Commemorate the 50th Anniversary of the Apollo 11 Moon Landing (The Apollo 11 Plus 50 Project)

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The 50th anniversary of the Apollo 11 moon landing is coming up in 2019. A mission to the moon to commemorate this most significant event in history would certainly be in order. Some type of a lunar landing close to one of the Apollo landing sites is a primary consideration. This would not be a single, one-time mission, but a foundational voyage for a campaign of flights to the moon in order to engage commercial companies in the extraction of resources from the moon to develop logistics for manned space travel to the planets.
A mission like this would have a plethora of benefits and a great deal of public interest. This paper will discuss the benefits, candidate options for the initial mission, candidate options for follow-up missions, and how to support subsequent campaign flights. The mission would be planned for a fixed launch time in 2019, which means that it is necessary to start right away (even without funding).

Nomenclature

i.e.	=	in other words
e.g.	=	for example
a.k.a.	=	Also Known As
LEO	=	Low Earth Orbit
GEO	=	Geosynchronous Orbit
TLI	=	Trans-Lunar Injection Orbit
SPST	=	Space Propulsion Synergy Team
GLXP	=	Google Lunar X Prize
HEOMD	=	Human Exploration and Operations Mission Directorate
MER	=	Mars Exploration Rovers
LRV	=	Lunar Roving Vehicle (a.k.a, moon buggy)

I. Introduction and Rationale for the Apollo 11 Plus 50 Project

On 20 JULY 1969, Neil Armstrong and Buzz Aldrin became the first people to walk on another heavenly body, the moon. In 2019, we propose to kick off a series of lunar landings that will result in establishing profitable commercial operations, lunar colonies, as well as a testing platform for missions to Mars.

During the Dark Ages, people in Europe were living in simple huts while they could see the great engineering feats by the Romans a 1,000 years earlier, and they knew that their civilization had regressed. In a similar manner, nearly 50 years after Americans walked on the moon, our astronauts cannot even get into space with an American rocket! Not only that, a percentage of the population actually believe the moon landings were completely fake.

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Compare the technical achievements of Coliseum to these guys from 1,000 years later

Compare the technological achievements of 1969 to today's aerospace abilities

As a result of one incredible American Political Leader, President John Kennedy, who had the ability to inspire the world to do seemingly impossible things, we ended up with one incredible year.
1969 gave us Man Walking on the Moon, the first jumbo jet (the Boeing 747), and the introduction of the only supersonic passenger jet (the French & British Concorde). What will 2019 give us? Will we find another American Political Leader who will make America Great Again by putting his political weight behind the Aerospace and Aeronautical community?

Here is a Commemorative Pin that NASA gave out during the 20th anniversary of the Apollo 11 moon landing. America spent $110 Billion to accomplish the most difficult technological achievement of all time and 20 years later we celebrate the event by giving out $0.25 medallions. Some say we must get other countries or commercial organizations to support any project that involves going back to the moon. Let's prove to the world that, by the shear will of the American people, only we can still be the greatest country by supporting the APOLLO 11 PLUS 50 PROJECT.

Additionally, we wish to acknowledge and celebrate the technical accomplishment and honor the approximately 400,000 Americans and over 20,000 industrial firms and universities involved in America's Manned Lunar Space Program, as well as those who provided the enthusiastic support of the American People, by setting aside funding and providing the authorization for the Apollo11plus50.com project.

Who We Are

Space Propulsion Synergy Team (SPST) are mostly retired ex-NASA and NASA contractor engineers and managers who were intimately involved in the planning, design, development, construction and operation of the Apollo/Saturn vehicles, facilities and systems that put Neil Armstrong and Buzz Aldrin on the moon on July 20, 1969. Some worked with Dr Von Braun at Marshall Space Flight Center in Huntsville, AL, others worked at the Kennedy Space Center in Florida, the Johnson Space Center in Houston, and at the many development centers, test sites and contractor facilities across the country. Please refer to the ABOUT US and PUBLICATIONS tabs on our website http://www.spacepropulsion.org for our credentials.

II. Initial Lunar Mission

The first mission needs to be a mission worthy of the event it's commemorating. It should include a lunar landing of some type and certainly utilize advanced technologies that were not available 50 years ago. It should be a fixed target date corresponding to the Apollo 11 landing date (July 20, 2019). It must be affordable and sustainable considering the expected economy and other ongoing activities. The mission should use evolving state of the art space vehicle capabilities. This first mission should initiate a campaign of lunar missions: in partnership with private industry, to explore and extract the potential resources of the Moon for commercial profit, to develop fuel and life support resources, to benefit people on Earth, to promote cis-lunar commercial development and advance our science and space exploration goals. The mission should leverage commercial capabilities as much as possible. It should demonstrate technologies that add value to ongoing commercial and exploration space activities. Mission planning should start immediately to assure adequate time and resources are available to accomplish this mission. It should be a National commitment!

Initial Mission Objectives

The Mission Objectives of the first couple of missions are to visit the Apollo landing sites and the polar regions. The missions will demonstrate, test, and evolve capabilities needed to: prospect for hydrogen volatiles to determine sites with high concentrations of water/ice; develop water extraction process from lunar regolith and to demonstrate processes for large-scale production and distribution of water. The first missions will also perform other lunar activities to accelerate commercial development and advance space exploration, such as: prospect and extract other resources, (such as Iron, Aluminum, and Titanium); support lunar far-side activities, and establish a permanently manned international lunar base

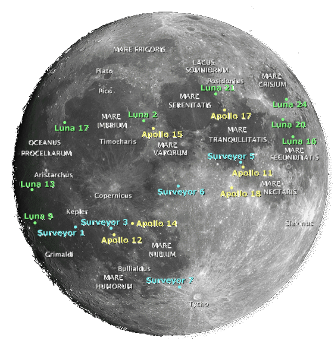
First Flight Options

The 50th anniversary of the Apollo 11 flight is less than 3 years away and it would appear that funding for the project will not occur until the next fiscal year. The first mission must be kept to a minimum in order to meet the hard deadline and to be within a reasonable budget. We have derived 4 options for the first flight as delineated below:

1. Land an unmanned mobile video surveyor near an Apollo site, image hardware and demonstrate equipment and instruments needed to search for water/ice
2. Land at the polar region and initiate searchers for water/ice, explore lava tubes or other sources while demonstrating and evaluating the latest equipment
3. Contract directly to the commercial community to land on the moon and exploit whatever is needed to find and process the lunar regolith for water.
4. Extend GLXP to add an Apollo anniversary flight

Potential Follow-On Activities

After the first mission objectives are accomplished and our rover is still functioning, here are possible follow-up activities. As shown in the picture to the right, several of the other Apollo, Luna, and Surveyor sites are relatively close, and if the rover can travel at a reasonable speed, it should be able to visit multiple landing sites. The rover may be repurposed so that it can demonstrate, test, and evolve capabilities needed to search for water/ice, develop water extraction processes, or more importantly, to produce of water from the regolith. Maybe the rover can be repurposed to perform follow-on lunar activities to benefit mankind and support space exploration such as exploit other resources (e.g., He3), support Lunar far-side activity, or support the establishment of a lunar base.



Recommended Management Strategy

- NASA oversight
- Commercial engagement
- Capitalize on GLXP teams and hardware
- Partner with commercial organizations to share costs and technical risk.
- Share launch cost when possible

Recommendations

- Define mission objectives and requirements in accordance with HEOMD leadership.
- Continue developing mission options and pursuing international and commercial partnership opportunities.
- Develop schedule and cost estimates for various mission options. Only pursue options that are within recommended budget limits and schedule for initial mission.
- Determine acquisition approaches for launch vehicles, lunar landers, rovers and payload.
- Obtain approval for Agency resources to start mission planning activities immediately to meet Apollo 50th anniversary mission schedule.
  - Recommend 3 to 4 FTE’s from NASA ARC and JSC to kick-start mission planning team to define viable mission options that fit within HEOMD guidance.
  - Mission concept package to be delivered within 6 months.

Next Steps

In order to carry this project forward, we must establish a mission concept team who will define guidelines, constraints and partnership opportunities. Based upon the 1st mission launch targeted date and proposed budget, the mission concept team must recommend initial mission options that fit within the guidelines and constraints, within the next six months. We must next establish project team who will proceed with approved mission options and release BAA or RFP for lunar lander and/or rover systems.

Issues

Perhaps the biggest issue with this project is **Who pays for it**? NASA (with the full support of the American people) spent $109 billion in today's money during the Apollo program and planted the USA flag on the moon. That was one of America's finest hours, and it should be a source of pride to show what we can accomplished when we have the America people and American political leadership behind a project. With that said, does it make any sense that we now ask global partners or commercial enterprise to help us to commemorate that feat? Does it make any sense that we can't find 1,000th as much funding to celebrate that accomplishment? Does it make any sense that we don't do something that is just as spectacular an the Spirit of Apollo?

Another issue would be who should manage the project. SPST has partnered with NASA-Ames (so far) to push the project along. When NASA-HQ takes up the project and dedicate millions of dollars, they should start to manage the project and we hope that they would include the current managers who are already very familiar with the project.

Commercial and international partnerships could develop an interest in the project and we must determine how to integrate them into the project as well as determine how to protect any proprietary rights. If a commercial company provides launch service gratis, would they be entitled to any resources (e.g., $B of He3) discovered on the lunar surface?

It would seem logical that a project of this magnitude become a national priority, but how is that accomplished? Both Presidential Candidates have been very quiet when it comes to space exploration. In 2008, candidate Obama stated that he would transfer funding from NASA to education[i], but nobody believed him. U.S. Presidents endeavor to leave a legacy. It was quite unfortunate that the Apollo program was funded and greatly championed by Kennedy and Johnson (who left great legacies; i.e., the Kennedy Space Center and the Johnson Space Center) while the actual manned lunar missions occurred during Nixon's administration. Because Nixon had little interest for the manned program, other than to place that one phone call to Armstrong and Buzz on the moon, there is no other evidence of Nixon in the space industry. What better legacy for a President than to fund a project and be in office while the climax of the project occurs?

No matter if the project is approved or not, the Apollo landing sites and hardware on the moon must be protected. If the Apollo 11 Plus 50 project goes forward, we must protect the sites and the most important sites are Apollo 11 and Apollo 17; the first and last Apollo missions. Later in this paper, you will read that on mission 3, we are planning to utilize the Apollo 15 or 16 lunar buggy. Because of the status of Apollo 17, we are forbidden from touching Apollo 17 lunar buggy. This means that when our landing craft approaches the site, we must land at least 1,000 meters away. Apollo 12 was able to land within 600 ft of Surveyor 3, but it was determined that dust was kicked up from the Apollo 12 decent stage blew onto the surveyor spacecraft. To prevent that from happening in the future, we have expanded the exclusion zone around the landing site. One exclusion zone would forbid any landers from coming within 1,000 meters of the Apollo hardware and a separate exclusion zone would forbid any rovers driving within 50 meters of Apollo hardware.

III. THE FIRST MISSION

During the first mission, we have created a tentative goal of visiting the Apollo 11 landing site. As discussed earlier, one of the mission options (and our first choice) was to conduct a photo/LAZE of the Apollo 11 site. It would be a tremendous boost to send back a picture of the Apollo 11 site and show where the American flag is laying on the ground and has been bleached white by the sun. The first mission would be a demonstration of the rover and its specialized instrumentation. It is hoped that we could leave behind a time capsule that contains a digitized human data base or at least a list of all the people and companies that participated in the Apollo program.

What's Needed?

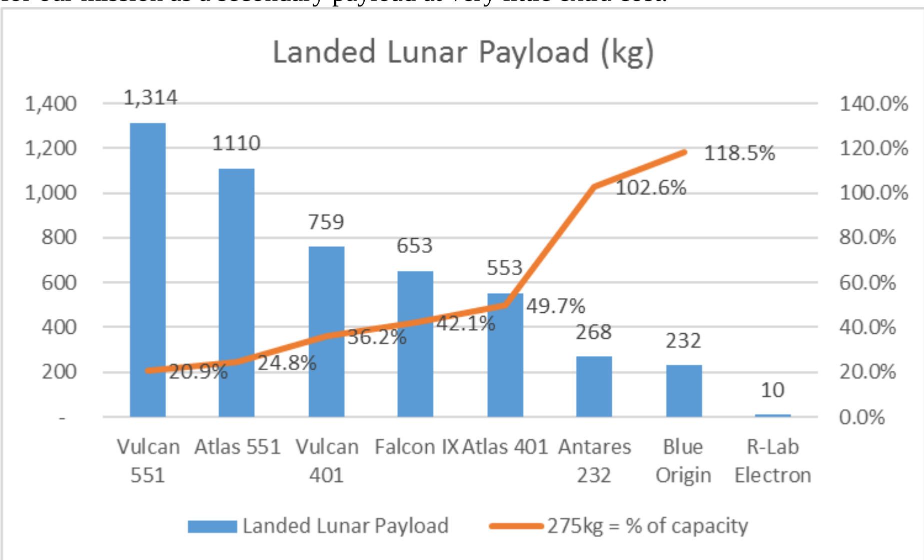
To make the Apollo 11 Plus 50 project possible we are going to need the following:

- **Earth to Low Earth Orbit (LEO) transportation:** As a point of reference, the Saturn V could deliver 260,000 lb of useful payload to LEO or 100,000 to Trans-Lunar Injection (TLI) Orbit around the moon[ii]. 100,000 lb at TLI can become 41,666 lb on the lunar surface[iii]. Using these numbers of merit, a 416.6 lb rover on the lunar surface will require as a minimum 2,600 lb that could have been delivered to LEO; basically, we divided the Saturn V capacity by 100 to get a starting point of a potential rover weight.

- **LEO to TLI transportation**: Getting from LEO to TLI is not as straight forward as it would seem. In-space propulsion stage could transport our equipment from LEO to TLI, but would require far more mass taken to LEO than if an upper stage delivered our equipment to Geosynchronous Transfer Orbit (GTO). Therefore, if we can hitch a ride with payload going to GTO, our 416.6 lb rover would only require 1,300 lb at GTO as a minimum.
- **A Lander for TLI to Lunar Surface Transportation**: The 4,783 lb Apollo descent stage (dry mass) plus 18,000 lb of propellant was able to deliver 10,300 lb of useful hardware plus itself on the lunar surface. Using these numbers as a figure of merit; our 416.6 lb rover will require a 193.5 lb descent stage and 728 lb of propellant for a total of 1,338 lb delivered to TLI.
- **Lunar Rover:** The 416.6 lb fictitious rover was derived from the payload capability of the Saturn V. Several rovers have been deployed on Mars. A rover on the moon would weigh half as much as it would on Mars. We need to determine how much would a Martian rover need to be modified in order to operate on moon.
- **Power & Thermal Management**: Our rover and test instruments must have power. But while on the moon, they will experience 168 hours (one week during a new moon) of continuous darkness after 3 weeks of continuous daylight. When the rover and test instruments are in sunshine they will be baking in 253 deg F while dropping to -243 deg F when in darkness[iv]. Unfiltered sunshine will provide 1,300 watts per square meter of solar energy to photovoltaic cells. Even at 10% efficiency, it wouldn't take very much surface area to have sufficient power for a rover and test instruments. A bigger problem is how will the batteries support a week long cold soak or how do we keep the solar cells, test instruments, and electric motors from overheating since there isn't a nice way of ejecting waste heat to a cold source.
- **Communication & Computers:** Our rover and test instruments must continuously stay in contact with mission operations people on earth. Some of the options of transmitting and receiving the signal would be to send the signal to one of several orbiters. The orbiters would be mapping the surface as well as relaying the signals from the rovers. By having two or more orbiters, we can guarantee there will always be an orbiter within range of the rover. The computers must be radiation hardened due to the intense solar and cosmic radiation the rover will expense, even though the earth will shelter the rover some of the time.
- **Payload:** We have often mentioned the test instruments, but what are they specifically. Our choices for payloads include: Rover/Drill, Spectrometer(s), Camera, Walking Robot, Digitized human data base.
- **Payload Properties.** Once we have been given a budget and determined what payloads will be on the rover, we will need to determine: Who is the Vender, Weight & Dimensions, Power requirements, and Cost.

What are the Potential Launch Vehicles that can provide Earth-to-Low Earth Orbit Transportation?

In the figure below, we show the Landed Lunar Payload capacity for several launch vehicles. The Mars Exploration Rovers (Opportunity and Discovery) weighed 408 lb (185.5 kg) each while Curiosity weighs in at a whopping 1,982 lbs. As shown previously, we calculated a descent stage would weigh 195.5 lb by scaling off of the Apollo Descent Stage. From these crude estimates, we would need at least a landed Lunar Payload capacity of 603.5 lb (275 kg). From the chart below, almost any of the launch vehicles should be able to transport a MER class of rover and lander to the lunar surface except the Blue Origin and R-Lab. The 232 Antares would be close at 102.6% of its Landed Lunar Payload capacity while the Vulcan 551 would only need 20.9%. It's highly likely that an Atlas 551 would have excess capacity on a GEO mission and would be able to provide the transportation energy for our mission as a secondary payload at very little extra cost.



Are there any potential Lunar Landers?

There are several lunar landers that could possible provide transportation from TLI orbit to the lunar surface for our rover. Of the five lunar landers that are currently being developed, only the Astrobotic's Griffin Lander and NASA JSC's Morpheus Lander have the capacity at 275 kg to land a MER class lunar rover.

Draft Lunar Lander Options	Payload Capability	Launch Vehicle Options	1st Mission Date
NASA JSC's Morpheus Lander	500 kg	SpaceX's Falcon 9 or Heavy or ULA's Atlas V	NA
Astrobotic's Griffin Lander	200-450 kg for Griffin	Primary Payload on SpaceX's Falcon 9 or Heavy or ULA's Atlas V	TBD
Astrobotic's Peregrine Lander	20-40 kg for Peregrine	Secondary Payload on SpaceX's Falcon or ULA's Atlas V	Q4 2017 or Q1 2018 to Lacus Mortis, 45^{o}N x 27.2^{o}E
Moon Express MX-1	Electron's cap: 150 kg to 500 km geocentric orbit. Or ~20 kg to lunar surface.	Rocket Lab's Electron Launch Vehicle	2017
Israel's SpaceIL GLXP team	1st mission is very mass limited (~1-2 kg available). Planned mobility is Hopper. No plans for deployment of a rover.	Co-manifested by Space Flight Industries on SpaceX's Falcon 9	Late 2017/Early 2018 to mid-Latitude site (30 to 60 deg)

What Potential Lunar Rovers could be available by July 2019?

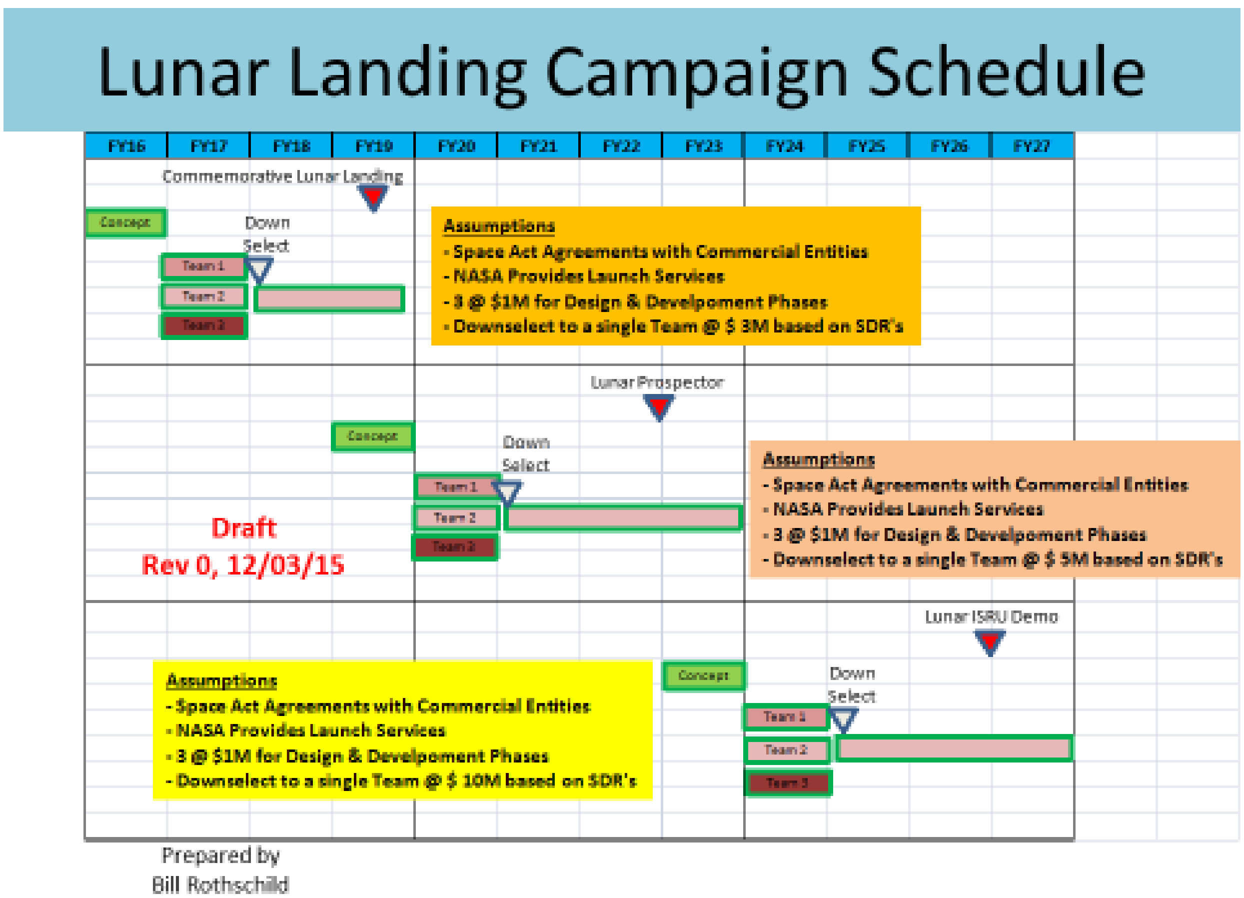
We have often stated the term MER class rovers; but Discovery and Opportunity Martian Rovers would be well suited as rovers for the moon. It is thought that minimum development work would be required since they have already operated successfully on Mars since 2004. Minimum development work also means minimum cost and minimum time, which is important if we wish to meet our July 2019 deadline. If the managers of the Apollo11plus50 project decide to utilize a MER, one is already built and fully tested, and is currently used for troubleshooting problems with Discovery and Opportunity. Since Discovery is already immobilized, it doesn't need any further assistance of the test article. If the July 2019 deadline is approaching and a rover has not been made available, wouldn't it be better to utilize this valuable hardware on the moon rather than to keep it on Earth in the chance that it is needed to solve a problem with a 15-year-old rover on Mars?

There are several other rovers that are currently being developed for operations on the moon. As you can see in the chart below, two of the rovers are being developed by Astrobotics, who are also developing lunar landers.

Draft Lunar Rover Options	Capabilities
Astrobotic/CMU's Andy Rover (For Peregrine, small 6U-size rover is being planned for first mission)	Contains unique pivoting axle suspension to drive faster in rugged terrain.
Astrobotic/CMU's Polar Rover	Designed to carry RESOLVE instrument suite. Also option for excavation equipment.
Japan's Hakuto GLXP Team (Partnered with Astrobotic on first mission)	Dual Rover system linked by a tether: MoonRaker and Tetris.
NASA's Resource Prospector Rover	Planned to deliver RESOLVE instrumentation suite to lunar poles

Lunar Landing Campaign Schedule

In the chart below, we show that FY2016 will be used to develop the Apollo 11 Plus 50 project concept for the campaign. In the following year, we would solicit several teams for the Commemorative Lunar Landing mission in July 2019. Also in 2019, we will start developing the concept for the Lunar Prospector mission with an anticipated landing at the end of FY2022. And finally, the 3rd mission with the Walking Robot would start to be developed in FY2023 with an anticipated landing at the end of FY2026.



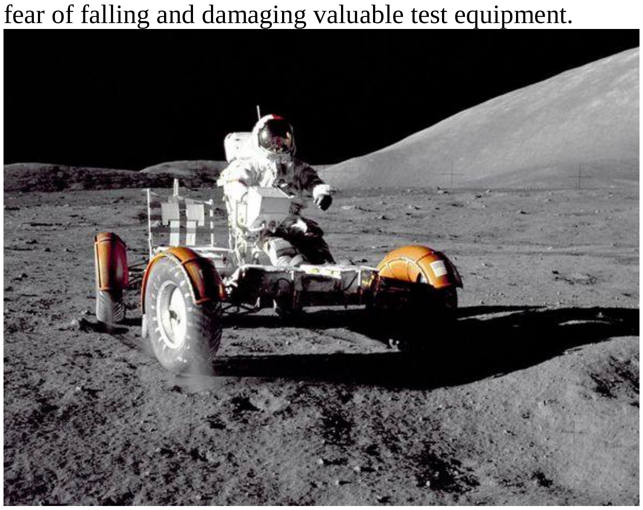
IV. THE THIRD MISSION – THE NEXT "MAN" (a walking robot) ON THE MOON

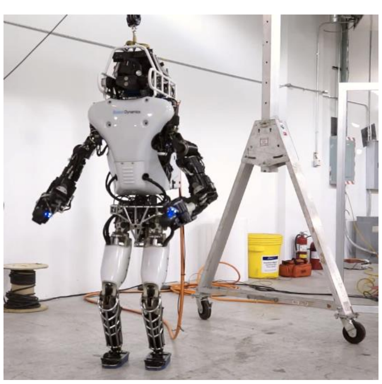
The purpose of this mission is to compliment the main goal of the project and that is to celebrate the Apollo Program. This mission is a follow-on to the main mission, which should take place in 2019. In the spirit of the Apollo Program, this mission must accomplish the seemingly impossible. The main objective of this mission is to demonstrate that a walking robot can operate on the lunar surface and perform tasks before humans arrive; namely those tasks are to:

1. Survive the rigors of travel from the earth's surface to the lunar surface (The new landing zone will be referred to as the Plus 50 site)
2. Transport a camera from the Plus 50 site to a site that overlooks an Apollo 15 or Apollo 16 landing zone
3. Set up the camera and other test equipment
4. Transport a replacement battery to the Lunar Roving Vehicle (LRV, aka, Moon Buggy) within the Apollo 15 or Apollo 16 landing area
5. Remove & Replace original, non-rechargeable Silver Zinc potassium hydroxide batteries with a replacement battery
6. Enter the driver's seat of the LRV and drive to the Plus 50 site. The Walking Robot may have 1, 2, 3, or more legs. But the LRV throttle and brake is controlled by hand levers.
7. Collect and mount Mobile Solar Panels to LRV
8. Collect and mount lunar miner/chemical lab in passenger seat of LRV
9. Drive LRV to pre-designated lunar sampling locations
10. Position LRV mounted Lunar Miner/Chemical lab over the sampling site and begin sample collection/analysis

HAZARDS: Operating on the lunar surface is much different than operating on the earth's surface. Without the benefit of air movement, electronics can quickly overheat without protection from the sun. Gravity on the moon is only 1.622 m/s^2 compared to earth's gravity of 9.81 m/s^2 so traveling on a sandy slope on the moon or Mars will be different than on the earth, which is how Discovery got stuck on Mars. Also, the surface is covered in dust and rocks that makes normal walking very difficult.

In the photo below, we show an astronaut driving the LRV on the moon. The following two photos show the state of the art for walking robots. One version can walk on a snowy surface while most must be tethered for fear of falling and damaging valuable test equipment.





Why a Walking Robot

This mission is to demonstrate and showcase the capability of the walking robot industry. During the last two nuclear disasters, humans had to pick up or shovel extremely hot nuclear material off of a roof at Chernobyl and a nuclear accident could have been prevented at Fukushima, Japan if a robot could have walked across a room and turned a valve.

We are planning on sending a chemical analyzer that drills deep in to the lunar soil. Rather than building a dedicated rover for the chemical analyzer/drill; it is thought that we can demonstrate the state of the art for the walking robot while reducing the weight and cost of transporting equipment to the moon. That is why the robot must drive back to the Apollo11plus50 landing site; and pick it up and place the chemical analyzer/drill in the passenger seat.

Mission Difficulties

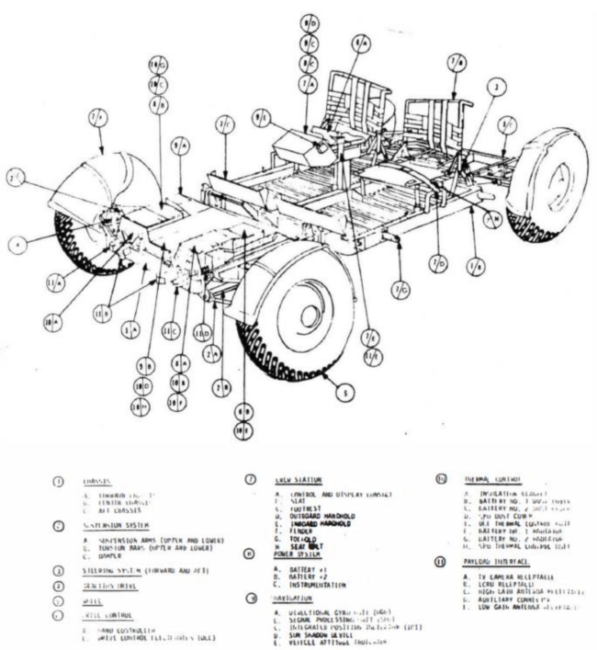
The biggest difficulty with this mission is that there are a lot of bolts to remove to get to the batteries. We hope that we could simply bypass the old batteries through the auxiliary connector (but it is limited to 7.5 amps) and install our new Li-Ion batteries and a solar umbrella. Fortunately, the walking robot would not be limited by lack of oxygen or strained by a cumbersome space suit. The robot would be limited by its internal battery, which would need to be recharged if the LRV batteries can't be replaced in a reasonable amount of time.

How Much Power is Needed for the LRV

The solar panels on the ISS generate 4.4 watts per square ft. The two original Moon Buggy batteries were rated 36 V +5/3V and 115 Amp-hour capacity each. The circuit breaker was rated 70 amps. Apollo 17 spent 22 hours on their EVA (not all of it driving the moon buggy). If we estimate that 80% of the batteries were drained after 11 hours of driving; the average amp draw would be 16.7 amp which would equal **600 watts**. This means our solar panels would need to be 136 sq ft to keep the moon buggy constantly power. 136 sq feet would equal a 13 feet diameter solar umbrella. If the moon buggy isn't constantly being driven, the solar umbrella would grow proportionally smaller.

Location of the LRV Batteries

From the Lunar Roving Vehicle (LRV) Operations Handbook[v], we have obtained several drawings on the Lunar Roving Vehicle. The first drawing shows the completed vehicle and to its right are sketches shows the front, side, and bottom views of the vehicle. From these sketches we see the position of the LRV batteries is between the front two wheels.



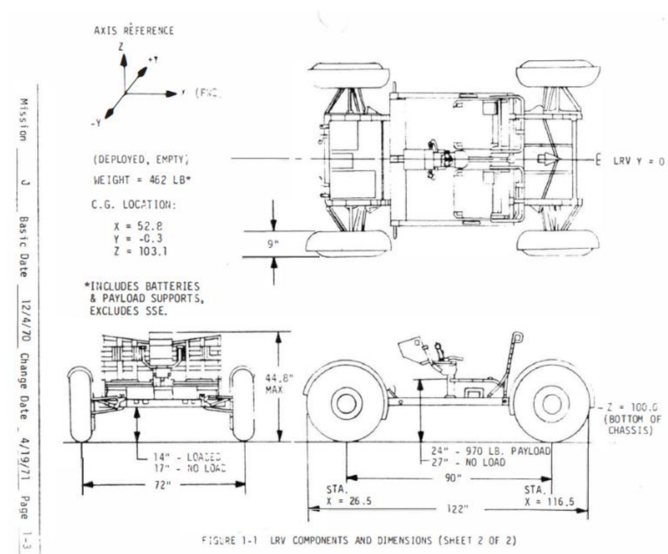
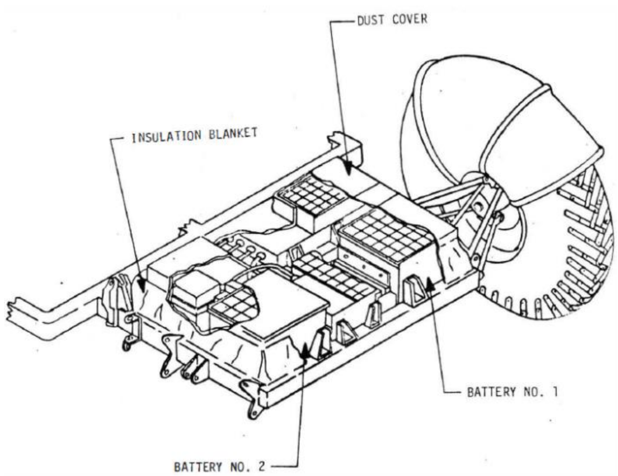


FIGURE 1-1 LRV COMPONENTS AND DIMENSIONS (SHEET 2 OF 2)

Below are two sketch which focus in on the batteries, which includes the insulation blanket and dust cover.



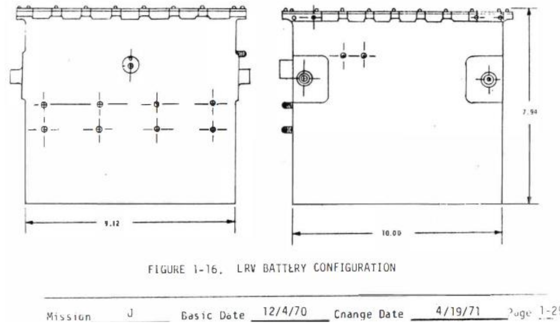
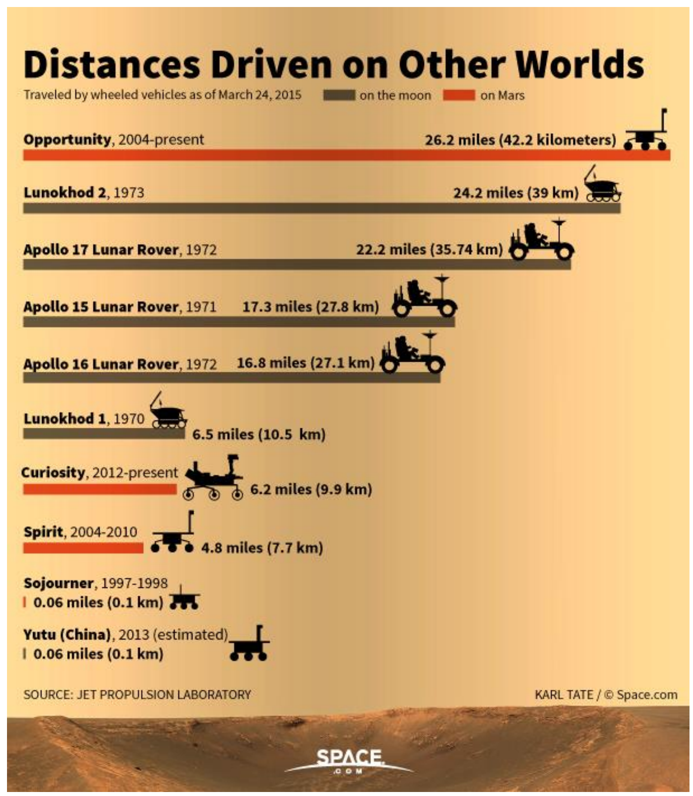


FIGURE 1-16. LRV BATTERY CONFIGURATION

Why is the LRV so Important?

From the chart to the right, we see the Apollo 17 LRV traveled 22.2 miles in the 11 hours that it was operated. On the other, Opportunity traveled only 26.2 miles in the 11 years that it has been operated. Sojourner traveled only 0.06 miles in the year that it operated. Having a Lunar Rover that is perfectly designed for the landscape, has shown to be able to quickly cover large distance, and is already located on the moon is far more valuable than to design and deploy a specialty designed rover with a chemical analyzer/drill instrumentation package. As shown previously, the LRV weighs 462 lb, which would require 28,800 lb delivered to LEO for a similar replacement. A SpaceX Falcon IX V1.1 can deliver 28,990 lb to LEO at a cost of $61.2M. Therefore, the Moon Buggy offers a savings of at least $61.2M to the program.



V: CONCLUSION:

The Apollo 11 Plus 50 project is the chance of a lifetime; this will be the last anniversary that many of the 12 men who walked on the moon as well as many of the workers who dedicated their lives to accomplish this incredible feat. It's very unlikely that many of these same people will be with us during the 75th anniversary. Never again will an Apollo program anniversary coincide with Presidential election; a Presidential candidate that embraces the project will get to see the climax of the project before they leave office. If we miss this opportunity to re-invigorate the world with a moon mission; we may well slip into a 'dark age' of space flight that is just as real as today as the dark ages of 1,000 years ago.

Nothing will be more spectacular, than to see a Walking Robot drive off in the distance on the moon with a bright earth in the back-ground; and nothing will be more disappointing to see the 50th anniversary pass without a whimper.

[i] http://www.spacepolitics.com/2007/11/20/obama-cut-constellation-to-pay-for-education/
[ii] https://en.wikipedia.org/wiki/Saturn_V
[iii] https://en.wikipedia.org/wiki/Apollo_Lunar_Module
[iv] http://www.space.com/18175-moon-temperature.html
[v] "Lunar Rover Operations Handbook", Doc. LS006-002-2H, Prepared by the Boeing Company, LRV Systems Engineering, Huntsville, Alabama, 19 April 1971 and 7 July 1971 revision