



# FUNDING LUNAR DEVELOPMENT

# 32 – Funding Lunar Development

## SUMMARY

Financing lunar development includes reducing expenses, of which cheap access to space (CATS) is the most important. Fixed-price contracting, recycling and ISRU can all help. Funding will likely start with NASA-led public-private partnerships (PPPs). As prices go down, the savings of private individuals will be a major source of funding.

Resource-based export income (e.g. propellant from ice, He-3, PGMs) will be a difficult business case. Rather, government budgets and private savings will likely dominate funding for the foreseeable future.

## REDUCING EXPENSES

It deserves to be mentioned up front that reducing expenses is a legitimate part of balancing a budget, making ends meet, the making of a business case, and sustaining operations. Given the traditionally very high expense of crewed and cargo missions, it makes a lot of sense to see what we can do to reduce costs. The commercial space perspective often emphasizes how money can be generated while neglecting how to reduce expenses. But as they say, "A penny saved is a penny earned".

### **Dramatically Reduced Space Transportation Costs**

By far, the major way that costs will be reduced is with the emergence of fully reusable launch vehicles. SpaceX's Starship fleet is the prime example, but Blue Origin's New Glenn is also working in that direction and we see other companies working towards full reusability if even at the medium lift vehicle level. It is hard to overstate just how huge an impact full reusability will have but we can reasonably say that it will lead to perhaps a 90% reduction in launch costs if not more.

### **Fixed Price Contracting**

For those phases funded by governments, we see that the old way of funding the development of space hardware (i.e. cost-plus contracting) is now being favored by fixed price contracts where any cost overruns is not placed on the government but on the companies that won the bid. And with competitive bidding we are seeing reduction in cost as much as 8-10 times the cost-plus contracting approach.

## **Commercial Competition**

With that sort of savings, NASA has typically been able to afford contracting with two commercial providers whether it is for cargo, crew, or lunar landers. Having multiple commercial providers not only results in lower bids but, after the development phase is completed and operations are ongoing, NASA can split the service contracts between two competing companies giving more launches to the lower bid provider.

## **Recycling**

An often-overlooked secret to reducing the cost of maintaining a permanent base or settlement is to develop ever-increasing levels of recycling. For example, on the ISS, water is being recycled at the 93% level. So, each liter of water can be recycled thereby effectively providing the equivalent of 14.3 liters. Recycling works best for consumables and less so for durable items.

## **In-Situ Resource Utilization (ISRU)**

It is obvious that using local resources could result in large savings by not having to ship them. Mars has the largest quantity of resources, but the Moon has all the resources needed to support a large, growing settlement. (See chapters 28 & 30).

The good news is that the development of a few items (water, metals, and organics) and processed into usable forms can result in a substantial reduction in shipping costs. The Space Development Network believes that significant reductions in shipping costs is possible in the relatively near-term (e.g. within a few years from when the first permanent habitat is established). And recycling and ISRU work together in that, the more one recycles, the less materials one has to produce from local resources.

So, advocates for commercial space development need to pay equal attention to the reduction of expenses and not only on what the source of revenue might be.

## **Extending Crew Stay**

A certain percentage of the cost of maintaining a permanent base will involve the rotating of crew. For the ISS, this is (currently) being done using SpaceX's Dragon capsule at about \$55 million per seat. For a permanent lunar base heading towards settlement, if crew stay can be doubled then the cost of crew rotation can be approximately halved. For settlers intending to remain off Earth indefinitely, the cost of rotations may not be such a large issue.

# THE FUNDING OF LUNAR DEVELOPMENT

There has been a lot of discussion in recent years about how space development would be funded to the point of economic sustainability. There are many ideas including manufacturing in low Earth orbit (LEO), space solar power, helium-3 on the Moon, etc.

It is clear that uncrewed satellites can turn a profit. Indeed, communications satellites in GEO orbit made up the large bulk of profit made by the space industry. Starlink's "Internet in the sky" is making currently about \$11 billion each year (and growing) and the selling of world-wide imagery can also make a profit. But what about human space-flight? Given the great expense of that, how could it pay for itself? The answer is not so obvious.

## **Public-Private Partnerships**

When NASA originally tried a public-private program in the form of the Commercial Orbital Transportation System (COTS) studies found that NASA was able to reduce its expenses by about 8-10 times compared to if they had used the cost-plus approach. By using the other transactional authority (OTA) they were able to partner with companies in a way in which NASA paid for development and service, but where the companies themselves ended up owning the technology that they developed and then were free to sell those services to other customers. In this way, NASA was able to get access to that service on a more commercial basis. It has been a very successful win-win approach.

What has happened with the reusable heavy lift vehicles is even more remarkable. NASA has been very fortunate to be returning to the Moon and going to Mars while two of the wealthiest individuals are using their own wealth to develop fully reusable launchers that NASA can conveniently take advantage of. As an example, the reason why SpaceX was able to bid an incredibly low about \$2.89 billion to develop the lunar lander was that this was the cost not to develop their Starship super heavy lift vehicle but only what it would cost to modify their rocket to meet NASA's lunar lander. By contrast, in today's dollars, it cost about \$41 and \$48 billion to develop the Saturn V and Space Shuttle vehicles respectively. Especially given SpaceX's Starlink revenue (easily exceeding NASA's annual human spaceflight budget), the public-private partnerships will be more a partnership of peers rather than commercial companies just fulfilling NASA's requirements.

Similarly, it is likely that there will come a point where NASA's limited vision for returning to the Moon and going to Mars will be faced with the reality that a fleet of fully reusable heavy lift vehicles provides the opportunity to do so much more than just having a few government astronauts picking up rocks. As SpaceX and Blue Origin move forward towards establishing large-scale infrastructure and habitats on the Moon and Mars, there can be little doubt that the space policy decision makers won't be satisfied with standing to the side but will change NASA's plan to coordinate with these and other companies to develop large and growing, American-led international bases which will set the stage nicely for private settlement. The sooner this realization occurs the better.

## **FUNDING THE PHASES OF DEVELOPMENT**

Lunar development could occur in six phases with clear funding approaches for each phase.

- **Phase 0** - Artemis Exploration Phase - NASA-funded
- **Phase 1** - Cargo Missions - Largely NASA-funded
- **Phase 2** - Initial Crew Missions - Mostly NASA-funded with some commercial revenue
- **Phase 3** - International Lunar Exploration Phase - National space budgets
- **Phase 4** - International Lunar Base - National space budgets
- **Phase 5** - Private Settlement - Private savings

### **Phase 0 - Artemis Exploration Phase**

This phase is listed as Phase 0 because it is not actually a phase of development but rather just of exploration. We are currently close enough to these long planned for missions that it seems likely that they will be conducted. But later planned missions (e.g. Artemis 4 and 5) will probably be overcome by circumstances showing that they are not visionary enough given the available of fleets of heavy lift vehicles at that time.

### **Phase 1 - Cargo Missions**

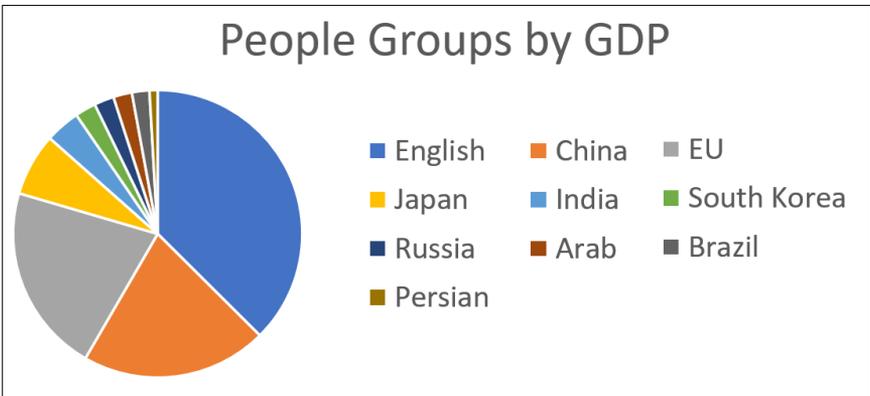
This book advocates that NASA be directed to largely fund Phase 2 which would be the Initial Permanent Crew (IPC) Phase. Immediately leading up to this, several cargo landers would land to human rate them. They will deliver rather large quantities of cargo including infrastructure (e.g. Solar Drapes), habitats, equipment, furniture, etc. so that the IPC will walk into a well-supplied Initial Permanent Base. NASA would fund these missions like their Commercial Resupply Missions to the ISS.

## Phase 2 - Initial Crew Missions

These pages advocate that the Initial Permanent Crew should not be a repeat of the Apollo program (i.e. flags and footprints to collect rocks for science) but that the Initial Crew should be private individuals working for companies whose purpose is to set up and maintain the infrastructure later used by astronauts from the US and other countries. Since they would be providing transportation and habitation services starting with NASA it would be appropriate that most of the funding for this infrastructure and the participating companies would come from NASA as part of a set of public-private programs very much like NASA Commercial Crew Program. In addition to this funding, there are several creative side streams of income that are possible.

## Phases 3 & 4 - International Lunar Exploration & Base

How can a small, permanent base become a growing settlement? Ultimately, if there is going to be a large private settlement then the cost of traveling to the Moon and sustaining oneself there must be affordable. An interim phase would be very helpful to increase the flight rate and build up the infrastructure until the base is able to support a growing population of private settlers. An International Lunar Exploration Phase



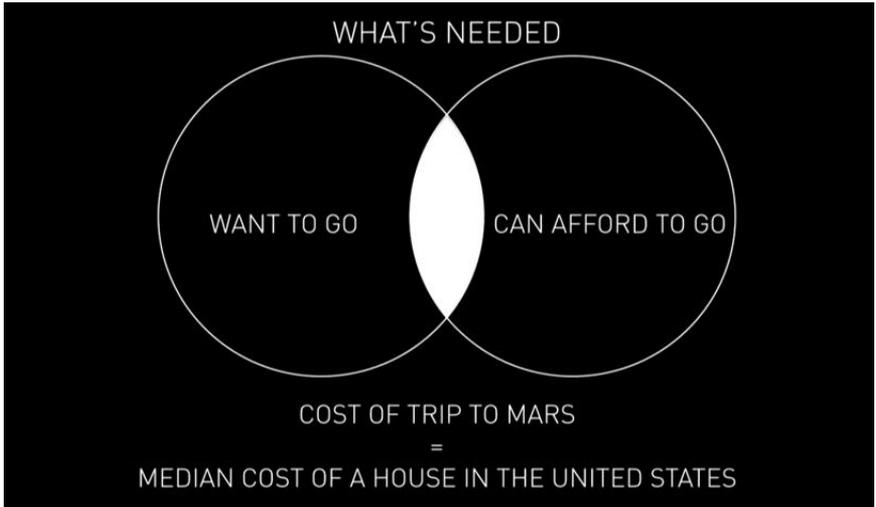
(ILEP) could be exactly what is needed as this interim phase.

It is likely that the initial seats on missions of lunar return will be very expensive. This is obviously true with an SLS-based approach but will also be true even if SpaceX succeeds in developing a fully and rapidly reusable Starship. After all, it would only be expected that SpaceX would want to recover its development costs.

Fortunately, there is a category of customers that can afford seats at these prices -- sovereign clients. Countries have far deeper pockets than even their wealthiest citizens. And there is a range of wealth among countries such that we could guess which countries could afford the early, middle, and then latter seats. From the number of countries that have sent astronauts to either the Mir or International space stations, we can conclude that countries, in general, really want to have astronauts of their own. And what country wouldn't also want to watch their national astronauts exploring the surface of the Moon, on behalf of their citizens, and in their own language?

Now, the participating countries would have a choice as to what they would do with their national astronauts. After their mission of lunar exploration, would they bring them home to serve as in-person heroes to students of the nation? Or would they prefer to leave them on the Moon to represent their country in a growing, international base? Likely it would depend upon the number of astronauts that they sent with a bias towards leaving them behind on the Moon. After all, they could always "Skype" back to be virtually present back in the nation's classrooms.

So, how would the countries pay for the seats for their national astronauts and how would they pay for them to stay and be maintained at the international base? Just like with all nations with space programs, the funding would come through a small portion of their national budgets (1/10th of 1% of their GDP).



*The people who will go are those can afford to go and want to – Elon Musk*

## **PHASE 5 – Private Settlement**

In his 2016 Guadalajara speech, Elon Musk described how the people who would go to Mars would be at the intersection of those who could afford to go and those who wanted to go. So, who could afford to go? Obviously, they will be people who have saved up enough money such that they could afford to go. In most cases, they would have to have lived long enough to have saved up enough money. Likewise, they would need to be people who go aren't too tied up with raising children or working their career on Earth. Retirees fit these criteria and younger people tend not to. So, it should be obvious that retirees will be over-represented among initial and latter private settlement phases.

Early private settlers will likely be motivated by the opportunity to play a very historically significant role in helping to establish the first, off-Earth settlement. But we may really need to focus on how the settlement could be made attractive for the latter private settlers (and especially their spouses) who might need spacious habitats, entertainment, and a leisurely lifestyle. So, income for early settlement will undoubtedly come not from resource extraction but from the private savings made in Earth markets at other times and places.

## **ADDITIONAL REVENUE**

Beyond the major sources of funding already mentioned, there are potentially a lot of different sources of income.

Chapter 20 includes a description of a multi-year TV series allowing the public to follow developments as humanity starts taking its first permanent steps off Earth. Media rights could generate a significant amount of revenue. Companies could also be charged for product placement in the TV series. Similarly, people could be charged for the virtual reality (VR) experiences of practically being present at these historic events.

But additional revenue from media wouldn't be the only additional source of income. Tourism would probably be a moderate source of revenue. Another noticeable source of revenue could be merchandising (e.g. A toy dog in its space suit, astronaut action figures, lunar habitat doll house, shirts, video games, etc.)

Believe it or not, jewelry made from lunar rocks might actually generate a significant amount of revenue. Consider ten 1 x 1 x 1 meter cubes of rock sent back to Earth as a single payload. Cut to 0.5 x 1 x 1 cm pieces, this payload would yield 50 million pieces of the Moon. This means that only one out of 175 people on the Earth could own a piece of the Moon

(or if you prefer, one out of 90 women). Even after shipping 10 cubic meters of rock to Earth, pieces of the Moon would still be rare within one's own, personal, social network. Pieces of the Moon would still be rarer than diamonds. If one charged \$300 for each piece of the Moon, the \$15 billion in revenue would go far to cover infrastructure costs on the Moon.

Will the mining of lunar polar ice for propellant, helium-3 for fusion power, platinum group metals, or materials for space based solar power or spinning habitats in free space every constitute profitable ventures? We will have to wait and see. But funding from national budgets and private savings will likely form the financial foundation upon which international bases and settlements will be established.

## **SPACE TOURISM**

### **Internal Vs External Tourism**

There is an important distinction between two types of tourism. Traditional tourism is "external tourism" in which people visit the Moon not to settle down there but only for tourism. There will be some of this but probably not a major part of the Moon's income. The reason is because this vacation would be far, far more expensive than any vacation on Earth. One would have to give up most of one's life savings for this one vacation. The situation is even worse for Mars in which one would also have to give up a chunk of one's life for such a "vacation".

But "internal tourism" is where the settlers on the Moon decide to tour the Moon after having settled down. Nearly 100% of the people who settle on the Moon or Mars would want to tour the place that they spent so much money to go to. So, there will be a tourism industry on the Moon and Mars. It is just that most of the tourists might be permanent residents there.

### **LEO Vs Lunar Vs Martian Tourism**

It is an interesting comparison between tourism in low Earth orbit (LEO), on the Moon, and on Mars. As mentioned above, there probably won't be much external tourism on Mars because those tourists would have to spend many months of their life during transit to and from Mars. LEO would be a favored destination for tourism since it takes less propellant to get to LEO than the other two destinations. But there is another relevant factor to bear in mind. Anyone travelling to the Moon and Mars will definitely want to hang out in LEO for several weeks enjoying the view and the experience of zero gravity. And for those travelling

to Mars, for a small percentage increase in their overall price, they could throw in a Lunar Grand Tour package as well. So, it could be that many of the LEO tourists will actually be settlers moving on to the Moon or Mars. If propellant is being produced on the Moon to fuel transportation between the Moon and LEO, then the additional cost might be reasonable to throw in a lunar tour to one's LEO tourism package. For these reasons, it would seem that the number of LEO tourists will be somewhat more than lunar tourists and with Mars tourist numbers being substantially smaller despite the spectacular views on Mars.

### **Is Tourism the Business Case?**

The very high price for vacations to the Moon, or Mars would seem to suggest that tourism will not be the major driver for settlement at those locations. And one should assume that, once the settlers are already on the surface of the Moon or Mars, that the internal tourism done using mostly electric vehicles would be a small percentage compared to their moving costs.

But LEO is primarily about tourism, especially with tourist hotels in inclined orbits covering most of the Earth. Yet again, due to the extremely high price tag for this form of vacation, it may be that most of the tourism in LEO will be by settlers on their way to the Moon or Mars.

### **The Lunar Grand Tour**

For those settlers on the Moon or visitors on their way to Mars, they will want to see the best sites that the Moon has to offer. At the top of the list is the Apollo 11 landing site. But the tourists would probably also like to get a taste of the different categories of sites such as a lava tube, a famous crater, an irregular mare patch, a magnetic anomaly, a lava tube trench, and one of the early Russian rovers.