13 – The International Lunar Exploration Phase (ILEP)

SUMMARY

In our scenario, immediately following the Initial Crew Phase lasting between six and twelve months, a large phase of international exploration would commence. A follow-on agreement to the Artemis Accords would coordinate the participating nations so that their astronauts would each have newsworthy missions. This would be a huge foreign policy achievement for the United States naturally leading to the establishment of an International Lunar Base.

OVERVIEW

Thanks to commercial launch companies dramatically lowering the cost of space access, we can imagine that soon, the per-seat price in a mission of lunar exploration will come down to the point where most countries could afford to purchase at least one seat. If wealthier countries were charged about 10% more per seat and there was cost-shifting in favor of poorer countries, then all countries could afford to purchase at least one seat. The opening of the Moon (and indeed the solar system) to the nations of the world would generate tremendous goodwill towards the US for having made it possible.

There are many artifacts, natural features, habitats, and activities which international astronauts could explore and participate in which would be at a newsworthy level. The pride of citizens watching their national astronauts exploring the Moon on their behalf and in their own language would provide the necessary motivation for countries to set aside a very small amount of their national budgets to purchase those seats thereby funding this Phase.

As countries choose to leave some of their astronauts on the Moon, a growing International Lunar Base (ILB) would form the first off-Earth settlement and provide the transportation and infrastructure foundation upon which private settlement could grow.

PER SEAT PRICE MAKES ALL THE DIFFERENCE

Space Launch System (SLS)

The SLS is NASA's Shuttle-derived super heavy lift vehicle (SHLV). It is very expensive both in terms of overall development costs as well as per-flight costs. Yet, it is the most developed, human-rated heavy lift vehicle. Additionally, the SLS would launch the expensive Orion capsule designed for deep space missions and would have to go through the Gateway station around the Moon which would utilize several SLS launches to be set up. If one assumes a per-mission, incremental cost of about $4.1 B each for a surface crew of two, then this would come to about $2 B per seat. At that cost, nine missions (through Artemis 9) would cost about $37B for eight missions and perhaps 20 astronauts on the surface of the Moon. Most of the seats would go to American astronauts and only up to seven other nations would be able to watch their astronauts exploring the Moon. This chapter proposes an American initiated program of lunar exploration far greater than that.

Starship

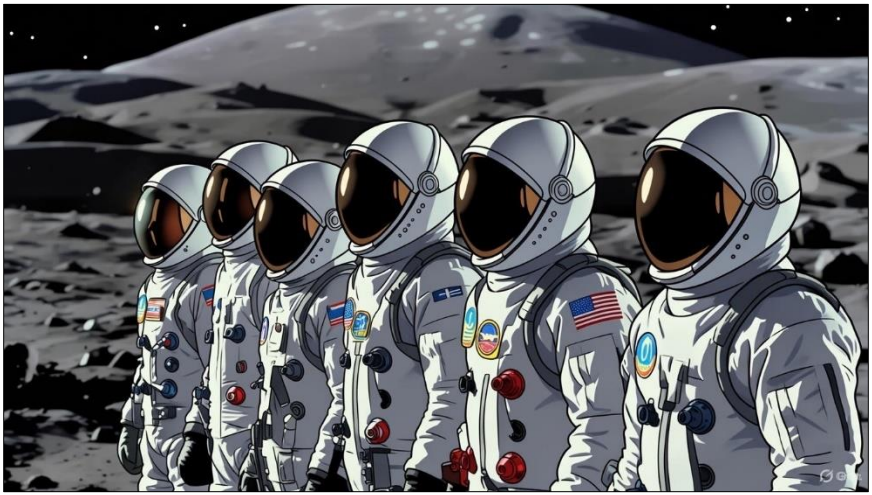
If SpaceX's Starship becomes a reality (likely) then it will be a complete game-changer for humanity. Intended to be the first, fully-reusable, orbital-class rocket, the cost would be just the refueling of the rocket. The decision makers in Washington DC should pay attention to the development of the Starship and be willing to transition to a public-private program with SpaceX if the Starship shows that it will likely be more cost-effective and about as capable as the SLS (i.e. the moment Starship refuels).

HOW MANY NATIONS COULD AFFORD A SEAT?

Assumptions

In policy chapter 33, it is proposed that initial lunar missions take full advantage of the Starship fleet starting as soon as it demonstrates LEO depot filling and storage (likely in late 2026). This chapter also assumes lunar missions using only SpaceX hardware (as Elon has indicated via an X post). In the early years to assure launch safety, it is assumed that six astronauts would fly to LEO on a Falcon 9 – Dragon and transfer to a cis-lunar Starship and then proceed to the Moon while refilling around EML1.

Estimates for such a mission run to a median point of about $1 B. So, for six seats, this comes to about $167 M per seat. With a high flight rate (aka Starlink launches) and already proven engine-out capability, crew safety can be better than the one in 300 level that NASA's ASAP safety committee set for commercial crewed missions. This is vaguely analogous to how passenger jets need no escape system because even one remaining engine is enough to safely land. So, if crew can launch on Starship, then the number of crew can be increased well above six in a Dragon capsule. One could theoretically stuff as many as 120 – 200 astronauts into a lunar Starship payload bay but let's choose a conservative crew of 50. This would bring the per-seat cost to $20 M per astronaut.



Teams of international astronauts during their "Apollo" moments.

Affordability

How much would nations be willing to pay for one seat on a mission of lunar exploration? The United States spends only 0.1% of its GDP each year on civil space. So, let's assume that other countries would be willing to set aside that same, small about of their smaller GDP and that they would be willing to set aside that amount each year for four years to save up for one seat on a mission. The QR code to the right links to a spreadsheet which shows the calculations. It turns out that nearly all countries (98%) would be able to afford at least one seat and nearly two-thirds of nations would be able to purchase an entire 50-person Lunar Starship.

Think about it, the United States could really benefit all of the other nations of the world by providing the leadership necessary to open up not only the Moon but the inner solar system to humanity. This is the legacy that is possible in the next few years. However, if we continue down the expensive SLS approach then, instead of 211 nations being able to go to the Moon, only about seven would be able to do so. The choice is ours to make.

INTERNATIONAL LUNAR EXPLORATION SCENARIO

The next QR code below illustrates a very hypothetical scenario of two years' worth of international lunar exploration expeditions at one mission per week. The specific series of missions included the following design choices:

Less naturally newsworthy locations and activities are done earlier and the more exciting ones later. In this way the firsts in each category will be exciting because they are first whereas the latter will be more exciting because they are naturally so.

Countries are matched to a site or activity if there is a natural association with them. So, for example, the crater named after Nicolaus Copernicus who was from Poland. Therefore, the choice of who gets to be the first to visit the crater named after him would be determined by Poland. Similarly, for example, Sweden (with its famous IKEA store) might choose for its team to set up the first HomeHab including specially designed furniture easily set up.

Certain activities are clustered to create a month-long theme. So, for example, the eleventh month of the second year would be the month that astronauts from different countries would be exploring ridges. This helps the world public pay attention to what is happening on the Moon rather than just being a random set of activities.

WHICH NATIONS VISIT WHICH SITES?

It would seem inappropriate for the first nations to visit the Moon to get to visit all the really cool sites and to leave less newsworthy sites for later, poorer nations. For example, one could imagine that, during the Artemis and American Phase, the United States could visit their Apollo sites, the Soviet rovers, be the first to enter a lava tube, the best magnetic and irregular patches, and conduct the first lunar race. That would be great for America but would leave it to other nations to only repeat what America had already done.

Rather, it is here proposed that the expeditions in the American and International Exploration Phase be assigned in an organized manner so that each mission would include enough unique elements to ensure that they were newsworthy. If nations are going to set aside something like 0.1% of their national budgets for four years it would need to be worth it. So, making sure that the missions are newsworthy would be important to have an ILEP large enough to ensure that the flight rate is high, per-seat prices low, and that the International Lunar Base be large enough to provide the foundation for private settlement. Our Google spreadsheet (visit the QR code to the right) shows our current list of sites and activities and their levels of newsworthiness.

So, what might the process of assigning mission locations and activities look like? An international committee should be set up that looks to assign missions in a fair manner and in an order that maintains newsworthiness. Letters of interest (LOIs) should be sought to determine how many missions to plan for.

Dr. Stooke and I have identified about 160 sites and activities for an estimated 130 missions. There are about 70 nations that could afford to purchase more than 1 full mission (where they buy six seats). In the case of the largest nations like the United States, they could afford to purchase as many as 267 complete expeditions. There just are not that many newsworthy sites and activities to support that many expeditions. So, it is suggested that the bigger nations be limited to the number of missions that they could perform during the ILEP. After the ILEP, nations could be free to conduct as many missions as they wish.

As part of the process of assigning missions, certain nations can be identified that should be given the right to assign specific missions. For example, Russia has several artifacts on the Moon. We can imagine that they would love to visit their Lunokhod rovers and it would seem inappropriate for the international committee to assign those missions to other nations. So, for example, they could choose which of their rovers to visit and then they could assign the missions to visit their other rover to a nation of their choice. Likewise, certain craters are named for historic astronomers from certain nations. Perhaps those nations would like to visit a crater that had been named after their historic astronomer. And if a nation has multiple such craters, then perhaps they would be allowed the choice to assign other of "their" craters to nations of their choice.

The Apollo Program demonstrated that the public's interest can wane as missions repeat the same sort of activities. So, missions should be assigned in a manner that maintains newsworthiness. This could be done by a variety of strategies. Missions within a category could be clustered in order to make a set of related missions. For example, the category of lunar pits includes: depressions, a larger pit, areas where pits are clustered, fractures, a small skylight, a large skylight, a small lava tube, the likely largest, accessible lava tube, and the one and only arch on the Moon (DevelopSpace.info/arch). This order is a sequence of increasing newsworthiness. These missions could be clustered within a two-month period and by ordering them in this manner, newsworthiness could be maintained in the public.

Also, six-person missions could be either of a single nation or a collection of nations. So, for example, there could be a mission involving six different Pacific island nations. In the spirit of the Apollo-Soyuz mission, even rival nations could join together in a mission as a step towards generating friendly relations.

WATCHING INTERNATIONAL EXPLORATION MISSIONS

Many of the international lunar exploration missions would be very newsworthy with people around the globe watching. But some percentage of the missions would get reported in the international news but wouldn't be top-of-the-page stuff. But, within the countries that had astronauts on the missions, the interest would likely be so strong that time would be taken out of classes for students to watch certain moments live.

TV Series

The TV series would start by following the Initial Crew. It could continue by showing the latest developments with the latest international team doing field exploration as well as any new developments at the International Lunar Base (ILB).

Live video from the current mission would likely be fed via the Internet for space advocates wanting to follow such things as well as for citizens within the country whose astronauts were doing the exploring. But mostly, people would follow the daily or weekly highlights to keep up with what was going on.

The choreography of the camera work would need to be planned well in advance and with the team during their training. If done well, even the live program could be done in such a manner to make for an interesting show.

Virtual Reality (VR)

Again, the virtual reality programming started during the Initial Crew Phase could be continued. During the ILEP, it may be mostly citizens within the country who are currently doing exploration who would be willing to pay in order to be virtually present along with their national astronauts to experience such missions as though they were there.

CameraBots

Telerobots specifically designed to be cameramen could follow the international crew as they explore. They could have telescoping poles to get different views from different heights.

HoverCams

Conceivably, each field mission could have a rover with safe propellant that a rocket drone craft could periodically refuel from. Then these rockets could fire their small rocket engines and perform fly-overs and hover in order to get perspectives that could be obtained in no other way.

VISITING ARTIFACTS

Apollo Landing Sites

Probably the expeditions of greatest interest would be a revisit of the Apollo mission landing sites. There was a total of six such missions (Apollo 11, 12, 14, 15, 16, & 17) that occurred between 1969 and 1972. Each site has the descent module remaining on the surface while the ascent module is missing due to the astronauts having departed in it.

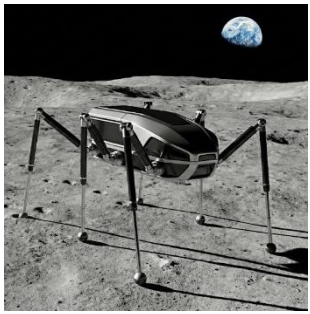
There are a set of artifacts associated with each site including footprints, flags, scientific instruments, and other items including even golf balls. These artifacts should be preserved and indeed the surrounding area should be preserved. Yet, international astronaut teams should be able to visit them while preserving the historic appearance of the site for future generations to visit. Chapter 42 describes how present and future landing and exploration sites could be managed in such a way to ensure their preservation while also ensuring that future visitors could get an up-close look at the artifacts. Using a crew-sized StickWalker, international astronauts could visit artifacts up close without leaving any evidence behind.

Obviously, the Apollo 11 missions (the first time humans set foot on the Moon) would be of great interest. Would it put the conspiracy theory to rest that we never visited the Moon? Yeah...probably not. But still, such a return mission would be watched by the whole world.

It is worth noting that the Apollo 12 mission landed very close to the Surveyor 3 lander. Whichever nation visited this site would get a "twofer".

The Apollo 14 mission site was located at the Fra Mauro formation. It was at this location that astronaut, Alan Shepard (first American in space in 1961) famously hit a couple of golf balls. In the 1/6th gravity they went pretty far. But photograph analysis has identified exactly where one of those balls probably is. Using the StickWalker, return astronauts could confirm their location.

The Apollo 15 site visited a very visually interesting site with a winding trough which is a collapsed lava tube. It was also the first site where the lunar rover was used.



During the Apollo 16 mission, the astronauts drove their rover nearly 27 kilometers (17 miles) leaving extensive tracks. During this mission, astronaut John Young jumped very high while performing a salute. We could imagine that the international astronauts visiting this location would also like to repeat this gesture perhaps to a world record height -- ok, a lunar record height.

The Apollo 17 site was at Taurus-Littrow valley. It was the only mission with a geologist (Harrison (Jack) Schmidt). They visited a large rock which later astronauts and tourists would like to visit. Return visitors could also go to the site where the original astronauts found orange dirt later to be identified as resulting from volcanic activity.

Landers & Rovers

There are currently 28 landers of which eight deposited rovers which drove the surface. Missions to visit these artifacts would be inherently newsworthy. Would these countries like to replace those vehicles with exact replicas and return the original to their national space museums? Maybe but probably not. But just the thought shows some of the possibilities.

By the time humans return to the Moon, there could well be more landers and rovers on the surface. In particular, NASA's CLPS program will likely already have delivered a few landers and rovers by then.

Impact Sites

Perhaps the least interesting of the artifact sites are the 40+ impacts caused by the probes and upper stages impacting the surface of the Moon. The speed of impact was so great that no pieces would be expected to remain to be discovered. The sizes of the impacts vary depending upon the size of the impacting piece of hardware. After dedicated missions visiting the first couple of impact sites, other impacts sites could be visited as a bonus side-show during other missions.

VISITING VOLCANOES AND LAVA TUBES

The Moon has had volcanic activity in the past resulting in some interesting features for international astronauts to visit.

Volcanoes

There are several volcanoes including the classic cinder cone-shaped volcanoes. International astronauts hiking up and reaching the peak of such volcanoes would be of interest to the viewing public. There are also regions with multiple volcanoes clustered together. In the floor of certain craters there are fractures from which volcanic material has vented.

Rilles

As volcanic lava flowed on the surface of the Moon, they exhibited a phenomenon of having channels of lava flowing like a stream. The upper surface of that stream, being exposed to the vacuum of space, cooled down the roof of the flow. If the lava drained out, then hollow channels would remain behind. With meteorite impacts causing fractures, the ceiling of the stream could collapse over time leaving behind trenches which are called rilles (rhymes with thrills). Imagine international astronauts driving their rover along such a winding rille.

Lunar Pits

If the lava tube remains intact, meteorite impacts could destabilize a lava tube's roof causing a localized collapse of the tube's ceiling. This could be partial or complete leaving either a depression or puncturing a skylight. Depressions are not as exciting as skylights which open into tubes to be explored. But their initial investigation would still be of interest.

Lava Tubes

One of the most striking missions would be when astronauts rappel down into such a lava tube for the first time. What will they see? To keep the excitement and glory reserved for humans instead of robots, it is here proposed that CLPS missions with rovers not be allowed to reveal the secrets of certain sites but leave those for humans to discover. Let's not let the robots have all the fun!

Lava tubes are often identified as potential good locations for a base or settlement. So, the explorations of lava tubes could act as the first surveys of what would eventually be settled. An international astronaut team could even set up a small inflatable habitat as the first non-polar base. Being under the ground, the temperatures would tend to be constant thereby making long-term habitation safer.

CRATERS YOUNG AND OLD

It is obvious that any program of lunar exploration would want to visit craters. There are so many of them and they would make for some dramatic footage. Imagine a crew as they just crest a ridge and get to see the whole inside of the crater for the first time. Then there is the footage of the crew walking or driving along the crater's rim. Then also imagine as they descend the inside wall of the crater, drive across the floor and then climb and reach the central peak.

An example of a young crater is Necho. This crater was named after an Egyptian pharaoh, and so Egypt should probably be given first dibs for visiting it. Necho sponsored an expedition to sail around the continent of Africa. It took three years. This crater has well-preserved geological features and a series of landslides that looks sort of like a bolt of yarn. Part of one of its walls is slumped.

One of the more dramatic pairs of craters is the Aristarchus & Herodotus set of large craters in the Moon's northwest region. From Herodotus comes the Moon's largest rille producing a large valley. Together, Herodotus and its valley have been termed the "Cobra Head".

Copernicus is one of those craters that has bright ray patterns extending from it in every direction. Rocks thrown out from this crater were visited by Apollo 12. It has very dramatic landscape including a large mountain ridge in the center of the crater.

Lalande Crater may be an important crater due to the potential resources that it contains. LaLande Crater is believed to have one of the highest concentrations of the KREEP rocks. This stands for potassium (K), phosphorus (P), and rare Earth elements (REE). It also contains thorium which could be very useful for fuel for nuclear reactors on the Moon. Potassium and phosphorus are key components of fertilizer (NPK) needed for the growth of plants for food.

The largest crater known in the solar system is the South Pole - Aitken (SPA) crater. As its name indicates, this crater extends from near the lunar south pole up to a Aitken Crater by the equator. The impact was so large and so deep that it is believed that the floor of this crater exposed the Moon's mantle.

On the back side of the Moon, one crater particularly stands out. Tsiolkovsky Crater is named after the famous Russian physicist who formulated the rocket equation and really began to help us understand how space travel could be done. Because the Moon always shows only one of its faces towards us, the backside of the Moon (incorrectly termed the dark side of the Moon) was completely unknown. That was until the Soviets were the first to fly a probe behind the Moon. For this reason, the craters, including Tsiolkovsky, tend to be named after Russians. This crater really sticks out visually because it is one of the few craters on the back side which was so deep that it created a lava flow which is much darker in color than the surrounding highlands. In this crater is a central peak which stands out because it is so bright compared to the floor.

Probably one of the most dramatic expeditions visiting a crater would be the one visiting Cabeus Crater. This is at the lunar south pole and is a permanently shadowed crater. Its ambient temperatures get down towards absolute zero (Kelvin). So, exploring it could be rather hazardous. Special measures would be needed to ensure that all equipment and crew in the mission was being heated throughout the mission. Could this be done simply by internal heaters? Could telerobots accompany the crew heating them with infrared lamps on top of poles? Could sunlight reflected by mirrors (or beamed energy) on neighboring peaks warm up the area where they are traversing? Or is all this just crazy thinking with such a crewed mission being impossible? Time will tell.

But, if possible, the crew could explore that environment to see if the water ice discovered by NASA's 2009 LCROSS mission is a general phenomenon throughout the crater floor. Such findings would be of value to future mining companies.

Perhaps my favorite young crater is Tycho. This is a very dramatic site as it is a relatively young crater with rays streaming out from it. Its floor is filled with lava but with a prominent central peak. At the very top of the peak is a large boulder about a football field across. Imagine the dramatic footage that could be obtained as international astronauts visit that boulder. Imagine as the cameras show them as they come up over the edge of the boulder, the view of the whole crater from that perspective, the group photo, and then the HoverCam flying up and away from the team as they wave to the camera. The TV crew would have a marvelous time planning and executing such footage.

VISITING MOUNTAINS AND VALLEYS

Mountains

Mountains on the Moon don't form the way that they do on Earth (i.e. mostly tectonically). Rather, the primary process for mountain formation on the Moon is due to large impacts. Certain mountains suggest themselves as locations for international exploration.

The central peaks of large craters can be considered as mountains which would be explored in the process of exploring the craters.

The Rumker mountains are a series of volcanic domes. It is a low shield-shaped plateau with multiple volcanoes on top. They are in the northwestern corner of the near side. The Chinese sample return will be from the plains around this area.

Malapert is a very important mountain which is directly in the direction of the Earth from the lunar south pole. For this reason, it could serve as an important communications relay station because it is always within view of the Earth, but it is also within view of much of the south pole area.

Ridges

The rims of craters could be considered ridges. Any crater is going to look dramatic when you look down from its ridge. Rims are rocky especially for the younger craters and so care would need to be taken when driving along them. Perhaps rovers could be sent ahead to scout a safe path.

The Smirnov Ridges are in Mare Serenitatis. These ridges fall into a category of ridges that formed when lava plains were put under pressure by the heavy lava flows. This one is one of the biggest and most dramatic.

There is a connecting ridge between Shackleton and De Gerlache craters. Being near the south pole, it is a ridge that is illuminated for a large part of the lunar year. This area will be a high priority site for development and is my preferred location for the ILB.

The rim of Peary Crater near the lunar north pole has several points that are highly illuminated. This ridge is immediately adjacent to permanently shadowed area with potentially valuable volatiles such as water and carbon and nitrogen-containing compounds. So, it too would be a high-priority site for development.

Valleys

On Earth, valleys tend to form by the process of erosion -- mainly due to water. But on the Moon, there is no such erosion. So, valleys on the Moon are rare but they do exist.

Schroteri is a giant sinuous rille. But it is far larger than most rilles and so it is placed in the valle category. It is so large that it is doubtful that it was ever roofed over.

The Alpine valley runs outwards from the Imbrium system. It is the largest valley on the Moon.

RATHER STRANGE FEATURES

Magnetic Anomalies

Reiner Gamma is by far the most prominent of the magnetic anomalies on the Moon. These may have formed when a lava tube solidified when the Moon had a magnetic field thereby creating a very large permanent magnet. Over time, as charged solar particles impacted the Moon, they were directed by the local magnetic field to strike some areas and were diverted away from other areas. As a result, an aurora pattern was created in the lunar dirt.

This feature is so large that it would probably not be apparent from the surface. So, to properly visit this site an incoming international team should come in for a landing over this feature so that they could see it from above. Upon landing, they would explore the area with instruments to measure the magnetism.

Irregular Mare Patches

We're not quite sure what created the irregular mare patches (IMPs). Current thinking is that volcanic gases came up from below and deposited material in very strange patterns. Crew visiting these sites would be exploring a very visually interesting location. In particular, Ina is the largest of the IMPs and so should be particularly interesting to visit. There are other IMPs that are less spectacular and so should probably be visited first in order to have a build-up of interest in the news.

ACTIVITIES FOR ASTRONAUTS

Expeditions don't have to be limited to visiting some distant location on the Moon. Very newsworthy activities could be conducted that don’t involve visiting an artifact or natural feature.

Habitats

A growing International Lunar Base would need astronaut teams to set up quite a number of specialty habs. Each of these would be newsworthy because of the usefulness of each of these habs to the base.

So, for example, Iraq is the country where, historically, the kingdom of Babylon was located. One of the seven wonders of the ancient world was Babylon's hanging gardens. So, perhaps they would be interested in being the country that set up the base's GardenHab with all the details about what that involves being the basis for a series of news reports.

Chapter 19 describes the ten categories of habs. The InstaBase at the lunar south pole would already have been set up prior to the ILEP.

Activities

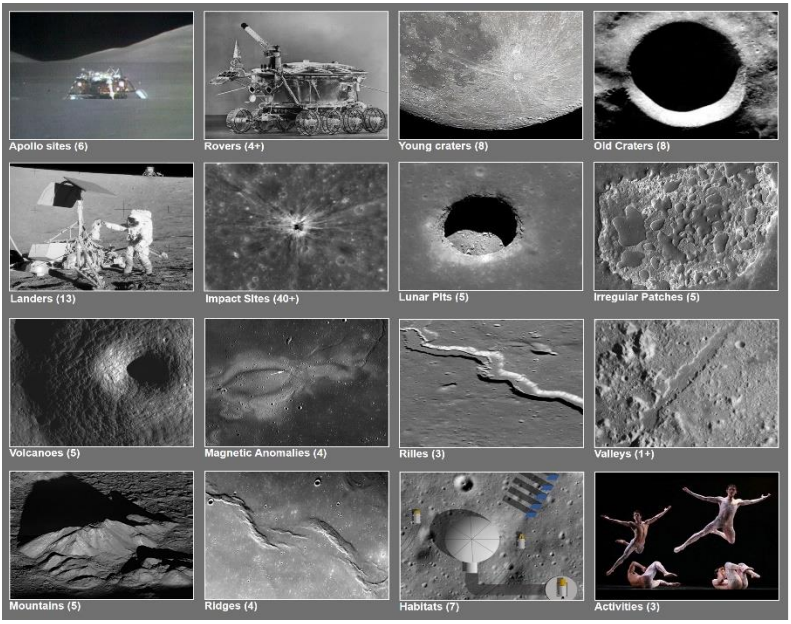
We can imagine some of the activities that international astronauts might engage in.

Performing Arts - Music would likely be a popular and common activity. Likewise, dance in 1/6th gravity would be explored with new styles of dance developed.

Sports - With 1/6th gravity, athletes could perform spectacularly, and it is likely that new types of sports would be invented to take advantage of the unique environment.

Races - These could also occur with the natural irregularities of the surface and the 1/6th gravity resulting in some pretty exciting moments!

And undoubtedly, more creative thinkers could come up with many more noteworthy activities.



Categories of lunar exploration: DevelopSpace.info/international