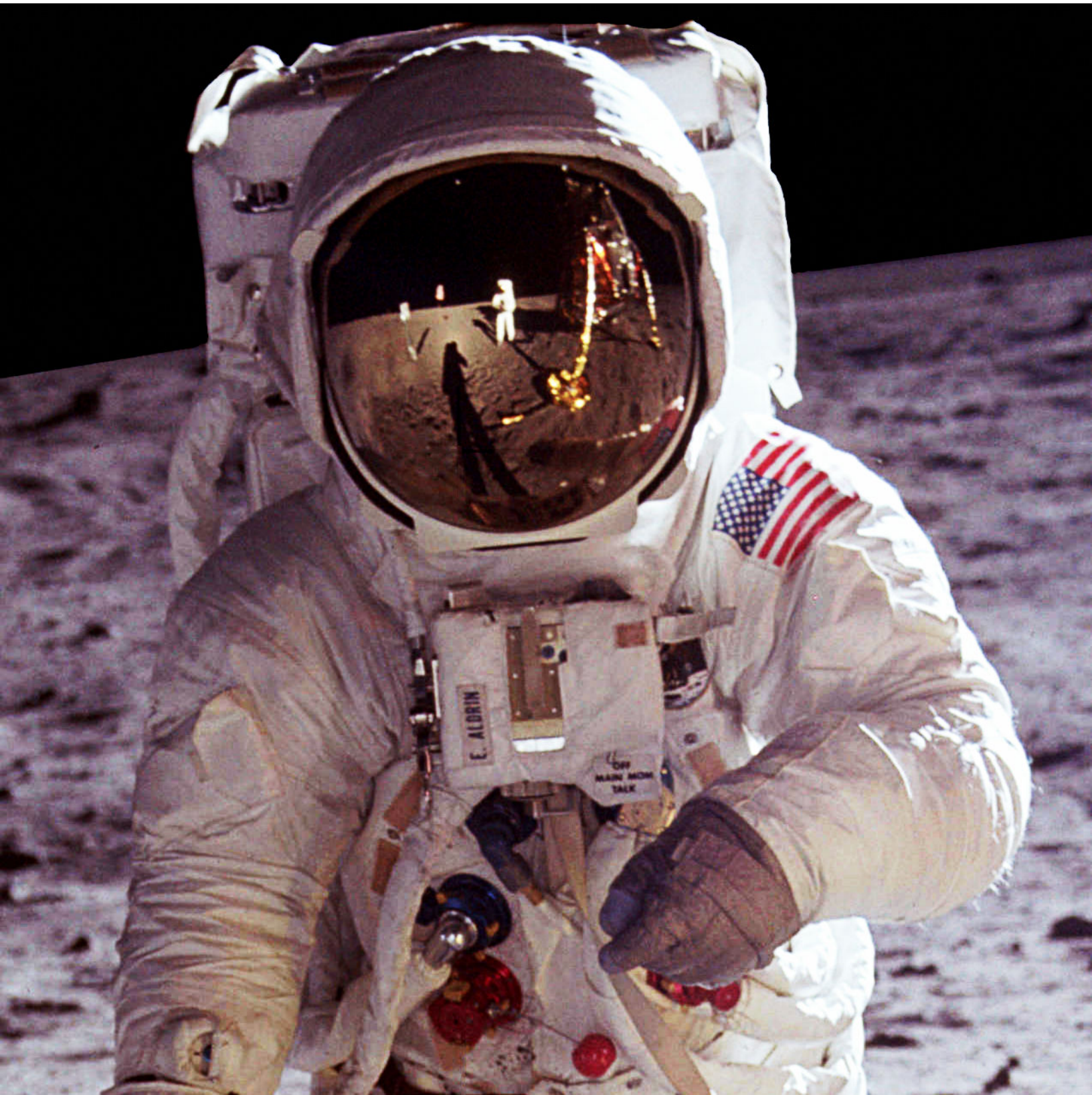
Towards an Earth-Moon Economy – Developing Off-Planet Resources

Moon Miners' Manifesto™

Since December 1986

#303



Moon Miners' Manifesto
Number 303

Special Issue: 50th Anniversary of Apollo 11

IN FOCUS Apollo 11

By James Gholston

The Apollo program is often viewed with mixed feelings by the Lunar activist community. In the words of Artemis Project and Moon Society founder Greg Bennett, "Apollo was glorious, but let's not do that again."

By operating with a race mentality, we made a number of sacrifices that doomed the program to be a mere prelude, not a true beginning. Plans that had existed long before were streamlined in ways that left no usable infrastructure in place, and the crushing burdens of the price that made sense during a cold wartime race were not politically sustainable, especially as a large percentage of the population lost all interest.

On the plus side it was a powerful proof of concept: we've already proven it can be done, we learned a number of things about Luna that we might not have known for a while without the incentive, we gained samples, and we have reflectors on the surface for precise measurements.

The price of our rush is still being paid today, however. The US followed up on Apollo 17 with absolutely nothing; The Soviets stopped in 1976; basically nothing at all happened in the 1980s. People interested in exploration turned their focus towards Mars, essentially forgetting that our moon even existed. A large percentage of the US population sees space as nothing but a waste of money.

Yes, Apollo was an unprecedented achievement, but in addition to the triumphs, we need to keep track of the object lessons of how *not* to go to Luna (or anywhere else, for that matter). We need to build infrastructure, have something to return to, and to paraphrase Niall Ferguson, pay special attention to the fact that the most important thing about the mission is what we do when we get there.

We have a lot of lost time to make up for. Fortunately, things are finally starting to heat back up. SpaceX has an interplanetary spacecraft in development; China and India may be able to avoid repeating the race-to-finish-and-then-ignore situation from the 20th Century; the US government has a new project with a target to finish before a subsequent presidential administration can throw the program away as not-invented-by-them; Bigelow has inflatable modules that can be used for surface settlements as well as orbital stations and hotels.

Here's to hoping that the next 50 years of Human Lunar activity will be far more notable than the previous 50.

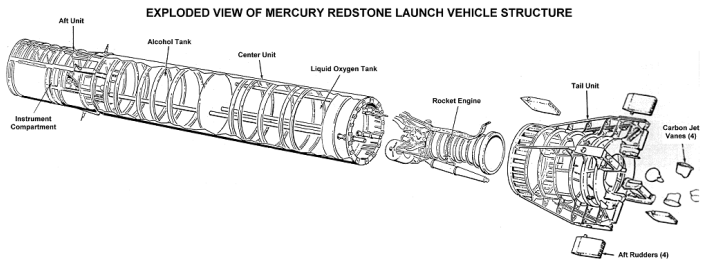


Image: NASA

Joining the Space Race

By Grady Woodard

On Monday, April 14, 1958, I reported to work at the Army Ballistic Missile Agency (ABMA) at Redstone Arsenal in Huntsville, Alabama. The famed German Rocket team was working for ABMA building rockets for War. The Soviet Union had launched two satellites, Sputnik I on October 4, 1957, and Sputnik II on November 3, 1957. These space firsts caught the United States by total surprise and Soviets had command of the skies. After the Navy and the Air Force had failures attempting to launch this country's first satellite, President Eisenhower ordered the ABMA team to do it in ninety days. That was done on January 31, 1958, with Explorer I in eighty-eight days with the Redstone rocket.

Both Nations were rushing to be the first to place a man into space. Project Mercury was conceived for the US to put up our first astronauts in a crash program. The Air Force was banking on their Atlas rocket and the Army (ABMA) looked at their Redstone for this task. It was the Mercury - Redstone rocket, with one man up and down in space payload, work for ABMA and the Mercury-Atlas rocket, one man orbit payload work for the Air Force. ABMA was to follow with developing a large Saturn rocket and the Air Force to follow with the two-man Gemini orbit docking project as this was needed for us to go into space exploration.

Before our first astronauts had been picked to fly into space in the Mercury Program, I was already doing upgrade man flight work on the Redstone A7 engine in May of 1958 with the Army at Redstone Arsenal. The Mercury Program was not initiated until October 7, 1958

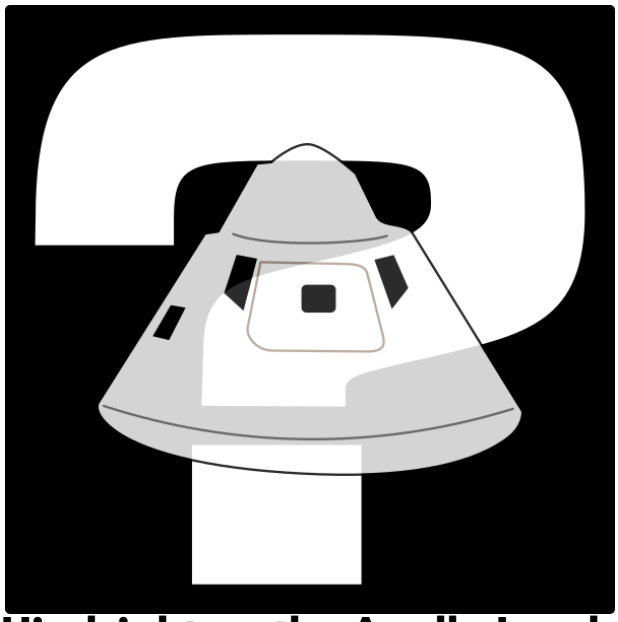
Our mission at ABMA was to prepare the Redstone rocket for our man flight rating. Three weeks after I arrived, I was assigned to man-rate the rocket engine. The seventy-eight thousand pound thrust Redstone A 7 used Liquid Oxygen and Kerosene fuels. The Redstone rocket was sixty-nine feet tall, seventy inches in diameter and had a payload weight of two thousand pounds.

The Mercury-Redstone Project started on a twelve hour - seven days a week overtime schedule. The production of new Mercury-Redstone rockets began in Building 4706. The directives, shop orders, memorandums and all documentation was stamped using a priority action system. A stamp saying "BLAST" and was used for the first step above routine priority. Two "BLAST - BLAST" stamps indicated a priority of urgent. Three "BLAST -BLAST - BLAST" stamps indicated a hand carry, emergency highest priority action.

Our work came with training. We were told that even a small mistake could cost a person's life. We were told to work as if we ourselves, were riding the rockets. That "huge consequences" would be paid to the one who "killed someone" and this was the first chance for the rocket team during in its long history, to explore space with man launches," said our Group Leader. "Dr. von Braun will not stand for failures or mistakes," he added.

We were unaware that on October 24, 1960, the Russian's large unmanned R-16 rocket exploded on its pad. The Russian leader, Nikita Khrushchev on September 23, 1960, was pounding his shoe on his desk in protest at the United Nations. Khrushchev had ordered his space officer, Marshall Nedelin, to launch the moon rocket while he was in the limelight. The window for a moon launch was about to close and the R-16 was in a delay because of a misfire. After a few minutes with fuel onboard, Nedelin ordered the technicians to inspect the failure when the R-16 blew up killing 165 people.

Mr. Khrushchev was irate that he had missed an important political event to prove that the Soviet Union was the better Nation. Later. Four accidents with the N1 moon rocket and money problems caused the Russians to abandon their moon project. We had won that race and didn't know it! We launched Apollo 8 moon fly by on 12/21/1968 and Apollo 11 moon landing on July 16, 1969.



Hindsight on the Apollo Lander

By Peter Kokh

√ A contest for designs of the Apollo cabin and lander that would have allowed longer stays with more comfort and less problems

√ An interior designed to allow astronauts to lay down stretched out even if they had to take turns doing so.

√ An awning structure easy to unfold and that would automatically turn to follow the sun to keep the Apollo module in the shade would have allowed longer stays without the interior overheating

√ An electrically charged "rug" under the ladder to remove moondust from boots and gloves.

√ Boots easy to step out of, and back into, so as not to bring dust inside

√ And/or an electrically charged blower to remove dust from spacesuits, particularly boots and legs, but also gloves and arms after handling moon dust or rocks, and butts if the astronaut sat down on the Moon's surface

√ NASA had planned three more missions, each one with new missions, at more interesting locations, but this was killed by Congress.

Photo: Executive Office of the President of the United States

President Kennedy Visits MSFC, Gives Moon Order

by Grady Woodward

On Tuesday, September 11, 1962, the President of the United States, John F. Kennedy, arrived on Air Force One at the Redstone Arsenal Air Strip at 10:35 AM. The President's visit to the Marshall Space Flight Center reason was to give an order to the Rocket Team in person and to visit the facilities.

It was a warm sunny day and 438 German Rocket Scientists, engineers (me included) and with special invited local City, County, State, Washington representatives to welcome President Kennedy, his family, staff and British scientists. The President

had with him, the first lady Jacqueline, his two children Caroline and John Jr. "John John", the kids' Nanny, Vice President Lyndon B. Johnson, Secretary of Defense Robert McNamara, NASA Administrator James Webb and the British leading rocket scientist Dr. Jerome Wiesner.

Local welcoming representatives were Senator John Sparkman, Huntsville's Mayor Speck Searcy, Dr. von Braun and the German Rocket Team including other Marshall Space Flight Center's (MSFC) leading engineers and managers. A reviewing stand and chairs were set up next to the Airstrip's hanger and office building on the tarmac with Air Force One in the background. A band was playing and things were appearing to be a very important event. The President had come to give an order to the MSFC Rocket Center employees in person. After things got settled down and all those present had found their seats, we all stood and the Army Band played. Washington's representatives were seated on the right side of the stand, the local representatives were on the left and the President with his family seated in the center behind the Presidential Seal Podium.

The first speaker, the Mayor of Huntsville who welcomed the visitors followed Dr. von Braun and Senator Sparkman introduced the President. The President recognized those present and thanked them for coming to the event.

"I am delighted to be here and I'm particularly delighted to be here on this occasion," the President said. "Recently, in a joint speech to the U.S. Congress, I told them about my dream of putting an American on the Moon. People asked, "Why should we place a man on the moon?" If the history of our progress teaches us anything, it is that man in his quest for knowledge and progress, is determined and cannot be deterred. The exploration of space will go ahead, whether we join in or not, and it is one of the great adventures of all time, and no nation which expects to be the leader of other nations can expect to stay behind in the race for space." President Kennedy said.

"Those who came before us made certain that this country rode the first waves of the industrial revolution, the first waves of modern invention, and the first wave of nuclear power, and this generation does not intend to founder in the backwash of the coming age of space. We mean to be a part of it-we mean to lead it. For the eyes of the world now look into space, to the moon and to the planets beyond, and we have vowed that we will not see it governed by a hostile flag of conquest, but by an banner of freedom and peace. We have vowed that we shall not see space filled with weapons of mass destruction, but with instruments of knowledge and understanding." the President expressly stated.

All eyes and ears were glued to the President, for this day has been an eternity coming for these great German Rocket Scientist, with all of the hardships they have endured. President Kennedy spoke with his eyes upon each face in the crowd and everyone knew he was speaking directly to them, as on a one to one level. Just as the President was well into his delivery, John John, got loose from his Nanny and was playing on the stand steps, jumping up and down on them and swinging on the handrails making loud noises. No one tried to quit him, even though he was disturbing, we had to endure John John's three-year-old mischief. We were not about to miss one word of the President's order.

"Yet, the vows of this Nation can only be fulfilled if we in this Nation are first, and, therefore, we intend to be first. In short, our leadership in science and in industry, our hopes for peace and security, our obligations to ourselves as well as others, all require us to make this effort, to solve these mysteries, to solve them for the good of all men, and to become the world's leading space-faring nation," said the President. "There is no strife, no prejudice, no national conflict in outer space as yet. Its hazards are hostile to us all conquest deserves the best of all mankind, and its opportunity for peaceful cooperation many never come again. But why, some say, the moon? Why

choose this as our goal?

And they may well ask why climb the highest mountain? Why, 35 years ago, fly the Atlantic. We choose to go to the moon. We choose to go to the moon in this decade and do the other things, not because they are easy, but because they are hard, because that goal will serve to organize and measure the best of our energies and skills, because that challenge is one that we are willing to accept, one we are unwilling to postpone, and one which we intend to win, and the others, too.

It is for these reasons that I regard the decision last year to shift our efforts in space from low to high gear among the most important decisions that will be made during my incumbency in the office of the President. I am asking this Rocket Team to place a man on the moon in this decade. I want it, the Congress wants it and the American people want it." President Kennedy said. Dr. von Braun responded and thanked the President and accepted the challenge saying, "We will put a man on the moon this decade." The Band played as everyone was leaving. The President's car departed with a following convoy.

It was after twelve noon, when everyone got away. We rushed to our Labs to get ready for the President's visit to see our facilities and a Saturn C-1 static firing. We in the Manufacturing Engineering Lab had an awesome display set up in our Missile Assembly Building 4705 for the President and his dignitaries.

The German Rocket Team members and all of the MSFC attendees were elated with smiles and handshakes. Finely, since 1927, the Team will build a rocket not intended for War but for space exploring of the new frontier. Excitement fell on the Marshall Space Flight Center, the Army's Redstone Arsenal, Huntsville, State and America.

Four years after the Soviet Union launched the Sputnik shock of 1957 greatly embarrassing us, Kennedy felt great pressure to have the United States "catch up to and overtake" the Russians in the space race. He wanted to announce a program that the U.S. had a strong chance at achieving before the Soviet Union. After consulting with Johnson, Webb, Dr. von Braun and others, that landing an American on the moon would be a very challenging technological feat, but an area of space exploration in which the U.S. actually had a potential lead because of having the famed German Rocket Team.

The enormous human efforts and expenditures for the Apollo Program would rank with the construction of the Panama Canal, the Manhattan Project were comparable. The Apollo was designed to execute Kennedy's goal. CIA reports were circulated often in MSFC to inform everyone how the Russians were progressing, a move to energize the workers.

President Kennedy promised the United States would let a man walk on the moon before the decade was out. Then, almost nobody believed him, except the German Rocket Team was very serious about taking the order from the Commanding Chief, and completing the project before the decade was out. During the Building 4705 tour, the British expert, Dr. Jerome Wiesner, and Dr. von Braun argued. The British wanted to directly hit the moon's broadside with a Nova rocket and Dr. von Braun had select a lunar orbit and descend to the surface of the moon. To end the argument, President Kennedy turned and said, "Show me something else!"

The next morning, activity was wide spread at MSFC. Meetings and conferences were taking place. Every aspects of the Saturn 5 vehicle was being reviewed and status reports compiled. Developing a schedule for the massive moon rocket was given the priority. A meeting was held in the Manufacturing Engineering Lab the following day and I was given the task to develop a Master Schedule Plan to place an American on the moon. The entire staff of the MSFC was beaming with joy and some concerns at the same time. The Rocket Team took command and orders were followed intensely. The President was pleased with the progress and offered his support to Dr. von

Braun in the coming years. The President was killed on November 22, 1963, and didn't see his dream come true. On July 20, 1969, an American walked on the moon.

Peter Kokh Interview

Lifetime member #2 of the National Space Society and author of *Pioneer's Guide to the Moon*, Peter Kokh is the founder of **Moon Miners' Manifesto** and served as editor for its first 301 issues.

We asked Peter a few questions about the Apollo Program.

MMM: What are your thoughts on this anniversary of Apollo 11 landing?

PK: It is a crime for Congress to have killed 3 additional Apollo missions to more interesting parts of the Moon.

NASA might have cut its budget by getting equipment for extended missions donated by companies involved at no cost, but for the publicity.

MMM: What did the Apollo program get right?

PK: Separating the lander into two sections, the bottom part remaining on the Moon.

MMM: What did the Apollo program almost get right?

PK: The design of the Apollo lander

MMM: What did it get terribly wrong? P**K**: Not providing pop up awnings to keep the lander in the shade. Not designing the cabin so that crew members could sleep stretched out instead of curled up.

MMM: What are the biggest lessons of Apollo for upcoming efforts?

PK: Plan extended stays if all is going well after the advertised stay, providing that food and other supplies are sufficient. Design the cabin for more comfortable sleeping.

MMM: What could have been done for a better followup to Apollo?

PK: The lander could have wheels to move to more interesting places once it had safely landed. (if there were more interesting places nearby. Taking pictures of the lander and a crew member from nearby high ground.

MMM: What could have been a better buildup for Apollo 11 that could have better motivated the general public at the time?

PK: Well, I think it would have been a mistake to broadcast all the things that "might go wrong."

We could have given a look at the possibilities of a permanent outpost on the Moon, but given Congress' indifference, that might have backfired. NASA did give Congress and the people a preview of future missions in the planning stages.

Could we have convinced NASA to choose one of each 3 person Apollo crew to be someone picked blind from a pile of interested healthy and talented volunteers to go through the training exercises?

MMM: Same question, but for the general public of today -- how can we motivate them on a lunar return?

PK: Describe more visually interesting locations, such as a collapsed entry into a lava tube or a hole in a lava tube ceiling created by an asteroid hit right on target, with equipment to take astronauts down into it to look around.

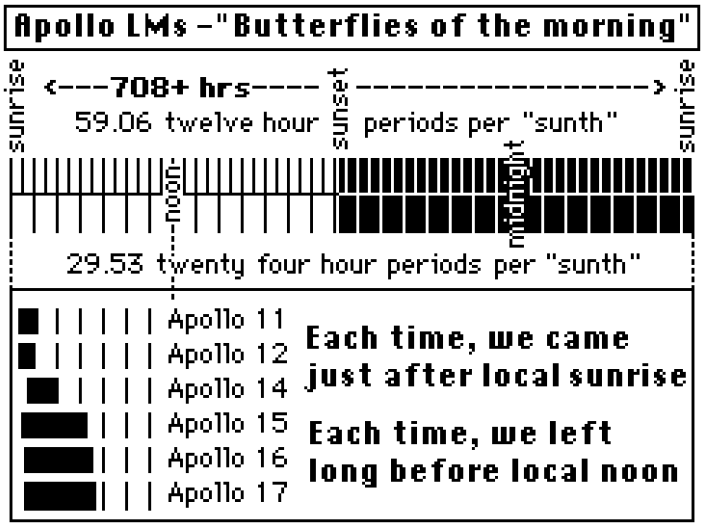
MMM: What projects and/or policies should the Moon Society be pursuing?

PK: The three cancelled Apollo missions to more interesting parts of the Moon Apollo 15 (J1)

Hadley–Apennine, July 1971.
Apollo 16 (J2) Descartes Highlands, April 1972.
Apollo 17 (J3) Taurus–Littrow valley, December 1972.

And demonstrating all the things that can be made of Lunar Basalt in and for a permanent "Outpost" on the Moon: cabins, furniture, furnishings and more. Given the Moon's assets, we can do so much more for less.

And Inform Congress, Corporations, and the public at large that using components made on the Moon, of glass, glass fiber composites, and/or basalt fibers, to make giant platforms in Geosynchronous orbit, at each available slot, capable of holding as much as a hundred satellites each, and with a robot to anchor them and service them - there are only so many allowable slots in GEO and they are filling up fast, With such platforms, GEO satellites could increase as much as a hundredfold.



Dawn Touchdowns, Pre-noon Liftoffs

From MMM #90 November 1995

For sake of best long-shadow lighting conditions as well as heat management, All the Apollo missions landed shortly after local sunrise, and as if subconsciously frightened senseless of nightfall, left well before local noon. We haven't come close to experiencing a full lunar dayspan/nightspan cycle! Here are the figures for each mission.

```
A 11 TD 10.93 hrs after local sunrise
LO 21.60 hrs after local sunrise
(like 6.22-7:06 am on Earth with 6:00 am
sunrise)

A12 TD 10.12 hrs after local sunrise
LO 19.52 hrs after local sunrise
(like 6:21-7:01 am on Earth with 6:00 am
sunrise)

A14 TD 20.75 hrs after local sunrise
LO 33.51 hrs after local sunrise
(like 6:42-7:50 am on Earth with 6:00 am
sunrise)

A15 TD 14.04 hrs after local sunrise
LO 68.91 hrs after local sunrise
(like 6:29-8:49 am on Earth with 6:00 am
sunrise)

A16 TD 17.82 hrs after local sunrise
LO 71.04 hrs after local sunrise
(like 6:36-9:00 am on Earth with 6:00 am
sunrise)

A17 TD 16.8 hrs after local sunrise
LO 75.00 hrs after local sunrise
(like 6:34-9:06 am on Earth with 6:00 am
sunrise)

Sunrise to Sunset: 354.367 hrs = 14.7653 days

Full Sunth (local day): 708.734 hrs = 29.5306 d.
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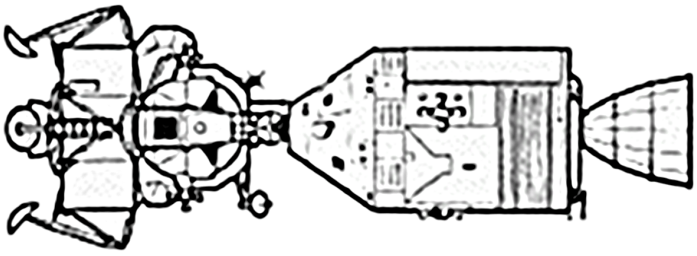


Could We Have Reused the Apollo Capsules, or Any Part of Them?

An exchange on artemis-list@asi.org November 22, 2000 Republished from MMM #141 December 2000

Greg Bennett

We did not reuse the Apollo capsules, or any part

of them. But, could we have?

I was just wondering if there were anything inherent in the design of the Apollo capsule that precluded reusing it. It was a tiny part of the spacecraft, but it did contain a lot of expensive equipment.

I often wonder whether flying a whole new spacecraft is really more safe than using one that has been proven in flight. Perhaps the fact that each capsule went through extensive testing made up for lack of operational experience with the spacecraft, Apollo 13 notwithstanding.

Wallace McClure

The short answer is yes to part of them, or at least some of them could have been refurbished to fly again. I also assume you are using a new Service Module with them. In particular, those used for Earth orbital missions could probably have been reused for Earth orbital missions.

- Structure -- Could have been reused, but you would have to inspect to ensure no sea water intrusion or corrosion (e.g. don't get salt water in the structure, particularly inside the pressure vessel.)
- Thermal Protection System -- This was sized for a direct return reentry from the Moon. Run the numbers and you see the heat load from an Earth orbital reentry was less than 50% of that of a lunar return. The heat shield was not replaceable in sections, but you could have theoretically remachined down the uneven remaining unablated honeycomb and reused it for an Earth orbital mission. (With inspections, of course!) Theoretically, you could replace the entire ablative reentry shield. But that was never considered.
- Avionics -- Reusable, yes, with replacement and testing of batteries, etc.
- ECLSS -- Most of the ECLSS was in the service module. You would have to renew the ECLSS LiOH [lithium hydroxide] and it was reusable. You would have to replace the connections to the service module.
- ACS -- The CM ACS was really only used post SM separation (and primarily for roll control). At a minimum, you would have to clean and replace all the burst disks, etc. But from a first look, you could probably reuse the tanks, valves, engines etc.
- Parachutes, etc. -- Definitely replace them. They were rampacked and certified for only one use. Also the pyros, etc. would need to be replaced.
- Soft Goods -- Inspect and replace seals, rubber gaskets, etc. You do need to look at them.
- Of course, if any vehicle was used outside of the expected operational conditions, reuse might not be possible -- land landing, hot-hot reentry, sea water sloshing around inside for weeks, etc. But for a run-of-the-mill Earth orbital mission -- probably most of it could have been refurbished and reused.

Dale Gray

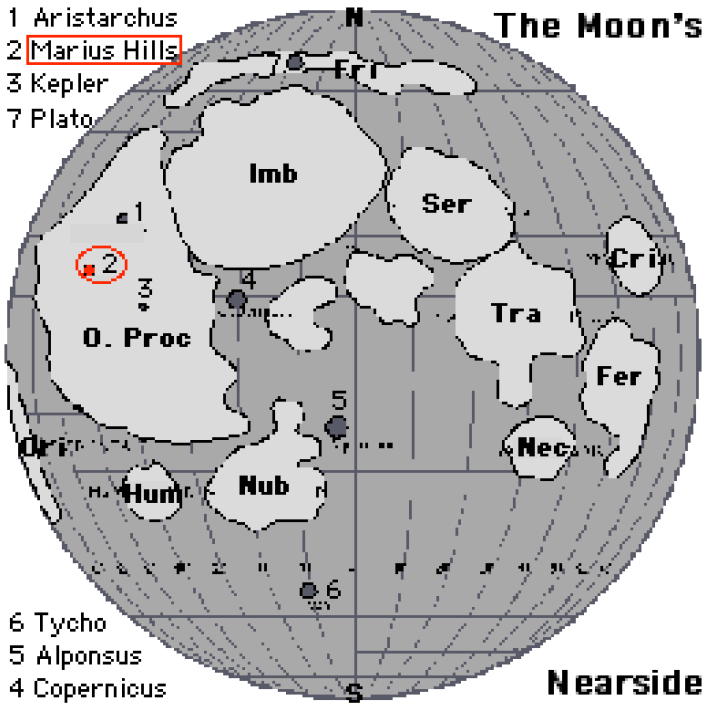
As I understand, the capsules evolved over time even after Apollo 8. Reusing an old capsule would be to take a step backward in safety, performance, mass. The returned capsules were far more valuable as national treasures, complete and untouched than any conceived salvage part or in whole.

Andrew Newstead

I believe the Apollo 14 docking probe was reused with one of the Skylab Apollos or the ASTP Apollo. Because of the difficulties with it during the flight of Apollo 14, it was brought back for engineering analysis, which found nothing wrong with it and it was reused as an economy measure. It gave trouble again when reflown, so go figure!

Ben Huset

To date, all the Soyuz capsules have been used only once.



Could the Originally Intended Landing Site for Apollo 17 Have Changed History? It may change the Future!

By Peter Kokh and David Dietzler
Reprinted from MMM #196, June 2006

Marius Hills (14°N, 56°W) What has intrigued us (Kokh & Dietzler) is the suspicion that the Marius Hills might someday be the Ruhr of the Moon, (its major industrial complex) and make an outstanding site for a major settlement. The

Hills offer:

- Variations in basalt
- Perhaps a good number of intact lavatubes
- Possible or likely pockets of unreleased volcanic volatiles that could change the prognosis for industrial development of the Moon

This area appears to have experienced a number of lava/magma flows, each successive flow somewhat different chemically than the one before - layered igneous intrusions, in geological parlance. On Earth, the most significant case is The Bushveld area in South Africa, source of much of that country's mineral wealth. The reserves of chromium, platinum, palladium, osmium, iridium, rhodium and ruthenium are the world's largest along with vast quantities of iron, tin, titanium and vanadium. South Africa is second only to the United States in the production of mineral resources.

The elements listed above are essential to a modern industrial complex. If the Lunar Frontier were to rely only on the elements most abundant on the Moon, oxygen, silicon, iron, aluminum, titanium, magnesium, and calcium, the result would be something like late nineteenth century industry, more than an advanced New Stone Age but not much more.

Lunar industry must find, or import at great expense, copper, gold, silver, platinum, zinc, lead, and other metals not well represented in the regolith at large. The Clementine and Lunar Prospector data have yielded helpful maps, but their resolution leaves much to be desired. New orbiters with more sensitive instruments able to detect specific signatures at very high resolution are essential. Prospecting from orbit is extremely cheap in comparison to fielding and supporting a veritable army of human prospectors on the ground! The later will be needed in time, but. they are best used in areas targeted for further ground truth investigation by orbiting chemical sleuths.

Clementine, Lunar Prospector, and Truth in Science

Clementine and Lunar Prospector have clearly shown that the Nearside Mareplex is much richer in iron, titanium, thorium and other useful elements than highland sites. The poles, in contrast, have little of industrial significance beyond the yet to be ground truth qualified and quantified hydrogen enriched permashade areas, and more round-the-month low angle sunlight in mountainous terrain that may be risky to traverse (ever-changing very long ink-black shadows as well as anything but level) with irregular plateaus of

eternal sunrise (To use the term eternal sunshine is very misleading.) At the poles, we may find water ice of yet unknown purity and mixture with regolith, and of yet unknown friendliness to mining techniques, and nothing to do with it except waste it as one-time-use rocket fuel. But these same Clementine & Lunar Prospector maps do not tell us where the real prizes are to be found, if anywhere. But looking at topographical and geological characteristics, the Marius Hills area certainly looks intriguing, perhaps even promising.

Questions and More Questions

David writes: study of the impact craters in the region revealed none that had penetrated through to the underlying highland bedrock. So if there are underground chambers, vesicles of volcanic gas, they might be intact.

So much for the "Moon is all homogenized, contains no surprises, the crust is all fractured, gas would have all leaked out" theory that I have come to believe is entirely false. I say this region could be like a volcanic gas field, truly a gold mine for lunans. One can see that there are no giant craters there or fissures in the surface.

Peter: I checked the reports on TLP, transient lunar phenomena which might include leaking gas. This does not seem to be a TLP area, unlike the nearby Aristarchus Plateau, which is the source of many TLP reports. But the major difference is that in the Aristarchus Plateau, we have a major relatively recent impact crater, Aristarchus itself, which has clearly penetrated into the highland crust underlying the basalt flows which formed the plateau.

David: clearly any gas in fractured basalt has already long escaped. I am growing confident that there may be intact pockets of volcanic volatiles in unfractured layers. Ground penetrating radar and landing teams with explosives and sonic sensors like the stuff they use for oil exploration are what we need. What we have to do is create a vision for others to be inspired by.

Volcanic Gases? The Envelope, Please!

On Earth, more than molten rock, thick fire-red lava escapes from the throats of active volcanoes! See: https://volcanoes.usgs.gov/vhp/hazards.html

> ***"Volcanic gases are dissolved in molten rock. But as magma rises toward the surface where the pressure is lower, gases held in the melt begin to form tiny bubbles. The increasing volume taken up by gas bubbles makes the magma less dense than the surrounding rock, which may allow the magma to continue its upward journey. Closer to the surface, the bubbles increase in number and size so that the gas volume may exceed the melt volume in the magma, thus creating a magma foam. The rapidly expanding gas bubbles of the foam can lead to explosive eruptions in which the melt is fragmented into pieces of volcanic rock, known as tephra. If the molten rock is not fragmented by explosive activity, a lava flow will be generated."***
>
> ***"The most abundant gas typically released into the atmosphere from volcanic systems is water vapor (H_20), followed by carbon dioxide ($C0_2$) and sulfur dioxide ($S0_2$). Volcanoes also release smaller amounts of others gases, including hydrogen sulfide (H_2S), hydrogen (H_2), carbon monoxide (CO), hydrogen chloride (HCL), hydrogen fluoride (HF), and helium (He)."***

Now given that the Moon was apparently formed from material from which any native volatiles had been driven off by heat, we will be most unlikely to find water or water vapor or hydrogen, either alone or in combination.

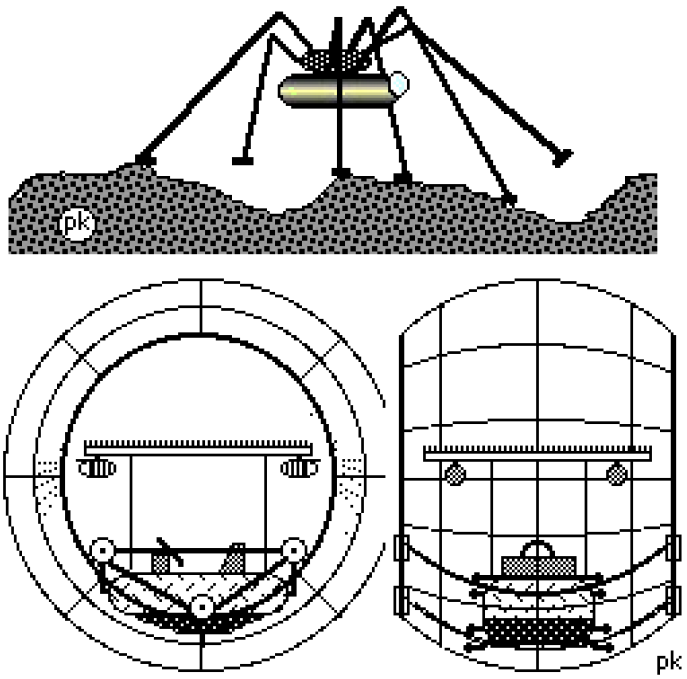
The Moon is also apparently *under*oxidized. Even though the regolith and the crust from which it is derived by impact gardening is 45% or so oxygen by weight, in the form of metal oxides and silicates, there is not enough oxygen to have rendered the vast majority of the Moon's crustal iron into the

ferric form, Fe_2O_3 predominant on Earth. The iron we find is predominantly ferrous, FeO, or even pure, not oxidized at all. That leads us to suspect that the fully oxidized forms of carbon and sulfur are also unlikely. Instead of carbon dioxide, we will be lucky to find carbon monoxide. Instead of sulfur dioxide, we will be lucky to find sulfur monoxide. Helium is also unlikely.

As there is enough sulfur, and enough oxygen in the regolith, the presence of SO gas is of no interest. The prize, perhaps the sole prize, as we see it, is pockets of carbon monoxide, CO, which would be most invaluable, both as a handy industrial reagent in itself, and as a source of carbon which is vital to life in all forms, as well as essential in making steel. We may never find enough carbon on the Moon to use profligately in plastics and other synthetics.

Gas pockets may be too small and insignificant in volume to show up as *negative* mascons, even at highest resolution. Radar designed to ferret out lavatubes might find such pockets. They would have characteristic shapes noticeably different from the long tubular lavatubes. The discovery of substantial carbon monoxide reservoirs on the Moon would rival the discovery of polar permashade ice reserves in brightening the prospects for fuller industrial diversification, and the chances of attaining economic self-sufficiency. We had previously considered the possibility of finding such “lacunae” (to suggest a Latin topographic term) but The Marius Hills are the first site to suggest that “here is a good place to look.”

We have a lot of prospecting homework to do on the Moon before we can be confident that any reestablished human presence on the Moon has a real chance of an open-ended future. Most lunar probes are designed by scientists with things on their minds other than resources. Scratching the itches of scientific curiosity is good. But it is not what we need. This should guide what missions we support.



On the Wild Side

by Peter Kokh

Two wild but possible vehicles

Upper: A Spider like “Gray Hound” that could take explorers or tourists on a wild ride over rugged terrain.

Lunar Spider with suspended crew cab goes anywhere

Much of the Moon's surface, especially in the highlands, is very rugged. A vehicle modeled after a "Daddy Longlegs" or Harvester spider would be able to traverse such terrain with ease, and probably at a respectable gait. Having the crew cab perched well above the surface would provide a commanding perspective of the surroundings and allow a better choice of a path to blaze ahead. A computer program would run the legs, allowing the crew to concentrate on the surroundings. A further advantage is that one or more Spiders would allow explorers to visit much of the Moon's "out-vac" back country without having to build roads, leaving visited areas in their pristine state.

Lower: ...And an “atlas mobile” bike, with a motor, but able to be peddled by the person inside and easy to keep upright

Bursting Apollo's Envelope

By Peter Kokh
Reprinted from MMM #88, September 1995

- Apollo was without precedent. For scouts of Earth to break free from their womb planet and set foot on what had always been an unreachable celestial sphere was a clean break with all that had gone before. It electrified civilization for a moment. Yet for all these nine manned missions to the Moon accomplished, six of them landing, *so many really basic things were left undone* that roundly shattering that precedent will be easy. We mean no disrespect! But, yes, easy.
- Twelve men set foot on the Moon. Yet none of them slept in a bed there. The LEMs had only hammock-slings. All twelve walked in one-sixth gravity, but only with cumbersome pack-laden pressure suits - the pressurized LEM "cage" was scarcely big enough to pace back and forth in place. So no one experienced what it is like to walk in lunar gravity, not really.
- All the missions were lunar morning ones. No one experienced a lunar sunset, a lunar night, a lunar dawn. We never even hung around into local afternoon.
- We ate and slept in our station wagon, not even pitching a tent. In effect, we just picnicked there. Since our vehicle was our shelter, we took it with us when we left, and there is no camp, no cottage, to which we might return. We never visited any site more than once. We left no building on the Moon, not bringing any with us, not erecting any.
- We never stayed long enough to plant, or grow, much less to harvest. Even the science we did was just fieldwork collection stuff. We brought along no lab. Nor did we play much. Sure we romped around in our suits, hit a golf ball, and playfully rigged our flags so they looked like they were flapping in some vacuous breeze. Playful, yes. Play, no.
- We were there, that's all. Like Kilroy. And then we were gone, and are gone still. We took samples from which to learn *what the Moon is made of*, but which have since been guarded so jealously by an intermediating priestly class "lest we never return" that we have not been free to learn from these samples *what we might* **make out of** *what the Moon is made of*, *as if to guarantee* that we would never find the confidence to return on a live-off-the-land basis.
- We left stuff too - more than footprints, stuff that could someday be prized pioneer relics in local lunar museums. But to date, more than two decades later, these leavings only remind us of our failure to build upon what we had done, to stand tall on the shoulders of our heroes. The "revolution in history" has been downgraded to an anomaly, a distraction.

A New Beginning

So much of both the technology and the expertise that carried the Apollo program on to its brilliant successes has been lost, dismantled, even deliberately destroyed, that we can no longer just repeat these humble sorties. They cannot even be called beginnings since they have been robbed of the chance to lead to something more that follows.

Not quite. W*e have the knowledge*, the record, and some teasing results of matter-starved experiments that suggest what we might be able to do with lunar regolith - make oxygen, iron and steel, aluminum and titanium, cast basalt and

ceramic objects, sinter blocks and concrete, glass and glass composites - in effect fuel, air, water, tankage, vehicle and habitat parts, furniture and furnishings. We could even do out-of-fashion soil-based farming. Bring back with us but talented people, tools, and seeds, and we might just make a go of it.

With the total absence of political will, any return will have to be humble, laying down a few foundation stones at a time. Our first beachhead can only become permanent in time. But even if the first crew returns home for some while before the next is sent, it will have been easy to shatter *all* Apollo's achievements with the first mission.

(1) We leave a habitat structure on the Moon, perhaps returning to an awaiting orbiting ferry (serving a function like Apollo's command modules) ascending on a **cabinless** platform (not unlike the Apollo rover) protected just by space suits.

(2) Our habitat has room enough to walk around, and to sleep horizontally in cots or on air mattresses, and is big enough to boast both private and common room areas.

(3) We dig in our shelter, placing it under a soil-shielded canopy or heaping soil directly upon it to make longer stays possible without high accumulative radiation exposure. Now we have a camp, a cabin, a cottage on the Moon, a permanent structure to come back to, and from which to expand in due course, as we learn to do so step by step, using primarily building materials made on location.

(4) We leave an electronic beacon so that follow on missions can make instrumented landings at the same spot.

Then What?

(5) We stay not only all "day" but past sunset, outlast the long two week night, and start a new lunar "day" before going home. This will be quite a feat, not unlike the first overwintering on Antarctica. Even with a nuke source for energy, we'll have less power than during the dayspan when we can tap sunlight as well. We'll have to switch from energy-intensive tasks during dayspan to manpower-intensive energy-light tasks during nightspan, establishing a lunar rhythm that may forever after give life on the Moon much of its characteristic flavor. In the process, we'll have to have in place an advanced, possibly bio-assisted, life support system regenerating our air and water supplies. We'll also have had to have demonstrated, probably in an unmanned dry run, thermal stability of the station through the nightspan. Shielding will help here too, minimizing exposure to the heat sink of space.

(6) If we stay six weeks or more, we can plant some salad stuffs and bring them to harvest. The first feat for lunar farming and agriculture to come.

(7) We might try some brief sorties outside the station during nightspan. That means headlights, that means lubricants that can take the cold - or magnetic bearings. That means heated spacesuits or an infrared radiating cage or a minimal cabin.

(8) We bring along pilot oxygen production equipment, demonstration iron fine and gas scavenging equipment, a solar furnace to experiment with cast basalt, ceramics firings, iron sintering, and glass production. We have brought along some basic tools for fabricating sample test objects.

(9) There is a parallel Earthside "Moon station" in which problems on the Moon can be addressed in close simulation, and in which terrestrial brainstormers can proactively outline suggested new experimental exploits for the lunar crew.

Exploring Metaphors

Settlement is a long way down the road. But since we are determined to make that journey, we have to humbly begin with some lowly first steps. What lies between our previous science picnic visits and settlement? Here are some more relevant meanings my dictionary offers for some of the words we've been bandying about. Running

through them might help clarify our thoughts about what comes first.

base: (1) a bottom support on which a thing stands or rests; (6) t*he point of attachment*; (7) a starting point or *point of departure*; (9) a *supply* installation that *supports* operations

camp: a place where a group of persons is lodged in *temporary* shelters.

fort: a fortified, protected place [here, living quarters and operations center, in a *physically* hostile environment, shielded against radiation, vacuum, and thermal extremes.]

habitat: (3) a special contained environment for living in over an extended period in a life-hostile setting.

hostel: an inexpensive, spartanly equipped lodging offering minimal shelter for short-stay travelers.

outpost: a station established **at a distance** from the main body; a post or settlement *in a foreign environment*.

station: (6) a place *equipped for some particular kind of* work, service, research, or activity, usually semipermanent

While all of these terms are applicable as far as they go, none of them are especially *instructive*. And most of them are static, not suggestive of leading anywhere, *thus requiring separate justification of any further steps*, and thus likely to become self-limiting. We suggest that we space advocates who really want to see human outsettlement wean ourselves of such terms as Moonbase, Lunar Outpost, etc. and *look for more pregnant terms that suggest a sequence of phases that lead to something much more*. If we find better terms we must popularize them and thus *alter the culture* in which space futures are discussed. **Words are not neutral.** We must pay attention to their downside or self-limiting connotations. We are in a battle for the soul of humanity. We have to stop using the weapons the enemy gives us and forge our own.

Let us suggest some other terms whose applicability might seem a little forced at first thought, but which we think you'll agree are rather appropriate:

beachhead: the area that is the *first* objective of a party *landing on an alien shore*, which once *secured and established*, can serve as a base of expansion of the occupation.

incubator: an artificial environment that enables fragile beginnings to become hardy enough to thrive outside.

interface: a common boundary [between two worlds i.e. the life coddling Earth, and the barren and sterile Moon]; something that *enables* separate and sometimes *incompatible* elements to *communicate*.

Interface Beachhead & Settlement Incubator

If our gambit strategy is to establish a habitat station which serves as an effective interface with the Moon and its realities, then we suggest that the menu of Apollo-besting items given above lists steps in the right direction. We need to learn how to exist on the Moon, on *its* terms, through *its* cycles, boosting our resources *with those it offers*. A successful first Interface Beachhead will allow us to carry on a whole range of human activities in a way that comes to terms with lunar vacuum, lunar sixthweight, lunar day/night cycles, lunar temperature swings, and the absence of organic materials in the lunar soil. More challenging, we must interface with the Moon and learn to do so flexibly, through the handicap of a microbiospheric barrier as bubble creatures.

We have to begin mastering how to thrive on stuffs and materials we can process from the lunar endowment. That means our interface station/camp/outpost/base/beachhead must have expanding dedicated space for processing and fabrication experiments, demonstrations, and production operations. That means we have to put together talent, materials, and opportunities for at

least part time artists and craftsman to learn how to express themselves in the lunar idiom. Call it survival, call it living off the land, call it acculturation, call it dealienization, call it adaptation, call it adoption, call it settling in.

We can't have wholesale rotation of crews. Even if everyone still goes home after a while, those with hard won on site experience have to teach the newcomers before they can turn things over. Our presence needs to be more than serial. There has to be an effective cultural memory giving enduring "soul" to our individual comings and goings. Given that, the outpost/base/camp/station/interface beachhead will take on a permanent life of its own, even though the day that reupping indefinitely, i.e. staying for the duration of one's natural life, may be a good ways down the trail.

"Permanent" can apply to the physical structure. That is easy - and "cheap" in a fully pejorative sense. At the other extreme of application, it can also apply individually to people who come to live out their remaining natural lives with no real thought of ever returning to the "old" planet - "forsakers".

In between is the permanence of a growing acculturation between human and Gaian on the one hand, and lunar on the other. While we never want to lose sight of the longer term goal, we need to reject rusting on the laurels of achieving permanence in the first naked sense. All that would achieve is the establishment of an eventual ruin or ghost camp.


Photo: Neil Armstrong


Photo: Harrison Schmitt

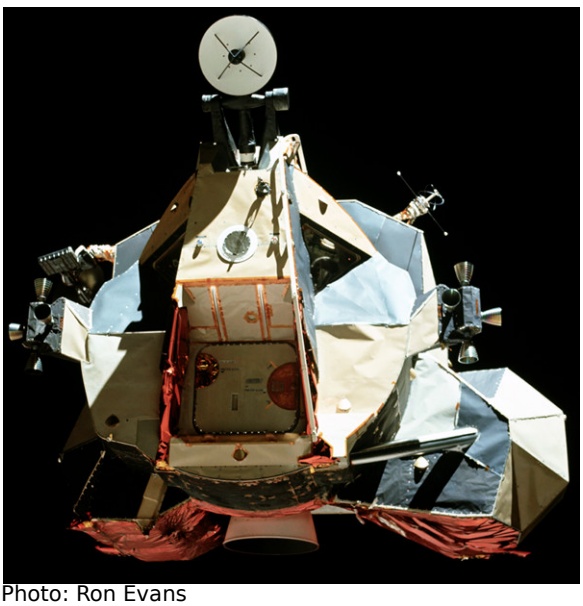


Photo: Ron Evans