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Apollo to the moon

The exploration imperative, revisited

This article discusses space exploration and the Apollo missions are the main subject in this article. Did the huge projects and expenses of the US have any results on the long term? Rod Pyle examines this with a retrospect view. What happened with the ambitions to explore space in the last two decades?

‘Superhuman effort isn’t worth a damn, unless it achieves results’ – Ernest Shackelton

Between 1968 and 1972, nine Apollo spacecraft left the Eastern United States on columns of flame, headed into the great void between Earth and its moon. Eight of those missions met with success, and all were milestones in space exploration and achievement.

In the nearly 40 years since the last Apollo lunar mission, humans have not left low Earth orbit. Nor have most seen much reason to. Other than the occasional flight of fancy regarding the crewed exploration of Mars, or NASA’s recently cancelled Constellation lunar program, US manned space efforts have been limited to space shuttle operations and the International Space Station. These are both worthy efforts, and have met with substantial success. But while innovative and accomplished, neither has captured the imagination like Apollo.

The reasons for this are many, and have been argued *ad nauseam*. More important to our discussion: does exploration of space beyond Earth orbit matter? If so, why? What can we learn from the Apollo program to apply to future space initiatives? And finally, what has become of the drive to explore space in the last half-century?

Origins of Apollo

When discussing motivations behind the exploration of space, one must always examine political issues in play at the time. For while the desire to

explore and advance knowledge is always a part of the equation, as are the various economic and technological rewards, political considerations have always ruled paramount.

Apollo was born in the 1950's. Technically, the project did not begin to take physical form until the 1960's. It was the Cold War environment, in which the Soviet Union and United States found themselves at odds, which spurred Apollo into being.

It is also no coincidence that some of the finest scientific minds produced by Germany were looking for a new home in this time period. Both the Soviet and US programs were heavily influenced by German science and engineering, and to various degrees staffed by German rocket scientists. By 1961, both the US and USSR were taking fledgling steps into space with tiny capsules crewed by a single man. It was in this singular moment, during these primitive developmental flights, that Apollo truly came into being. At this time the total US manned spaceflight experience totaled about 15 minutes. But there were great political pressures here – the USSR's first orbital mission, a failed attempt to support a coup in Cuba, and others – that demanded a bold response from the young American president.¹ After conferring with his science advisors on what the US might actually be able to achieve, a manned lunar landing was chosen. Kennedy announced the new endeavor at a 1961 Congressional speech, and elaborated upon it in September of 1962 during a speech at Rice University in Houston, Texas.

So the American moon program, as seen with the benefit of hindsight, can arguably be called a political stunt conceived by the Kennedy administration. It was a challenge to the emerging Soviet Union to fight a non-shooting war on technical grounds, to prove which system of government was superior in creating technological prowess. In short, it was a war over domination of the heavens fought in largely non-military terms. It should be noted, however, that the militaries of both powers were involved (more in the USSR than the US) with the programs and stood to benefit from any technological advances that occurred as a result.

Perhaps the biggest driver of Apollo, though (and one that could not have been foreseen), resulted from complete chance: the death of John Kennedy. He had specified that the United States land on the moon 'Before this decade in out...'. While this might have been sufficient motivation to accomplish the task, when Kennedy was assassinated in 1963 the resulting

1 The failed Bay of Pigs effort, in which CIA-backed Cuban rebels attempted to invade Cuba and organize revolutionary elements.

ghost of a martyred president may have been the one factor that propelled Apollo into a successful trajectory. Nobody in any administration, in any political party, wanted to go on record as wishing ill towards a Kennedy Memorial Space Program. It would be political suicide.

But what of the great desire to achieve, to explore? Wasn't that the motive force behind America's voyage to the moon? While it's tempting to view the Apollo program in this gauzy light, it is not realistic. In America the exploration imperative took a back seat to political motivations until the Apollo program was already underway. Then exploration and scientific curiosity was allowed into the discussion, as various universities and top science teams were invited to participate in the massive endeavor.

But how this grand scheme would be carried out was another matter. The commitment of national will, and money, had been made. But at the time this occurred, the US had sent one man into space in a tiny capsule atop a modified ballistic missile for a 15-minute sub-orbital hop. It was a bit like planning an international flight after playing with a paper airplane – we had decided to do it, but had to discover how. There were plans on paper, but little existed in reality. It would take the best of German engineering and American industrial resources to make the leap.

Die Rakete

The technology behind the Saturn 1 booster program dated back to the NAZI V2, German rocket genius Wernher von Braun's crowning achievement until he joined NASA. That weapon, developed with German war funding, was the first reliable liquid-fueled rocket. When the V2 was brought to America after the war, it served as the template for the development of the Redstone missile, the rocket that took Alan Shepard on America's first manned spaceflight.

This rocket, in turn, provided the basis for the Saturn 1 booster designs, by clustering Redstone components. It was effective, and opened space to NASA, but it was not going to get America to the moon. That would require the exponentially larger Saturn V and vast amounts of capital.

By the mid-1960's, the US moon program was moving ahead at high speed. At this point, the exploration imperative was beginning to emerge in a purer form. Scientists from dozens of universities all over the country joined the effort. The Apollo program was gaining scientific respectability.

But to recap, let us not forget that the motivations behind this vast,

treasury draining effort were not purely scientific. The US space program began as a military exercise in rocketry, advanced through nuclear missile development, was briefly viewed as the 'high-ground' of manned military application, and finally became a *mea culpa* for Kennedy after the Bay of Pigs, as ultimately the Apollo program represented political leverage against the Soviet Union.²

Capitalism

The United States is a nation founded on capitalistic ideals, and the execution of the Apollo program would evolve via this system. The companies who built the lunar hardware for the Apollo program were primarily profit-driven. And while most of these were started only decades earlier by visionaries and idealists, to whom flying was more a sacred calling and less a business, by the 1960's the companies had evolved into big corporate businesses. Space travel, while new and exciting, was ultimately yet another contract to be sought and won.

The Apollo capsule would be built by North American (soon to become North American Rockwell), the lunar lander by Grumman Aerospace, and Von Braun's boosters by auto manufacturer Chrysler and civil aviation giant Boeing. The contracts assigned to these corporations were huge. Clearly, there was money to be made in the moon program. In defense of the contractors, what they were undertaking required vastly expanded life-support abilities and exponentially larger and more complex spacecraft and boosters than were ever built. It was a vast undertaking on the scale of the Manhattan Project (America's effort to develop atomic weapons), and these corporate giants were heading off into unknown territory. And they were well paid to do so. The result, as with so much else in the Apollo program, was an almost magical partnership which resulted in engineering brilliance.

Reaching the moon

As the technology to achieve spaceflight took form, a design to reach the moon had evolved as well. Once the major decisions on which the technology would be based had been made, the steps to the lunar landing itself were

2 John Pike, 'Apollo, Perspectives and Provocations', address to Cold War History Symposium, Ripley Center, Smithsonian Institution (11 May 1994 Washington, DC).



Wernher von Braun. Source: *Encyclopedia Britannica*.

planned. Again, the engineers of Germany had an inordinately large footprint here, and a logical yet cautiously incremental approach was taken, often in contrast to a seemingly reckless Soviet space program. Von Braun, in conjunction with the legions of program directors and managers at NASA, developed a carefully planned, step-by-cautious-step development process for Mercury, Gemini and Apollo.

In the Soviet Union, space efforts were much closer to the military and were ultimately directly driven by the Politburo, and therefore by political demands. There were also multiple concurrent space programs, dividing already very limited resources, and often unnecessarily duplicating efforts. But it was fast. NASA felt the pressure, but soldiered on as planned. The lunar landing was the big prize, and they kept their eyes firmly affixed to it.

Lunar progression

To recap the lunar effort in a short article is not easy, but for the sake of historical hindsight, here is the progression of projects that led to the America's lunar triumph:

Project Mercury: Mercury represented America's fledgling steps into manned spaceflight. The tiny one-man craft was fixed atop first a Redstone booster, then later upon an Atlas. Mercury served as a platform to get Americans into orbit and test life-support technologies and re-entry and recovery techniques.

Project Gemini: Gemini carried two astronauts aloft with only slightly more interior room per man than Mercury. It flew atop a Titan ballistic missile. A huge leap forward in complexity and capability over Mercury, the capsule offered life support for weeks instead of days. Where Mercury used batteries for power, Gemini augmented this with the new technology of fuel cells, which generated power with storable liquid fuels, greatly enhancing its orbital endurance. The capsule also had maneuvering capability, with the addition of small reaction-control jets on the nose and tail. This allowed

Gemini to not only continue to forge ahead with the developments of Mercury, but also to act as a testbed for maneuvering once in orbit. This was a critical component of the lunar missions to come, and was perhaps Gemini's crowning achievement.

Project Apollo: The Apollo capsule and maneuvering module was an exponential increase in both capability and complexity. With miles of wiring and complex control systems, Apollo raised the stakes – and dangers – to new heights. Any doubts about the difficulty of this endeavor were quickly erased when an early Apollo capsule burst into flame during a ground-based test in 1967, killing the three astronauts aboard. But with a redesign and massive quality improvement program, the Apollo capsule ultimately proved itself many times over in widely varied roles (it was used well beyond the lunar missions).

The Lunar Module was the most difficult of the Apollo components to design and build. Ultimately, the craft was engineered to accomplish its mission with a minimum of waste or contingency. The hull was paper-thin aluminum, the engines of a new and revolutionary design, and the flight controls simple yet sophisticated.

These machines sat atop the Saturn V booster (after testing on a smaller Saturn 1B), the largest rocket to date. Unprecedented in complexity and sheer scale, it was a mammoth engineering feat. And once man-rated, it also had a perfect launch record. But getting to the moon required one more major component. Apollo would use an entirely new and untried control and navigation system... the digital computer.

Computers

While this accomplishment deserves a lengthy article of its own, suffice it to say that Project Apollo's greatest triumph was the flight-readiness of the digital computer. In overly simple terms, Apollo engineers took the computers of the 1950s and '60s, which filled rooms at NASA and MIT, and compressed the bare essentials into a unit about the size of a small shoebox. The ultimate benefits of this are obvious, and we live with the results of these technological advancements to this day. The computers of Apollo were a miracle of engineering. Using early integrated circuits, with programming provided by MIT, the Apollo Guidance Computer was capable of flying to the moon, landing, ascending, all rendezvous maneuvers and returning to Earth with 32 kb of memory operating at 1.02 MHz. Without

them, a lunar landing simply could not have been achieved.

The master plan

Once a basic lunar mission profile had been worked out, the planned line of progression looked like this: First, NASA would have to develop vehicles: the capsules, maneuvering stages, and boosters were all tested extensively without astronauts aboard. The tests involved boosting, recovering, and deliberately crashing these units until any weaknesses that could be resolved, were. These were the flights of Apollos 4, 5, and 6.

Next, the new hardware had to be tested outside of Earth's atmosphere. The capsule and its maneuvering unit were tested during the Apollo 7 mission. Then the Lunar Module was added for an Earth orbital test on Apollo 9. Apollo 10 tested the capsule, maneuvering unit and lunar module in lunar orbit without a landing. The major mission objective, which was both a flight-test and seminal accomplishment of Apollo's mandate, was to land humans on the moon with Apollo 11.

Finally, the remainder of the Apollo flights would delve deeply into research targeted at understanding the origins and formation of the moon. Apollos 12 through 17 would extend these landing missions and allow astronauts to spend increasingly longer times on the lunar surface, conducting extensive geological studies and other scientific experiments (there were plans for Apollos 18-20, but these were cancelled by the Nixon administration).

Each step pressed the limits of both technology and human endurance. And they were not without their accidents and shortfalls. But in each advancement was the promise of the prize, and lessons learned from each mission were quickly corrected and applied to the next flight.

The missions

Once Apollo 7 had successfully flown in Earth orbit with three astronauts aboard, the next logical step was to test the lunar lander in the same environment. But the Lunar Module was beset with terrible developmental problems, and Grumman could simply not guarantee the safety or flightworthiness of the craft. Apollo now had a dead spot in its timeline.

In addition, there was political pressure to contend with. In the international intelligence haze of the space race, little was known about

the Soviet program beyond the fact that they would do almost anything to beat America to the moon. What the West did know was that the new Soviet Soyuz spacecraft was designed to fly to the moon and back, but at the time nobody in the US could know how close to this goal they were. The biggest fear was that the Soviets might orbit the moon without landing on it, therefore stealing much of Apollo's thunder. This generated a radical new line of thinking that ultimately resulted in the redirection of the next flight.

Apollo 8: With the Lunar Module beset by weight and technical problems, the choice was fairly simple: wait until it was ready or try something risky. As we later learned with the near-disaster of Apollo 13, the Apollo spacecraft had inside it dangers that could lead to disastrous consequences. But in 1968, America was less concerned with these possibilities than 'losing' the moon to the Soviet Union. So in a radical departure from the slow-and-steady process so coveted by Von Braun, the decision was made to send Apollo 8 off to the moon. Without the Lunar Module there could be no landing, but the Apollo spacecraft itself had proved to be very robust. So in December of 1968, three astronauts were sent off to the moon to enter lunar orbit, stay for 20 hours, and return to Earth. It was dangerous and bold, and there were doubters within the program, but ultimately it worked brilliantly. America had claimed the moon as its own.

Apollo 9: With the delivery, finally, of a flight-capable Lunar Module, Apollo 9 rocketed skyward in March of 1969. But the flight stopped in Earth orbit, and served as a test of the capabilities of the Lunar Module and lunar exploration suits in the hard vacuum of space. Again, a near total success was scored.

Apollo 10: The next incremental mission took place in May of 1969. Apollo 10 utilized the Saturn V in its intended role and the mission carried the complete spacecraft system, capsule, maneuvering unit and lunar lander to the moon. But the LM was still too heavy to land and return, it was used on this mission to test undocking, descending to within a few miles of the moon's surface, and return to the command ship, all in lunar orbit.

Apollo 11: The first landing on the moon took place in July of 1969, on Mare Tranquillitatis, the Sea of Tranquility. This mission was, in a real sense, the beginning of the end of the Apollo program, for once the landing was complete, the major goal of JFK was also complete. This was the first landing-capable Lunar Module, and the landing itself was the only major untried element of the mission. But this landing included leaving the lander, using the suits in a vacuum on a very hostile surface, doing experiments

once there, returning to the lander, and ascending from the moon. There was also the element of lunar orbit rendezvous with the Command Module, tried only once before with Apollo 10. Many within the government and even within NASA felt that only a few more flights should be attempted as the risk increased with each mission.

Apollo 12: Just weeks later, in November of 1969, Apollo 12 followed to the moon. This mission attempted, and achieved, a pinpoint landing in Oceanus Procellarum (Ocean of Storms,) near an old unmanned lunar probe, Surveyor 3. The surface exploration time was longer (with two moonwalks over Apollo 11's one) and included a nuclear-powered experiment package.

Apollo 13: Known as 'the successful failure', Apollo 13 suffered a critical explosion between Earth orbit and the moon. With life support failing and little power, Mission Control had to scramble to save the lives of the three astronauts aboard. It was an unintended test of the Lunar Module as a lifeboat for both motive force, power supply and life support. The craft performed brilliantly, and the crew returned safely by the narrowest of margins.

Apollo 14: Launched in January of 1970, this was the last of the 'H' missions (denoting the less capable, early Lunar Module design). Apollo 14 traveled to a more geologically complex region called Fra Mauro, near the Mare Imbrium basin. This hilly, undulating area included material thrown-up by a basin-forming impact, and allowed the moonwalkers to collect samples from that event.

Apollo 15: The first of the extended 'J' missions, Apollo 15 landed at the Hadley-Apennine region, near Mare Imbrium. This flight also included the first lunar rover, which extended the area explored by the astronauts. The landing zone was 12,000 feet about the surrounding terrain, and thought to be older material exposed by lunar impacts. This was extensively sampled by the rover-capable moonwalkers.

Apollo 16: This second of the 'J' missions landed at the Descartes highlands, part of the older, higher elevation regions generally known as the lunar highlands. Apollo 16 carried another lunar rover and extensively sampled the area, revealing much about the nature of nearby impact events.

Apollo 17: The final Apollo mission landed at Taurus-Littrow. It was the only Apollo flight to include a true scientist, Harrison Schmitt, who had a Ph.D. in geology. More geological science was performed on this flight than any other, and it yielded the best samples of any mission. The

area explored was a border of highland and basin areas, and allowed for the exploration of that interaction.

With the completion of these flights, the lunar chapter of Apollo was complete. Apollos 18-20 had been cancelled in 1969, and the hardware from these missions, already built and ready to go, was partially used for two more missions, Skylab in 1973, and the Apollo-Soyuz Test Program (ASTP) in 1975.

After the moon landings were completed, NASA returned its focus for manned programs entirely to Earth orbit and replaced the Saturn V and Apollo hardware with the Space Shuttle, which will remain in service through early 2011.



Launch of the Apollo 11 mission. Source: http://scienceblogs.com/startswithabang200907/happy_moonday.php.jpg

A legacy of exploration

The United States declared returning to the moon as a national objective in 2004 with the new Constellation program. Unfortunately, this bold proclamation was not accompanied by sufficient funding. Some work was done toward this goal, but for a variety of motivations, in 2009/2010 the Obama administration shelved these plans.³ As of today there is no clear plan for a successor to the shuttle; no single program has emerged to replace the scuttled Constellation effort. Development will continue on the Orion orbital capsule as a rescue craft, but with no booster to loft it, it is a child without a parent.

So what will become of the American manned space program? Rumors abound, ranging from the emergence of a private space industry to a mission to a nearby asteroid in 2025. None are set in stone, and the future of all is uncertain. The only near-certainty is a plan to use Russian Soyuz spacecraft to continue servicing the International Space Station through 2020, but this

3 See the *Review of United States Human Space Flight Plans Committee* (also known as the Augustine Committee Report), the US Office of Science and Technology Policy, 2009.

too could fall victim to multinational budget cuts. In light of the current financial crisis, this seems increasingly likely. During the height of Apollo, NASA's budget was about five percent of the US total. Currently it stands at less than one percent. This includes unmanned missions to the planets, increasingly important Earth-orbital observation platforms, and general aerospace research. It's not all about 'rocket men'.

From the mouths of kings

Many have spoken out against the doldrums that NASA finds itself in. Neil Armstrong, the first man on the moon, recently railed against the decision to cut the Constellation moon program from NASA's agenda. In a recent statement, Armstrong said: 'I believe the President was poorly advised'. He continued to say that the United States is risking losing its role as a leader in space exploration with its new plan, and that he was concerned with the looming gap in American human spaceflight. 'Other nations will surely step in where we have faltered', Armstrong stated.⁴

Alternatively, Apollo 9 astronaut Russell Schweickart has come forth supporting at least a part of the Obama administration's plan. In a recent letter to relevant politicians, he opined: 'NASA should, as proposed by the new space program... encourage and assist US enterprise in meeting the performance and safety requirements inherent in flying both cargo and people to low Earth orbit without absorbing all of the cost.'⁵ This cooperative effort would both minimize the existing gap and bring into being an exciting, new US industrial capability, replete with industrial innovation and job creation'. Which if either of these opinions may count remains to be seen.

Lessons from Apollo

Many have looked back at the Apollo program seeking inspiration to move ahead. What, if any, are the lessons to be learned from those first bold steps beyond Earth? We have discussed the many reasons that Apollo became a national priority in the 1960's, and these conditions are not likely to recur

4 Open letter to president Obama from Neil Armstrong, Commander, Apollo 11, James Lovell, Commander, Apollo 13, and Eugene Cernan, Commander, Apollo 17. As released to international media, April 2010.

5 Letter from Apollo Astronaut Russell Schweickart to Sen. Bill Nelson (and others) Regarding President Obama's Proposed NASA Budget, May 17, 2010.

in a similar fashion. But there was a basic wisdom behind the design of the program that can be instructional, and for proof we need look no further than Apollo's competition – the Russian Soyuz spacecraft.

Soyuz was the Soviet Union's answer to Apollo, and was designed along generally similar lines. It was, and remains, a self-contained capsule and life support unit like Apollo. It was over-engineered for its task and very robust and reliable. Originally designed to make the voyage to the moon and back, Soyuz was tested in this role, though it was unmanned at the time. Had other problems not cursed the Soviet program (in particular a defective booster design, the unreliable N-1), there is little doubt that a manned Soviet circumlunar voyage would have been made by 1970.⁶

Flash forward 40 years: Soyuz has been in continual use since the late 1960's, and has an excellent record of operational success. It has accomplished orbital research, ferried cosmonauts and supplies to the Soviet Salyut and Mir space stations, and continues to supply men and material to the International Space Station. Soyuz has further been licensed and adapted by the Chinese for use in their own space program with great success, and in all cases for far less per flight than the US shuttle program.⁷

So if there is a lesson to future space planners from the Apollo years, it might be that some designs are timeless, and there are times when reusability and new technologies are not the best goals to be seeking; sometimes 'what works' is good enough. The shuttle has been a remarkable spacecraft, but a solid argument can be made that incrementally improved continuation of Apollo hardware would have been far less expensive than the US shuttle program.⁸ And while the absolute (2010 adjusted dollars) cost of the Apollo program was, per launch, higher than the shuttle program, this included much 'pathfinding' research which was a one-time investment. Had the Saturn V and Apollo capsule assembly lines been kept operating for roughly 115 more launches, the cost per launch would likely have been dramatically lower than the shuttle, which rests at about \$1.4 billion per launch.⁹ In part, this was the inspiration behind the now-cancelled Constellation program. Sometimes, to move forward, one must first take a step back and take a hard look at what works versus

6 Nicholas L. Johnson, *The Soviet Reach for the Moon* (Washington, DC 1994).

7 Even allowing for differing political and economic systems.

8 NASA, *Apollo Program Budget Appropriations*, (history.nasa.gov).

9 This figure is derived by dividing the number of flights into the total STS expenditures since its inception. This is the same method by which the Apollo per-launch costs have been computed.

what can be created.¹⁰

Restoring the imperative

So what is missing in the 21st Century United States' quest for space exploration? Have we lost the 'fire in the belly' that birthed the Apollo program? Will it take another bitter enemy (North Korea or Iran are unlikely candidates to spark a technology race), another martyred president, another post-WWII flush of technology and national hubris, or another technological explosion to set our path to other worlds?

Few if any of these elements are likely to fall into place, and if they do, it will probably not result in another space race. Most of these occurrences involve international crises, and could result in a global war before they spawned new exploration in space.

One possibility is that when another party reaches the moon, America will regain the drive to renew manned exploration. That party will likely be China, and the time window is probably sometime around 2020. If that does occur, US senators and congressmen will undoubtedly look at one another and say, 'How could you let this happen? America, beaten in outer space! Unthinkable!'

The short answer is swift and clear: America's elected let it happen. Pet 'pork-barrel' projects and re-election concerns have long held sway above space exploration. But the reasons behind the 'loss of dominance in space' go beyond this simple sentiment.

First, the citizens of the United States have not fully understood the many benefits of NASA's space exploration efforts. NASA has not helped this; indeed they have consistently failed to 'build their case' to the American public since the end of Apollo. This includes technological spinoffs, educational benefits, and economic benefits.

Second, the massive aerospace conglomerates, many of which are comprised of marriages of former Apollo and shuttle contractors, have often priced themselves out of budgetary consideration when bidding on space hardware. This situation is addressed, at least in part, by the Obama administration's emphasis on private-sector entrepreneurial development in NASA's 2011 space budget.¹¹

10 NASA, *Nasa's integrated space transportation plan and orbital space plan program*, Hearing before the subcommittee on space and aeronautics, U.S. House of Representatives, May 8, 2003.

11 NASA FY 2011 budget: <http://www.nasa.gov/news/budget/index.html>.

Third, the US media, which grew disinterested in Apollo by the time Apollo 12 flew (and was already pre-empting moonwalk coverage with soap operas!) bears some responsibility. They have consistently failed to cover the US space program in a compelling fashion, instead increasingly devoting available time to tabloid journalism and entertainment/celebrity news.



One of the most famous pictures of the moonlanding. Source: <http://e-ducation.net/discoveryandexploration.htm.jpg>

Fourth and finally, the popular culture of the US has moved toward growing consumerism and ‘pop culture’, and has paid little attention to the programs so poorly represented by NASA and the media at large.

The cost of exploration initiatives in space, while arresting to the casual reader, are a mere fraction of America’s financial ‘bailouts’ of 2008/2009. These would have financed multiple space programs, and would have resulted in new technologies, improved university-level education, many thousands of new technology-sector jobs and large, lucrative contracts for the aerospace companies.¹²

Looking within

Self-examination is never easy, but the world’s leading economy and richest nation must bear the blame for the failure to accomplish its own far-reaching goals in science, exploration and space. This is a disservice to our own unique history, capability and our overarching accomplishments in the 20th Century.

If this self-examination occurs, it should spawn a new era of space exploration for the United States. It is not magic, it is not impossible, and it is not something that we do not understand or cannot afford. It just needs to be done. For, as Ernest Shackleton said: ‘Difficulties are just things to overcome, after all’.

12 Reddy, Sudeep, ‘The Real Cost of the Bailouts’, *The Wall Street Journal* (September 3, 2008).