Selling the Space Age: NASA and Earth's Environment, 1958–1990

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ABSTRACT

The National Aeronautics and Space Administration (NASA) was created in 1958 to develop America's non-military space effort. But the early leaders of a self-consciously elite science and technology agency rarely saw Earth as a part of 'space' or solar system exploration. This is clear when examining NASA's relations with earthly applications in the late 1950s and 1960s and with fast-emergent environmentalism in the 1970s and 1980s. NASA consistently misread the importance of the most popular science-based political movement of the late twentieth century. NASA was advised from 1959 onwards that earthly concerns – and practical worldly benefits – were necessary to create broad and enduring support for space explorations. Despite this, NASA leaders consistently underestimated, ignored or spun-off Earth 'applications' in the formative period of America's civilian space programme. Power and prestige-focused human spaceflight, Moon and Mars missions, and human settlement of the solar system, became NASA's enduring 'human spaceflight culture'.

KEY WORDS

Environmentalism, space exploration, space policy, earth resource satellites, ecology and state, United States, astronautics

Political ironies abounded in the early space age. Earthly frontiers are developed for use, resources, settlement, profit and protection. NASA's space frontiers, however, normally lack all these characteristics. Fifty years after the birth of the Space Age, space advocates are only beginning to understand that the cosmic place most people care about most deeply is Earth. NASA became a major player in Earth science in the late 1980s. Overall, however, it lagged behind

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much ecological, climatological and other research undertaken by other agencies and nations into the 1990s. NASA's institutional blinders and group-think failed to connect it strongly to the major science-based social movement of the late twentieth and early twenty-first centuries.

In July of 1973, the top two managers at the National Aeronautics and Space Administration (NASA) considered a proposal. NASA headquarters' Public Affairs director had been pushing Administrator Dr James C. Fletcher and Deputy Administrator George M. Low about it 'for quite some time'. The idea was, Low recorded, that 'we consider, for P[ublic] R[elations] purposes, the entire NASA program in terms of an environmental theme: the Study of the Earth and Its Environment'.[1]

The 'PR' proposal was clearly relevant. NASA's budget and workforce had fallen by one-third since the Apollo II lunar landing of July 1969. It was over three years since the first Earth Day in April 1970. As lunar and planetary enthusiasms lagged, earthly environmentalism had transformed from a collection of local, state-based and specialised groups into a large and growing national and international movement. Five important national environmental organisations including the Natural Resources Defense Council and Friends of the Earth came into existence in the US between 1967 and 1971. Older conservationist groups like the Sierra Club and the National Audubon Society had their memberships double and redouble. Congress took note. The first strong Clean Air Act and the Environmental Protection Agency were legislated into existence in 1970 as NASA's first effort to inaugurate a thirty-year Apollo programme for Mars failed utterly. Most poll respondents wanted NASA spending cut. Public concern with pollution and ecology as an 'important national problem', however, simultaneously rose from one in a hundred to one in every five respondents, and, to the surprise of many pollsters, stayed high. Sixty to ninety per cent of Americans wanted higher spending for cleaner air and water, or for environmental improvements generally. Prominent big business executives who had equated 1960s ecology and product safety efforts by reform-minded public interest lawyers like Ralph Nader with fads 'of the same order as the hula hoop' now muted their voices. Nader wasn't going away; environmentalism wasn't either. By 4 January 1971, even conservative *Time* magazine claimed environmentalism was the 'issue of the year' and was 'a national obsession'.[2]

The view from the top at NASA, however, was very different. 'Fletcher and I', Low noted in his diary,

> have discussed this [environmental theme for NASA] on several occasions and were generally disenchanted with the idea, first, because it doesn't really represent the truth, and secondly, because we believe that the environmental theme in the country as a whole will soon be outdated. In other words, we may be jumping on a bandwagon just about the time everybody else is jumping off.[3]

Low and Fletcher thus avoided trying to improve NASA's fading political and budgetary fortunes by attaching what the agency did to the most dynamic and popular science-based mass movement of the age – even though one of NASA's dozen labs (Goddard Research Center in Maryland) had important earthly interests and expertise. Vague pieties, instead, substituted for policy change. Fletcher, for instance, claimed NASA 'could be called an environmental Agency' because 'space is our environment' and because 'virtually everything we do, manned or unmanned, science or applications, helps in some practical way to improve [or understand] the environment of our planet…' to the Senate space committee later that year. Despite such testimony, Low privately admitted NASA had no 'uniform or unifying approach' to explaining what it did; and, instead explained itself 'only in terms of specific projects' in scores of different scientific specialties.[4]

UNDERSTANDING EARTH

Presuming environmentalism was passé in 1973 was not the first time NASA's leaders had misread the shape of things to come – or the shape of things that already were. From NASA's formative years, it had consistently mishandled opportunities to increase its political support by providing practical and understandable earthly services to citizens and taxpayers.

Mistakes, selective perception and bureaucratic rationalisation for inactivity all began early. A few weeks after the *New York Times* and the *Washington Post* observed Sputnik 1's first anniversary by complaining that a supposedly fickle and uncaring public had lost interest in US space efforts, the Administrator of NASA sought expert advice about gaining popular support for his new agency. T. Keith Glennan, his number two man Hugh L. Dryden and NASA's chief counsel John A. Johnson met with nine experts from Harvard, MIT, Yale, Columbia, Illinois, the Social Science Research Council, the Council on Foreign Relations and the RAND Corporation.

'It is probably not enough', the social science advisors concluded, 'to base our interest in space research and space activities on either (a) military factors or (b) competition with Russia.' Cold War power and prestige races weren't going to legitimise space explorations officially cast in primarily peaceful and scientific terms. In addition to making international agreements and drawing clearer lines between military and civilian space programmes, NASA had to pay close attention to 'public education, public understanding, and public support'. This meant NASA had to listen and learn – not just instruct. It needed to know what interested and informed people most wanted done in space. Strong candidates included space-based weather and communications satellites, with clear worldly benefits.[5]

Keith Glennan, however, was someone who avoided extended and informal meetings with journalists during his two and a half years as NASA's first Administrator. He wanted Americans to love science, learning, liberty and capitalism. But social scientists asked Glennan what kinds of support he wanted from what sector(s) of the population? People – or Congresspeople – weren't going to write blank cheques for all kinds of science and for space exploration simultaneously – and Glennan knew it. Which specific priorities were voters or Congresspeople supposed to support; and what specific non-military, non-Cold War prestige race advantages were NASA's programmes supposed to provide? At a time when only one in ten Americans could specify scientific applications for satellites; one in four knew that any such uses existed; and only one in five were even vaguely aware of new military uses of space, clarifying such issues was important politically.[6]

Despite this, Glennan downplayed his blue ribbon panel's advice about making earthly applications satellites central to NASA's programme. A year later he and a high-level presidential advisory committee opted for a Cold War global prestige-based rationale for NASA centered on the Gemini and Apollo manned spaceflight programmes.[7]

As NASA leaders accented Cold War power and prestige rationales and 'space races', practical applications became a poor relation. The Moon and Mars mattered more than the Earth. This was ironic. Congress modelled NASA on an Atomic Energy Commission whose nuclear mandates were civilian, commercial, energy-centred, military and even medical. New technologies like weather and communications satellites illustrated NASA's relative unconcern with worldly matters. The NASA Act was also written broadly, not narrowly. Space was a place, not a programme. NASA leaders had a menu of responsibilities. NASA was a research and development (R&D) operation to create air and space vehicles. It was to keep the US an aerospace leader and share relevant findings with military agencies. But that is not all it was supposed to do. The legislation creating NASA also said it should do long-range technical and social studies to maximise social understanding and use of aeronautical and space projects for peaceful and scientific purposes. It was also to cooperate with 'all interested agencies' of government to perform 'such other activities as may be required for the exploration of space'. NASA, for instance, needed to locate, track, control and communicate with varied spacecraft and satellites. It built a global Deep Space Network to accomplish this, operated it, and regularly shared access with others.[8]

NASA'S TWO CULTURES

The Deep Space Network was part of an Army Ballistic Missile Agency (or ABMA) in-house or 'arsenal' subculture of NASA's early years. Army rocket-

eers like Wernher Von Braun had designed, built and operated America's first orbital satellite, Explorer I, in January of 1958. To gain their rocketry expertise, first NASA chief Glennan convinced retired Army general President Dwight D. Eisenhower to move ABMA into the new space agency in 1959 and 1960 over sometimes-strenuous Army opposition. Ex-ABMA people in Von Braun's rocket facility in what became the Marshall Spaceflight Center in Huntsville, Alabama were used to creating things in-house and then operating them. So, key portions of the huge orbital and lunar rockets like the Saturn 1-B and the Saturn 5 were accordingly built in Huntsville (where no fewer then one-quarter of all NASA employees worked in the early 1960s). They were initially launched at what became the Kennedy Space Center in Florida by ex-ABMA operations chiefs. Since JPL was also an Army created and funded lab with long ABMA associations, it, too, was accustomed to building, and operating and tracking, planetary spacecraft in-house.[9]

The ABMA almost-half of NASA employees in its formative years, however, were joined to another quite different, and dominant, half. This half was the National Advisory Committee for Aeronautics (or NACA). NACA was a federal research and development lab that had no in-house, operational, or 'arsenal' tradition. It was an R&D-only operation which designed things and sometimes built prototypes and 'technology demonstrators'. Once it had completed this 'mission', however, NACA promptly handed whatever it had accomplished off to private sector aerospace firms or to other government agencies for further development and for all operational purposes.[10]

NACA's 'R&D only' traditions subsumed the ABMA's 'arsenal' and internal development and operations folkways in NASA's formative years. The head of NACA, not of ABMA, was NASA's top deputy administrator from 1958 to 1965. Hugh L. Dryden of NACA and NASA had no desire to take on uncustomary activities. NASA, to Dryden and men like him – including Keith Glennan – should develop things and launch satellites. But it should not go looking for operational, service-providing, roles that might even conceivably interfere with the missions given to other government agencies, or compete in any fashion with private or state-sponsored corporations.[11]

The difference between the NACA and the ABMA approach is illustrated in how NASA Deputy Administrator Hugh L. Dryden and Dr. William L. Pickering, director of the Jet Propulsion Laboratory in Pasadena, California, responded to early space initiatives by other civilian government agencies, or to policy debates within NASA's top leadership. In May of 1960, the chief of the US Weather Service wrote to Dryden politely informing him that he was going to ask Congress for more R&D money for his agency. The world's first meteorological satellite, Tiros 1, had just started transmitting data. NASA had largely built this satellite; and would build and operate others for the Weather Service. Doing such things 'for research purposes', Dryden replied, was all NASA's mission involved. 'NASA', he added, 'has recognized from the beginning that research

in meteorology…and the exploitation of data from weather satellites either for research purposes or for weather forecasting are not within the function assigned to NASA by the NASA Act of 1958.' No legislative history of NASA exists to clarify the point. What is clear is that Dryden's decision demonstrated the NACA R&D-only tradition. Climatological research (which was not then part of the major missions of the Weather Service) was not undertaken by NASA.[12]

Instead, meteorologists, ecologists and oceanographers joined forces. There was a second civilian space agency, the National Oceanic and Atmospheric Administration (or NOAA), half of whose budget went to weather satellites and climate research, after 1970. None of NOAA's post-Earth Day accomplishments benefited NASA. These achievements included discovery of an ozone hole over the Antarctic in 1985, causing political agreement which began the phasing-out of chemicals like chlorofluorocarbons degrading Earth's atmosphere and demonstrated the need for enhanced global environmental awareness.[13]

Combinations of weather satellites, supercomputers and computer modelling also quietly revolutionised the ways hundreds of millions of people looked at deforestation, global warming and other environmental issues from the 1970s to the 1990s. Yet NASA remained only marginally involved in that process until the 1990s.[14]

A top aide Dryden worked with in the 1960s later used the weather satellite decision as his best example of NASA's 'frontier mentality' in conversation with the policy historian Howard E. McCurdy. He recalled that NASA leaders 'had a yelling and screaming session [for] several days' when the final transfer of technology development and operations went to the Weather Service in 1965. But NASA was 'not an operational agency, and we never pretended we were'. McCurdy observed that 'operational agencies concentrate on mastering routine. Most NASA officials concentrated on new frontiers. When a NASA programme moved out of the research and development phase and became operational, the dominant philosophy required that it be spun off to another agency'. Then citing one of 'NASA's leading space scientists', McCurdy closed his discussion with the thought that:

> Designing something and getting it to operate smoothly, nicely, so that you can use it time and time again forever is not something that gives great numbers of our [NASA] engineers the jollies.[15]

Yelling and screaming took place within NASA for several days in 1965, however, precisely because the frontier mentality and the NACA R&D-only approach was the 'dominant', but not the only, way of doing things or thinking about them within NASA. NASA was – and remains – a decentralised agency in which the now-twelve laboratory directors at facilities all around the country possess large degrees of authority. One of these directors was William L. Pickering of the Jet Propulsion Laboratory, or JPL. Pickering, a graduate of the California

Institute of Technology in America's aerospace heartland, saw earthly applications – especially via geosynchronous orbiting weather and communications satellites that NASA technically pioneered – had 'public utility' aspects which NASA should prominently identify and involve itself with to sell its frontier exploration and political prestige projects.[16]

Pickering's arguments were never made to newspapers, but at two of NASA's semi-annual conferences for top staff in October of 1960 and March of 1961, and in speeches to expert audiences. During that time, key decisions were made to take NASA out of not only weather/climatology matters, but also out of the fledgling communications satellite industry: another technical arena in which NASA was early and importantly involved.[17].

Pickering disputed Dryden's R&D-only approach. He wanted NASA to maintain the 'dominant role' in partnerships with both the US Weather Service and with private telecommunications corporations. He saw the satellite design, launch and communication infrastructure NASA possessed as equivalent to a government-built hydroelectric dam from which others could purchase or draw energy benefits. Meteorological and communications satellites, Pickering also believed, showed the 'man in the street' the concrete advantages of space explorations; while the 'international public' would learn the prestige and power lessons from US 'lunar and planetary achievement'. To a prescient and un-radical Pickering, the fundamental political problem of the Space Age was that the taxpayer paying for progressively more expensive prestige-based space missions was 'ultimately going to revolt against paying rather large bills for something he really doesn't understand'. Practical earthly advantages directly connected to NASA were thus a basic political necessity.[18]

Pickering's voice was not a lonely one at the October 1960 gathering of top staff debating 'Where Should NASA's Program Be Headed'. Ira H. Abbott, a 30-year government aerospace research veteran then directing NASA's Office of Advanced Research Programs, seconded Pickering. Earthly applications were 'perhaps our most important area'. NASA should cooperate with industry and other government agencies, but 'should not take too modest a view of its own role' and must 'exercise leadership'. 'The psychological impact of practical applications is great.' Echoing this leadership argument, the head of NASA's oldest lab concluded NASA had a 'statutory duty to exploit space for peaceful purposes, and no other agency has a comparable duty'.[19]

Despite such divisions within NASA, Administrator Glennan, Deputy Administrator Dryden and Glennan's successor James Webb pushed the two highest profile early earthly aspects of space out of their agency by late 1962. Despite loud Senate opposition regarding comsats, NASA administrators ignored Pickering's public utility arguments. Their preferred solution to selling space exploration and development was John F. Kennedy's Cold War power and prestige-rationalised 'space race' Apollo lunar programme of May 1961.[20]

WARNINGS AND DENIALS

Shortly afterwards, in January of 1962, as John Glenn prepared to become the US's first orbital astronaut, the editors of *Aviation Week and Space Technology*, premier trade magazine for the aerospace industry, begged to differ from this analysis. They accurately warned that extraterrestrial power and prestige alone could not guarantee a future for the space programme. Congress expected huge investments in space to pay off in clear earthly benefits for taxpayers. Unless NASA provided 'lucid, effective explanation to Congress and the American people of the full technical and economic significance of the Apollo program [starting to account for a widely-reported 70 per cent of the agency's budget]…they can expect a reaction of public and Congressional indifference in 1963'. After Glenn returned successfully, *Aviation Week* renewed its warnings. Apollo was underway and NASA's budget was doubling every year. But 56 per cent of 100 Congresspeople polled by the magazine also said a majority of their *constituents* felt unsure about billions for space rationalised in Cold War competition terms. A statistically insignificant six per cent felt the people who elected them thought what NASA was doing was a 'waste of money'. Finally, a 38 per cent minority affirmed their constituents believed NASA's activities were a 'worth-while investment'. A Wisconsin Republican quoted at length in *Aviation Week* elaborated that his constituents generally lacked deep feelings about space exploration; while a Connecticut Democrat serving on the House space committee was rightly concerned that NASA programmes were so intertwined with Cold War power and prestige issues that civilian space exploration could not 'stand on its own' or receive 'the continuous support it will need in the years ahead'.[21]

Within three months, *Aviation Week*'s forewarnings bore fruit. In May of 1962, after the return of America's second orbital astronaut, *New York Times* editor and columnist James Reston used Kennedy's own words to a White House conservation conference on 26 May to argue that America's global scientific, technological and political priorities were askew. Earthly problems like clean water and enhanced food production were getting much less attention than they deserved, as compared with space. Or, as Kennedy put it, the country that was first in making cheap fresh water out of salt water would have a more lasting benefit than the country that was first in space races.[22]

Reston's well-timed dissent was very important. The *Times* was the highest status information bridge in America. Reston headed the paper's Washington bureau, the largest of any news agency. He was both well-connected and influential. His column was also syndicated to over 300 other newspapers nationwide. When, therefore, Reston subsequently wrote five articles in a year arguing ever more strongly that America's lunar or planetary space races should be replaced with international space cooperation, NASA began losing distinguished supporters. Nobel Prize winners Ralph Bunche and Glenn W. Seaborg, *Science* magazine

editor Dr. Philip Abelson, Senate Foreign Relations Committee chair William J. Fulbright, growing numbers of restive Congressmen, and, by mid 1963, the editors of the *New York Times* itself all began attacking NASA spending – and particularly the Apollo programme. NASA's budget was ten times bigger in 1963 than it had been in 1958. But further NASA budget increases were cut back four different times in 1963. President Lyndon Johnson took note. He quickly capped total NASA spending in 1964 to avoid what the *Times*' top space reporter then called the 'growing sales resistance' in Congress.[23]

Faced with unexpected opposition, Kennedy's NASA Administrator James Webb sought to resurrect NASA's largely defunct earthly applications role. From 1964 to 1966, Webb asked major research universities flush with NASA R&D awards to apply some of their scientific and technical expertise to the betterment of urban social problems. Webb also believed the management system he'd created for Apollo could successfully address social problems as well. Thus, from a mix of political and philosophical motivations, Webb sought to make NASA part of Lyndon Johnson's Great Society domestic social reform drive. NASA signed agreements with over 25 university presidents. Webb, his biographer concludes, 'probably gave more of his personal time to this small component of NASA's overall effort than to any other non-manned space activity'. Results, however, were minimal. Academics did little, and NASA forced little. There were a few NASA-funded experiments with Webb's 'Space Age Management'. 'Technology utilisation', Webb's new name for 'practical applications', had its official status raised. Early directors, however, lasted an average of only one year.[24]

Webb's efforts might have been more successful had they gained more backing within the agency. Applied physicist Hugh L. Dryden was NASA's number two administrator from the agency's creation until his death in December 1965. Dryden, however, also basically saw earthly matters as distractions. Less than two weeks before his death, Dryden made his ideas crystal clear in a letter to Neal Bosco, a Master of Science in meteorology from Colorado. Bosco had earlier written to the White House suggesting that pictures of Earth taken at long distance would be of great public and scientific interest; and could help the space programme. The White House staff had then forwarded the letter to NASA for a serious response. Dryden, however, airily dismissed Bosco's idea by dismissing Earth's scientific potential to NASA. 'Such pictures, it is true, would be considerable general interest, but not of great scientific value.'[25]

Three years later, however, complaining astronauts began being forced to carry cameras on missions. December 1968 Apollo 8 photographs of Earthrise over the Moon thus ironically became one of the most enduring and important images of the Apollo lunar programme. A few months further on, in April of 1970, the images of a 'little blue ball' of humanity's home planet became a central symbol of the first Earth Day, and of fast-growing environmental movements in the US and elsewhere. Dryden died, however, lacking any idea how wildly wrong he was.[26]

Nor was Dryden unique. Webb left NASA in October, 1968. Dr. Thomas O. Paine of General Electric then took over as NASA's third Administrator in October of 1968. From then until his embittered resignation in July of 1970, just after Earth Day, Paine tried – and signally failed – to recreate a grand new Apollo-style manned spaceflight programme aimed at getting men to Mars in 30 years. Paine was a self-styled buccaneer as oblivious to environmentalism as Dryden. Again like Dryden, he ignored realities he didn't like. Once NASA was not spared the cuts affecting all major science-based agencies in 1970, Paine left NASA feeling – and saying – that the nation was in the hands of hippies, radicals and Black Power advocates who despised reason and science.[27]

Polemic and paranoia aside, contemporary Americans were not generally hostile to science or technology. They were, however, more discriminating about the uses to which particular sciences were put. More people in a more-educated society, sociologists found, thought of science and technology issues in terms of particular specialisations, goals and effects. Science was no longer a poor relation. As much as one-eighth of the federal budget was allocated to science and technology R&D in the affluent 1960s. In the less-affluent 1970s, however, priorities inevitably mattered more. Scientists and engineers, meanwhile, also faced declines in levels of popular confidence affecting lawyers, physicians, educators and all other major professional groups. Status became more conditional and priorities more important because US politics, society and the professions opened up to new groups, notably racial minorities and women, in the decade from 1965 to 1975. Simultaneously, polls of the general public (eight per cent of whom were then university graduates) and the 50 per cent PhD-ed membership of the American Association for the Advancement of Science from 1964 onwards both showed a trend away from physical sciences, specialisations like engineering, spaceflight and high energy particle physics, and a trend towards environment, medicine, energy use, genetic research and life sciences research priorities. Space exploration had trumped earthly issues like the environment, oceanography and genetics in official Washington before 1970. After 1970, that situation was reversed.[28]

NASA'S GEORGE M. LOW

Among those at NASA operating within these unsettling new realities was Thomas Paine's deputy and successor, George M. Low. Low, an aerospace engineer, had far fewer buccaneering illusions than Paine. He was an 'insider' manager whose experience as Acting NASA Administrator for six months following Paine's sudden resignation in 1970 and 1971 was a thorough reality-check. NASA's budget continued falling (to one-half its Apollo Era peak by 1975). One of Low's first official acts was to cut the agency's civil service workforce by ten

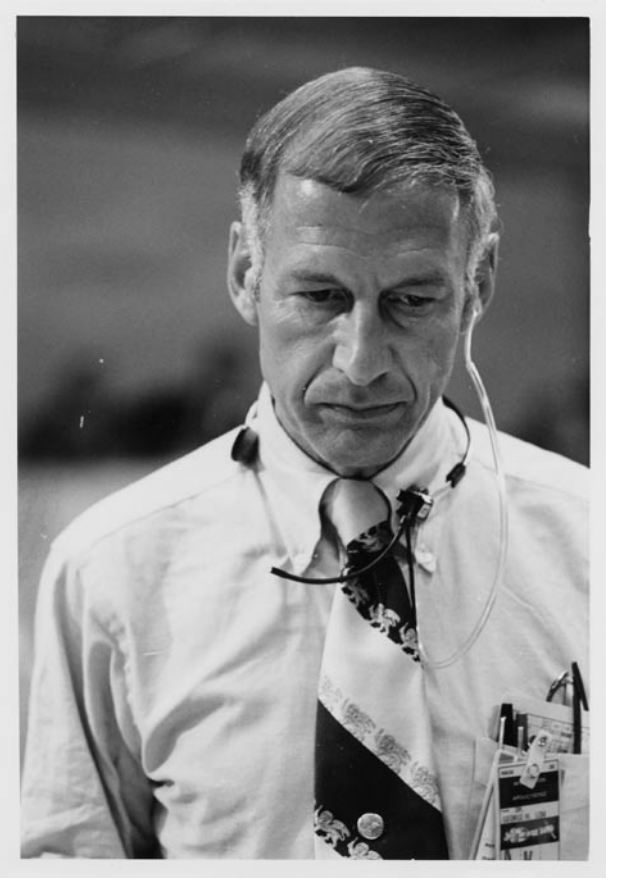

FIGURE 1. Deputy Administrator of NASA George M. Low. Photograph courtesy of Rensselaer Polytechnic Institute Archives.

per cent. Low heard Paine's Mars project ideas dismissed – sometimes in angry four-letter terms – by Congresspeople long supportive of NASA.[29]

It did not take long, then, for Low to try and improve on Paine's dismal performance. Earthly issues could no longer be ignored or dismissed. Low concluded his first meeting with NASA's twelve Center Directors with a thoughtful summary. In the 1960s, the US had looked outwards towards global leadership. Apollo was the high technology symbol of that primacy. In the 1970s, however, the nation was looking inwards, to issues like environment, education and the

quality of life at home. Space and national defence now had little appeal: a truth demonstrated by 'every poll that has recently been conducted' and by Congress and Executive branch actions as well. 'It is clear', Low concluded,

> that if we are to move forward with a strong space program, it, too, must be useful to the people here on earth. This means that a space applications program and, specifically, an earth resources program should be the keystone for the space effort of the 70s.[30]

A strong human spaceflight programme, Low added, must also continue. So there must also 'be some association between the manned flight program and the earth resources program'. It was all basically William Pickering's logic of a decade before.[31]

Low's ideas were also easier to formulate personally than implement organisationally. To change NASA's ways of doing things and habits of mind from Cold War prestige projects, like a long-proposed space station, space shuttles and lunar and planetary exploration bases, to what Low later termed 'by-products' was not going to be easy.

Low himself seemed ambivalent. He quickly consulted with former NASA Administrator James Webb. Webb emphasised resource-location, aviation and water quality, and introduced Low to the chief federal water quality commissioner. Rocket man and Air Force General Bernard Schriever, meanwhile, proposed a high-level government-industry-public board chaired by NASA's Administrator to propose government-funded advanced technology projects with high civilian payoffs. Low did nothing with Webb's introduction. He told Schriever that he did not wish to engage in 'a lobbying type of activity' which might alienate the President.[32]

Simultaneously, Low also kept hold of an idea that 'we cannot sell the space program on its by-product'. This made his approaches towards all earthly matters basically contradictory. The same contradictions, an associate remembered, characterised other Low initiatives, including cost reduction at the agency. Low wanted 'a catechism' not 'a reformation'.[33]

As Low considered, a quiet environmental revolution was underway. Seventy to ninety per cent of Americans polled in the two decades after 1970 wanted more government support for key environmental efforts. This compared to only eight to twenty per cent who wanted more support for space exploration. The advantages of NASA alliances with earthly ecologists were increasingly obvious. As early as mid-1970, NASA's Manned Spacecraft Center in Houston published a booklet, *Ecological Surveys From Space*, illustrated with 46 Gemini and Apollo orbital photos. Soon afterwards, there was *This Island Earth*, a much better-produced NASA offering with 162 pages of full-color photos. Lauding the Apollo 8 astronauts, who had helped humanity appreciate Earth for the first time, Low affirmed NASA's skills would now alleviate worldly problems.[34]

NASA's inclusion of Earth in its definition of solar system exploration priorities, however, didn't produce automatic credibility. This was demonstrated when the Manned Spacecraft Center began advertising its use of a spy plane it had first borrowed from the Air Force in 1962 to fly over 26 American cities taking photos from 50,000 feet, to monitor land use patterns, suburbanisation and slum growth in August of 1970.[35]

The editors of the *New York Times*, in particular, were unimpressed by NASA's new look and by its devotion to the social welfare of cities. In an editorial, they bitterly attacked NASA for hucksterism. 'There may, of course', they began, 'be some value' in planes or satellites 'detecting growth patterns' and revealing 'signs of spreading urban decay'. 'No one', however,

> has to go up in the sky to know these signs [of urban blight] are already pretty far along in New York City and in most other metropolitan centers. And it doesn't take a satellite to recognize that one reason for the blight is that distorted national priorities have poured too much money into space programs and too little into domestic ones.[36]

Journalistic indignation then turned savage. *Times* editors had opposed high levels of prestige-fuelled, space-race Apollo spending for seven years. It wanted a lower-cost programme based on science and international cooperation. The Earth, not the Moon, mattered most. One and one-half million of New York's population – one person in four – was 'living in squalor' or homeless, the editorial continued. Waiting lists for low-cost public housing were 130,000 families – and, at present construction levels, 51 years – long. Meanwhile, 20,000 apartments were being abandoned as uninhabitable annually. 'We trust', the editors concluded, 'that NASA will not consider New Yorkers churlish if they fail to smile into a satellite reconnaissance camera while it is recording this spread of urban cancer.'[37]

NASA, clearly, had an elite opinion-maker credibility gap. Editors at the highest status paper in the country did not identify the agency with any concrete earthly advantages whatsoever. Earlier decisions not to partner-up with other government agencies regarding weather or to keep a piece of the 'public utility' action regarding communications satellites left NASA with few interest constituencies: as prominent social scientists had earlier predicted. The *Times*' embittered editors treated NASA as an arrogant and uncaring agency producing prestige spectaculars in space at the cost of political tension and social decay at home. 'Bread and circuses' criticisms that *Times* editors had aimed at Russia's communist despots immediately after Sputnik were aimed squarely at NASA leaders now.[38]

George Low normally avoided television, but he got the printed message. In March of 1971, James Fletcher became NASA's fourth Administrator. Low, at Fletcher's request, resumed his duties as number-two in the agency. Immedi-

ately afterwards, Low went to New York City to ask *Life* magazine how to sell NASA's programmes. *Life* had run a ten-year series of celebratory astronaut exclusives from 1959 to 1969. Its reporters, a senior *Life* editor later recalled, 'virtually abdicated skepticism' while doing so. *Life*'s managing editor Ralph Graves was hardly antipathetic to NASA.[39]

But *Life*'s Graves was also frank, Low recorded. Selling space exploration via astronauts was 'impossible because all of the astronauts "come out of the same mold" and human beings cannot relate to them'. NASA had 'a terrible reputation for telling the stories only the way we would like to see them printed'. NASA looked from the outside like 'a completely non-responsive outfit'. NASA wasn't impolite; but it ignored anything that didn't fit into its established patterns of belief and action.[40]

CATECHISMS VERSUS REFORMATIONS

After returning to Washington, Low promptly sacked Julian Scheer, NASA's Public Affairs head since 1963. Other changes were harder. NASA produced noble expressions of good intentions if given lots of funding first. But it avoided demonstration projects aimed at building public credibility and support. A Global Atmosphere Research Program (GARP) the Commerce Department and others were starting in 1970, for instance, failed to interest NASA because no expensive hardware-building projects for a 'next generation global meteorological system' were involved. NASA so informed the White House. Energy and environment projects generally were also non-starters. Low and Center Directors decided '…we should not take on new jobs when we aren't even doing our existing jobs in space and aeronautics as well as we should'. 'The national ills' and NASA were not related. Even small ecological projects already underway were rolled back because they were supposedly not very good experiments. These included early wildlife tracking of elk (in Wyoming) and polar bear (in Alaska). Animals were fitted with electronic collars and then tracked via Nimbus weather satellites first developed at the NASA-Goddard lab in Greenbelt, Maryland. Even pleas from the Governor of Alaska didn't sway Low. Wildlife tracking via satellite was too trivial for NASA to fund in an era of declining budgets. A fledgling earth resources satellite programme started in 1969 was also presumed to be of little importance or potential to NASA or private industry users.[41]

Overall, NASA's four aeronautical labs belatedly sought – with uneven success – to link their aeronautical work to the passenger aviation revolution of the late 1960s and early 1970s that doubled (to one-half) those American adults who had experienced flight in only ten years.[42] Meanwhile, NASA's space labs and leadership developed incremental policy strategies. They sold particular projects one-by-one. By 1972, Fletcher and Low got Nixon to approve space

shuttle development, which became NASA's major programme until 1986, when Ronald Reagan authorised what began as a US-only space station.[43]

However, NASA's ongoing reticence about emphasising Earth applications still cost it heavily in Official Washington. The Energy Crisis hit the US full-force in 1973. Congresses and Presidents put together many and varied directives, Executive Orders and legislative acts calling on federal agencies to expand their activities to assist in resolving the crisis. Prominent Democratic Senators especially introduced bills giving NASA opportunities to restructure itself into a 'civilian research and development agency'. Reversing themselves, Fletcher and Low now concluded 'that for the sake of NASA's future, it does become very important to take on new areas of work'. The alternative, Low wrote, was stagnation and decline.[44]

Environment, however, was something NASA remained hesitant about. Fletcher and Low's 'environmental theme' discussions of mid-1973, as we've seen, saw environmentalism as fundamentally wrong and politically passé. Instead, NASA leaders belatedly tried to concentrate on energy research and development. By 1974, NASA cooperated with a newly-created Energy Research and Development Administration (ERDA), headed by Robert Seamans, third-ranking NASA headquarters manager in the Webb years. Again, however, NASA came up short. NASA refused to move on terrestrial solar power R&D, for example, until convinced that 'there was a firm Administration policy on this subject, and if, so, who had made the policy and on what basis'.[45]

Such hauteur and delay were fatal. As policy entrepreneurs, NASA leaders lagged. NASA – in Fletcher's view – had 'dropped the ball' and 'missed the boat in not throwing our hat in the ring in connection with the energy problem' by mid-1973. Interior, the Atomic Energy Commission and the National Science Foundation all gained. NASA got nothing.[46]

Meanwhile, NASA even avoided expanding some of its most traditional research areas in energy-related directions. As planes became the nation's primary long-distance transport system in the 1970s, aviation fuel conservation became more important. But NASA's second highest-ranking administrator knew of no substantive aeronautical energy-saving research work until Low forced the issue in January, 1975. This helped free up resources for projects like an advanced turboprop effort formally begun at NASA-Lewis in Cleveland, Ohio in 1976. Fletcher thereupon assured Vice President Nelson Rockefeller that 'NASA today is much more "earth oriented" than we were when we first went to the moon'. Low, however, privately concluded ten months later that NASA's upper atmosphere research programme was stalled, and work on issues like ozone depletion and ultraviolet radiation levels at Earth's surface was effectively non-existent. When chlorofluorocarbons were banned in the late 1970s, accordingly, other agencies than NASA discovered problems and proposed solutions. Later efforts to remake the NASA-Lewis lab into a solar energy research centre were unavailing. NASA lost the 'energy' portion of its budget by January of 1976

as a new Cabinet-level Department of Energy was formed. Belated efforts to re-establish NASA as a major player in communications or 'meteorological science' also misfired.[47]

Meanwhile, NASA lost one-fifth of its civil service employees from 1970 to 1975 and about the same proportion of its budget, in purchasing power terms. NASA kept making broad claims about what it could do; but actions still lagged. Low privately admitted that NASA was left in a 'minimum position'.[48]

A major reason why is clarified by a note Low made in March of 1974. Low had participated in four Senate hearings. 'Most of them went quite well', a forceful and assured Low began,

> Except that once again I was unprepared in answering [Democratic] Senator [of Ohio Howard M.] Metzenbaum's question concerning why we should do all these space activities. He is looking for simple answers, and we have not been able to give those to him.[49]

Cleveland-born Metzenbaum had earlier impressed Low. Metzenbaum was not only querying Low about human spaceflight (which most scientists had long opposed), but about NASA's programmes generally. He came from the city where NASA had its third-oldest aerospace research centre, built in 1940. Jewish Lawyer Metzenbaum had built his practice and his fortunes in and around Cleveland as Low, a young Austrian-born Jewish refugee from Hitlerism, began his aeronautical engineering career in Cleveland at what became NASA-Lewis (now NASA-Glenn) Research Center. NASA's first Administrator T. Keith Glennan also ran a technical school (now Case Western Reserve University) in Cleveland before and after creating the new agency. That an educated professional like Metzenbaum had little sense of what earthly differences a federal aviation and space agency made which employed thousands of people in his native city spoke volumes. That Low was unable to tell Metzenbaum what practical differences NASA made 16 years after the agency was created spoke volumes more.[50]

In part, the problem was that NASA was unaccustomed to talking with people outside small portions of the Executive branch of the government. *Aviation Week* was still the premier aerospace industry trade journal. Its readers were often bound to NASA by ties of immediate economic interest. *Aviation Week*'s editor, Robert Hotz, was still criticising NASA for not knowing how to market itself, and for other reasons. Fletcher so disliked these criticisms he refused to meet with Hotz for three years after becoming NASA Administrator in 1972. Low didn't talk with Hotz either. *Aviation Week* reporters were also routinely denied access to key managers at NASA labs. At the same time, Low and Fletcher were advised that only going to see the long-time chair of the House space subcommittee when they had problems was insufficient. NASA already had significant problems with Congress, the presidential Office of Management and Budget, with other federal science-related agencies including the National Science Foundation. Its withdrawals were self-defeating. But NASA still saw itself in

transcendent, frontier, Cold War terms. Many of its top managers, accordingly, still didn't think NASA should even have to address 'what can we do for you?' questions. NASA should do solar physics; it should not help understand why earth had droughts. NASA was also an elite agency demonstrating America's Cold War prestige and power. It should stay that way.[51]

Given such institutional mindsets, Low sent mixed signals. Half the time, he said earthly issues like drought were important. The other half of the time, they vanished amidst catalogues of transcendent exploration goals and cavils by traditionalist lab directors. This vacillation alienated executive branch policymakers who handed NASA major opportunities like stratospheric research only to have NASA do nothing with them. It also increased the list of those government agencies – particularly the National Science Foundation, the Defense Department and the White House's Office of Management and Budget – which believed NASA could not cooperate effectively regarding energy or environmental projects.[52]

LANDSAT

NASA's LANDSAT (Environmental Resources Technology Satellite (ERTS)) showed what the critics complained about. Here was working earthly environmental hardware. LANDSAT was relatively quick and cheap. The programme cost only about US $120 million from 1966 until the first of an eventual five NASA LANDSATs was launched in 1972. This included US $32 million for the first satellite itself. In contrast, NASA's two Viking Mars landers, begun in 1970 and launched in 1976, cost NASA US $1 billion to build.[53]

LANDSAT's chequered history, however, demonstrated how inexperienced, unwilling or incapable NASA was at providing services to earthly constituents, even when NASA's public was defined (by NASA's James Fletcher) only as 'other government agencies'. NASA built a system without a business plan about how that system might be used. In addition to not knowing much about what it had to sell or who its customers might be, NASA also ensured it had comparatively little to sell, didn't coordinate users, and couldn't deliver the goods. Muddle followed.[54]

LANDSAT cameras illustrated NASA problems. Earth resources imaging and sensing technology (like weather satellites) evolved out of military spy satellites. But using spying-derived imaging systems to their maximum potential could give away strategic secrets. The Communist enemy could know what Americans could – or couldn't – see. Spymasters helped ensure LANDSAT earthly imagers stayed insensitive…even as compared with out-of-date military technology NASA was then using to map the Moon. Initial LANDSAT images had a resolution of only about 100 metres or 320 feet. Later this was reduced to 61 metres or 190 feet.[55]

The benefits of using such a low-resolution system were also low. In July 1974, to illustrate, NASA was part of a high-level US delegation to Senegal. The group, led by the Director of a new National Oceanic and Atmospheric Administration, was advertising the advantages of Senegalese participation in a Global Atmospheric Research Program NASA leaders had earlier refused to cooperate with when it and NOAA began in 1970. Now, however, George Low wanted to sell LANDSAT – via GARP – as a tool for use for map creation, water source location, crop identification and land-use, dam construction and urban planning.

When Low presented LANDSAT to nine Senegalese environmental, economic and other ministers in Dakar on 25 July, however, he wasn't very persuasive. Low began by stating his knowledge of LANDSAT's technical capabilities was limited; and that he did not even know whether any spectrographic photos of Senegal taken from the satellite existed. Low then affirmed that such maybe-nonexistent spectrographic views could enable fields of wheat to be differentiated from fields of rice if examined by specially trained personnel. After this rousing start, Senegal's Minister of Public Works and the Environment asked his colleagues what their needs were. A deputy minister for urban affairs wanted maps on a scale of 1/50,000 and identification of geological points in the northern portions of Senegal. Low replied NASA's satellite mapping had only been undertaken on a 1/125,000 scale; that he did not know whether a 1/50,000 scale was possible; and that he was also not sure LANDSAT's 100 metre resolution was precise enough to identify prominent geographic features.[56]

Senegal's Public Works and Environment minister then said he needed photos regarding two river deltas and two dam sites to assist planning. Low reiterated he didn't know whether any photos existed for Senegal; probably added that LANDSAT 1 did not have a standard optical (as opposed to a spectrographic) camera; and said that 'perhaps' any photos of Senegal that did exist could be found – if the Minister made an official request for them via the US Ambassador. NASA, a tepid Low continued, would be glad to train Senegalese regarding spectrographic photo interpretation techniques, though 10 per cent of the work required specialised computers. The minister said such training was a good idea, and the meeting closed. NASA had brought no images along. Nor had Low given Senegalese administrators any reasons to value NASA's satellite over, say, high-flying aeroplanes. Low's curious lack of preparation may also not have been accidental. Senegal was a non-aligned nation in the Cold War. International environmental cooperation, Low was warned by NASA's long-time International Affairs chief a month before his Senegal trip, could allow communist enemies to spy on the US and find new reserves of important raw materials in their home territories. Cold War mindsets may thus have weakened more than optical resolution. They possibly weakened NASA's political resolution as well.[57]

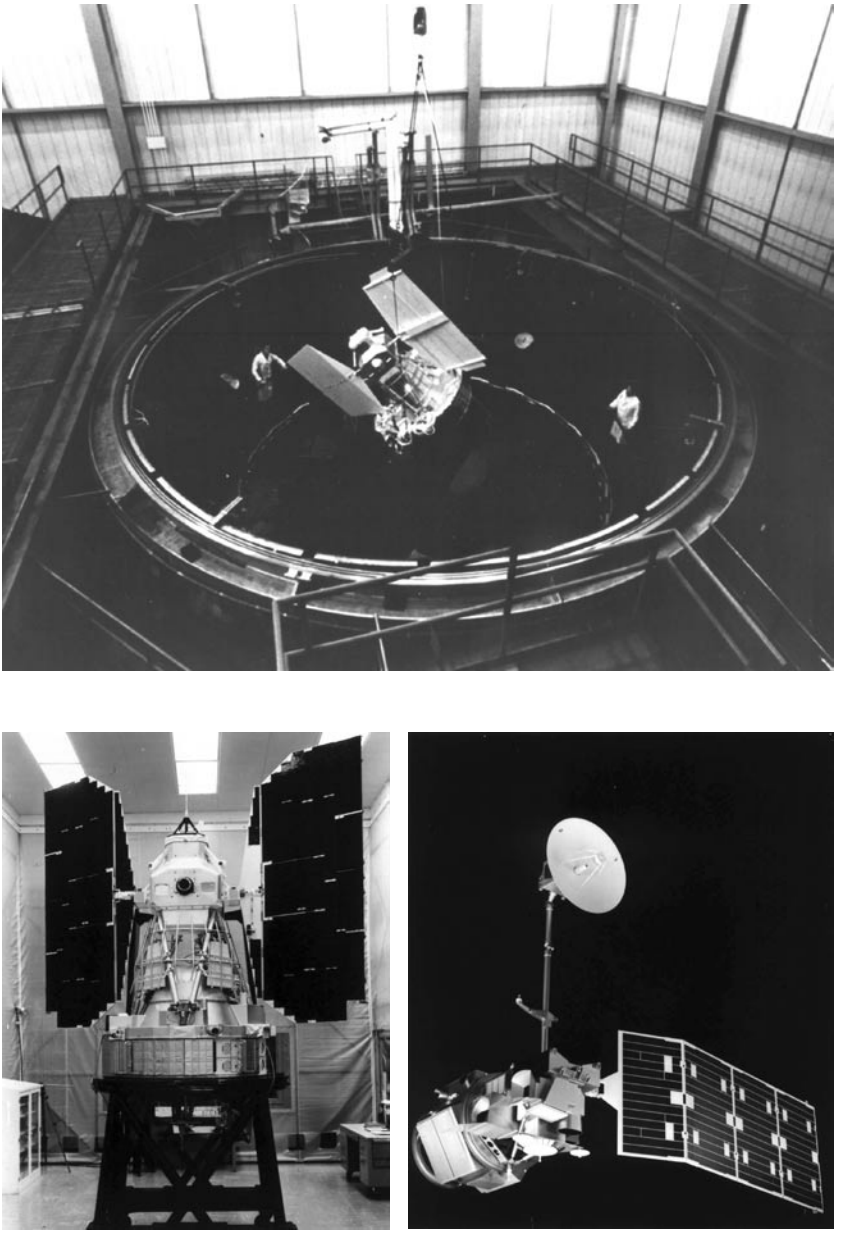

FIGURE 2. LANDSAT 1 (top), LANDSAT 3 (lower left) and LANDSAT 4 (lower right). Photographs courtesy of NASA.

Back home in America, NASA was simultaneously losing the 'first round in the battle for future earth resources satellites'. The agency resembled an academic department trying to run a hardware store. It regularly took NASA six weeks to answer LANDSAT mail. NASA Administrator Fletcher knew even less about LANDSAT than Low. He couldn't, for example, tell the Secretary of the Interior and the chair of the House Science Committee's space subcommittee whether stereoscopic photography might give later LANDSATs better energy resource locating potential in May of 1974. NASA also could not work well with the Department of Agriculture or the Department of the Interior: the former because of NASA's frontier mentality technical overkill; the latter because it wanted LANDSAT for itself. OMB budgeters, meanwhile, thought LANDSAT costs exceeded its benefits. OMB distrusted NASA statistics. It also noted Earth was an afterthought, and that NASA 'indicates its view of priorities through its relative budget requests – i.e., [earth] applications is last'. OMB finally raked NASA for not cooperating with other government agencies to develop linkages to 'real users' who wanted satellite data for everything from crop estimates to pipeline repairs to the elk and polar bear tracking NASA had earlier refused to fund.[58]

So LANDSAT limped along, in Pamela Mack's words, 'tangled in conflicts based on budgetary issues, security concerns, divergence of interests between the developers of the technology and the potential users and bureaucratic competition'. All this made for 'particularly bitter' funding fights within Congress and the Executive Branch. In 1978, President Jimmy Carter finally tired of gridlock and transferred the programme to NOAA. By 1985, President Ronald Reagan made LANDSAT private; and its data soon competed with that of a state-sponsored French imaging firm (SPOT) and even with Russian spy satellite data after 1991.[59]

As NASA lost control of LANDSAT, its failure to include Earth prominently in its solar system exploration programmes had increasingly negative results. 'Science' was technology and useful applications in the popular view, noted contemporary historian of science A. Hunter Dupree. America's government spent more than any other on science R&D. But even 'pure' or 'basic' scientific research got funding on 'deferred practicality' grounds. Sociologist of science Dorothy Nelkin agreed. 'Public acceptance of science', she later wrote, 'appears largely to be based on expectations of immediate applications'.[60]

Nothing NASA did, however, produced clear earthly advantages – immediate or deferred. This spelled political trouble for the agency as Cold War power and prestige started mattering less than energy, the environment, inflation and global economic and industrial competition in the 1970s. Present and former NASA administrators responded to NASA's difficulties in different ways in the 1970s. Glennan misremembered, denying he'd led the campaign to get rid of NASA's highest profile involvements in Earth-focused programmes. Webb advocated water and petroleum finding. Paine and Fletcher reiterated prestige,

frontier and human settlement rationales. Fletcher also quietly supported – and fundraised for – the first general membership US space advocacy organisation ever created in 1974, a National Space Society supporting Apollo-style efforts to expand the Space frontier.[61]

Former NASA Administrator Paine, meanwhile, lauded even grander 'Humanity Unlimited' ideas first put forward by Princeton physicist Gerard P. O'Neill in 1973 and 1974. Published in 1977, O'Neill's *The High Frontier: Human Colonies in Space* proposed creating huge solar-powered space habitats to provide 'new sources of energy and materials while preserving our environment'. Spinning hollow cylinders about four miles wide and 20 miles long would hold between 10,000 and 25,000 people each. They would be built with lunar materials, and located at one of those few locations in space where the forces exerted by the Earth and the Moon's gravitational fields exactly coincide. Such stable orbiting space cities would feed themselves, and earn operating revenue via solar energy and other exports back to Earth. Paine and O'Neill (and O'Neill's several thousand devoted followers, who created two more space advocacy groups late in the 1970s) made a bold environmental promise. They claimed NASA, if given enough billions, would do, in creating worlds-in-miniature over 100,000 miles distant, what it had yet to demonstrate it wished to do regarding Earth itself. O'Neill's designs for orbital human settlements mixed big science, frontier expansionism and 1970s concerns about ecology and resource scarcity in about equal proportions. But space advocates who could not sell a 30-year plan to get astronauts to Mars to Congress or country in 1969 had no hope of selling a vastly more expensive 100-year plan by wrapping it up in environmental clothing less than a decade later.[62]

In comparison to Thomas Paine, then, NASA's George Low was realistic. He knew the golden age of Apollo was over. He knew grand space visions meant little or nothing without broad and deep popular support. Low understood, as Fletcher and Paine apparently did not, that US politics was opening up during and after the 1970s, particularly to women and minorities. A bruising civil rights in employment fight which NASA (and Low) lost in 1973 and 1974 taught Low that NASA could not prosper if its astronauts stayed all white and male and its strongest supporters stayed largely male, Caucasian, college-educated, born between the years of 1930 to 1950, and in their formative years in the Apollo decade. By early 1975, Low spent more and more of his time trying to market NASA programmes.[63]

CARL SAGAN AND JACQUES COUSTEAU

All this led Low in some unusual directions. Instead of focusing on space-friendly conservatives like Donald Rumsfeld and his assistant Dick Cheney, then reorganising the White House staff for President Gerald R. Ford in 1974

and 1975, Low concentrated instead on liberals like planetary astronomer Carl Sagan and foreigners including French oceanographer Jacques Cousteau. 'Space buffs' Rumsfeld and Cheney's primary concerns with space were near-Earth and military. Sagan and Cousteau, meanwhile, were the two primary scientist-popularisers of their day.[64]

Low looked to scientists like Sagan and (especially) Cousteau as counterweights to military spacemen who might seek to end NASA's independent existence, and as spokesmen who could give NASA more bipartisan political legitimacy than it enjoyed. Sagan's rise to intellectual scientific celebrity began in 1973. He presented space exploration as a substitute for earthly war; proposed a search for extraterrestrial life theme as a way for NASA to garner widespread public support; and opposed militarising space as strongly as he supported international scientific and technical space cooperation.[65]

In 1974, Sagan hoped discovering life in the Universe (and especially on the planet Mars) would very soon transform human mindsets on Earth. So Sagan wanted NASA to fund a Search for Extraterrestrial Intelligence (SETI) via radio telescopes and to restart UFO investigations the Air Force had ceased in 1969. Sagan's approach was utterly extraterrestrial. To Sagan, as to Low, most of the time, it was impossible to equate space exploration's transcendent purposes with mere worldly things. '[A]ny thinking audience', Sagan pronounced, 'will realize you cannot sell a product by its byproduct'. Using this logic, electricity could not be sold by the invention of the incandescent light bulb, and unintended beneficial consequences never mattered much. The Space Age itself, ironically, was a largely-unintended consequence of military rocketry during and after World War Two. The Apollo programme was also consistently over-sold on the basis of its supposed political prestige 'by-product' by NASA itself.[66]

However wrong he was, however, Sagan told Low what he already knew. Martian ecology thus meant more to NASA than earthly ecology. Low and Sagan pitched the idea of doing a television special about the upcoming Viking lander missions to Mars to Fletcher in November. Sagan, however, didn't impress a key Fletcher aide. He memoed Low in January, 1975 that Sagan struck him as 'an insufferably egotistical man' who 'talked down' to people and would never be a good populariser of space programmes. Sagan made science of secondary importance to himself.[67]

About Sagan's abilities, the aide was wildly wrong. But he liked another rising star science populariser, French oceanographer Jacques Cousteau. Cousteau had many advantages over Sagan to Low. Sagan, for instance, was hip, academic and antiwar. Many of NASA's military-spawned aerospace engineers might hate him. Cousteau, in comparison, had been a career French Navy captain. During World War Two, Cousteau had co-invented scuba diving technology that allowed divers to breathe pressurised air from tanks strapped to their backs. Sagan was an astronomer who had theories about things. Cousteau was an engineer and explorer who built things. His inventions included the proto-

types for all modern deep-sea human and robotic submersibles. Cousteau was to 1950s and 1960s oceanography what Wernher Von Braun was to 1950s and 1960s rocketry. Cousteau made it possible to get to alien environments at all. Moreover, he made many of the trips himself. The same year Sputnik orbited, Cousteau resigned his naval commission and began using deep-sea cameras and other technology he also helped create to popularise the world's oceans to elites and masses alike.[68]

To accomplish his goals, Cousteau developed impressive media connections. He became a fixture in the pages of *National Geographic*, one of the US's top-ten selling magazines, after the mid-1950s. Best-selling books followed: first *The Living Sea* in 1963; then others including *Oasis In Space* by 1972. Hour-long National Geographic and other television specials further broadened Cousteau's exposure in the post-Earth Day 1970s. Earth, after all, was 70 per cent oceans.[69]

Jacques Cousteau thus became a hot intellectual property in a decade of fast-emergent environmentalism. He was a credible and experienced explorer with a military and engineering background. Conservatives at the Johnson Manned Spaceflight Center in Houston and elsewhere in NASA who dismissed Sagan as an arrogant liberal could not ignore Cousteau. The same key Fletcher aide who despised Sagan came from a long-time naval and maritime family whose own father was 'an ardent follower' of Cousteau. Low, a talented amateur photographer who also shot underwater in scuba gear, had similar direct experience with the sea.[70]

Low sought to use Cousteau to gain NASA earthly credibility. Low also wanted – and got – extended direct experience with Cousteau. In December of 1974, NASA's Deputy Administrator spent five days cruising in the Caribbean with Cousteau on his research ship the Calypso. Cousteau was a 'concerned environmentalist' whom Low, normally a very private and very distant man, related to in 'long philosophical discussions' every morning. The French oceanographer, in turn, respected what Low was doing. Not only did Cousteau strongly believe 'the space program will contribute a great deal to oceanography and all other earth-bound sciences', he wanted to go into space himself when the Space Shuttle flew.[71]

NASA and Cousteau fit like a hand in a glove. Low hoped this prominent environmentalist might also save a failing LANDSAT and other earth satellite programmes for NASA. Low soon invited Cousteau to NASA to show him LANDSAT, Nimbus G, SEASAT and Skylab space station data and plans. Low also told Cousteau that the manned space station NASA was planning after Shuttle flights began would have a large 'ocean studies' component.[72]

Cousteau stayed very interested. In May of 1975, he spent four days visiting four NASA labs and one aerospace contractor. Cousteau proposed a film series using LANDSAT data; and talked about the possibilities of the Cousteau Society of America leasing the Space Shuttle and any space station NASA would later

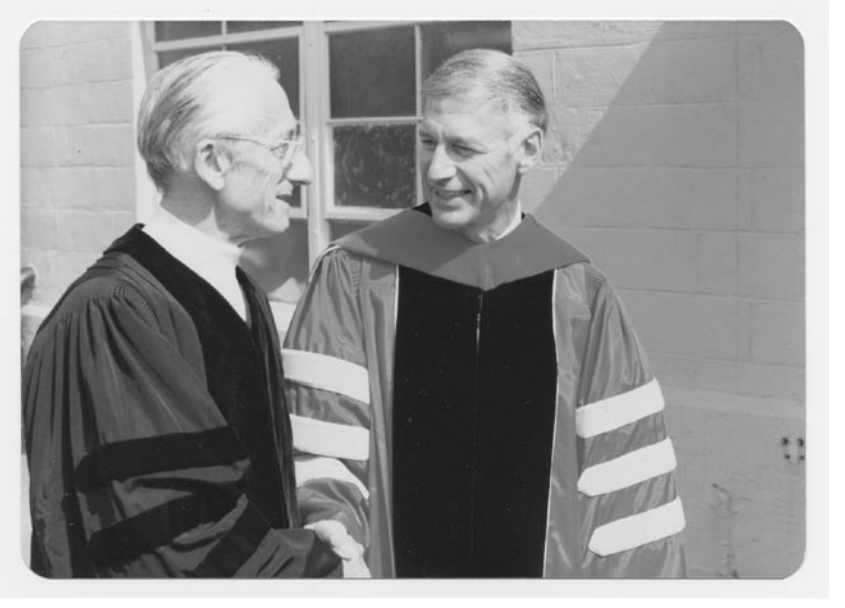

FIGURE 3. Jacques Cousteau and George Low. Photograph courtesy of Rensselaer Polytechnic Institute Archives.

orbit 'for an oceanographic mission'. 'Altogether', Low concluded, 'I think this is the beginning of a very rewarding relationship, not only for Cousteau but especially for NASA.'[73]

Low pushed ahead. Cousteau came to the Manned Spaceflight Center in Houston in July of 1975, the day of the Apollo-Soyuz docking, to get acquainted. Immediately, internal opposition surfaced. 'Some of our people within NASA', Low noted, 'think that Cousteau is not a real scientist but just a publicity seeker.' Low sought compromises to smooth ruffled bureaucratic feathers and scientific egos. The head of the Goddard NASA lab would have to OK the Cousteau project as 'a good thing for NASA as a whole'. Frenchman Cousteau was also going to be teamed with an American academic 'who will make sure that some good science comes out of the project'. NASA's institutionalised support for international cooperation stayed minimal. Its suspicions about scientific popularisers stayed high.[74]

Gradually, such nay-sayers wore Low down. Experiments on Calypso involving LANDSAT and other satellites began off the Bahamas in September, 1975. Low visited Cousteau's ship again to watch technicians including President Gerald R. Ford's son Jack. Perhaps sensing something was going awry, Cousteau strongly reiterated his interest in selling NASA via 'down to earth'

means emphasising 'earthly benefits', offered to do all his part of the work for free, and talked about his 'greatest ambition' being 'to fly in space himself' – or to have his pilot son Philippe do so. A normally-undemonstrative Low used phrases like 'strongly believes' and 'very serious' to describe one of those rare men for whom he had a great deal of personal respect. NASA Administrator Fletcher, Low advised almost emotionally, should meet Cousteau because 'it is important that we handle Cousteau properly and really make him a part of the team, rather than [to] give him the feeling that we are using him'.[75]

No meeting ever took place, and things unravelled. Low, meanwhile, was secretly a very ill man facing a possible medical death sentence. He developed a 'rather major melanoma' in the summer of 1975 which was then 'essentially fatal' if untreated. Extensive surgery and immunotherapy followed. Low had cancer and maybe not even five years to live. His energies regarding pushing unwilling or uninterested NASA managers – including Fletcher – to support his Cousteau initiative began to lag. So did Low's proposals to fly either Philippe Cousteau or widely-respected CBS News television anchorman Walter Cronkite on an early Shuttle flight to generate interest and support in NASA's human spaceflight programme. Problems, meanwhile, surfaced with LANDSAT data-availability. Cousteau proposed inexpensive new ideas to highlight NASA 's commitment to oceanic research in February of 1976. But a burned-out Low promptly handed them off to a less-than-interested head of the National Oceanic and Atmospheric Administration.[76]

Low, meanwhile, went looking for a new job. Aerospace firms weren't interested. He tried for a job as Federal Aviation Administrator that wasn't really there. Relations with Fletcher seemed cool. Finally, Low's alma mater, Rensselaer Polytechnic Institute, hired him to become their President starting in June of 1976. There he laboured until his death from brain cancer in 1985.[77]

DENIAL TRIUMPHANT

For a decade after George M. Low's departure in mid-1976, environmentalism declined within NASA. A meeting of NASA's dozen centre directors and about the same number of top headquarters managers in mid-1976 illustrated why. NASA once again argued itself into earthly irrelevance. At a two-day retreat, pseudo-profundities abounded. NASA's long-time chief financial officer, for instance, confused cause and effect: arguing that NASA should never have created an Office of Applications and should abolish the one it had immediately. Thus NASA would, somehow, be spared unwelcome questions about doing practical worldly things for people. Academician Bruce Murray, soon to become director of the Jet Propulsion Laboratory, meanwhile, argued that NASA didn't have to concern itself about (bad, and getting worse) public opinion polls because NASA's real constituents were Congress and the White House (where, as Murray

didn't note, NASA wasn't doing well either). Christopher Kraft of the Manned Spaceflight Center in Houston, to whom women and minorities were a bother, differed. He believed 'the business community' was NASA's important audience. Murray concluded this 'lively discussion' of NASA's leadership by saying NASA was 'leaning too much toward a desire to be practical', and should instead make some transcendent 'exciting things…such as the search for extraterrestrial intelligence' priority goals instead. The thought was pure Carl Sagan[78]

'All agreed to Murray's comment', Low noted. Given such mindsets, earthly environments or applications were non-starters. NASA leaders also concluded again that every earthly matter was some other federal agency's property. Crops belonged to the Agriculture Department; mineral resources belonged to the US Geological Survey; and so on. All the pretty girls were taken. So NASA didn't need to go to the political dance. This was the same narrow reading of the NASA Act Glennan and Dryden had used in 1959 and 1960. It insured NASA understood itself as a research-only agency which only built prototypes and operated nothing. This even as it designed Space Shuttles it claimed it would operate on a regular, continuing and low-cost basis.[79]

Murray and Sagan's cosmic consciousness, meanwhile, didn't develop as expected. Neither the Viking missions of 1976 nor the Voyagers' grand tour to the outer planets beginning with Jupiter in March and July of 1979 excited the quick burst of public interest that Bruce Murray, Sagan and others whose careers were made possible by NASA's science missions expected. Murray and Sagan co-founded the Planetary Society, the fourth single-interest space exploration advocacy group of the Space Age, in 1980. Public interest in deep space and planetary missions rose in the 1980s, not least via Carl Sagan's path-breaking TV series 'Cosmos'. But Planetary Society membership, once at 100,000, had declined to 57,600 by 2004. Other space advocacy organisations have faced similar declines[80]

The big issues of the late 1970s, concurrently, involved earthly energy and the environment, not solar system exploration. The price of gasoline quadrupled again. An era of cheap energy began to end. US inflation rates reached a twentieth-century peak of 20 per cent per year, as official unemployment rates reached 12 per cent, with actual rates twice that. Finally, in March of 1979, as the first Voyager spacecraft approached Jupiter, a major nuclear accident occurred at Three Mile Island nuclear energy plant in Middleton, Pennsylvania.[81]

Twenty years of local opposition to nuclear power then quickly reached critical mass and went national. At the same time, NOAA began warning of 'Greenhouse Effect' global warming threats. In April of 1986, a terrible nuclear accident at Chernobyl in the Ukraine irradiated large portions of Russia and Europe, killing thousands.

NASA, meanwhile, had its own tragedy to deal with. In January of 1986, the Space Shuttle Challenger exploded during launch, killing its crew. Challenger rocked NASA far more than the 'public' generally. Most Americans polled by

the National Science Foundation in the most rigorous poll ever undertaken about space understood very well space missions were high risk. NASA's organisational habits-of-mind, however, took a beating. For it still saw things in Cold War prestige terms. America had just failed spectacularly, while Russia hadn't lost any cosmonauts since 1971.[82]

During the 32 months during which NASA was grounded, a long debate about priorities took place within the agency. Should NASA seek somehow to revive the perceived golden age of the Apollo programme – as NASA 'insiders' like flier, aeronautical engineer and post-Challenger Shuttle astronaut Richard W. Truly proposed? Or should it go for a Low-Cousteau type 'Mission to Planet Earth' – as NASA 'outsiders' like first female astronaut and astrophysicist Sally Ride preferred? The Ride Commission issued a report in August 1987 arguing against high-technology grand leaps like astronauts to Mars, and in favour of an incremental and lower-cost strategy emphasising Earth's environment, robotic science missions and establishing a lunar research base.[83]

Ride, however, had already made enemies at NASA while on a presidential panel investigating the Challenger explosion. The so-called 'Ride Report' made her more. She left NASA shortly after her report appeared. Truly stayed on, and was chosen as NASA's sixth Administrator in 1989. An unbudgeted thirty-year Moon-Mars astronautics proposal also speedily won out over earthly or environmental priorities. In 1989–1990, a newly-elected George Herbert Walker Bush, America's first aviator president, sought to recreate the grand plans of NASA's Thomas Paine. Fittingly, Paine had recommended Bush as his successor as NASA head in 1970. Again appropriately, Truly, Bush's NASA Administrator, failed as badly as Paine had 20 years before. Even a 25-year and US $30 billion 'Mission to Planet Earth' environmental satellite system Truly added onto Bush's US $300–$500 billion 'Space Exploration Initiative' didn't help. Space had been partisanised by President Ronald Reagan's multi-billion dollar 'Star Wars'/Strategic Defense Initiative programme after 1983. Truly opposed Bush's Moon-Mars plans. He wanted to emphasise, instead, an ever-more over-budget space station and an ailing Shuttle. Bush spent little political capital pushing his own creation. Astronauts to Mars or lunar bases were still not something Congress wanted to pay for, particularly without trustworthy cost estimates.[84]

BACK TO THE FUTURE (AGAIN)

Fifteen years later, in February of 2004, matters looked eerily similar. Congress was majority Republican in both houses by then, something the country hadn't seen since before Sputnik. Another Shuttle – Columbia – had burned-up on re-entry to Earth's atmosphere. Another aviator-President, George Walker Bush, then suddenly and unexpectedly proposed a new space vision reiterating that of Thomas Paine, his own father and NASA traditionalists. Again, in 30 years,

many billions would be spent to reassert America's strength, determination and resolve with an astronautics and prestige-based Moon-Mars effort. Sean O'Keefe, a self-described 'bean counter' outsider from the Office of Management and Budget whom Bush had appointed NASA head in December, 2001 to bring order to NASA's 'notoriously optimistic cost estimates', had strongly argued against any 'destination-driven', Apollo-like approach to setting NASA priorities before Columbia was destroyed. But afterwards, O'Keefe quickly reversed himself. Now he supported what *Aviation Week* called a 'Back to the Future' Moon-Mars human exploration programme. Many in and out of official Washington wondered. Bush, after all, had 'no known previous interest in space'. He had never even visited the major NASA lab in his state while Governor of Texas.[85]

Lost in all of this resurgent Apollo-style prestige approach, yet-again, were earthly applications. From 1992 (when George Bush appointed him to replace a failed Truly) until 2001 (when cost over-runs caused George W. Bush to appoint O'Keefe to replace him) engineer Dan Goldin was NASA's longest-lived agency head. He fervently believed in solar system exploration. He had worked on advanced Mars spacecraft propulsion systems for NASA in his youth. But Goldin also understood that NASA had, finally, to respond to changed political circumstances. Important among these changes was environmentalism: a major concern of both Vice-President Al Gore and President Bill Clinton during their eight years in office from 1993 to 2001. Gore's book *Earth in the Balance: Ecology and the Human Spirit* was his claim to intellectual rigour and political respectability alike in both the 1992 and the 2000 presidential elections. NASA was one of the earliest federal agencies Gore studied as he and Clinton sought to 'reinvent government' to make it more efficient and responsive in the 1990s.[86]

Goldin didn't need to be told anything twice. Environmental applications finally became a NASA priority during the Goldin decade. Especially after Clinton was re-elected in 1996, NASA mission statements moved in a progressively earthly direction. By the time Goldin departed, verbose and something-for-everybody NASA policy priorities got summarised in three punchy lines:

> To improve life here.
> To extend life to there.
> To find life beyond.

Elaborations of this mission statement said NASA's chief purpose was 'to understand and protect our home planet' as well as to search for life and 'inspire the next generation of explorers'.[87]

To ensure such pithy pieties were put into practice, Goldin's NASA started cooperating with NOAA, the military, the European Space Agency and others to build a series of specialised satellites which will soon combine into a Global Earth Observation System. Beginning in 1999, the first Earth Observing Satellite (Terra) was launched; then came Aqua in 2002, and Aura in mid-2004. By then,

a multibillion-dollar six-satellite constellation funded by the US, Canada and France was under construction to make unprecedented efforts to monitor global climate changes on both land and sea, and in the atmosphere. After almost 50 years, NASA even rolled out a new organisational chart: part of which aimed at demonstrating, as a NASA official put it, 'that Earth is a card-carrying member of the solar system too'. Decades of unwillingness to cooperate with other agencies at home or abroad were slowly being replaced with an awareness that issues like global warming were now matters for international agreements and the beginnings of global regulation.[88]

George W. Bush's presidential victories in 2000 and 2004, however, put a chill on NASA's fledgling and long-delayed environmental efforts. Opposed to key international environmental accords, Bush's post-2004 space policy was one in which prestige mattered far more than pollution. Bush's new NASA head Michael Griffin proposed cutting US $1 billion in five years from NASA's Earth Science budget in mid-2005 to pay for solar system exploration over strong Congressional opposition. The sands of Mars mattered far more than the sands, forests, or plains of Earth – in the White House, at least. Findings by reputable NASA scientists regarding global climate change as a major and growing problem got muzzled by political appointees within the agency in 2005 and early 2006. Scandal then erupted in the columns of the *New York Times*, and reforms were promised.[89]

THE GOSPEL OF OUTER SPACE

Almost 40 years after 'Spaceship Earth' became an ever-present icon of global environmental movements, space advocates inside and outside of NASA cannot quite decide whether Earth should be part of their definition of space; or whether Earth is an essential factor in the success of space exploration.

Such confusion began in NASA's formative years. Power and (especially) prestige particularly mattered to NASA creators because they grew up in a pre-1950s era, one in which flight was a secular religion of educated professionals, a symbol of technological utopia and a marker for military dominance and national power: what Joseph Corn calls *The Winged Gospel*. Planes were panaceas for worldly ills. A major factor that brought this era to an end was the replacement of planes by rockets as symbols of military dominance. Another was the modern passenger aviation revolution of the 1960s. As many as two-thirds of American adults had flown by the end of the 1970s, aeroplanes were no longer panaceas. They were simply everyday tools. Technoutopian symbols had turned into taxicabs.[90]

This utilitarian shift has yet to occur fully in spaceflight, where analogies to Charles A. Lindbergh, Sir Francis Drake, Daniel Boone and Christopher Columbus remain commonplace. Many space advocates are still waiting for a utopian

transformation to occur that will produce a Copernican shift in the way humanity views itself and its relation to the universe. Once this intellectual transformation takes place, the way will be open to the planets and the cosmos beyond. The Golden Age of Apollo will be recovered by astronauts on Mars. Problems will disappear once they are put in spacesuits. A new cosmic consciousness waits to be found: perhaps in Martian micro-fossils.

It was no accident, then, that President Bush waited to announce his space vision of 2004 until immediately after the attempted flight of a replica of the Wright brothers' aircraft on the centennial of the first powered human flight at Kitty Hawk, North Carolina. Heroic symbolism like this still suffuses America's space programme; so does the concept of human spaceflight as a transcendent event. Secular religions and the technological sublime will certainly remain commonplace in US culture. But, as *Saturday Review* editor Norman Cousins put it in 1975, what was – and remains – most significant about Apollo was '…not that man set his foot on the Moon, but that he set his eye on the Earth'. Space advocates, accordingly, must one day learn to pay more sustained attention to their home planet, because earthly environmentalism, not space exploration, still remains the major science-based social movement of the late twentieth and early twenty-first centuries.[91]

NOTES

[1] 'NASA Environmental Theme', Personal Notes #97, 7 July 1973, 6; George M. Low Papers, Personal Files, Rensselaer Polytechnic Institute Archives, Troy, New York (hereafter: Low/RPI, PN).

[2] David Vogel, *Fluctuating Fortunes: The Political Power of Business in America* (New York, Basic Books, 1989), 64–81; Kim McQuaid, *Uneasy Partners: Big Business in American Politics, 1945–1990* (Baltimore, Johns Hopkins, 1994), 138–9; McQuaid, 'The Roundtable: Getting Results in Washington', *Harvard Business Review*, May-June, 1981, 114–21; Samuel P. Hays, *Beauty, Health, and Permanence: Environmental Politics in the US, 1955–1985* (New York, Cambridge, 1987), 13–70; Gaylord Nelson, 'All About Earth Day', http://www.earthday.wilderness.org/history/ ; Benjamin I. Page and Robert Y. Shapiro, *The Rational Public: 50 Years of Trends in Americans' Policy Preferences* (Chicago, University of Chicago, 1992), 150–9, esp. 156.

[3] Low/RPI, PN #97 (7 July 1973), 6.

[4] Ibid; for Fletcher's pieties, see: Roger D. Launius, 'A Western Mormon in Washington, DC: James C. Fletcher, NASA, and the Final Frontier', *Pacific Historical Review* (May, 1995), 217–41, esp. 236–7. Launius claims a 'liberal view of the environment' for Fletcher in this essay.

[5] 'Discussion of Non-Scientific Problems in the Space Age', Washington, 18 December 1958, passim; in: T. Keith Glennan Papers, Subject Files, NASA History Office, Washington, DC (hereafter: Glennan/NHO).

[6] Survey Research Center, Institute of Social Research, University of Michigan, 'Satellites, Science, and the Public: A Report of a National Survey on the Public Impact of Early Satellite Launchings for the National Association of Science Writers', (Ann Arbor, February 1959), 1–6, 39. This 57-page survey, financed by the Rockefeller Foundation, was the most rigorous single opinion survey of the formative years of the Space Age. The writer has found no evidence it ever featured in NASA planning, or in other advisory reports to NASA (e.g. by the RAND Corporation).

[7] For Glennan's low opinion of social scientists, see: i.e., Glennan to Vannevar Bush, 2 February 2 1959; Glennan to Philip C. Jessup, 31 December 1958; Glennan to Donald N. Michael, 2 February 1959; Glennan to David Riesman, 24 December 1958; all: Glennan/NHO.

For the choice for prestige by the 'Greenewalt Committee' in December of 1959, see, for example, Walter A. McDougall, *The Heavens and the Earth: A Political History of the Space Age* (New York, Basic Books, 1985), 203ff.

[8] For the NASA Act, see: John L. Logsdon, et al., (eds), *Exploring the Unknown, Selected Documents in the History of the US Civil Space Program, Volume I: Organizing For Exploration* (Washington, DC, NASA, 1995), 335–6. For the DSN, see: Douglas J. Mudgway, *Uplink-Downlink: A History of the Deep Space Network, 1957–1997* (Washington, DC, NASA, 2001), esp. 1–79.

[9] For the ABMA after 1956, see: John G. Medaris and Arthur Gordon, *Countdown for Decision* (New York, Putnam, 1960); Paul Dickson, *Sputnik: The Shock of the Century* (New York, Walker, 2001), esp. 87ff; Clayton R. Koppes, *JPL and the American Space Program* (New Haven, Yale, 1982), esp. 78–101.

[10] For NACA, see: Alex Roland, *Model Research: The National Advisory Committee for Aeronautics 1915–1958* (Washington, DC, NASA, 1985).

[11] For Dryden, see: i.e., Michael H. Gorn, *Hugh L. Dryden's Career in Aviation and Space* (Washington, DC, NASA, Monographs in Aerospace History number 5, 1996). The best source for Dryden is his papers, deposited at the Johns Hopkins University Archives in Baltimore, Maryland.

[12] F.W. Reichenfelder to Dryden, 2 May 1960 and Dryden to Reichenfelder, 6 May 1960, NASA-1960 Chronological File, Hugh L. Dryden Papers, Johns Hopkins University archives. (hereafter: Dryden Papers/JHU). For the rise of modern weather reporting based on satellite data and supercomputer models, see: i.e., Frank Batten, with Jeffrey L. Cruikshank, *The Weather Channel: The Improbable Rise of a Media Phenomenon* (Boston, Harvard Business School Press, 2002); Fred Guterl, 'The Nerds of Weather', *Newsweek*, 30 September 2002, 48–9 (re: Accu-Weather radio and TV service, founded in 1962). For a survey of the hardware, see: Janice Hill, *Weather From Above: America's Meteorological Satellites* (Washington, DC, Smithsonian, 1991).

[13] Robert Langreth, 'Lost At Sea: The National Oceanic and Atmospheric Administration', *Popular Science*, May 1995, 32–5. For the Ozone Hole, see: Nigel Calder, *Spaceship Earth* (London, Viking/Penguin, 1991), esp. 18–21; 'Ozone Hole Report', *Chemical Week*, 31 October 2001, 41; W.L. Smith, et al., 'The Meteorology Satellite: Overview of 25 years of Operation', *Science*, 31 January 1986, 455–63.

[14] Calder, op. cit., is a good introduction.

[15] Howard E. McCurdy, *Inside NASA: High Technology and Organizational Change in the US Space Program* (Baltimore, Johns Hopkins, 1993), 72–3.

[16] No biography of Pickering yet exists. For what is, de facto, one written by *Time Magazine*'s chief science writer, see: Jeffrey Kluger, *Journey Beyond Selene: Remarkable Expeditions Past Our Moon and to the Ends of the Solar System* (New York, Simon and Schuster, 1999).

[17] For two recent surveys, see: David J. Whalen, *The Origins of Satellite Communications, 1945–1965* (Washington, DC, Smithsonian Institution, 2002) and Craig Mellow, 'The Rise and Fall of Iridium', *Air and Space Smithsonian*, August-September, 2002, 60–5, esp. 65.

[18] 'NASA: Fourth Semi-Annual Staff Conference, Williamsburg, Virginia, 16–19 October 1960', 'Where Should NASA's Program Be Headed?' section, 37–38, NASA-Staff Conference box, NHO; Glennan to Dryden, 25 October 1960, Chronological Files, NASA-1960, Dryden papers/JHU; *New York Times*, 25 July 1960, 1; idem, 13 October 1960, 1; 'Public Understanding In the Space Age: An Address by Dr. William L. Pickering…April 6, 1960', 3–4; 'Impact-Social, 1958–64' file, NHO; 'Summary of Presentations and Discussions at the Fifth Semi-annual Staff Conference of NASA…March 8–10, 1961', NASA Staff Conference Box, NHO.

[19] 'NASA Fourth…Staff Conference', 37–9, NHO.

[20] For the fierce Senate fight over COMSAT, see: *New York Times*, 8 February 1962, 1, 12; *idem*, 9 August 1962, 8; *idem*, 12 August 1962, 1; *idem*, 19 August 1962, section 4, 6; *idem*, 18 August 1962, 1, 5; *idem*, 15 August 1962, 1, 16.

[21] Robert Hotz, 'Program Focal Point', *Aviation Week and Space Technology*, 15 January 1962, 21; George C. Wilson, 'Expanded Space Effort Viewed as Cold War Need, Poll Shows' (sic), *idem*, 5 February 1962, 34.

[22] See Reston's *Times* columns of 27 May 1962, section 4, 12; 12 August 1962, section 4, 10; 25 March 1963, 6; 5 April 1963, 46, 24 April 1963, 34.

[23] For Reston's importance, see: John F. Stacks, *Scotty: James B. Reston and the Rise and Fall of American Journalism* (Boston, Little Brown, 2002); See also *New York Times,* 5 January 1963, 5; 5 May 1963, 8; 5 May 1963, 31; 26 May 1963, section 6, 10, 23–4; and James L. Kauffman, *Selling Outer Space: Kennedy, the Media, and Funding for Project Apollo* (Tuscaloosa, University of Alabama, 1994), 10ff.

[24] W. Henry Lambright, *Powering Apollo: James E. Webb of NASA* (Baltimore, Johns Hopkins, 1995), 121–2, 136–9. The main 'spinoffs' from NASA's activities were not in products, but in procedures (e.g. quality control) via which things were made. The effects were 'secondary, not primary.' See: Denver Research Institute, *Space Benefits: The Secondary Application of Aerospace Technology in Other Areas of the Economy* (Washington, DC, NASA, 1976).

[25] Dryden to Neal Bosco, 23 November 1965, Chronological Files, Dryden Papers/JHU.

[26] A biographical essay with facsimile documents is: Michael H. Gorn, *Hugh L. Dryden's Career in Aviation and Space* (Washington, DC, NASA, 1996).

[27] For Paine, see: i.e., Thomas A. Heppenheimer, *The Space Shuttle Decision* (Washington, DC, NASA, 1999), 105–90; Hans Mark, *The Space Station* (Durham, North Carolina, Duke, 1987), 30–9.

[28] 'Space Program: Results of Poll of AAAS Members', *Science*, 24 July 1964, 368; Georgine M. Pion and Mark W. Lipsey, 'Public Attitudes Towards Science and Technology: What Have the Surveys Told Us?', *Public Opinion Quarterly*, Vol. 45 (1981),

303–16, esp. 313; Amitai Etzioni and Clyde Nunn, 'The Public Appreciation of Science in Contemporary America', *Daedalus*, Vol. 103 (Summer, 1974), esp. 192–4; Sylvia D. Fries, 'The Ideology of Science in the Nixon Years', *Social Studies of Science*, (Beverly Hills, Sage, 1984), 323–41, esp. 325.

[29] See: i.e., 'Nuclear Rocket Engine/Chet Holifield', Personal Notes #13, 28 February 1970, 2, 4, and 'Launch with Tiger Teague', Personal Notes #14, 7 March 1970, Box 70, Low/RPI.

[30] PN #27, 18 July 1970, 'Fiscal Year 1972 Budget and Programmatic Discussions', 13–4, Box 70, Low/RPI.

[31] Ibid., p. 14.

[32] 'Schriever Activities', PN #42, 21 February 1971, 5–6 and 'Discussions with Jim Webb', PN #32, Box 70, 6–7, Low/RPI.

[33] Francis T. Hoban, *Where Do You Go After You've Been to the Moon?* (Malabar, Florida, Krieger, 1997) is a good survey of Low's management style. See 192 for quotation. For Low quotation, see: PN #33, 25 October 1970, 4, Low/RPI.

[34] Oran Nicks (ed.), *This Island Earth* (Washington, NASA, October, 1970), esp. iv-vi; for polls, see: Page and Shapiro, op. cit., 49, 156.

[35] Harold M. Schmeck, Jr., 'Satellites to Get Urban Plans Role', *New York Times*, 7 August 1970, 33.

[36] 'Urban Overview', editorial, *New York Times*, 8 August 1970, 22.

[37] Ibid.

[38] See: i.e., 'Cost of the Satellite', *idem*, 8 October 1957, 34; Merrill, op. cit., 40–1; For the *Times*' continuing influence, see: i.e., Todd Gitlin, 'It was a Very Bad Year', *The American Prospect* (July 2004), 31–3.

[39] Loudon Wainwright, *The Great American Magazine: An Inside Story of Life* (New York, Knopf, 1986), 251–79, esp. 263.

[40] 'Fletcher Confirmed' and 'Public Affairs', PN #44, 21 March 1971, 1–3, Box 70, Low/RPI.

[41] 'Global Atmosphere Research Program', PN #12, 21 February 1970, 3–4; 'Center Directors Meeting', PN #5, 17 January 1970, 2; 'Elk Experiment', PN #15, 14 March 1970, 2–3; 'Animal Tracking', PN #25, 21 June 1970, 7 – all in Box 70, Low/RPI.

[42] For air travel, see: John B. Lansing, et. al., 'The Travel Market-1955' (Survey Research Center, Institute of Social Research, University of Michigan, 1955), 5ff; 'Air Travel Survey: 1993' (Princeton, Gallup Organization, 1993), 111–2. Both reports were prepared for the Air Transport Association of America, Washington, DC.

[43] Incrementalism is covered in Howard E. McCurdy, *The Space Station Decision: Incremental Politics and Technological Choice* (Baltimore, Johns Hopkins, 1996); see also McCurdy's *Inside NASA: High Technology and Organizational Change in the US Space Program* (Baltimore, Johns Hopkins, 1993).

[44] 'NASA and Civilian Applications', PN #109, 6 October 1973, 9–11, Box 68, Low/RPI.

[45] Low to Fletcher, 'Meeting with Bill McGlashan', 19 March 1973, and 'NASA and Civilian Applications', PN #104, 6 October 1973, esp. 10, both in Box 68, Low/RPI.

[46] 'Solar Energy Meeting with Congressmen McCormick and Symington, 23 April 1973', 'NASA in the Energy Business', PN #96, 23 June 1973, 6, and 'NASA and the Energy Problem', PN #99, 4 August 1973, 7, all in Box 68, Low/RPI.

[47] Low noted 'a complete absence' of discussions on how one might save energy by having more efficient aircraft power plants at NASA's three aviation labs during visits in May 1974. The Arab OPEC oil embargo had quadrupled gasoline prices eight months before. PN #121, 25 May 1974, 7, Box 67, Low/RPI. See also PN #159, 25 January 1976, 1, Box 65, Low/RPU; PN #150, 9 August 1975, 6, Box 66, Low/RPI.

[48] See, i.e., 'Low to Fletcher, Telephone Conversation with Mike McElroy', 13 January 1975, Box 66, Low/RPI; 'Meeting on Stratosphere with Mike McElroy', 15 January 1976, Box 65, Low/RPI; and 'Research on the Stratosphere', PN #136, 19 January 1975, 5, Low/RPI.

[49] 'Senate Hearings', PN #115, 2 March 1974, Box 67, Low/RPI.

[50] For Metzenbaum, see: 'Biographical Directory of the US Congress', http://www.bioguide.congress.gov/scripts/biodisplay.pl?index=M000678.

Low's life was very personal. I owe my knowledge of key aspects to Ms. Shirley Molloy and Mr. Stephen Wiberley of Rensselaer Polytechnic Institute in Troy, New York. Molloy was Low's longtime personal secretary; Wiberley a longtime colleague.

For NASA-Lewis, see: Virginia P. Dawson, *Engines and Innovation: Lewis Laboratory and American Propulsion Technology* (Washington, DC, NASA, 1991).

[51] For a typical example of how reluctant top-ranking administrators were to see NASA in 'what can we do for you?' terms, see: 'Minutes of the Center Directors' Meeting', 21–22 April 1976, 9–10, Box 65; For *Aviation Week*, see: 'Meeting with Aviation Week', PN #132, 10 November 1974, 4–5, Box 66, and 'Meeting with Bob Hotz', PN #153, 4 October 1975, 3, Box 65. For OMB (and General Accounting Office) problems, see: 'Meeting with Elmer Staats', 7 February 1973 and 'Meeting with Jim Lynn', PN #148, 15 July 1975, 8–9 – both in Box 66; For OMB's power, see: i.e., Lynn to Fletcher, 14 April 1976, Box 65; For inattention to Congress, see: Low to Fletcher, Very Sensitive-Eyes Only, 'Discussion with Dan Harnett 17 June 1974', Box 67; For Senatorial lack of interest, see: 'Senate Committee Reorganization', PN #84, 7 January 1973, 3, Box 68 – all in Low/RPI.

[52] For examples, see: 'Meeting with Mike McElroy, 15 January 1976', PN #158, 11 January 1976, 2–3, 6–7, Box 65, Low/RPI.

[53] Pamela Mack, *Viewing the Earth: The Social Construction of the LANDSAT Satellite System* (Cambridge, MIT, 1990) is the standard source. For costs, see: 1, 83. For Viking costs, see: Edward C. and Linda N. Ezell, *On Mars* (Washington, DC, NASA, 1984), 251.

[54] Fletcher's definition is in 'Minutes of the Senior Management Conference', 17–19 March 1976, Reston, Virginia, P. 9, Box 65, RPI.

[55] Mack, *op. cit.*, 3–6, 31–7, 62–7, 75, 89–90, 82. Initial Resolution figures range from 98 to 106 metres.

[56] 'Trip to West Africa and the Azores, 22–31 July 1974', dictated 19 August 1974, and Low to Frutkin, 'Visit With Senegalese Officials, 1 August 1974', both in Box 67, Low/RPI; For NASA's earlier refusal to participate in the GARP, see: PN #12, 21 February 1970, 3–4, Low/RPI.

[57] 'Memorandum of Conference [with Senegalese officials]…, 25 July 1974', 3-page attachment to Low to Arthur Frutkin, August 1, 1974, and Frutkin to Low, 6 June 1974 – both in Box 67, Low/RPI.

[58] The 'lost the first round' phrase is Low's, see: PN #125, 20 July 1974, 4; Low to NASA HQ personnel, 'The Movement of Correspondence in NASA Headquarters', 12 February 1975, both in Box 66, Low/RPI. (Low called a six week delay '…horrible – but not too unusual'.) 'Memo for the Record Meeting with [OMB Deputy Director Frank] Zarb and Taft, 18 July 1974, Box 67 and David Williamson, Jr., 'Note for Dr. Low', 16 October 1974, 3, Box 66, both Low/RPI; Mack, op. cit., 146–70, esp. 146–50.

[59] Mack, op. cit., pp. 5, 126–7, 131, 176. NASA was left with a lovely folio volume, *Mission to Earth: LANDSAT Views the World* (Washington, NASA, 1976), which sold for 10 times its original government document cover-price only 25 years later.

[60] Dupree, quoted in: Rae Goodell, *The Visible Scientists* (Boston, Little Brown, 1977), 47; Dorothy Nelkin, *Selling Science: How the Press Covers Science and Technology* (New York, W.H. Freeman, 1987), 77, 79, 114–5. Every NSF-funded survey of public attitudes towards science and technology since 1978 confirms Dupree and Nelkin. See the relevant chapters of NSF's biennial *Science and Engineering Indicators* volumes.

[61] For Fletcher, NASA, and the founding of NSS, see: Michael A.G. Michaud, *Reaching For the High Frontier: The American Pro-Space Movement, 1972–1984* (New York, Praeger, 1986), 48–54; Ernst Stuhlinger and Frederick I. Ordway III, *Wernher Von Braun: A biographical Memoir* (Malabar, Florida, Krieger, 1994), 318–23; Low to Fletcher, 'Conversation with Dick McCurdy on 15 May 1974', 'Space Buffs', PN #98, 21 July 1973, 7; Low to Fletcher, 'Miscellaneous Items – First Week, 19 April 1976', 1–2, all Box 67, 68, 65 respectively, Low/RPI.

[62] Gerard K. O'Neill, *The High Frontier: Human Colonies in Space* (1977); third edition, Apogee Books/Space Frontier Foundation, 2000, 10ff; Thomas O. Paine, 'Humanity Unlimited', *Newsweek*, 25 August 1975, 11; Michaud, op. cit., 81–121; Greg Klerkx, *Lost in Space: The Fall of NASA and the Dream of a New Space Age* (New York, Pantheon, 2004), 66–90.

[63] For pro-NASA demographics, see: Michaud, op. cit., 112–14; For civil rights fights NASA lost, see: Kim McQuaid, 'Racism, Sexism, and Space Ventures: Civil Rights at NASA in the Nixon Era' (under consideration at a journal) and Betty Ann Holtzmann Kevles, *Almost Heaven: The Story of Women in Space* (New York, Basic Books, 2003), 1–77.

[64] For Rumsfeld and Cheney, see: Low to Fletcher, 'Miscellaneous Items of Interest,15 October 1974', 2, Box 66, Low/RPI.

[65] Carl Sagan, *The Cosmic Connection* (1973) (New York, Cambridge University Press reprinted ed., 2000), esp. 59–65. For Sagan's career, see: William Poundstone, *Carl Sagan: A Life* (New York, Wiley, 1999). Poundstone is better for the scientific Sagan; Davidson is better for Sagan the celebrity.

[66] Low to Fletcher, 'Discussions with Carl Sagan, 12 September 1974 – Eyes Only', and Low to Fletcher, 'Miscellaneous Items – 2, 12 September 1974, Eyes Only'; Low and Fletcher in November, see: 'Meeting with Carl Sagan', PN #133, 30 November 1974, 4–6. All in Box 66, Low/RPI.

[67] 'Meeting with Carl Sagan', PN #133, 30 November 1974, 5–6, and Harvey W. Herring to Low, 'Additional Thoughts on Television Productions, 8 January 1975', esp. 3, both in Box 66, Low/RPI.

[68] For an admiring summary of Cousteau's importance to oceanographic research, see: Robert D. Ballard, with Will Hively, *Eternal Darkness: A Personal History of Deep Sea Exploration* (Princeton, Princeton University Press, 2000), esp. 41ff, 58, 62–5, 299.

[69] For National Geographic's importance, see: Robert M. Poole, *Explorers House: National Geographic and the World It Made* (New York, Penguin, 2004). By the 1970s, a multi-volume series, *The Ocean World of Jacques Cousteau*, was being published at the rate of a book a year. A TV series of the same name followed in the 1980s.

[70] 'Herring to Low, 13 January 1975', 1–2, Box 66, Low/RPI.

[71] 'Personal Notes: Visit to Calypso, 26–30 December 1974', esp. 8–9, Box 66, Low/RPI.

[72] 'Low to Cousteau', 13 February 1975, Box 66, Low/RPI.

[73] 'Jacques Cousteau', 31 May 1975, PN #145, 3, Box 66, Low/RPI.

[74] 'Arrangement with Jacques Cousteau', 26 July 1975, PN #149, 6–7, Box 66, Low/RPI.

[75] 'Memo for the Record – 5 January 1976', with a carbon copy to James Fletcher, Box 66, and 'Visit to Calypso', 7 September 1975, PN #151, 4–5, Box 65 – both Low-RPI.

[76] Sealed Memo to the Archives, dated 31 May 1984 and 19 June 1984, Faculty/Alumni files, Low/RPI, Low to Flecther, 'An Experiment That Failed, 24 March 1976', Box 65; Low to Cousteau, 10 June 1975, Box 65; 'Meeting with Cousteau', PN #161, 22 February 1976, 2–3, Box 65, all: Low/RPI.

[77] 'The Resignation', 21 March 1976, PN #163, 1–6; 'Special Notes on Consideration as FAA Administrator, 13 May 1975', and 'Epilogue to Special Notes…FAA Administrator, 31 May 1975', – both in Box 65; and handwritten notes re: FAA job, with typed notation from Low's executive secretary dated 23 June 1975 stating that he 'accepted the FAA job', Box 66 – all: Low/RPI.

[78] 'Minutes of Center Directors' Meeting, 21–22 April 1976', 12–3, Box 65, Low/RPI.

[79] Ibid.; For the cooperation with other civilian government agencies, social research, international cooperation, and studying the most effective use of scientific and technical resources and 'such other activities as may be required for the exploration of space' legislative language NASA ignored, see: Logsdon, et al., op. cit., 335. For the first of many arguments that it was impossible for NASA to do what its leaders didn't want to do anyway, see: Homer Newell, *Beyond the Atmosphere: The Early Years of Space Science* (Washington, NASA, 1980), 374.

[80] Poundstone, op. cit., 290; Davidson, op. cit., 348–9; For the Planetary Society, world membership was 63,000 as of 30 September 2003; and 57,600 a year later, See: 'Financial Statements: Planetary Society, 30 September 2003 and 30 September 2004' (available from the Planetary Society upon request). The National Space Society has also fallen recently from 35,000 to 20,000, though a very capable new Executive Director of the organisation has started increasing numbers again, via the Internet. George T. Whitesides to author, 15 April 2005.

[81] *New York Times*, 29 March 1979; *idem*, 2 January 1979, 1.

[82] For the Challenger reaction, see: Jon D. Miller, 'The Impact of the Challenger Accident on Public Attitudes Towards the Space Program: A Report to the National Science Foundation, 25 January 1987', 2, NHO; Burrows, op. cit., 551–77.

[83] *Leadership and America's Future in Space: A Report to the Administrator by Dr. Sally Ride, August, 1987* (Washington, DC, NASA, nd. [1987], 7ff.

[84] Cost estimates for the Space Exploration Initiative ranged all over the map. Burrows, op. cit., 576 says US $400 billion. The *Economist* of London reported US $500 - $600 billion (five times the cost of Apollo in constant dollars). *Space News* put internal NASA estimates at US $500 billion. *America As The Threshold: Report of the Synthesis Group on America's Space Exploration Initiative* (Washington, DC, GPO, 1991) is the official argument. Lynn Ragsdale's Chapter in Launius and McCurdy, op. cit., provides an overview. 'NASA: Cold War On Mars', *Economist*, 10 March 1990, 94, 96.

[85] Frank Morring, Jr., (Back to the Future', *Aviation Week and Space Technology*, 12 January 2004, 22–3; 'Bush's Space Plan: Bold Vision or 'Moondoggle?', *idem*, 26 January 2004, 58; Frank Sietzen, Jr., 'Rekindling the Dream', *Ad Astra* (January-March, 2004), 16–7; Frank Sietzen, Jr. and Keith L. Cowing, *New Moon Rising: The Making of America's New Space Vision and the Re-Making of NASA* (Burlington, Ontario, Apogee Books, 2004), esp. 147ff is both polemical and valuable. Based on insider interviews, it will likely long remain the only book-length treatment.

[86] For critiques of Gore's environmentalist positions, see: John A. Badan (ed.), 'Environmental Gore: A Constructive Response to 'Earth in the Balance'', (San Francisco, Pacific Research Institute, 1994). For Gore and NASA, see: *National Performance Review: NASA* (Washington, GPO, 1994). Gore headed the group doing these agency studies.

[87] George Cooper III (head of Cuyahoga Valley Space Society chapter of the National Space Society, to author, 3 December 2004, attaching discussion of NASA mission statement by other NSS members and affiliates. For earlier vision statements, see: *NASA Strategic Plan* (February, 1996), (Washington, DC, NASA), 1–2.

[88] For the quotation, see: 'Shake-up', *Aviation Week and Space Technology*, 14 June 2004, 21. For International and interagency environmental cooperation, see: Michael Taverna, 'Climate Agrees with Them', *idem*, 7 June 2003; Frank Morring, 'Weather Report', *idem*, 10 November 2003, pp. 64ff; Michael Mecham, 'The Big Sniff', *idem*, 14 June 2004, 46–8; Michael Taverna, 'Takin' the A-Train', *idem*, 14 June 2004; Michael Taverna, 'World Watch Widens', *idem*, 25 October 2004, 86–8; Juliet Eilperin, 'Taking the Pulse of the Planet', *Washington Post National Weekly Edition*, 2–8 August 2004, 35.

[89] See, 'Explore Earth First', *Aviation Week and Space Technology*, 2 May 2005, 21. For the global warming censorship scandals at NASA regarding Dr. James E. Hansen and others, see the coverage in the *New York Times* for 29 January and 16 February 2006, and the 'Washington Outlook' commentaries in *Aviation Week and Space Technology* for 13 February, 20 February, 27 February and 13 March 2006.

[90] Joseph J. Corn, *The Winged Gospel: America's Romance with Aviation* (Baltimore, Johns Hopkins, 2002 – reprint of original 1983 edition with new preface).

[91] The quotation comes from 'Fiscal Year 1972 Strategy', handwritten notes by George Low, Box 70, and 'The US Space Program…'Eurospace Conference, Monte Carlo, 4 October 1975, 3, Box 65 – both Low/RPI.