LUNAR ECONOMIC ACTION PLAN

COMMUNICATIONS ARCHITECTURE

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1 INTRODUCTION

Telecommunications has played a significant role in the development and advancement of mankind and is one of the key enabling capabilities that has fuelled the rate and pace of growth. Telecommunications is deemed to be a critical infrastructure with a significant social, cultural and economic impact on society, in fact a stark contrast can be seen between those communities and individuals in areas with good infrastructure and those without.

The provision of telecommunications services is today primarily a commercial endeavour, with a business model based on revenues derived from provision of capacity to other companies or direct to consumers, having transitioned from the early days of being government or institutionally owned and operated.

Taking the experience and lessons learnt from growth on Earth, it is evident that telecommunications will play a critical role in the exploration, habitation and settlement of the moon, with the success and rate of development being heavily dependent on the approach adopted and the corresponding infrastructure deployed.

The lunar related activities to date can best be described as piecemeal and largely uncoordinated with individual counties, and more recently entities, each doing their own thing, or at best teaming on specific missions or opportunities. Many missions have carried their own communications capabilities, enabling them to communicate with the Earth, independent of other missions occurring at the same time, and few have utilised or exploited the communications capabilities of other missions to fulfil or enhance their own mission objectives. It must be acknowledged that there are limited choices as the infrastructure does not currently exist to enable missions to lease capacity for communication to and from Earth.

The current situation should not be taken as a criticism of any of the parties involved in lunar exploration, but simply a recognition of the fledgling or adolescent nature of this application and associated market.

If we are to implement a lunar economic action plan and to facilitate the timely and cost effective habitation of the moon, then it would be advantageous to attempt to coordinate efforts, to establish a common telecommunications architecture or framework, and to encourage the commercial provision of telecommunications services.

The following chapter first looks at the phases of lunar settlement, an understanding of which is necessary to anticipate the communications infrastructure requirements over time. A reference lunar communications architecture is then discussed, providing the assumptions or context on which the commercialisation can be addressed, and technical, political and economic factors discussed. With radio communications spectrum being a finite resource it is also prudent to consider the regulatory aspects from the outset so that the issues are considered from the beginning. The key actions are then identified that would enable the commercial provision of lunar communications services throughout the various phases of lunar settlement, a critical part of the lunar economic action plan.

2 PHASES OF LUNAR SETTLEMENT

Whether as a staging post for more expansive human space exploration or planetary settlement, or in the pursuit of strategic or economic gain from utilisation or exploitation of the lunar environment and resources, one can assume the eventual settlement of the moon.

From a simplistic perspective one can consider three phases or stages on the path to lunar settlement; exploration, habitation and eventual settlement. These are not discrete sequential phases, rather parallel tracts or activities that drive an ever-increasing occupancy of the moon. It is however useful to consider them as three separate elements especially when considering and anticipating the telecommunications requirements.

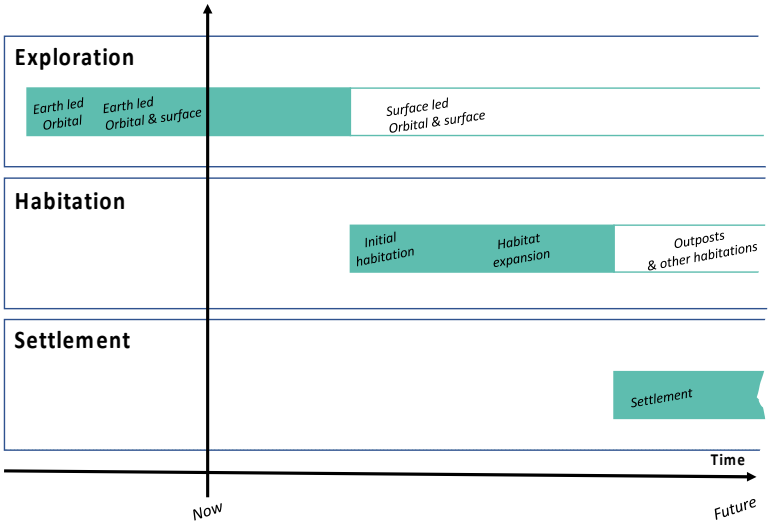


Figure 1 – Stages of lunar settlement

Today we are very much in the exploration phase, with missions intended to improve our knowledge and understanding of the lunar environment, conditions and resources. Even the activities of the Apollo era can be considered to have been exploratory in nature, rather than an early attempt at establishing habitation or settlement.

The habitation phase is the establishment of single outposts with a semi-permanent presence, to a large extent reliant on the provision of resources and support from more established and permanent establishments. The habitation phase has begun, although activities have so far been constrained to efforts in low earth orbit, with the deployment and operation of a small number of space stations. Habitation of the lunar surface has yet to begin in earnest and has until now largely been the subject of study and science fiction writing, although there are now clear signs of the intent to establish habitation beyond the Earth and Low Earth Orbit and we can therefore expect a lunar habitation within the next decade. Efforts such as the Lunar Economic Action Plan, and other initiatives, are all aimed at achieving this goal.

Figure 2 – Lunar habitation ©ESA

Settlement can be considered as the act of appropriating a place or domain for one's own use, and in this context, can be considered as the establishment of much larger, autonomous and self-sustaining settlements. If humanity is to become a multi-planetary society then settlement is the ultimate intent. Establishment of a settlement should not however be considered as the end goal, rather the staging post for further exploration of space and expansion of the human society, with those efforts being driven from the settlement rather than from the Earth.

Figure 3 – Lunar settlement

To enable a structured discussion of telecommunications requirements it is beneficial to assume a baseline scenario and corresponding lunar road map and to divide it into steps. It can be envisaged that there will be a period of increased exploration activity prior to deployment of the first lunar habitation. Once a habitation has been established, one can assume surface exploration activities, growth of the habitation to a point that it becomes a minor settlement, longer range exploration activities, led from the settlement, and establishment of distant outposts or habitations, and further growth of the settlement. The actual extent of the lunar settlement will be largely dependent on the strategic and economic gain bought about by the utilisation and exploitation of the lunar environment and resources.

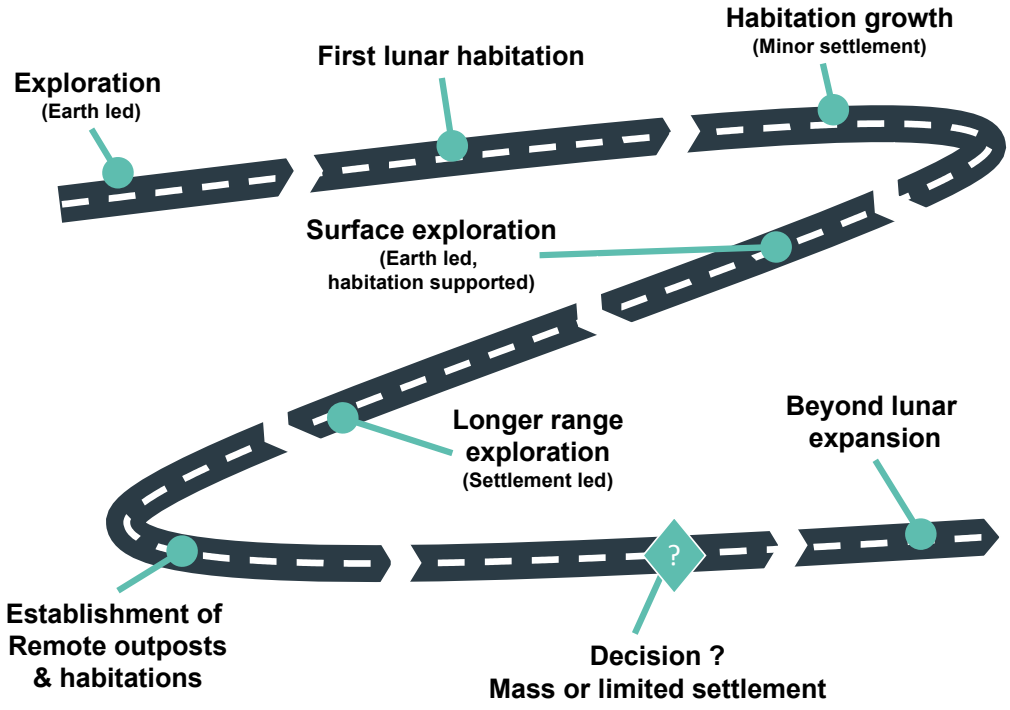


Figure 4 – Lunar road map

It should be noted that while it may be highly advantageous and efficient to coordinate efforts into a single unified lunar activity, the likelihood is that there will be parallel endeavours with separate nations or even commercial consortia each pursuing their own plan. While it may not be possible to completely coordinate, and consolidate efforts, there are still significant benefits in assuming some degree of coordination, interoperability and common utilisation of telecommunications infrastructure and services.

3 COMMUNICATIONS, THE HISTORICAL APPROACH

Lunar and space exploration programmes have traditionally carried their own communications infrastructure and employed point-to-point direct to Earth communications links for command, control and data or information retrieval. Except in unique circumstances where missions have consisted of multiple space based assets, command, telemetry and communication have been directly between Earth based ground stations and space based assets.

Missions have typically used large ground based antennas to support communications. The NASA 26m antennas at Goldstone were originally built to support the Apollo missions and the 70m Deep Space Network antenna was used to receive Neil Armstrong's famous quote from the Apollo 11 mission, "That's one small step for a man. One giant leap for mankind."

Figure 5 – NASA DSN 34m Antennas, Goldstone, California ©NASA

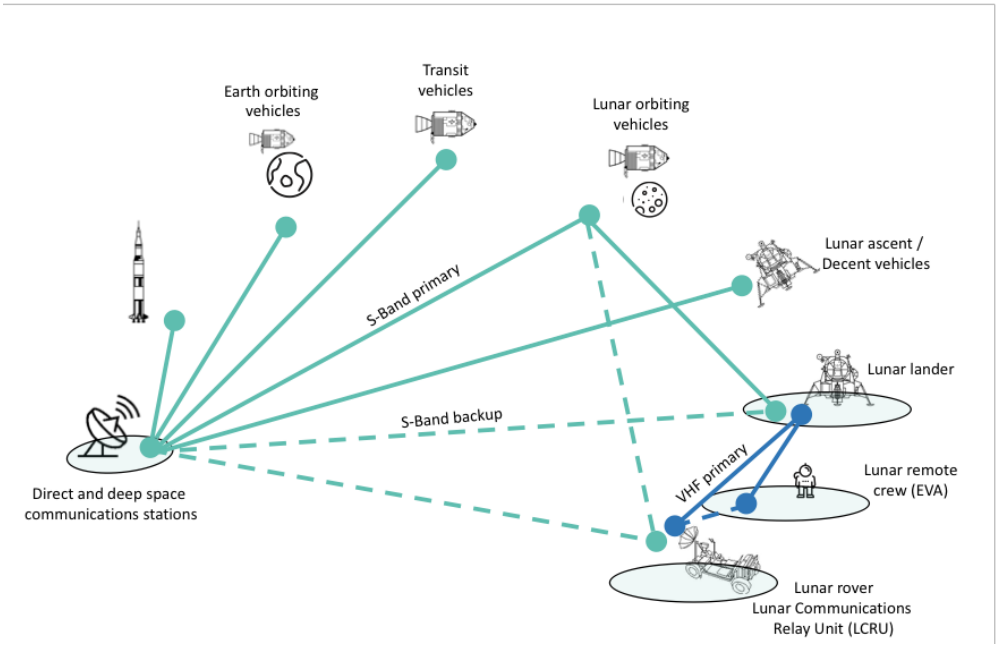


Figure 6 – Simplified communications architecture for Apollo era manned flight operation

While the solution taken so far may have been acceptable, given that there have been a limited number of spacecraft acting individually, it will become increasingly difficult to adopt this approach when dealing with spacecraft that need to communicate with each other and as the number of spacecraft operating at any one time, and the level of activity, increases significantly.

4 FUTURE COMMUNICATIONS REQUIREMENTS

Communications requirements will change through the various stages of lunar settlement, in terms of the types of services needed, the method of delivery, and the volume of capacity required.

4.1 INITIAL EXPLORATION PHASE

During the initial exploration phase, activities will continue to be controlled and monitored from the Earth. This will be largely a continuation of the activities undertaken so far, with additional orbiting instruments and payloads, lunar landers and small rovers for short range exploration. The requirement to support these activities will be for near real time command and control and for payload data recovery, with processing being done on the Earth in a non-real time environment. To address increased capacity requirements, provide increased coverage and to support missions unable to carry their own direct to Earth communications equipment, there will be a growing requirement for communications relay capability.

To improve the efficiency and cost effectiveness of the exploration activities it will be necessary to stop considering the missions in isolation, and to start to support activities across multiple programmes. Groups are considering, for example, the use of very small satellites and landers for further exploration, which cannot physically accommodate the equipment needed for direct to Earth communication and require use of a lunar communications relay to provide connectivity to the Earth. Today the groups are struggling to bring their programmes to fruition as the cost of implementing the lunar relay in addition to the experimental satellites and landers makes it prohibitive.

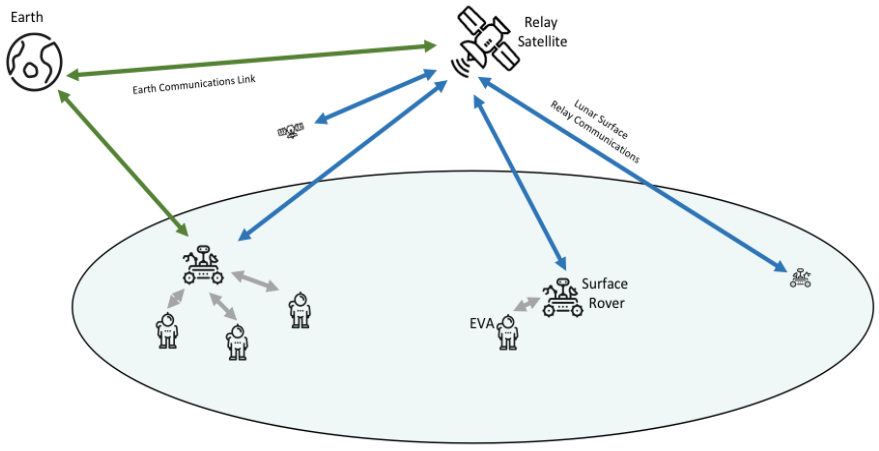


Figure 7 – Exploration phase, direct to Earth and lunar communications relay capability

While the communications capacity requirements for command and control are likely to be relatively modest, we can anticipate the capacity requirements for payload data retrieval increasing significantly over time, especially as more instruments and payloads are deployed. This will inevitably place a high demand on the lunar to Earth communications link, both direct and via relay.

4.2 INITIAL LUNAR HABITATION

With the transition from exploration to habitation phase, the communications requirements will increase significantly. Activities will continue to be Earth led at this stage. One can envisage a period of robotic assembly and preparation prior to manned arrival, which will increase the level of command and control capacity required, and increase the amount of data being returned to the earth and a need for real time and near real time assessment of the recovered information. Once manned activities commence the need will exist for two-way voice and video communications between the Earth and the moon, and for limited range audio, video and data surface communications to support Astronaut surface activities.

Communications will continue to be supported by direct to Earth and communications relay infrastructure. With the development of the habitation, a more robust direct to Earth communications infrastructure can start to be implemented, with the habitat then activing as the hub or gateway for communications back to the Earth.

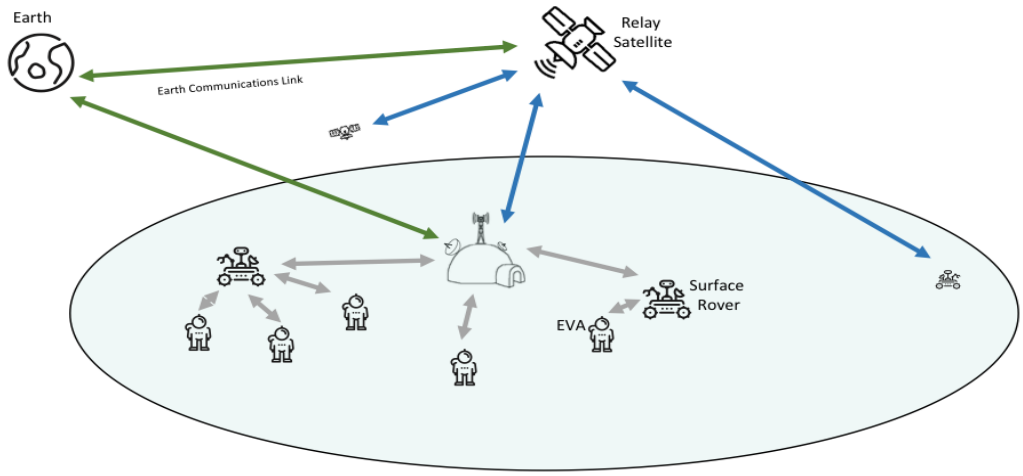


Figure 8 – Habitation phase communications capability

4.3 SURFACE EXPLORATION

With a habitat established the level of surface exploration will increase, with sorties moving further and further afield. It is anticipated that activities would be Earth led initially, with the habitation personnel supporting, however as the capabilities of the habitat increase there will inevitably be a transition to activities being led from the habitat. This will result in an increase in the level of communications capacity needed between the habitat and lunar surface operations. Although habitat led activities may reduce the command and control requirement from the Earth, capacity requirements are unlikely to reduce as the requirement will still exist to monitor operations.

In addition to the direct to Earth, communications relay and short range surface communications infrastructure, high rate short range and longer range line of sight surface communications will now be required.

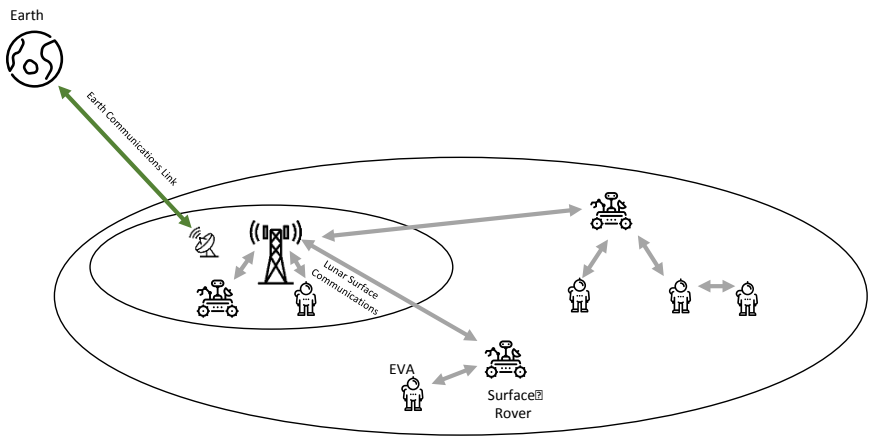


Figure 9 – Surface exploration phase communications capability

4.4 HABITAT GROWTH

With the initial habitation established, and the goal being human settlement, then it can be anticipated that the habitat will continue to be developed with additional capabilities and infrastructure will be added. The goal will be for the lunar outpost to be largely self-sufficient and not reliant for Earth supply for its day to day needs, thereby becoming a minor settlement.

The underlying communications service requirements remain largely unchanged, however the capacity requirement will continually increase.

4.5 LONG RANGE EXPLORATION

With a settlement established surface operations will move further and further afield, bringing with it the need for beyond line of site communications and navigation capability. The extent of the infrastructure needed will start to depend at this stage on the extent to which the moon is to be explored and settled.

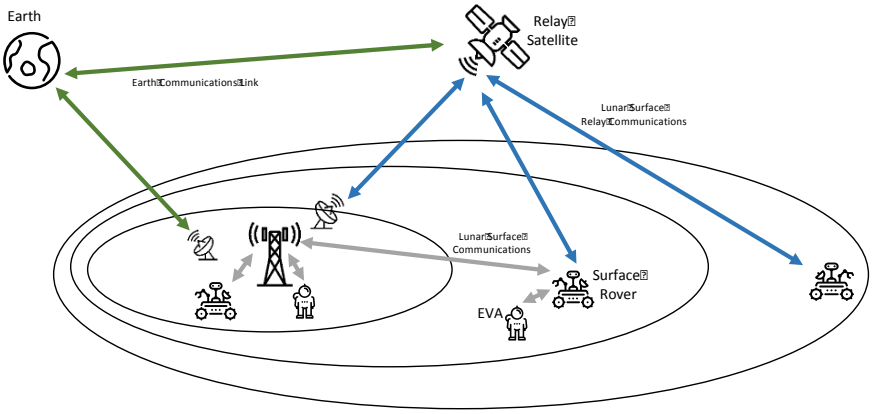


Figure 10 – Extended surface exploration phase communications capability

If the strategic and economic benefit for large scale settlement exists, then the need will exist for robust, high bandwidth communications and a back bone to provide connectivity across regions of the moon. If the economic and strategic benefit are limited and only a small outpost is to be supported then the long-range communications requirement will be to support sorties to other areas of the moon.

4.6 INTER SETTLEMENT COMMUNICATIONS

In the event that more than one settlement is established on the lunar surface the requirement will exist for inter settlement communications. Two contrasting scenario can be considered, in the first the different settlements are a result of independent efforts, with individual nations, groups of nations or consortia each establishing their own. In this instance inter settlement communication would most likely be limited in scope. In the second scenario, the increased settlement could be because of cooperation, strategic or economic gain, and in this event the need would likely be for open communications between groups and therefore a high communications capacity requirement.

4.7 BEYOND LUNAR COMMUNICATIONS

Finally, one further communications capability that can be anticipated would be the establishment of beyond Earth communications infrastructure, able to support further space exploration and beyond Earth communications. With favourable propagation conditions, and a relative ease of operations and maintenance once a manned presence has been established, a lunar surface based infrastructure would enable the moon to act as a repeater for planetary communications, and provide a valuable addition to the Deep Space Network, supporting interplanetary and deep space exploration. As an aside, one can also anticipate the radio astronomy and scientific community also wishing to place infrastructure on the far side of the moon, the only place in our solar system that never faces the Earth, and therefore a good vantage point to be able to perform measurement without the Earth's background interference.

4.8 SUMMARY OF COMMUNICATIONS INFRASTRUCTURE REQUIREMENTS

Examining the various phases of lunar settlement, the requirement exists for four core communications capabilities, point-to-point direct to Earth, communications relay, line of site lunar surface and beyond line of site surface communications capability. The complexity, functionality and capacity requirements will increase with the progression of the lunar settlement and as a function of the level of orbital and surface activity.

The development of the various capabilities is illustrated in the communications capability roadmap shown overleaf. In addition to the implementation of the various capabilities there will also exist the requirement for increasing amounts of capacity, which in the case of the direct to Earth and communications relay capabilities will inevitably result in greater utilisations of optical communications in addition to traditional radio frequency communications.

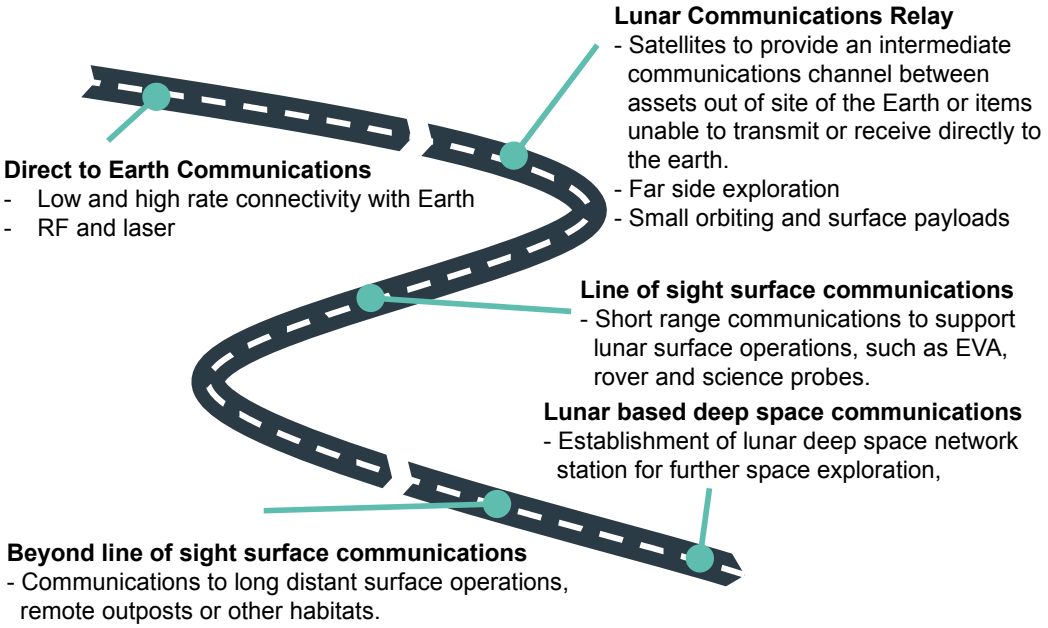


Figure 11 – Communications capability roadmap

5 LUNAR COMMUNICATIONS ARCHITECTURE

In many ways, the requirements for a space based communications network are like those of a terrestrial environment, the network needs to allow for varying types of data to flow across the system and should be able to scale as the level of activity, number of users and capacity requirements increase.

Taking the anticipated phases of lunar settlement and the associated communications requirements, a reference communications architecture can be devised to support the various exploration, habitation and settlement activities.

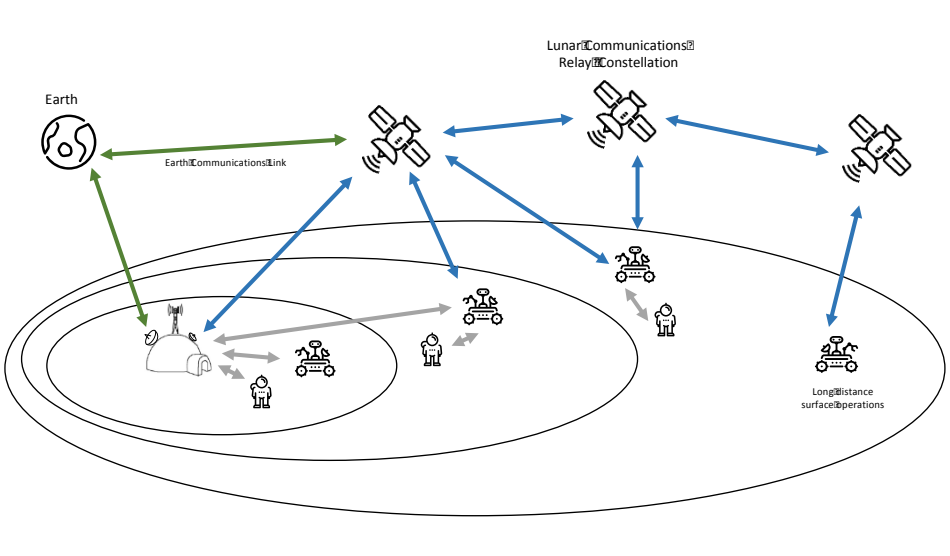
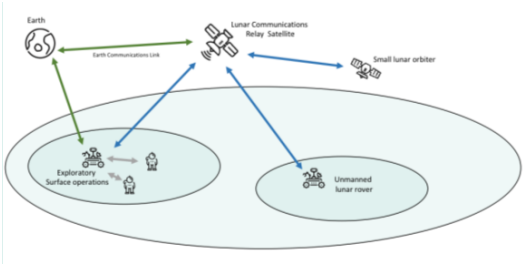


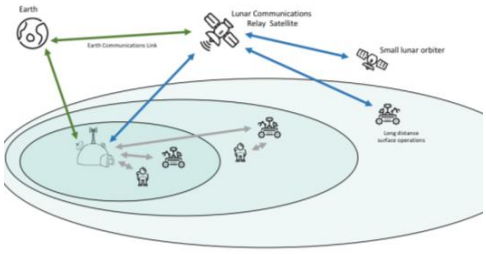
Figure 12 – Reference communications architecture

The reference architecture assumes several key components, a lunar communications relay constellation, direct to earth lunar surface gateway, short range and long range lunar surface communications and a deep space communications capability, with the deployment being phased to align with the anticipated stages of lunar settlement and the corresponding communications requirement.

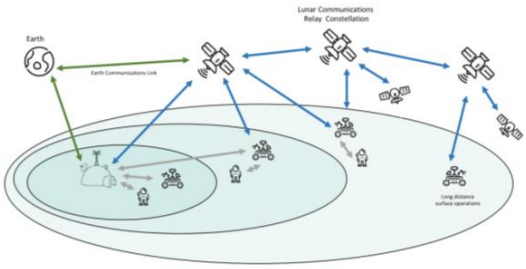
One can anticipate for example only a partial population of the lunar relay constellation initially, sufficient to relay communications to the Earth for the various exploration programmes. As the number of mission increases, a habitat is established and more surface exploration is undertaken, the constellation can be expanded to provide greater coverage and beyond line of site communications capability.



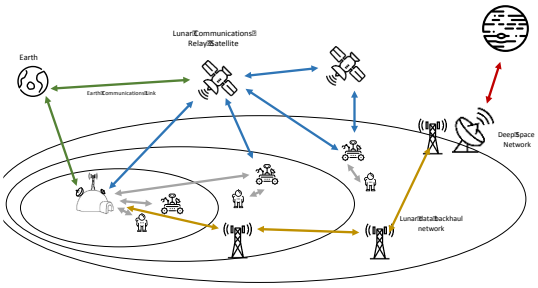
a) Lunar communications relay
- Provides increased coverage
- Supports small orbiters and landers



b) Lunar habitation
- Permanent direct to earth link.
- Surface communications to support exploratory activities



c) Lunar relay constellation
- Increased coverage of lunar surface.



d) Full lunar communications infrastructure.
- Lunar data backhaul
- Moon based deep space network

Figure 13 – Phased implementation of the reference architecture

6 TOWARD A UNIFIED APPROACH

The cost of exploration, habitation and settlement of the moon will be significant, and to some extent will be exacerbated if programmes continue to be carried out in isolation. Just considering the communications aspects, if each mission carries its own equipment to be able to communicate with the Earth, that duplicates capabilities, takes up valuable accommodation that could otherwise have been used for carrying additional instruments and payloads, decreasing efficiency, and in some instances, prevents missions from taking place. There would be much to be gained from taking a more unified approach.

The ideal solution would be for all parties to collaborate toward a single plan for lunar settlement, enabling resources to be better employed, efficiency to be maximised and costs kept to a minimum. Unfortunately, different motivations and objectives will prevent that from occurring and it can be anticipated that several parties will each progress their own plan toward lunar settlement, in the same as the settlement of parts of the Earth.

While it may not be possible to encourage a single lunar settlement programme, it may be possible to encourage a more unified approach to the provision of communications infrastructure and capabilities, especially if such a capability were established on an independent or commercial basis. There will likely be reluctance from the colonizing groups to rely solely on a third-party communications system for what they will consider to be a critical infrastructure, and a desire, at least in the initial stages to carry their own communications capabilities. It should still be possible however to work towards a unified approach, by anticipating the sensitivities of the various parties, encouraging the adoption of standards and interoperability and exploiting the ever-increasing capacity requirements as the level of activity increases.

One could envisage the scenario where each of the major lunar colonizing groups maintains its own minimal critical infrastructure, but is encouraged to utilise commercial infrastructure for higher capacity and less critical services, in much the same way as many governments operate today. Under such a scenario, other entities not so limited by the need to maintain their own core infrastructure, can also be supported.

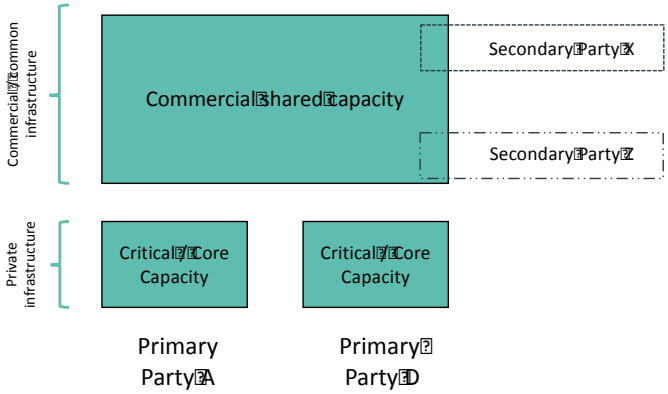


Figure 14 – Combined service provision scenario

7 COMMERCIALISATION OF LUNAR COMMUNICATIONS

While we are seeing an ever-increasing commercialisation of space based applications and services, satellite communications, and in particular geostationary communications, is by far the most mature. With a clear and understandable business model, the geostationary communications market rapidly evolved from being largely government funded, to now being primarily commercial, and has been that way for more than twenty years. While there is continuous pressure to reduce the prices, a large and growing market exists that can support commercial provision.

7.1 CURRENT ENVIRONMENT

Although we can anticipate the eventual commercialisation of lunar communications, market conditions today are not conducive to enable commercial service provision, and intervention or support will almost certainly be necessary in the early stages, in much the same way as institutional or government involvement in the early days of geostationary communications service provision.

At present, we are still in the Earth led exploration phase, with several different types or classes of exploration programme under varying stages of design, development, implementation and operation.

Several government or institutional programmes are ongoing, the majority of which are handled as isolated missions, carrying their own communications infrastructure. The need to carry their own equipment arising from the lack of existing communications infrastructure, the desire to minimise dependencies on other programmes, and to reduce risks associated with achieving the mission goals and objectives.

In parallel with the large programmes, there is significant interest in low cost lunar exploration with several academic, institutional and commercial entities exploring ideas and designs for small orbiters, landers and rovers. One difficulty faced by these programmes, due to size and budgetary constraints, is the ability to communicate to the Earth or deploy infrastructure necessary to support the missions. Because of these difficulties, very few of the programmes have proceeded beyond the drawing board.

7.2 LOOKING TOWARD THE FUTURE

The lunar communications scenario is analogous with what has been seen historically with Earth based communications. Where parties need to operate in regions with an absence of good existing communications infrastructure, they are forced to carry or implement their own. Where existing infrastructure exists, they utilise it, but may continue to carry their own infrastructure for secure or critical connectivity. When good, reliable infrastructure exists, social wellbeing and economic growth can thrive, more so than in areas with poor connectivity.

If one assumes the existence of a cost-effective, resilient, commercial lunar communications infrastructure then it can be anticipated that it would support a wide range of different users, at one end both the large government and institutional programmes, and at the other smaller academic, institutional and commercial endeavours. In fact, it is anticipated that the provision of such an infrastructure would become a key enabler for many of the developments and activities, as good communications infrastructure has been shown to lead to social, economic and technological advancement.

7.3 ENABLING THE COMMERCIAL PROVISION OF LUNAR COMMUNICATIONS

Lunar communications may commercialise naturally once the market for such services reaches a level, or size, and the cost of the infrastructure is low enough that it becomes economically viable to provide the services and close the business case. Unfortunately, that is not currently the case, and without intervention or support, is unlikely to be the case for many years to come.

The question is, given that the provision of lunar communication infrastructure is not currently commercially viable, yet once established such an infrastructure is likely to become a catalyst for future growth, how to stimulate or accelerate the development and future commercialisation.

One of the most critical aspects is the creation and growth of the market. The quicker the market can be established and grown, the more rapid the transition to commercial service provision.

- Standardisation and interoperability

  With many of the existing programmes operating in isolation, and having their own unique communications requirements, providing a system that is compatible with each would be complex and expensive. Encouraging the standardisation and interoperability on future programmes would help to reduce the complexity and cost of a future communications infrastructure.

- Reference framework or lunar development roadmap

  Although it may not be possible to unify lunar development activities into a single coherent programme, and there are likely to be several parallel efforts, developing, maintaining and openly communicating a reference framework or lunar development roadmap should allow entities to better gauge future requirements and to identify opportunities for commercial provision of service.

  It is currently extremely difficult to access information on future programme plans and therefore determine system and capacity requirements. Improving the transparency to the planning and implementation of future stages, acknowledging that plans are always be subject to change, would aid significantly in encouraging the commercialisation.

- Anchor tenancy

  While the large government or institutional missions may be reluctant to solely use a third-party communications infrastructure for command, control and payload data recover from their mission, at least until such an infrastructure has been proven to be ready, robust and reliable, they could be encouraged to use the service for partial communications requirements. One could envisaged for example that a mission carries its own communications infrastructure to achieve its core goals, but that it leases capacity from a commercial service for extended mission operations or additional payment or instrument data recovery. If the government or institution could commit to be an anchor tenant for the extended mission service, then this could help underwrite market risks associated with deployment of the commercial communications infrastructure.

- Exploitation of upcoming and future mission opportunities

  While past programmes have carried their own communications infrastructure, and some have included an orbital communications relay element, the missions have been largely optimised toward their primary mission objective. Excess capacity has been limited, and where capacity may have existed it has not been available or accessible to external parties.

  Designing in excess capacity into future programmes, and making the capacity readily available to other parties, preferably on a commercial basis, would encourage a greater deal of system interoperability, provide communications redundancy and additional capacity to other missions and even be an enabler for many of the smaller orbiter, lander and rover programmes currently under consideration.

- Institutionally funded lunar communications infrastructure

  One approach that could be adopted by a government, institution or coalition of key stakeholders, would be the funding and implementation of a lunar communications infrastructure. The provision of such an infrastructure could be used to support and enable the lunar exploration, habitation and settlement efforts, and thereby grow the communications requirement and stimulate the market. Such a solution should however anticipate future commercialisation from the outset, to avoid creating an environment that is not commercially sustainable in the long term. Provision of free communications capacity for example would help to stimulate a user base, yet it sets a pricing expectation that is unsustainable in the long term without continuous subsidy or intervention.

8 TECHNICAL, POLITICAL AND ECONOMIC FACTORS

While the creation and growth of the market is one critical factor for the commercialisation of lunar communications, there are many other technical, political and economic factors that will affect the viability and sustainability of such a system.

From a technical perspective, there are several key or enabling technologies that need development or further refinement. The lunar orbit and surface provide a harsh operating environment for electronic subsystems and equipment, with severe temperature extremes and high radiation levels. While systems can be designed that can survive such an environment, they make use of expensive parts and materials which would make large scale deployment prohibitively expensive. The development of more cost-effective techniques, parts and materials for long lifetime, harsh environmental use is a key enabler.

Although the scope of activities will change during the various phases of lunar colonization, communications to the Earth will remain critical and the amount of capacity required will continue to rapidly increase. While radio frequency communications has been used extensively in the past, and optical communications has been experimented with in recent years, optical communications is likely to take a more dominant role in the future in the back haul architecture. The radio frequency spectrum is a finite resource, and must be shared with other Earth bound terrestrial and satellite based systems, and without the development of extremely large, narrow beam width antennas, frequency reuse and interference mitigation will be limiting factors for the capacity of point to point communications links.

The regulatory environment will also be an important factor for both the direct to Earth communications links but also the regulation of spectrum use in lunar orbit and on the lunar surface. The licensing of radio communications spectrum for lunar based communications is a largely unchartered territory.

Governments could play a substantive role in the commercialisation of a lunar communications infrastructure, as many of the large exploration programmes will be government or institutionally led. Development, maintenance and open communications of a lunar development road map, and the encouragement of the adoption of standards and interoperability will all help in aiding organisations to identify commercial opportunities and in the stimulation and growth of the market. The governments could also act as a real catalyst to the commercialisation by providing long term framework contracts or anchor tenancy for communications services, underpinning a business on which a commercial operator could grow. It is acknowledged that in todays political and economic environment is difficult for governments to provide multiyear commitments to service providers, however such an issue should be relatively easy to resolve in context of the other challenges that will be faced in striving for humanity to become a multi planetary society.

Finally, from an economic view point, although the deployment and maintenance of a lunar communications infrastructure would be more cost-effective than each future programme acting in isolation, the costs associated with such an undertaking are still significant and much needs to be done to reduce the level for it to become truly commercially viable. Recent developments of new launchers and space based systems are certainly helping to drive down cost, but there is still a long way to do. Continued investment, be it government, institutional or commercial, is needed to improve the cost effectiveness of future technologies and systems.

9 REGULATORY ASPECTS: AN ITU REGION 4?

No spectrum, no satellite, as the adage goes, and this is especially true in regards to Lunar settlement as the proper regulation and provision of useable spectrum, even with optical communications, will be a key success factor. Settlements on the Moon will need to communicate effectively and efficiently with the Earth, each other, and then potentially acting as a communications hub and relay for further later settlements in deep space all without causing harmful interference while successfully landing signals throughout Cis-Lunar space. Here the International Telecommunications Union (ITU) will have a logical and increasing role to play.

The ITU is the United Nations specialized agency for Information and Communication Technologies (ICTs). The ITU 'allocates global radio spectrum and satellite orbits, develops the technical standards that ensure networks and technologies seamlessly interconnect, and strive to improve access to ICTs to underserved communities worldwide'. Further, the ITU's mission is 'to connect all the world's people, wherever they live and whatever their means. Through their work, they protect and support everyone's fundamental right to communicate.[1]'

In terms of equipment and spectrum use, a Lunar settlement will not be a stand alone venture in terms of frequencies. Proximity to Earth, a reliance upon communications

[1] Source: International Telecommunications Union www.itu.int

infrastructure, commercial, military and civil, in Earth Orbit and on the ground will necessitate a need for clean spectrum in terms of application to the ITU Radio Regulations. Operations on the Moon cannot cause interference to communications on the Earth, especially given that the Moon's orbit intersects all three present ITU regions.

There will be an anticipated need for the traditional segmentation of spectrum use as well on the Moon: commercial; civil; military; and search and rescue.

Lunar communications must work in harmony with those existing infrastructures already in place and in operation on the Earth as well as those of other settlements on the Moon. Indeed, they will most likely need to use much of the same equipment and will need to interface seamlessly to work.

Hence clear regulatory understanding is needed. The Moon cannot be a 'wild west' of spectrum use given its proximity to Earth, never forgetting that 100% of the money 'spent in space' is not, it is spent on Earth in a very clear regulatory and legal environment where action can be taken against those causing harmful interference.

At present no known commercial spectrum has been allocated outside of Geostationary orbit. Various working groups are meeting at the ITU to discuss this need, though as of time of publication no concrete results are yet known.

The ITU has split the Earth into three specific communications regions to aid in the proper regulation of spectrum use. An ITU Region Four, a fourth region has unofficially been suggested to encompass the Moon, CIS- Lunar Space and Deep Space[2] and the authors believe that this idea has real merit.

As it is important to understand that, as with satellite, a clear well understood path to spectrum licensing also enables investment in bandwidth, infrastructure by facilitating commerce with regulatory certainty. This is no small matter and is a key consideration: a clear regulatory path will enable investment whether by government agency or by commercial interests in turn enabling the three phases of Lunar settlement.

10 KEY ACTIONS

The commercialization of a lunar communications infrastructure is feasible, and there is much that the government can do to facilitate and support it. Several actions have been identified that would aid the commercialisation.

- Development, maintenance and communications of a reference framework or lunar development roadmap.

  Given that the government and its agencies are actively involved in the planning and implementation of many of the lunar exploration, habitation and settlement efforts, and have significant insight and visibility into the planning of other commercial and nation state activities, it is well place to develop, maintain and openly communicate a reference framework and lunar development roadmap, that outlines the anticipated stages, programme profiles and communications requirements.

[2] Mr. Attilla Mathus, ITU Bureau of Radio Communication.

- Encourage the implementation of standards and interoperability.

  Facilitation of efforts between the key global lunar exploration stakeholders, such as the ITU, encouraging the standardisation of communications interfaces and interoperability between missions. Given the international nature of the endeavour, the government would be well place to lead such an activity with the goal of simplifying the future communications system infrastructure requirements and thereby minimising the cost of infrastructure.

- Incorporate requirement for additional communications capacity in future missions.

  Incorporating additional capacity into future programmes and activity exploiting the capability to support other third party activities, on commercial basis, will aid in stimulating the market for future commercial service provision and may also be an enabler to many of the smaller academic, institutional and commercial programmes during user design and consideration.

- Provision of anchor tenancy

  While it is understood that the government has difficulties in providing long term, multiyear commitment, to procurement of services, addressing this issue and enabling the government to become an anchor tenant would have a significant positive impact on the commercialisation of a lunar communications system. By acting as an anchor tenant the government can underpin, and mitigate market risks, for parties looking to provide commercial services.