (USSR).[6] Although Kennedy had earlier made similar commitments, that speech act in Houston created an existential benchmark for JSC and for much of the rest of NASA—a benchmark that was met the instant Armstrong's foot touched the lunar surface.

Meeting that benchmark required expenditures that are hard to fathom today. In 1965, 4.3 percent of the total federal budget went to NASA—an agency that didn't exist before 1958![7] In 1966, NASA's funding peaked at 4.4 percent of the federal budget, or roughly 0.7 percent of US GDP. Much of that money was spent on the rapid construction of semipermanent infrastructure such as the gigantic Vehicle Assembly Building at Cape Canaveral. By 1967 most of that infrastructure was in place, and therefore expenditures dropped rapidly. By 1975, NASA's budget had stabilized at around 1 percent of the federal budget (or roughly 0.2 percent of GDP). It would stay close to that level until the late 1990s, when it would again decline to approximately 0.5 percent of the federal budget (0.1 percent of GDP) today.

Much of NASA's spending in the 1960s took the form of contracts with aerospace companies such as North American Aviation and Grumman. Thus, the rapid decline in NASA's budget had an immediate effect on the military–industrial complex. As George Low, NASA's acting administrator, reported to Congress in 1971:

> Since the peak NASA employment level established in early 1966, NASA contractor employment has shown a sharp decline. Estimated total employment on NASA programs in early 1966 was 420,000. The comparable figure in June 1970 is 161,000.[8]

Historians have documented the employment crisis among engineers in the early 1970s, usually with reference to cutbacks in defense spending caused by a drawdown in US involvement in the Vietnam War.[9] But NASA's cuts also contributed significantly to engineers' employment woes. Importantly, NASA's cuts were almost inevitable—once infrastructural elements such as rocket test stands and vehicle assembly buildings were built, NASA didn't need to build them again. Maintaining that infrastructure did take money and personnel, but not at nearly the scale required to build them in the first place. So most of the engineers who designed and constructed that infrastructure had to be either put onto new projects or let go.

The US space program's retrenchment had a similar effect in the sciences. Historians have shown that NASA's money and unusual requirements stimulated rapid gains across a wide variety of disciplines, from the obvious (astronomy, planetary geology, climate science) to the less so (cybernetics, ecology, medicine, botany, surface science, systems engineering, etc.).[10] Those achievements—especially in the less-obvious fields—were most associated with the era of NASA's rapid growth and slowed with NASA's budgetary retreat. Across much of American science, particularly the physical and engineering sciences, researchers made unprecedented strides with NASA's help up to 1966, then had to adjust when that patronage began to fade.

Some did so by finding other patrons to allow them to continue the work that NASA had earlier supported. In chapter 3, for instance, we saw how John Linvill and James Bliss's initial Optacon research was funded by NASA, but then in the late 1960s they had to turn to other agencies to keep the Optacon going. Other researchers reacted to NASA's cuts by dropping the topics that had won them funding from the space program; yet the easiest way forward for this group was to find new ways to apply the space age *skills* that that funding had helped them develop. This group therefore went in search of new but related topics, often ones in keeping with the cultural experimentation of the times. Again from chapter 3, we saw how John Chowning first learned the fundamentals of computer music during his time in the NASA-supported SAIL before founding his own computer music center. Other electronic music innovators such as Don Buchla and Alan R. Pearlman worked on nonmusical NASA projects during the agency's budgetary inflation, then turned to developing their synthesizers when the space program contracted.[11] Across many fields one can find similar figures who gained fundamental insights while working with NASA—insights that they then had to adapt outside the context of space once NASA became a less generous patron.

EXISTENTIAL SUCCESS

This dynamic, in which an organization or initiative makes an outsized contribution to a number of fields during its heyday, then makes a rather different contribution during their decline (by releasing researchers to do other things), is a recurrent feature of American science and engineering.[12] Sometimes, this dynamic occurs because the organization or initiative breaks apart after failing to accomplish what it set out to do. For instance, Robin Scheffler argues that the biotechnology industry benefited from the cadre of young researchers who were recruited into Nixon's War on Cancer and then set loose when the "war" effort bogged down.[13] In other cases, though, organizations break up because they *succeed* in their existential goals. One can see this quite clearly with many of the organizations set up during World War II, which released a generation of scientists back into (more or less) civilian life with a new set of skills, contacts, and questions earned from their wartime work. And in yet other cases, the distinction between success and failure is less clear, but the dynamic is the same. The collapse of AT&T's Bell Laboratories in the 1990s, for instance, gave a one-time boost to many fields that recruited ex–Bell Labs staff. Yet Bell Labs didn't disintegrate because it failed—its existence was simply no longer sustainable in a changing economic, political, and regulatory environment.

NASA falls quite easily into the category of organizations that succeeded to the point of failure—a dynamic that I have already introduced under the label of *existential success*. The thumbnail history of the space race that I've sketched shows why I apply that label to NASA's difficulties in the long 1970s. The space program, after all, was founded with the existential aim of denying the Soviets' monopoly on space achievements. By 1962, one achievement in particular—putting "a man on the moon"—had come to define the piloted side of the space program. In 1969 that existence-justifying benchmark was reached. Although the Soviets continued to make piloted space firsts after that—particularly in long-term human occupation of low earth orbit—American observers no longer cared in the way that they had a few years earlier. The US piloted space program had succeeded in its existential mission—but with the Soviets definitively outrun, the US piloted program had no *new* mission in place to define and justify its continued existence.

On the unpiloted side, the Soviets kept pace for a bit longer (to about 1975) in firsts that American observers deemed important. After that, NASA ran through a series of unpiloted achievements (photos from the Martian surface and flybys of Jupiter, Saturn, Uranus, and Neptune) that were widely heralded in the United States. The Soviet unpiloted program continued making gains—for example, a series of landers on Venus—but after 1975 most American observers took the Soviets' unpiloted achievements to be narrower and less impressive than the US program's. Thus, although the space race had some reality as a guide to action in the 1960s, by the 1970s that was no longer the case, at least in terms of US views of the Soviets. Even as early as August, 1969, President Nixon's Space Task Group could say

> The attitude of the American people has gradually been changing and public frustration over Soviet achievements in space, an important force in support of the Nation's acceptance of the lunar landing goal in 1961, is not now present. Today, new Soviet achievements are not likely to have the same effect of those in the past.[14]

If anything, in the 1970s NASA started to view Europe as a more relevant international space power than the Soviets, both as a collaborator and competitor.[15]

Apollo 11 and its aftermath mean that NASA offers an especially stark instance of existential success. For the purposes of this book, though, I take NASA as representative of—or a synecdoche for—the wider, less clear-cut existential success of postwar (and especially post-Sputnik) US science and engineering more generally. That is, the arc of the US research system from the end of World War II until the late 1960s overcame the same more-or-less existential challenge as NASA; thus the US research system (in general) faced many of the same problems that NASA did (in particular) during the long 1970s.

Indeed, the research system as a whole was structured by a perceived race against the Soviets that closely resembled the space race—not least in that both races had more or less been won by 1969. In the early Cold War there were a number of science and engineering fields in which the Soviets appeared to be "ahead" of their US counterparts, or where the US "lead" appeared to be small and growing smaller.[16] In particular, Soviet gains from the late 1940s to the mid-1960s in fields most closely related to nuclear strategy—building different kinds of nuclear weapons, different means of delivering them to a target, and different means of preventing the enemy's bombs from reaching their target—led to panic, purges, and budgetary largesse on the part of US policymakers.

Fears that the Soviets were or would soon be ahead in weapons-related fields were deftly exploited by American opportunists such as Edward Teller to get funding for far-out projects such as a nuclear airplane, a nuclear spaceship, and nuclear environmental modification and earth-moving.[17] But the two superpowers also raced each other in fields that were less obviously related to weapons production—especially ones where there was some easy metric of who was ahead. For instance, the US and Soviets leapfrogged each other in building ever-larger particle accelerators of various types through the 1950s and 1960s—though, again, after 1970 the United States regarded Western Europe, not the USSR, as its main competitor in accelerator design.[18]

By the 1970s, the number of fields in which American scientists, engineers, or policymakers cared about a possible Soviet lead had dwindled. Usually that meant that US actors now viewed the Soviets as hopelessly lagging: as Kremlinologist Thane Gustafson put it in 1980, "by any measure . . . U.S. scientists lead their Soviet colleagues in most disciplines, and in many there is simply no competition."[19] Admittedly, there were a few fields in which a Soviet lead was still acknowledged in the 1970s, but these were now largely written off as unimportant.

Probably no domain better captures this attitude than that of high-speed circuitry. By the early 1970s virtually no one believed that the Soviets would ever catch up to American firms in the speed of solid-state integrated circuits. National priorities in this area therefore shifted to ensuring that Japanese and Western European firms did not pull ahead and that Soviet and Eastern European intelligence services could not access and reverse-engineer American circuits.[20] There were, however, varieties of high-speed circuitry for which the Soviets were still competitive with US firms and researchers, yet without causing American observers much concern. Some of these were cutting edge but rather limited areas, such as molecular electronics and superconducting electronics.[21] But in one ostensibly low(ish)-tech area, Soviet capabilities completely eclipsed the United States: high-quality vacuum tubes. Even today, the (now extinct) Soviet Union is still the source of the vacuum tubes that audio enthusiasts prize and comb the world for![22] Yet in the United States the vacuum tube was mostly regarded as a relic of a bygone age, something that belonged in a museum rather than in a useful piece of equipment. Soviet dominance in vacuum tubes therefore caused no sleepless nights in the United States after 1970.[23]

Does this state of affairs qualify as existential success? The label is a slight exaggeration, less easily applied to American science and engineering as a whole than to the particular case of NASA. Yet I believe that we can still usefully (if cautiously) use the concept. The US research paradigm that policymakers such as Vannevar Bush and Lloyd Berkner set up in the late war/early postwar period was not existentially predicated on competition with the Soviets at first, but it was designed to keep American science and engineering capacity in a high state of readiness in case of a future global conflict.[24] The Soviets must always have been prominent in the list of potential foes against whom US scientists and engineers could be mobilized. With the Soviet testing of a fission weapon in 1949 (and perhaps even before), preventing or blunting Soviet technoscientific advantage became an overriding if not existential priority for much of the US research system.

As with the space program, meeting that priority required enormous expenditures. And, as with NASA, in the early phase infrastructure building *temporarily* boosted those expenditures. As Hyungsub Choi and Brittany Shields have shown, until the mid-1960s the federal government was quite willing to earmark research funds for very expensive brick-and-mortar building projects.[25] Once a laboratory is built, though, it doesn't need to be built again. Over the long term, maintaining buildings isn't cheap, but in terms of annual budgets, maintaining an old building is a far smaller expense than constructing a new one. Thus, money for laboratory construction was one of the first things to disappear when federal R&D funding was retrenched starting in the late 1960s. From then on, if universities wanted a new building, they had to rely on alumni, philanthropies, companies, and internal accounts to cover construction costs. Universities eventually became quite good at soliciting donations for new buildings, but that hard-won expertise was still rudimentary in the 1970s. Thus, laboratory construction—which had exploded in the early 1960s—nearly halted during the long 1970s. Even finding money for maintenance of labs, lab equipment, and lab buildings became a struggle, such that by the early 1980s experts worried that the deterioration in research infrastructure was hindering American science.[26]

The US research system's retrenchment in the long 1970s was to some extent inevitable. Presumably, federal R&D budgets could not have continued to rise at post-Sputnik rates forever. But few predicted that the political will to continue those increases would evaporate as early as it did—many American scientists and engineers seem to have been truly caught off guard. You could ascribe that tipping point to economic malaise or the budgetary pull of the Great Society and the Vietnam War, yet those factors could only have been decisive once the Soviet threat was no longer seen as overwhelming other considerations. By the late 1960s, national priorities *other* than the struggle against communism had come to the fore, thanks to the convergence of several developments: demographic, economic, and cultural change; the civil, environmental, and other social movements; decolonization; and the first steps toward détente. The Cold

War wasn't over, of course, but the urgency of staying ahead of the Soviets had diminished. Those parts of American society that had been mobilized against the Soviets—including American scientists and engineers—were seen as having fulfilled their existential task. Thus, they could now be given other tasks, or find new tasks for themselves. This book is filled with examples of scientists and engineers doing just that.

TOO SUCCESSFUL TO EXPAND, BUT TOO BIG TO FAIL

Some scientists and engineers perceived that sea change early, others much later. To continue the nautical metaphor, some got out ahead of the tide, some moved with it, and some fought it. Among the latter were those NASA personnel who made the moon landing possible but did not see—or wish to see—that Apollo 11 was an end rather than a beginning. In particular, one of the main architects of Apollo—Wernher von Braun—laid out plans for the moon landing to lead to continued expansion of the space program and continued elevation of its aims: a permanently crewed space station, a permanent base on the moon, and a crewed trip to the Martian surface and back.[27] After July, 1969, this "von Braun paradigm" continued to exist, but only within what the physicist Freeman Dyson dubbed the "paper NASA" of long-range planning.[28] It also continued to resonate with enthusiasts outside NASA, especially among the generation of young men who had grown up with von Braun's 1950s magazine articles and television appearances and NASA's 1960s missions, and who became captivated in the 1970s by von Braun's visionary successors, most notably Gerard K. O'Neill.[29] As we'll see, NASA and its vendors made opportunistic use of O'Neill's proposals for space "colonies" and the enthusiasm that they generated, but most people in the space program recognized that O'Neill's designs required laughably high expenditures (and leaps in technical ability) and so would never come to fruition.

Administrators and engineers within what Dyson called the "real NASA" therefore understood that existential success left the von Braun paradigm with no traction. The Soviets seemed to be in no position to put a human on Mars or a permanent settlement on the moon, and Congress could never be convinced to continue expanding NASA just to stay in a race where the other runner had dropped out. Indeed, given the public mood and the state of public finances, Congress and the Nixon administration were eager to *shrink* the space program, not expand it. Thus, all that NASA's administrators could hope for was to contain the scale of cuts in budgets and personnel.[30] For that, one of their most powerful arguments was that NASA's sunk costs were too large to be thrown away. Communities all across the nation (read: voters across many, many Congressional districts) benefited from employment at nearby NASA facilities or NASA vendors. Their other main argument was that the moon landing demonstrated the competence of NASA personnel in a world hungry for technical expertise, and that some societally beneficial use could therefore be found for such talent.

So at the moment when Armstrong's foot hit the moon, almost no will existed for NASA to continue the von Braun paradigm. Indeed, there was little will even to continue the moon landings. President Nixon pressed to cancel the Apollo 16 and 17 missions and had to be personally persuaded that doing so would provide no budgetary surplus. At the same time, few policymakers wanted NASA to immediately close up shop. The medium-term debate therefore concerned what NASA should do next. After considerable confusion and horse-trading, that discussion eventually settled on the space "shuttle" as NASA's next marquee piloted initiative. As John Logsdon and others have shown, though, NASA was unable to resist other parts of the government's imposing their interests on the shuttle program. The final shuttle design was therefore a mish-mash that satisfied no one.

With the shuttle under discussion and Apollo winding down, NASA administrators of the early 1970s had to figure out how to shrink the space program, in a semicontrolled fashion, down to a sustainable size. The ensuing contraction set up one outcome of NASA's existential success: an outflow of personnel who went on to do other things. Most visible in that diaspora were former astronauts who moved into jobs for which the relevance of their previous experience was opaque: politician, artist, chief executive officer, diplomat, even a vice president of a National Football League team.[31] But the astronauts were by no means alone. Engineers left NASA and its vendors in droves, creating a political headache for the Nixon administration. As one strategist noted

> About 100,000 aerospace workers are now unemployed in Southern California. . . . [T]he Administration is not seen as doing anything. . . . [D]emocratic Senators and Congressmen from Southern California are "cutting the Administration apart" by showing concern.[32]

Many of those unemployed engineers moved into new industries, into government, and even into new disciplines, some with help from Nixon administration "projects to retrain displaced aerospace engineers and scientists in bio-medical, environmental engineering, and State and local administrative fields."[33] As we'll see, these administration programs that were targeted at individuals were replicated at the organizational level with projects that redirected NASA itself into biomedicine, environmental engineering, and state and local administration.

Budgetary contraction meant many people were pushed out of NASA and the aerospace industry; but existential success meant other organizations also *pulled* NASA and aerospace industry personnel toward them. Everyone could see that NASA personnel were effective—they had come from behind to accomplish their organization's existential mission against daunting odds. What organization would not want people of that caliber? And because that existential mission had been completed with no new one to take its place, there was little to keep personnel at NASA. Budget cuts meant some personnel were simply dismissed, but many *chose* to leave NASA to seek new challenges or because other organizations offered them attractive inducements. The NSF's RANN program, for instance, was run during its heyday by Alfred Eggers, a former NASA Deputy Associate Administrator for Advanced Research Technology.[34] In this chapter we will encounter some other members of the NASA diaspora in the Department of Housing and Urban Development (HUD) and elsewhere.

This aspect of NASA's existential success demands further research—we need to know more about where NASA people went and what organizations, industries, and fields were changed by their presence. It's more difficult to apply this aspect of existential success to the rest of the US research system in the long 1970s, but nevertheless we should also pay more attention to the mobility of non-NASA scientists and engineers during those lean years. We know a bit about what people chose to research when the pressure to conform to national security aims lifted. But we know less about the organizations that recruited such people precisely because their professions had proven their competence in the struggle against communism. My guess is that if we followed scientists and engineers who switched fields or industries during the long 1970s we would find interesting fingerprints in areas such as computing, video game development, and finance.

Those who stayed at NASA and its aerospace vendors, meanwhile, experienced a mirror-image version of existential success. Their organizations had succeeded; few people wanted those organizations to disappear entirely; yet almost no one wanted those organizations to continue as they had before. Other organizations saw that NASA and its vendors could accomplish preset goals and therefore tried to make their own organizational priorities part of the space program's next set of goals. The Nixon administration, for its part, believed that NASA should accede to such demands. Per Lawrence Goldmuntz (a scientist in the White House Office of Science and Technology):

> NASA should assume responsibility for certain technical developments that would be within their areas of competence and that would enrich the civilian life and economy . . . in certain new areas of transportation . . . communications and information processing for improved mail handling, in urban crime and alarm and location . . . in weather modification and water resources. These areas are the normal responsibilities of some of the civilian mission oriented agencies, but they are not being accomplished with the attention they deserve because of preoccupation by the mission oriented agencies with the more immediate responsibilities. It is suggested that such projects be funded through the mission oriented agencies—HUD [Department of Housing and Urban Development], DOT [Department of

> Transportation], EPA [Environmental Protection Agency], [Department of the] Interior—but accomplished by NASA. This would tend to assure overall project relevance while making use of NASA facilities and personnel.[35]

Some NASA personnel welcomed this turn toward relevance. NASA administrators could view collaboration on projects not directly related to spaceflight as a "'gap-filler' or 'insurance' program . . . to reduce the manned [space]flight gap" and keep NASA's infrastructure and staff (and its vendors' engineers) occupied while waiting for shuttle operations to begin.[36] But we shouldn't view NASA's attitude in entirely cynical terms. We cannot discount the likelihood that some scientists and engineers and perhaps even upper administrators viewed these projects as an enjoyable opportunity to work on something different, with interesting technical challenges and visible benefit to society.

JOHNSON SPACE CENTER AND JET PROPULSION LABORATORY

Both external pressure and internal priorities, then, led NASA and its vendors to pursue a variety of projects that brought the concerns of civilian, terrestrial society into contact with space-age expertise in the long 1970s. In this chapter I will concentrate on projects associated with the Johnson Space Center outside Houston, Texas, and the Jet Propulsion Laboratory (JPL) outside Los Angeles, California. These facilities were particularly ensnared by existential success: JSC by the success of piloted missions and JPL unpiloted ones. Readers should not take JPL and JSC as entirely representative sites, though geographically they nicely stand for the regions (California and the South/Southwest) where NASA and the aerospace industry were most concentrated. Still, there was considerable variation in how NASA's facilities experienced the predicaments of the long 1970s, such that no sample of two would capture the full range. Some NASA sites, such as Cape Canaveral, faced dilemmas similar to JSC and JPL's but were more constrained in dealing with them. One—but only one!—facility, the Electronics Research Center in Cambridge, Massachusetts, was actually closed.[37] And a few facilities experienced the long

1970s quite differently: the Ames Research Center in the San Francisco Bay area, for instance, thrived by cultivating stronger ties with industry and universities while at the same time lending its reputation to O'Neill and the space colonization community.[38]

That said, many of NASA's facilities did see major programs shut down and responded in ways similar to what I will describe for JSC and JPL. Mark Bowles, for instance, has written about NASA's nuclear reactor facility at Plum Brook, Ohio, which was built in 1961 to generate neutron flux to test designs for a nuclear airplane and then a nuclear spaceship before becoming a more mundane but very useful tool in materials research.[39] The reactor program was then summarily ended in mid-1973, leaving NASA to desperately seek new partners such as the Cleveland Clinic and the EPA. Those attempts failed and the reactor was mothballed, leaving the Plum Brook site to struggle through the 1970s by retooling to support, among other things, NASA's programs in terrestrial alternative energy. Plum Brook was part of the Lewis Research Center, which similarly partnered with local agencies to monitor pollution levels in the Cleveland area and obtained funding from the EPA to develop a more efficient, less polluting car engine.[40]

That path through the long 1970s was mirrored at JSC and JPL, though with slightly different organizational logics. And it is at the level of organizational logic that this chapter will focus: the sources that I offer were largely written in a bureaucratic tone that effaced personal motivations. In places I will speculate about the people behind those sources, but for the most part the sources force me to ask what was going on with the *organization*—and not the individual—at the time that the source was written. My other chapters bring out individual voices more clearly, so we can use those chapters to infer what individuals at NASA thought. Conversely, we can use this chapter to get a sense of the organizational logics that constrained and enabled individual expression within the organizations profiled in my other case studies.

At JSC, the overriding organizational context was the gap between the Apollo and shuttle programs. Staff at JSC understood the 1970s as a (painful) transition period, but one with some kind of end in sight. In the early 1970s that transition was made bearable by convincing the Nixon administration to allow the piloted program to adapt Apollo hardware for other purposes: first for three missions to the Skylab space station (itself a kitted-out third stage of the Saturn V rocket) and then the joint US–Soviet Apollo–Soyuz Test Project.[41] Meanwhile, JSC's activities gradually increased pace over the course of the decade under the umbrella of the piloted program's next existential effort: the space shuttle.

Readers should therefore picture JSC's experience of the 1970s as a reasonably fast ramp down *from* full capacity in the Apollo era, superimposed on a slow ramp up *to* full (though lower) capacity in the shuttle era. That left a significant period, though, when JSC's engineers were not fully occupied and were therefore in danger of being laid off. Although the number of full-time–equivalent NASA employees (or civil service "man-years" in contemporary lingo) at JSC declined only by about 13 percent between fiscal years 1969 and 1974, *contract* employment (i.e., people working at JSC but employed by aerospace and consulting companies) shrank by more than a third before starting to recover.[42] During that time, administrators looked for short-term projects that would tide JSC engineers over from Apollo to the space shuttle so that they wouldn't permanently lose highly trained personnel (and thus slow down or endanger the shuttle program). As the following sections will show, projects similar to what we saw at Stanford and UCSB in previous chapters fit that bill and therefore briefly became more common at JSC before being squeezed out again as the shuttle program intensified.

In contrast, the situation was more open ended at JPL. That facility was technically run by the California Institute of Technology (Caltech) on NASA's behalf, so academic administrators (and to some extent even students) exerted some influence over JPL's direction. Even at conservative Caltech, some of the national debate about military funding of academic research filtered through. As a result, the institute released reports on the JPL–Caltech relationship in 1970 and 1976, with particular focus (as at Stanford) on the propriety of allowing classified research at a (nominally) academic institution.[43] Thus, JPL had to deal with the short-term ups and downs of academic politics, but it also had to surf the much longer waves of unpiloted space exploration. Unpiloted missions can last much longer than piloted ones. In fact, Voyager 1—launched in 1977—is still an active mission. Thus, missions that entered the pipeline when there was still political will to deny the Soviet monopoly on space firsts could potentially outlive that political will by many decades. Indeed, JPL's most dramatic missions of the 1970s were set in motion before that decade.

During the 1970s, however, the lab's mission queue became much shorter.[44] There was a real possibility that the will to undertake unpiloted space exploration would disappear completely and that JPL—if it were to continue to exist—would need to find some other mission. As we will see, JPL went a long way in exploring other organizational objectives, and for a time it seemed as though other missions—particularly terrestrial energy conservation and alternative energy—would take up as much of its attention as space exploration. In the early 1980s, though, those new organizational objectives were quashed by the Reagan administration, and JPL returned to space exploration as well as to its military–industrial roots.

Despite their differences, therefore, JSC and JPL followed similar arcs: from existential success in beating the Soviets, to a period of uncertainty characterized by collaborations with other organizations in aid of societal relevance, followed by the establishment of a new existential mission and the dissolution of projects aimed at solving civilian, terrestrial problems. To the extent that problems of civil society continued to occupy these organizations after 1980, it was in the mode familiar from other chapters: the societal problems considered most worth solving after roughly 1980 were those set by the market, to be approached in collaboration with industry and *not* in partnership with nongovernmental organizations (NGOs) or state and federal agencies associated with the social safety net. As in other chapters, we will see that the long 1970s introduced new ways for scientists and engineers to work with industry, but that initially their aims were not overtly commercial. It was only at the end of the long 1970s that those new practices were reconfigured in ways that can today be seen as an accommodation to neoliberalism.

FROM THE MOON TO THE EARTH

Of course, in some sense NASA was always supposed to contribute to solving problems of civil society. The agency's organic charter contained a vague reference to applications of "aeronautical and space science and technology . . . within and outside the atmosphere," which headquarters used to justify opening a Technology Utilization Office in 1962.[45] Through the 1960s this office was best known for annual reports enumerating dozens of supposed "spin-offs" of space programs. Yet, as Bruce Seely argues, early on NASA seems to have measured "utilization" by how widely its documentation circulated, rather than by whether its discoveries ended up in civilian technologies.[46]

Around 1970, though, headquarters-sponsored "applications teams" were "diversif[ying] into other, nonmedical, public-sector areas" such as "air and water pollution, fire safety, housing and urban development, transportation, law enforcement, criminalistics, the postal services, and mine safety."[47] There then seems to have been a fairly rapid transition in the early 1970s from headquarters pushing the field sites to create application teams to "the Field Centers themselves submit[ing] proposals based on their own perceptions of the relevance of their in-house skills and capabilities to public-sector problems."[48] At the same time, external actors seem to have become more interested in working with NASA on terrestrial applications. For instance, industrial requests to NASA's Technology Utilization program went from ten to twenty per year in the late 1960s to seventy to ninety per year in the early 1970s.[49] Similarly, reports from this era offered long lists of other government agencies with whom the Technology Utilization program collaborated: the "Department of Health, Education, and Welfare; the Department of Housing and Urban Development; the Bureau of Mines; the Department of Transportation; Environmental Protection Agency; the Law Enforcement Assistance

Association; the National Bureau of Standards; the Veterans Administration and others."[50]

In keeping with the Nixon administration's ideological commitments, many of these projects aimed to alleviate market failure by ushering a prototype to the point where a private entity could profitably manufacture and sell a commercial version. As Lawrence Goldmuntz's 1971 memo outlined,

> These projects cannot be undertaken by the private sector because of their long range character requiring extensive development and/or because national standards must be developed before a market can aggregate. Nevertheless once the research and development is completed and once a national demonstration is accomplished, substantial domestic and foreign markets would materialize for development by the private sector.[51]

This mode of working was aided by a new patent policy in 1972 that allowed NASA to grant exclusive licenses on its patents nine months after filing rather than two years after issuance.[52]

An illustrative example of how this worked in practice was a test of whether the lunar rover could be adapted for use by people with lower-body paralysis conducted at the JSC in 1974 to 1975. As Goldmuntz would have encouraged, the project's leaders saw it as an attempt to resolve a market failure:

> It is unlikely that specialty equipment manufacturers can afford to develop a high-quality, well-engineered product such as the proposed Lunar Rover controller for automobiles. This is an opportunity for NASA, as a public agency responsible for the technology, and the VA [Veterans Administration], as a public agency responsible for the care and service of a large segment of the physically impaired population, to sponsor the development of such a system.[53]

As the quote implies, the lunar rover conversion project partnered NASA with the VA—but also with the US Department of Transportation, as well as a number of Texas state agencies and NGOs that worked with people with physical disabilities. These kinds of complex collaborations with organizations that represented possible users or sources of expertise relevant to terrestrial applications of space technology were quite common.

The focus on disability technologies was also quite typical. As we saw in chapters 2 and 3, projects to aid people with visual, hearing, or mobility impairments were common responses to calls for civilianization of the R&D system in the years around 1970.

One of the more colorful examples of this market failure approach was a program in the mid-1970s to adapt astronaut food for delivery to elderly shut-ins by mail, volunteer, or social worker. The program started in 1974

> when Anne Kohler, Director of the Texas Governor's Committee on Aging Research Utilization Program (now a part of the Texas Department of Public Welfare) made a request of NASA: could the space agency help to improve nutritional services for the elderly, particularly those in areas not reached by meals-on-wheels programs? As it turned out, NASA's experience in developing a shelf-stable, nutritious, easily transportable meals system provided the foundation for design and development of a meals system intended to meet the special needs of the elderly.[54]

Eventually, the project expanded to include the JSC, the Texas Research Institute of Mental Sciences, United Action for the Elderly (an affiliate of Meals on Wheels), and researchers from the University of Texas (both the School of Public Affairs in Austin and the UT Medical Branch in Galveston). The Army's Natick Research and Development Command also provided some support for the project, though this was not always publicly acknowledged.[55] The cost was around a quarter million dollars ($2 to $3 million in today's dollars), about half paid by NASA; the Texas Department of Public Welfare and the Ford Foundation also contributed money. Some of this funding went to an aerospace contractor, Martin Marietta, to develop the "meal system for the elderly" and run field tests.

Programs such as Meal System for the Elderly illustrate how issues and groups that were spotlighted by the era's political debates and social movements were incorporated into NASA's post-Apollo search for relevance. In the 1960s, Lyndon Johnson's Great Society programs had (briefly) made the alleviation of poverty in rural and urban areas and among people of color and the elderly a federal priority. Even though many of Johnson's programs were gone or in decline by 1974, those groups were still the ones that Meal System for the Elderly was intended to aid. Admittedly, none of NASA's publications about the meal system mentioned social justice or civil rights. Yet almost half the participants in the project's field trials were beneficiaries of the USDA Food Stamp program; two thirds were women, 44 percent were African American, and project reports identified another 29 percent as "Mexican-American."[56] Project reports suggested that the same meal system could benefit the nonelderly poor, people with physical or mental disabilities, and prisoners. All these were groups whose interests were promoted by the civil rights movement and the new social movements of the late 1960s and 1970s.

Perhaps unsurprisingly, NASA viewed the concerns of these movements through a paternalist prism. For instance, an official report suggested that the system could be useful to "some urban elderly [who] are within walking distance of stores, but fear to venture out of their homes."[57] A few sentences later the same report observed that

> Some also criticize the food stamp program, because it does not guarantee that recipients will buy food items that contribute to a balanced diet. Such a criticism might be quelled if a balanced, nutritious meal such as that developed by NASA were available for use by food stamp participants.[58]

Nor should it be surprising that attention to the needs of prisoners, the poor, people of color, and those with disabilities waned once NASA handed the project over to commercial manufacturers. At least two companies commercialized technologies developed within the Meal System for the Elderly program: Sky-Lab Foods and Oregon Freeze Dry Foods. In the end, though, these companies saw greater potential for profit from selling meals to campers or homeowners preparing hurricane kits than to people of limited means. These companies did market to some elderly users, as the original NASA program hoped. For instance, Oregon Freeze Dry advertised its Easy Meal as "Space Age Food, developed for Adults of Retirement Age."[59] Yet as figures 4.1 and 4.2 indicate, Easy Meal's imagined elderly customer was whiter and more middle-class than the Meal System for the Elderly's field trial participants.

That Meal System for the Elderly gave rise to a consumer product at all is probably a testament to the short leap from astronaut food to a

Figure 4.1
Fieldworker (right) demonstrating the Meal System for the Elderly in the home of a trial participant (left). *Source*: Technology Utilization Program, *Meal System for the Elderly*, JSC-11191 (Houston: Johnson Space Center, 1976), 9.

terrestrial analogue. Indeed, many of NASA's forays into public sector problems in the early 1970s involved fairly straightforward translations of aerospace technologies. For instance, NASA partnered with the Federal Aviation Administration to develop better air traffic control technologies, and with ERDA to create new designs for wind turbines (which are in some respects just giant propellers) and fuel-efficient airplane engines.[60] In other cases, though, NASA's relevance to solving social problems was thought to stem from its abstract expertise in systems engineering and "space age management" rather than a specific technology.[61] And in yet other cases NASA's engineers argued for the societal relevance of space technology by drawing debatable analogies between spaceflight and what

Figure 4.2
Publicity shot used in advertising for the Easy Meal line of products sold by Oregon Freeze Dry Foods. The company collaborated on the Meal System for the Elderly, as noted in its ads. The company's participation in the project was also noted by NASA, for instance in the publication this shot is taken from. *Source*: Technology Utilization Division, *Spinoff 1978: An Annual Report* (Washington, DC: NASA, 1978), 91.

they believed to be the typical situations of the people they claimed to be trying to help.

For instance, NASA staff with expertise in biomedicine and communications were deeply involved in a number of efforts to improve the delivery of health care to poor rural communities, especially those with a large proportion of ethnic minorities. These projects were justified on the basis of an explicit analogy between the remoteness and low population density of outer space and that of rural areas. As one proposal put it,

> The medical information obtained from an abnormal electrocardiogram on a crewman in space may be identical to that obtained from an electrocardiogram on a patient in a remote location on earth. A high resolution, slow scan TV presentation of an x-ray picture . . . from a space base crewman might be the same as that obtained from a farmer's x-ray taken and developed in a remote area health services unit on the ground and transmitted to a medical center. . . . After considering these parallels . . . NASA is considering the development of a demonstration program for a remote area health services system on earth as a necessary step to the agency's development and verification of a remote health services capability for space.[62]

This proposal later evolved into the STARPAHC (Space Technology Applied to Rural Papago Advanced Health Care) project, sited on the lands of the Tohono O'odham Nation in southern Arizona and begun in 1973. ("Papago" was at the time the common non-Indigenous term used for the Tohono O'odham.) Because the leader of STARPAHC, JSC's Sam Pool, became prominent in the telemedicine community, this project is frequently mentioned in histories of that technology, both by medical practitioners and by anthropologists and historians.[63] So far, though, STARPAHC has not been placed in the context of the space program's existential success and contemporary calls for the civilianization of NASA and of American R&D more generally.

Yet there are at least two reasons to place STARPAHC in exactly that context. First, Pool and his collaborators explicitly did so themselves. The proposal quoted earlier framed the project in terms of national needs articulated by the highest civil authorities:

> We also believe this earth based remote health services system demonstration project to have significant potential for general public benefit as well as for future space systems development. President Nixon pointed out in his message to Congress in February 1971 that, "For some Americans—especially those who live in remote rural areas or in the inner city—(health) care is simply not available." The Department of Health, Education and Welfare and the American Medical Association have endorsed the idea of "the provision of access to quality health care for every American. . . ." as a major national goal."[64]

The other reason to view STARPAHC in the context of NASA's existential success is that it was not unique. NASA was involved in nontelemedicine projects that treated communities on Tohono O'odham land as analogous to space capsules; in particular, in 1978 NASA's Lewis Research Center built an experimental solar farm to power the village of Schuchuli, Arizona.[65] With respect to telemedicine, NASA was involved in (or proposed as a partner for) STARPAHC-like efforts in rural areas of New Mexico, Nevada, Alaska, Missouri, northern Alabama, and the Permian Basin region of West Texas.[66] As with STARPAHC, these were economically disadvantaged areas with either majority-minority or substantial minority populations whose interests were being vocally represented in the 1970s by the civil rights movement, the American Indian Movement, the Chicano Movement, and other social justice movements of the day.

And, again, all these efforts did (or planned to) partner NASA and its aerospace vendors with nonspace organizations to make space technology societally relevant. In some of these projects, NASA led the collaboration. In STARPAHC, for instance, JSC personnel headed a team that included Lockheed; the Department of Health, Education, and Welfare; and the Tohono O'odham nation and its Executive Health Council. Similarly, for the Schuchuli solar farm, NASA Lewis Research Center personnel brought together support from the Department of Energy, the US Public Health Service, and the Tohono O'odham. In other projects, though, NASA seems to have been drafted in. For instance, a Remote Area Health Services Research Demonstration and Evaluation Project in New Mexico was run by the Physical Science Laboratory at New Mexico State University on behalf of the state's Health and Social Services Department, with

NASA and the Air Force's School of Aerospace Medicine brought in once the program was running. Either way, the 1970s were an era in which NASA and its vendors could not go it alone but instead needed (and had difficulty resisting) partnerships with organizations representing civil society.

SPACE AND THE CITY

Both Meal System for the Elderly and STARPAHC (and other telemedicine projects) operated primarily in rural areas. Yet urban problems were of at least equal concern within NASA for much of the 1970s. In fact, many of the publications issued by NASA's public sector projects pictured urban and rural areas as similarly amenable to interventions with aerospace technology. Sometimes this supposed similarity led to arguments that solutions to rural problems would also find application in cities and vice versa. As the researchers leading STARPAHC put it, "Consider groups who live in remote areas or, for that matter, in the inner cities who should have access to local health services and to the health care establishment."[67] At other times, the concentration of poverty in rural and urban areas was taken to mean that city and countryside would compete for scarce resources. As a report on the remote health care project in New Mexico put it, "More is heard of ghetto problems, but rural health care has suffered particularly because most young physicians . . . and their wives prefer to settle in urban areas. . . . Even ghetto practice is often near splendid medical centers."[68]

The sentiment is grating, but the author was correct that public discourse concerning urban problems was mounting rapidly in this era. Recall the Ngram from figure 1.5, where we saw a rise in mentions of "urban problems" and an "urban crisis" starting around 1964 and peaking in 1968 or 1969. Ngrams are a crude measure, but this periodization maps reasonably well onto the prevalence of talk about urban problems at NASA (with a little bureaucratic lag). It also maps onto aerospace firms' explorations of, for instance, new markets in public transportation and other urban infrastructure. Rohr Aircraft, for instance, became an important maker of city buses and subway systems in the early 1970s; later in the decade Rohr, and its mass transit products, were bought by a much larger aerospace firm, Grumman.[69] Other military–industrial companies tried to follow Rohr's lead, sometimes with poor results, as with Westinghouse's failed attempt to build controls for the Bay Area Rapid Transit system (today a classic case in engineering ethics).[70] Most companies dabbled for a few years, then pulled out. A good instance is Boeing's participation (with JPL oversight) in the Personal Rapid Transit system in Morgantown, West Virginia—which, though successfully built, never led to hoped-for replications in other US cities nor to any long-term business for Boeing.[71]

Even more than NASA, aerospace firms had to deal with their association with the war in Vietnam *and* budgetary cutbacks. Demonstrating the societal relevance of their expertise was an obvious answer to both problems; no form of societal relevance was more valorized in the early 1970s than relevance to the urban crisis. A good indicator is a 1970 pamphlet issued by the Aerospace Industries Association entitled *Aerospace Technology: Creating Social Progress*, in which "urban affairs" were the first site of "social progress" presented (figure 4.3).

In Nixon's America, though, there was considerable disagreement as to what urban problems were and how they should be addressed.[72] From the point of view of many in the New Left and the civil rights movement, the urban crisis was caused by institutions—including the institutions of American science and engineering such as NASA—that had a vested interest in bringing about, or at least doing nothing to reverse, the second-class citizenship of most city dwellers, especially those of color.[73] On the other hand, many Nixon voters no doubt believed that the urban crisis stemmed from what they saw as growing disregard for authority among African-Americans, young people, and the antiwar Left.[74]

From the point of view of NASA and aerospace companies, though, these differing explanations for the urban crisis simply meant that there was an even wider array of research topics by which they could make

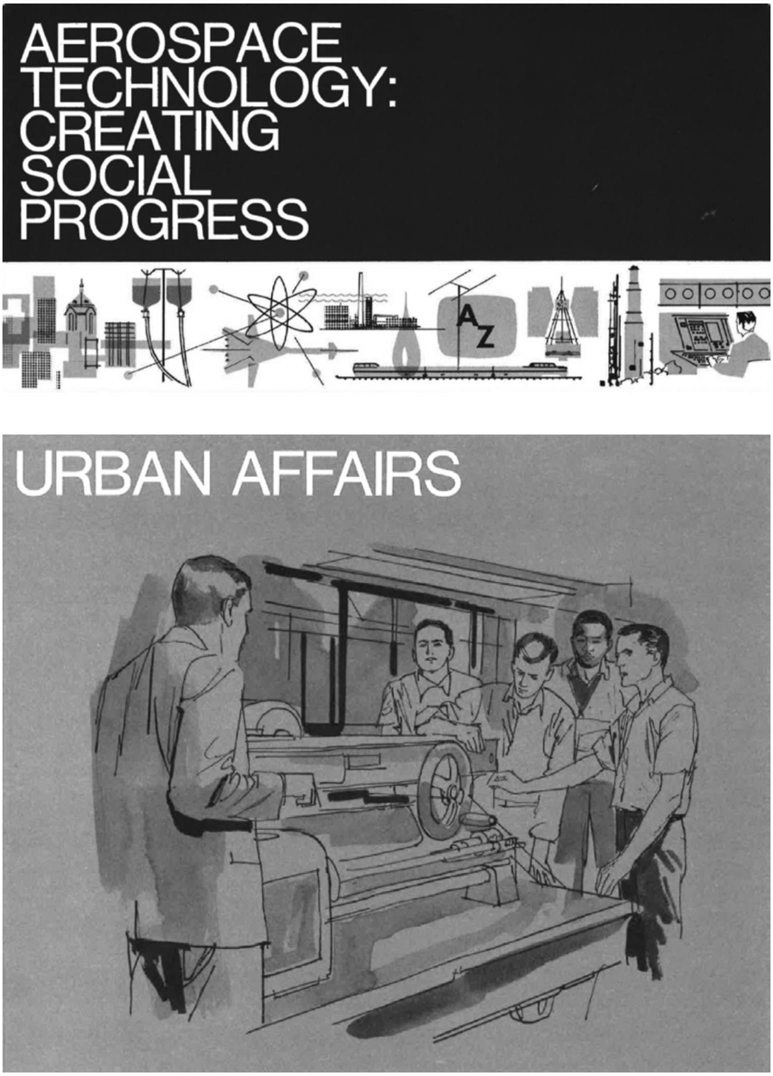

Figure 4.3
Cover and page 2 of *Aerospace Technology: Creating Social Progress* (Washington, DC: Aerospace Industries Association, undated but probably 1970). *Source*: Permission granted by the Aerospace Industries Association.

themselves relevant to the pressing social issues of the day. Thus, on the one hand, NASA (particularly JPL) and aerospace firms were deeply implicated in Nixon's "law and order" rhetoric aimed at harvesting the votes of white Democrats who disliked both the civil rights and antiwar movements. JPL had projects to help local law enforcement agencies communicate better with each other (using NASA's communications networking expertise) and to develop fingerprint recognition software for the FBI (using image processing software originally developed for the planetary probe program).[75] In 1974, JPL researchers even invented an Automated Drug Identification device to detect "drugs in blood or urine samples taken from suspected narcotics users" at the request of the Los Angeles Police Department.[76] JPL was hardly alone, though; for instance, its drug identification device was similar to a "portable device for detecting extraordinarily small amounts of heroin in a urine sample" developed by a short-lived NASA–New York City Applications Project in 1973.[77]

On the other hand, NASA also positioned itself relative to the "urban crisis" in a way that would put the Nixon administration in a good light with the nominally more liberal Nelson Rockefeller and George Romney wing of the Republican party. JPL, for instance, ran a multiyear "four cities program" in which the city managers of four municipalities (Anaheim, Pasadena, San Jose, and Fresno) were each teamed with a JPL engineer and an engineer from an aerospace firm (TRW, Lockheed, Aerojet, and Northrop) to see how aerospace and systems engineering might be applied to their cities' issues.[78] The AIA similarly coopted talk of an urban crisis in several different ways. On the one hand, its 1970 pamphlet bragged of AIA members' efforts in "school community relations . . . job training . . . city programming and budgeting . . . [and] justice, welfare studies."[79] The *first* illustration in that pamphlet, under "Urban Affairs," showed a group of young men—at least one of them seemingly African American—receiving vocational instruction from an (apparently white) aerospace engineer. The *second* illustration, however, showed two police officers surrounded by banks of computers under the caption "Information Systems."

At JSC, urban applications actually made their way onto the organizational chart in the form of an Urban Systems Project Office (USPO). This group was formed in 1972 with a staff of thirty-five, including both civil servants and contract personnel from Lockheed and Boeing.[80] The unit was NASA's stake in a project headed by HUD, which also included the Environmental Protection Agency and Oak Ridge National Laboratory (then part of the AEC). The NASA–HUD collaboration seems to have come about in part because HUD Secretary Romney had earlier poached his Assistant Secretary for Research and Technology, Harold Finger, from NASA. In the late 1960s Romney apparently hoped that Finger (and his NASA contacts) could bring space-age expertise to HUD while securing NASA's help in future collaborations. However, the HUD–NASA collaboration slipped from Romney's control when it was coopted by the New Technology Opportunities program, a high-profile Nixon administration initiative put forward in 1971 by William Magruder (a special assistant to Nixon) with help from Edward David (Nixon's science adviser) and others.[81]

The main focus of the NASA–HUD collaboration was the Modular Integrated Utility System (MIUS) project, which aimed to apply NASA expertise to making residential utility systems cheaper, more efficient, and friendlier to the environment. Again, as with STARPAHC, the promoters of MIUS invoked somewhat debatable analogies to tie their work to the national priorities set out by the administration:

> In his February, 1971, address on environmental quality, President Nixon said: "A great deal of our space research has been toward creating self-sustaining environments, in which people can live for long periods of time by reprocessing, recycling, and reusing the same materials. We need to apply this kind of thinking more consciously and more broadly to our pattern of use and disposal of materials here on earth." Programs have been conducted to develop semiclosed ecological systems to support crewmen for long-term space missions. The spacecraft for which these systems have been developed is, in many respects, a housing unit which must contend with many of the logistic supply and ecological problems we face on earth today.[82]

As the quote indicates, urban and environmental problems were, at this point in the 1970s, still closely aligned—a conjunction that environmental historians are starting to contend with.[83]

Indeed, this quote will sound familiar to environmental historians, who have documented a number of ties connecting the environmental movement with architecture and space capsule design.[84] Yet such studies have so far mostly focused on rather groovy groups such as the New Alchemists and the Biospherians and their plans for habitats for the few. The MIUS project, by contrast, was *very* square and aimed at an architecture for the many. Admittedly, there are indications that at the beginning of the project, some NASA engineers imagined their space technology embedded in futurist luxury homes à la John Lautner.[85] But relatively quickly they reoriented the project toward a type of large garden apartment complex commonly found in working-class neighborhoods in the Houston metropolitan area near the JSC.[86]

In applying their expertise to such mundane settings, however, MIUS engineers ran into an equally mundane but stubborn problem: lack of trust from other organizations, including both their erstwhile partners at HUD and potential competitors in the utility industry. Throughout the program, NASA engineers complained that "HUD doesn't really grasp our approach to the problem. Whatever the 'hang up,' we need to understand and correct it. If we don't it will be most difficult to justify" further funding.[87] JSC staff also thought that "HUD has been less than candid on their program funding availability."[88]

For its part, HUD viewed NASA as oblivious to the sensitive politics of housing, particularly the need to represent MIUS "as an alternate means of supplying services, to be employed by existing utility companies, and not an alternate to those entities."[89] It's likely that HUD faced pressure on this point both from the utilities themselves and from the Nixon administration. As one NASA engineer noted, the utilities "have heard of MIUS and the consensus seems to be 'The government is in competition with us,' especially the electric people."[90] Nixon's powerful

Office of Management and Budget, meanwhile, questioned the need for MIUS at all, arguing that "development and demonstration of subsystems is already underway in the private sector and in EPA and HUD" and that the HUD–NASA–AEC project should therefore be given low priority.[91]

To get around objections from utilities and to placate Nixon officials, NASA proposed to experiment with MIUS prototypes in situations where it would not compete with the private sector. For instance, in 1972 JSC's USPO conducted a "Mini-MIUS Feasibility Study" in partnership with the National Bureau of Standards and the EPA in an isolated village in Alaska that was not served by utility companies and that had access to only limited amounts of electricity supplied by diesel generator.[92] Similarly, John Ehrlichman (Nixon's Chief Domestic Adviser) argued that although MIUS was

> something that the private sector probably can and should do . . . there are two ways that we might finesse the problem and still get the job done. One was to use moral suasion with some of the major utility companies or equipment producing companies, such as GE, and encourage them to conduct the experiment. The other was to conduct the experiment the next time the Federal Government builds some large installation. Perhaps such an experiment might fit into plans for a major rehabilitation of a defense base.[93]

We'll see again in chapter 5 that efforts to convert military–industrial R&D to address civilian problems often ran afoul of established civilian actors—and that a common proposal for overcoming such obstacles was to fall back on the military as a captive market.

But an even more fundamental issue led to the cancellation of MIUS and closure of the USPO: money. During NASA's peak years of the mid-1960s, its engineers could request almost any amount of money to help them build components for a one-of-a-kind space vehicle that would be used once and thrown away. As Diane Vaughan showed in her study of the 1986 Challenger disaster, that mindset persisted at NASA long after the agency's budgets declined.[94] HUD, by contrast, had never received sufficient funding, much less the superabundance that NASA experienced in the 1960s. HUD therefore needed MIUS to yield something cheap and scalable to thousands of housing units.

It was only after the project started that the two agencies realized that their different budgetary histories led to divergent expectations. As a 1981 report on MIUS put it,

> After about 6 months of intensive design work [i.e., late 1972 or early 1973], the USPO team made its first presentation to HUD, and was shocked to find out that HUD did not intend to use advanced technology but, instead, planned to build MIUS systems using only existing equipment. HUD set a new rule for the project—only bondable catalog-available hardware could be used in the MIUS development."[95]

From that point on, JSC staff complained that they were "constrained by the guidelines which require that we consider only off-the-shelf hardware. This precludes the inclusion of solar space heating and fuel cells and other attractive technologies in our design studies."[96]

In other words, for JSC engineers, the scheme was too *low-tech*, and they continued adding in higher-tech, designed-from-scratch elements. But for HUD, even the initial design was too *high-tech*; they would never be able to get developers to include it without a government subsidy, which HUD was never in a position to supply. From HUD's vantage, NASA's continued involvement only made things worse! These disagreements, plus the increasing pace of the shuttle program, meant that JSC director Chris Kraft began looking for ways to extricate NASA. With the New Technology Opportunities program canceled and one of its proponents, Edward David, forced out of the Nixon administration in 1973, Kraft saw his chance. The next year he abruptly cancelled future MIUS planning and started winding the project down to a close in 1976.

As USPO Deputy Manager Harold Benson reported it, Kraft reminded project personnel that

> they were working for the Manned Spacecraft Center and that what they were working on was not in any way related to manned space. Dr. Kraft went on to say that the JSC has the best engineers in the world, and the world is full of problems; if he would allow his engineers to go to work on all the world's problems, they would fragment the agency and the NASA's mission.[97]

By that logic, though, the USPO should never have been formed. Yet it was formed, and it received resources and personnel so long as urban problems were a major focus of the Nixon administration and so long as the shuttle was only in the planning stages at JSC. In 1970 to 1971, as the Apollo program was winding down, much of the American public and government believed that "NASA has a competence which should be used to complement HUD's activities in developing new housing."[98] It was only later that a project aimed at improving multifamily housing no longer seemed desirable within America's space agency.

CRISIS CREEP ONE: URBAN TO ENVIRONMENT AND ENERGY AT JSC

JSC's USPO, JPL's Four Cities Program, and similar projects of the early 1970s briefly focused NASA's attention on the urban crisis. By 1973, though, that attention was wandering, especially to environmental and then to energy issues. Before then, energy and environment were seen to a significant extent as subordinate *parts* of the urban crisis, rather than as separate issues. As the MIUS prospectus put it in 1971,

> The expanding population, the decay of our cities, and the continued demand to increase the American standard of living have created a shortage of acceptable housing which can be afforded by all U.S. citizens. However, providing these new home units should be considered an opportunity as well as a problem. This new generation of homes not only should be as economical, livable, and durable as possible, but also should be designed to improve fire safety, to minimize environmental pollution, and to conserve water, energy fuels, and electrical power.[99]

After 1973, though, use of the keyword "urban" dropped away and environmental and energy projects came to the fore in their own right. There was still an urban dimension to some of these projects—for example, studies of the aerodynamics of subway trains in tunnels—but their "urban-ness" was deemphasized in favor of their relevance to energy conservation, pollution reduction, and other topics.[100]

At JSC, energy and environmental research flourished in the mid-1970s—but in a relatively chaotic, uncoordinated way. There were a number of small efforts, some in partnership with local aerospace companies or social groups. For instance, the Rotary Club of Space Center spawned an Earth Awareness Foundation that partnered with JSC to assist a group of local high school students in a water quality monitoring project.[101] JSC engineers themselves built a "trailer-mounted automated water monitoring system" in partnership with Boeing and the Gulf Coast Waste Disposal Authority.[102] JSC was also brought into a solar energy project that involved HUD, the Bureau of Standards, and the NSF, as mandated by the Solar Heating and Cooling Demonstration Act of 1974.[103]

Two energy and environmental efforts did gain some longer-term traction at JSC, one involving the "real NASA" and one the "paper NASA." The former was the Earth Resources Survey Program Office, which served as JSC's stake in the Landsat remote-sensing project. The Landsat program has already received quite a bit of attention from historians for two reasons: first, it shows how NASA responded to the growing environmental movement; and second, Landsat's later privatization shows how commercial objectives increasingly permeated the agency from the late 1970s onward.[104] I would simply add that there were ways in which Landsat linked to the concerns of the long 1970s beyond environmentalism. For instance, JSC proudly drew attention to Landsat's use on behalf of indigenous communities.[105] Similarly, JSC partnered with the University of Texas School of Public Health on a remote sensing project to monitor how changes in land use affected public health—a topic that incorporates but goes beyond environmental monitoring, and which is also rather difficult to imagine getting much attention during Landsat's later, commercial phase.[106]

The "paper" JSC, meanwhile, was deeply involved in one of the wildest, most hubristic proposals of the era: a solar power satellite (SPS). This would have been a permanent crewed solar farm in space, collecting photovoltaic energy and converting it into electromagnetic radiation to beam to earth, where it would be converted into electricity. The idea has a long history, but its modern form is usually credited to Peter Glaser, an engineer at the Arthur D. Little Corporation, who gave a much-cited talk on the subject in 1968. In 1971 Glaser wrote a proposal for an SPS that somehow reached William Magruder (among others).[107] The idea then seems to have languished until it was taken up by Gerard O'Neill as a way to justify the enormous expense of building giant space "colonies." Patrick McCray has documented how O'Neill and other "visioneers"—supported by technophile impresarios such as Stewart Brand—publicized the SPS concept.[108] The interest that they stoked led to pressure on NASA to investigate the idea, and in 1976 JSC issued a call for proposals for an SPS "system definition study." That study was awarded to Boeing, which then undertook a wide-ranging examination of the engineering requirements of a hypothetical SPS.[109]

As Jeff Womack argues, JSC leadership saw the SPS largely as an opportunity to keep people occupied and to think through engineering issues of likely relevance to projects that NASA was more seriously contemplating (such as what later became the International Space Station).[110] There is little evidence that NASA was enthusiastic about the prospect of beaming vast amounts of energy into the earth's atmosphere, most likely aimed at points in proximity to urban areas (such that a very small error in beam alignment could result in costly damage or even fatalities). Nevertheless, JSC's initial study soon morphed into a more ambitious assessment led by the Department of Energy.[111] This project, in which NASA continued to be involved, persisted even after the shuttle began flying—a testament, as Womack argues, to the bureaucracy's ability to hijack crisis talk to ensure the bureaucracy's own continuing work.

CRISIS CREEP TWO: JPL'S "DUAL MISSION"

At JPL, R&D oriented to public-sector projects, and then alternative energy and energy conservation, was centrally coordinated much more than at JSC. In 1969, the lab formed a Civil Systems Projects Office, which housed a growing portfolio of work in biomedicine, urban affairs, criminology, environmental monitoring and remediation, alternative energy, and assorted other topics such as an automated system for taking attendance in schools![112] A few, broadly similar projects were also paid for from the Director's Discretionary Fund, but for the most part the Civil

Systems office oversaw JPL's overtures to societal relevance. That meant that JPL's public sector work could be steered more effectively than the scattered efforts at JSC.

Thus, when JPL signed a memorandum of understanding in 1975 with ERDA (later renewed when ERDA became the Department of Energy [DOE]), the Civil Systems office turned sharply in the direction of energy research. Other projects were mostly set aside, and by 1978 the office had been renamed Energy and Technology Applications.[113] Under the memorandum of understanding, ERDA–DOE referred a varied portfolio of projects to JPL. Some were short-term, rather mundane contracts, such as testing the fuel efficiency of modified engines placed in AMC Pacers and Volkswagen Rabbits.[114] Rather deliciously, the site where these "test vehicles" were driven was a runway at Edwards Air Force Base, a location better known for the X-plane flights chronicled in *The Right Stuff*.

The largest and most enduring projects operating under the agreement with ERDA–DOE, though, were in solar energy, particularly the Low-Cost Solar Array Project and the Thermal Power Systems Project.[115] We will return to JPL's solar activities in chapter 5 when we look at a residential solar energy system developed by Texas Instruments; that's because "the Department of Energy has assigned the Laboratory as the lead center for the national photovoltaic program" in 1978.[116] Thus, anyone wanting or receiving federal funding for solar R&D in the late 1970s had to contend with JPL's experts. As we'll see in chapter 5, not everyone was happy about JPL's role as the American solar community's obligatory passage point.

Indeed, JPL sometimes gave people plenty to be unhappy about. Moving from space into civil systems required the lab to acquire expertise with which its personnel were unfamiliar and sometimes uncomfortable. For instance, ERDA commissioned a series of reports on coal mining that were, in part, technological, but which also involved sociological studies of coal mining communities and even historical and philosophical studies of the acceptance of new technologies.[117] These forays into new territory were sometimes scientifically unsound and sometimes politically inept—and sometimes both. Perhaps the most glaring example is a 1975 report on "alternative automotive powerplants" entitled "Should We Have a New Engine?" (JPL SP 43–17).[118] Although this research was funded by Ford Motor Company (with some assistance from Chrysler), it provoked such heated opposition from across the entire car industry that JPL later had to issue a "Compendium of Critiques of JPL Report SP 43–17."[119]

The potential for JPL's civil systems researchers to venture out onto interdisciplinary thin ice elicited considerable concern from Caltech faculty, who were afraid that their reputations would be damaged or that they would have to clean up JPL's mess. Caltech—with its small and until 1970 all-male student body of scientists and engineers—was never home to an organized anti-JPL movement similar to the anti-SRI movement at Stanford.[120] But divestment initiatives on other campuses did spur a 1970 report on Caltech–JPL relations that recommended some mild reforms, even if it generally "found the JPL connection sound and worthwhile."[121] The 1970 report didn't settle matters, however. "As the Civil Systems Operations at JPL have expanded, conflicts have arisen between JPL and the [Caltech] Faculty over the question of the competence of JPL to undertake work in certain areas," leading to a new study of JPL's status in 1976.[122]

From Caltech's side, the concern was that JPL staff were unqualified to pursue civil systems work that was so far removed from missiles, space tracking, and planetary probe technology. JPL staff didn't disagree, per se—they simply viewed civil systems R&D as necessary given the lab's budgetary situation, and appropriate given the nature of engineering knowledge. As a former JPL engineer wrote to the Caltech Ad Hoc Study Group on JPL/Campus Interaction in 1976:

> Currently, much effort at JPL is being directed toward programs pertaining to the so-called civil systems sector. These activities involve issues and problems of a socio-economic and health care nature. These are certainly a large step away from past experiences with space and military matters. Again, a Caltech faculty member views the Laboratory's movement in this direction with much unease and concern. Why is there concern and uneasiness? . . . [T]he civil systems program involves personal interaction with the public on issues which are complex and difficult. . . . Caltech today is primarily a body of scientific talent. It had at

> one time some considerable engineering skill, but little today. . . . Unfortunately, some of the Caltech faculty is alarmed by these steps and arrogantly demands, “What are those clowns at JPL up to now? We must monitor what they are doing closely or they will wreck our reputations.” I question who should be monitoring whom in a situation such as this, because by instruction, training, and experience, engineers are expected to work with the public, certainly to a greater degree than is the scientist.[123]

Not that this engineer’s views should be taken at face value: Caltech still had plenty of engineers, such as John Pierce (Rudi Kompfner and Calvin Quate’s former Bell Labs colleague and one of John Chowning’s computer music mentors). Although Pierce seems not to have worried that JPL would harm Caltech’s reputation, he did believe “If JPL cannot in any large and useful way be successful in energy without a change in form, then either JPL will have to drop energy or it will have to change form.”[124]

For a time, it seemed as though JPL *would* “change form” to accommodate energy R&D. In 1978, when Civil Systems changed its named to Energy and Technology Applications, energy R&D constituted “about one-seventh of JPL’s total activity” or possibly closer to one-fifth of JPL’s “manpower distribution.”[125] The lab’s director, Bruce Murray, was at that point broadcasting that “JPL is well along toward the goal of a dual mission, in energy and space.”[126] Yet JPL’s commitment to its new mission in energy was light, and based more on institutional survival than on a clear vision for renewable energy. As one Civil Systems manager put it, “JPL’s decision to favor energy over biomedical systems seems based primarily on which gets the most federal budget, which makes sense only if one expects JPL’s competence in an area to be marginal”—a view supported by Caltech faculty members who worried that “quality is quite uneven” in the Civil Systems program.[127]

When Ronald Reagan took office in 1981, therefore, JPL’s shift toward energy R&D was halted. Reagan was opposed to federal agencies competing with private interests, and he particularly disliked federal support for alternative energy and energy conservation. He had also run on a platform of reintensifying the armed standoff with the Soviet Union. As we will see again in chapter 6, the new administration slashed federal alternative energy funding, including at JPL. By 1983 "reduced federal priorities in energy [resulted in] a decidedly smaller effort in Civil Programs," with DOE work down to 8 percent of JPL activities, down from a high of more than 14 percent.[128] To avoid mass layoffs Murray made up for the losses by seeking military contracts. As he told his management committee in 1982, "the only *really* urgent matter . . . is: what is our best strategy for achieving rapid growth of DOD business, and what actions do we need to take to support it?"[129]

EXISTENTIAL SUCCESS, THE LONG 1970S, AND SPACE HISTORY

And with that, the long 1970s came to an end at JPL. There, and at NASA's other facilities, the public sector projects I've surveyed left few traces. A few endured in some form—most notably Sam Pool's experiments with telemedicine—but even major efforts like MIUS or JPL's Low-Cost Solar Array Project had disappeared almost completely by the mid-1980s. The cultural and political changes of the long 1970s did leave an imprint on NASA itself—the space program became more diverse, as symbolized in particular by an astronaut corps that began to include women, non-whites, non-Americans, and more civilians. These changes have indeed drawn much attention from historians.[130] But their connection—or lack thereof—to NASA's brief interest in civilian, terrestrial social relevance has not been much explored, with the notable exception of Neil Maher's *Apollo in the Age of Aquarius.*[131]

My analysis does not significantly complicate Maher's. Like him, I want to put the "who" of NASA in the 1970s in the same frame as the "what." That is, like Maher I argue that the space program's shifts in personnel that were inspired by the civil rights movement and second-wave feminism are not separable from its ventures into alternative energy that were inspired by the environmental movement. A nice emblem of this confluence is a 1975 newsletter from NASA's Goddard Space Flight Center in Greenbelt, Maryland, which juxtaposed an article about a collaboration with the Greenbelt municipality to develop energy conservation and solar heating technologies; a photo essay on Goddard's observation of Black History Week; and a profile of John Bogert, a blind computer programmer and user of a commercial version of the Stanford Optacon.[132] These different strands of the 1970s were entangled at the time, even if some of them left few traces in the organization—or in the organization's historical memory—today.

What this chapter adds to Maher's argument is the concept of existential success as a way of understanding the near-inevitability, and the contours, of NASA's predicament in the long 1970s. It is hard to imagine a scenario in which NASA could have avoided severe budget cuts in the early 1970s. Some outflow of personnel to other organizations—and the export of space-age expertise to those organizations—was therefore close to inevitable. It is perhaps easier to imagine NASA avoiding entanglements with the era's socially relevant research agenda, and certainly much of NASA did remain aloof from civil society. But at the time many actors were trying to guide NASA in that direction, and for many people within NASA engagement with public sector projects was the best (or only) option available.

I have also argued that NASA's predicament in the long 1970s casts light on the situation of American science and engineering more generally. I have therefore drawn out parallels between, for instance, the Meal System for the Elderly project and some of the Master of Scientific Instrumentation theses surveyed in chapter 2 or the acoustic microscope in chapter 3. Those parallels are probably clearest when talking about the origins of socially relevant projects; but the concept of existential success also tells us something about why these projects mostly petered out. Socially relevant R&D flourished in a time when one existential mission had ended and a new one was not yet in place. By the end of the 1970s, though, NASA had been given a new set of priorities—priorities that did not include nearly as much room for urban, environmental, or energy research.

Those new priorities were varied and sometimes contradictory: to support remobilization for the Cold War; to improve diplomatic relations with Europe, the Pacific Rim, the Soviet bloc, and elsewhere; to assist private industry in the commercialization of space; and to give taxpayers an accountable return on the use of "their" money.[133] Together, those new priorities allowed NASA to justify a fairly stable budget; but none of these priorities uniquely justified NASA's *existence* in the way that the space race had. NASA's history since July 20, 1969, has therefore seen a fairly steady if gradual decline in funding and public faith.

The same applies to American science and engineering more generally. From the end of World War II until the late 1960s, there was a clear mission justifying the government's investment in (and the public's deference to) American science and engineering: to contribute prestigious discoveries, militarily valuable technology, and mobilizable personnel to the struggle against communism. That mission lost priority in the late 1960s—that is, it no longer functioned as an existential mission. Through the early 1970s American scientists and engineers bumped from one new existential mission to another: urban problems, environmental problems, the energy crisis, global economic competition. By the late 1970s some of the same priorities that took hold at NASA had begun to restructure American science and engineering more generally. But, again, those new priorities were sometimes contradictory, and none could uniquely justify the enterprise as a whole to its various beneficiaries. After 1970, no one thought that they were getting everything that they wanted in return for their support of American scientists and engineers. The history of the American R&D enterprise since July 20, 1969, has thus been one of long-term decline in public funding and public faith as well.

The Squares

US Physical and Engineering Scientists in the Long 1970s

By: Cyrus C. M. Mody

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