

Drilling the MOHOLE - More Difficult than Landing Men on the Moon?

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I understand my invitation to speak this afternoon was predicated on being able to provide some historical perspective and share some wisdom gained while helping to develop the science program for Apollo. I must confess I had a difficult time deciding which stories might be best considering some might not have direct memories of that time 40 years ago when humans first set foot on another part of our solar system or, perhaps, only fuzzy memories of fuzzy TV pictures. I see a few gray heads out there but not too many. And guests from other countries may not be able to relate to how our political processes work. So now, from a vast collection, all attested to to be true, are a few old stories that might be useful as you look ahead.

First, as we are approaching the dinner hour, I thought I would begin with a breakfast story about two early champions of drilling the Mohole, one of whom also played an important role in the Apollo program.

In April, 1986, I was sitting in a small restaurant in Monteria, Colombia, having breakfast with Hollis Hedberg. I had met Hollis for the first time the day before but, of course, I was very familiar with his body of work. We were in Colombia as consultants to Chevron which was beginning an extensive exploration campaign in northwest Colombia.

Hollis was there because of his knowledge of petroleum source rocks found in northern South America. I was there because I had mapped the same area Chevron was beginning to study while working for Mobil Oil.

Our first breakfast together was interesting. Hollis told me whenever he was working in South America he always ordered the same breakfast. First *bistec a caballo* - that's one egg sunny side up served on top of a small steak. At the end of the meal he always ordered *papaya con dos semillas* - a slice of papaya with two, tiny, black seeds. He said starting his

day with this meal was why he had such a long productive life and he was still very spry at 83 climbing up and down the outcrops. For the next week I joined Hollis in that morning ritual, and now, whenever possible, I have that breakfast and eat a slice of papaya con dos semillas. I'm not sure it has made much of a difference but I can use all the help I can get - and those of you who work or travel in the tropics may want to keep that breakfast in mind.

Our conversation turned to discuss a mutual friend, Harry Hess, who once had been Hollis' neighbor in Princeton. During Apollo, Harry was the chairman of the National Academy of Science - Space Science Board that provided advice and recommendations to NASA and told Hollis the story of the last time I was with Harry.

After Apollo-11's successful flight Harry convened a meeting of the Board on August 25, 1969 at Woods Hole. Perhaps some of you attended meetings at the lovely house on the hill with wide porches on all sides and a view of the bay. It was a favorite Academy summer meeting place.

Harry was concerned that congress and the public were already tired of supporting Apollo missions. NASA's budgets had steadily declined after FY 1965, four years before the Apollo-11 flight. Harry wanted to take advantage of the Apollo-11 mission success and all the publicity to be sure the scientific community would not join the congressional chorus to terminate Apollo, but would actively support further lunar exploration.

Harry invited me to attend to describe the experiments and exploration program that we planned for the remaining Apollo missions. Each of the six scheduled flights would be scientifically more ambitious than the last. For the last three, you may remember, there was a small two-man vehicle in the payload that would greatly improve the astronauts ability to study their landing sites. Over 50 experiments had been built or were in the process of being built specifically designed to take advantage of the Moon's unique environment and conditions where they would be deployed.

At the coffee-break the first morning, Harry said he wasn't feeling well and went to lay down.

He complained of chest pains so we immediately drove him to a nearby doctor's office where he died. The Board chairmanship was passed to Bill Rubey who in 1968 had been appointed Director of the newly established Lunar Science Institute (not to be confused with the LSI recently formed at NASA Ames). All the attendees agreed to continue the meeting and the Academy issued a report strongly supporting the remaining missions.

Before I get to some lessons learned during the Apollo program, a couple of other stories that may be useful to attendees from NSF and other government agencies that plan on providing funds for MOHO. You will have to listen to the three-legged stool analogy to accept this wisdom.

How many remember Senator William Proxmire of Wisconsin? Do you remember what he was famous for besides jogging down Conn. Ave. every morning in his shorts on the way to Capital Hill? The Golden Fleece Award! His way to show how he thought money provided by taxpayers was wasted. His first award in 1975 was to NSF for a study it funded at the University of Wisconsin on "The nature of passionate love and sexual desire." Bet you didn't think you would hear a discussion about sexual desire this afternoon.

Sorry you won't, but NSF was one of his favorite targets. I learned the senator was considering awarding a Golden Fleece to one of my projects at NSF, drilling a deep well to a geothermal hotspot in Montana to determine if it was possible to utilize the heat by circulating water, creating steam and running a turbine. I talked to one of the senator's staffers and explained why it was an important experiment. I convinced the staffer of its importance and the senator gave the award that month to some other poor soul.

How many remember Senator Dale Bumpers of Arkansas? Do you remember why he was famous or infamous, depending on your point of view? Among other achievements he liked to brag that he killed the Super Collider that was to be built in Texas. He also led the Senate debate in 1993 that came within one vote of killing the Space Station. Perhaps some of you wish he had received the one vote. I'm glad he didn't.

Although those two gentlemen have gone on to the happy hunting ground, there are other young bucks in Congress who have taken up the spear to protect the taxpayer. And although earmarks are supposed to be no-nos for future congresses, I won't hold my breath to see if they are curbed. Pet projects will probably continue to replace valuable projects for needed funding.

Having testified before House and Senate committee, my experience was that few members really understood what was needed when I discussed my programs. Staffers who were plugged in gave their members the questions to ask. I would often have one of my staffers feed questions to committee staffers in order to have a rational discussion when testifying. Keeping House and Senate members supportive of a long-term - government funded - big science program is a full-time job all by itself. The first leg of the stool.

OMB is the second leg that must support a government program. For our visitors from overseas the Office of Management and Budget is located in a large, red brick building on 17th street just north of the White House. It is a beehive of faceless bureaucrats but is where all the real decisions are made in Washington.

OMB program examiners, in my experience, are very junior civil servants. They have never managed a S&T program, or any program for that matter. In most cases they understand little about the science and technology involved in programs where they decide what a president will ask for in his budget. Not a problem, they know how to add and subtract. They get their directions from higher management, the highest being political appointees, and they follow that direction to the letter.

Few, if any, of the more senior OMB managers have ever managed a S&T program. These senior OMB political appointees usually do not remain on the job throughout an administration so there is the problem of continuing education. The current director as you know is leaving after 18 months. But the civil servants are there for very long careers, through several administrations, and seldom change their opinions as to what is needed.

Those are two constituencies you must deal with in order to be successful when you undertake a costly S&T program, and you must continue to receive their support for many years. It is not an encouraging situation and those who wish to have a successful program must be strong of heart in dealing with OMB and Congress - never give up! You must find champions on both House and Senate appropriation committees to see you through.

Now back to the Apollo program. Twenty years after Apollo a Yale sociologist, Gary Brewer, opined that NASA during the Apollo program was close to being “a perfect place” to work. Obviously he hadn't worked at NASA. It wasn't perfect but it was a great place to work because the senior managers who eventually led NASA made it a great place. The country was fortunate to have some extraordinary leaders and managers who carried us through tough times as the program proceeded. That is one memory I retain after 40 years. Good managers are essential to the success of any program, and an agency's management is the third leg that keeps the stool from toppling over

However, when President Kennedy mandated we would send men to the Moon and return them safely he didn't mention performing any science on the Moon. Many senior NASA managers at the beginning of the program weren't very interested in including experiments on the missions. Among other reasons, carrying experiments would add to the many concerns about how much payload could be put in lunar orbit and on the Moon's surface.

We had to convince senior manned space flight management that the science we wanted to do was beneficial to the program as a whole and would add support to keep the program going. If you were on the staff at the Manned Spacecraft Center in Houston you knew that your management was committed to only one landing, just what President Kennedy mandated. In their minds, after a successful landing, NASA would go on to other programs. Sending astronauts, their neighbors and office colleagues, to the Moon was too dangerous to continue.

Even on NASA's science side, the senior manager advising NASA's Associate Administrator for Science as to what Apollo experiments should be supported was

convinced that robotic missions were the best way to conduct space exploration. Reluctantly, he participated in selecting experiments for the Apollo missions and NASA began to think about what experiments could be carried.

Despite this rather negative environment, some down in the bowels of NASA ignored all the nay-sayers and charged ahead. But, for the next two years little progress was made. For planning purposes, we were told to plan on a payload of 100 to 200 pounds, but very little funding was available to start developing the experiments.

In contrast, those planning missions that would come after Apollo, perhaps even lunar bases, did receive funding. We weren't confined to most of the restrictions that had been placed on Apollo science. As a result, from the beginning we planned on having vehicles to travel over the lunar surface and large science payloads, up to 7000 pounds. The good news was, after these plans were scuttled, much of what had been done was directly transferrable after restrictions were eased on the Apollo missions.

Starting in 1965 we began holding a continuous series of lunar symposia, conferences and workshops inviting well known scientists such as Harold Urey, Louis Alvarez, Maurice Ewing, Gordon McDonald and Frank Press to present papers and become principal investigators. Urey's attendance was guaranteed to attract attention from the media and get a few favorable press releases. His opinion on how the Moon was formed differed from most other researchers.

We used Announcements of Flight Opportunities to solicit proposals from the science community. It was a transparent peer review system similar to that used at NSF by which we selected those who had the expertise to participate. Eventually, by the time Apollo-11 lifted off, we had more than 400 scientists from all over the world lined up to study the returned samples and data from the experiments the astronauts would deploy on the Moon.

Often, the international media were more enthusiastic about what we hoped to accomplish

than some in the US. New York Times editorials, for example, could be counted on to point out the waste of taxpayer dollars. It believed the nation would be much better off spending the Apollo funds on low-cost housing, health care, or other social programs.

An estimate I made at the end of the program was that the science, including developing the experiments, training the astronauts, reducing and studying the data and samples, building the Lunar Receiving Lab in Houston, and more, came to about \$350 million in 1972 dollars. About 1.5% of the total cost of Apollo. Using an inflation multiplier I guess that would equate to about \$1 billion today.

Was it necessary to get the scientific community behind the program to assure the success of Apollo missions after Apollo-11? I believe it was. The first flight was a given. After that it was anyone's guess as to what would follow. Thus the story about Harry Hess.

Now, allow me to put on my old well site aluminum hard hat, perform a little instant engineering and provide some comments that might apply to the MOHO. They should be taken with great caution as my understanding of the state of preparation for the MOHO is not extensive.

I would guess drilling to the Mohorovicic discontinuity will be as difficult an undertaking as sending men to the Moon and returning them safely. Perhaps more difficult.

Why? For example, we knew rather precisely the distance to the Moon. We had already successfully sent a number of unmanned missions, some landing on the Moon. We knew the temperature extremes experiments would need to survive for long periods of time in order to be useful. And before the first landing we had maps of the landing site with one meter resolution. Then we practiced all aspects of the mission from launch to just short of Armstrong and Aldrin's actual landing.

All the crews had spent hundreds of hours practicing on simulated lunar terrain what they would do after they landed. Working with the PIs they were familiar with all the experiments

they would deploy. And remember, perhaps most importantly, we were operating under a presidential mandate to achieve a national objective.

Based on my understanding of where you are, some of the operations you will need to successfully carry out have never been done before. Perhaps in the next days you will convince me otherwise. And because it will be a program of international scope I think the MOHO project is more like the International Space Station and International Thermonuclear Experimental Reactor - ITER - than Apollo.

Why? Because if it is to be successful it will probably take many years of continued support, longer than that needed for the Apollo program. The ISS, for example, is just beginning to achieve its initial goals after 26 years.

As a member of NASA's space station advisory committee for seven years, I witnessed and was a part of many changes from what would be built, to how it would be built, to who would be the partners and what would be their contributions, to management turn over and continuing battles with both administrations and Congress to get required appropriations. Not to mention the simultaneous problem of needing to develop new technology.

ITER was proposed over ten years ago. The initial cost estimate, as I remember, was \$5 billion dollars. I believe the estimate now is over \$20 billion. I would guess ITER, after experiencing a long delay deciding where it would be built and budget growth, will have the same problems as the ISS when Congress is asked to provide the US share.

I understand that a proposal to go forward with the MOHO may be released next year. If true, I hope that it will have been carefully analyzed and vetted. Both the ISS and ITER demonstrate how difficult it is to manage and control large multinational programs.

The following are not original thoughts but are based on my reading, and a little past experience. Clearly spudding in a well in 10,000 feet or more of water, for a well scheduled to go to great depths, will present many challenges. Important lessons have been learned

from the Super-Deep well on the Kola Peninsula, SG-1, Nankai Trough and the deep well drilled at Gravberg Sweden, perhaps others. However, wherever you choose to drill, subsurface conditions will be largely unknown. So I must assume there will be questions as to how transferrable those lessons will be at a new location.

The Saturday agenda will discuss some of the technology that will be required, high temperature electronics, subsea equipment, borehole management and mud, the last a subject once dear to my heart. I would anticipate that the MOHO mud program will be one of the more challenging plans to design and implement. I worked on two wildcat wells where we were forced to carry 20 pound mud after we encountered Miocene heaving shale. Maintaining the chemistry of 20 pound mud was very difficult and we still stuck the drill-string several times. I look forward to hearing about the latest advances in mud programs and hope you won't have to use 20 pound mud.

So with those comments I 'll take my old hard hat off, wish you well in pursuing an ambitious and challenging program and answer questions you may have. Thank you.