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SCIENCE DIRECT
Space Policy 21 (2005) 267–275
Space Policy
www.elsevier.com/locate/spacepol

# Public–private models for lunar development and commerce ☆

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Available online 13 October 2005

**Abstract**

Visions about the establishment of a lunar base and development of the Moon for scientific, technical and commercial ends have been on the political agenda since the beginning of the Space Age. In the past few years a number of spacefaring nations, including the USA, European states through ESA, Japan, India, China and Russia have proposed missions directed at the robotic and human exploration and development of the Moon. This paper argues that an important factor in advancing these missions lies in a partnership between the pubic, governmental sector and the private sector. The paper analyzes the dynamics of this partnership as applied to the case of the US Vision for Space Exploration. The results of the analysis suggest that public–private partnerships directed at lunar development and commerce depend on how government reduces risks for the private sector. The risks identified and discussed herein include political and legal risks, technological risks, and financial and market risks.
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## 1. Introduction

Mission concepts and plans directed at lunar base development have been proposed since the beginning of the Space Age. In January 2004, a new US civil space policy was announced based on space development to support robotic and human space exploration of the Moon, then Mars. Previous concepts and plans for lunar development, including the 2004 policy, have remained either on the political agenda or as proposed ideas for the commercial sector. Given that this has been the case, why has there not been political formulation and implementation of lunar base missions or implementation of commercial development of the Moon? This paper assesses the issues facing those in both the public and private sectors who view lunar development as a desirable goal and offers suggestions, based on partnerships between the public and private sectors in the USA, on how to make that goal a reality. Public–private partnerships (PPPs) depend on how the government reduces risks for the private sector. Identified and discussed herein are political, legal, financial, market and technical risks.

There are several issues that have entrapped lunar development ideas on both the political and business agendas. First, an environment of uncertainty concerning political and legal regimes constrains the prospects for commercial sector interest in lunar development. Second, public policy evolves on an incremental basis. Past policies and practices change slowly and usually in response to a particular crisis or focusing event that warrants public attention. Third, lunar development advocates focus on scientific and technological benefits of lunar development, while providing weak links to economic competitiveness and national security issues that are of interest to political decision makers. Arguments for lunar development based on unspecified technological spin-offs are ineffective. Political rationales in support of lunar development are constrained because of weak public support for space in general and to reduced budgets and downsizing in government support for research and development (R&D). Fourth, even though lunar commerce enjoys a

☆Previous versions of this paper were presented at the following conferences: Space Technology and Applications International Forum 2004, Albuquerque, NM, USA; and the International Lunar Conference 2003, Kohala Coast, HI, USA.

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doi:10.1016/j.spacepol.2005.08.004

prestige status in the private sector (numerous companies have plans to carry out commercially viable robotic ventures on the Moon), plausible business plans for lunar settlement, catering to scientific, mining and tourism projects, remain elusive and in the more distant future. The business plans that have been proposed for lunar settlement lack realistic return on investment (ROI) calculations to make the venture attractive to capital markets. These plans fail to properly identify and quantify sustainable long-term markets for the proposed ventures.

Partnerships between the public and private sectors are essential to deal with these issues and to enable prospects for lunar development. The idea of PPPs implies the existence of political support and government funding, and aspects in the lunar development that would attract investor interest and private capital. The issue to be discussed here is how to fashion a synergistic PPP relationship. To this end, there are a number of important factors that cut across the political, legal, financial, market and technical risks inherent in the formulation and implementation of PPPs for lunar development. These factors concern the roles of governments, technology, and the private sector in the PPP equation. The roles related to each of these factors are analyzed below.

## 2. Government

The government, whose motivation is to act in the public interest and create public value, undertakes the risk of R&D and formulates an appropriate legal regime that facilitates PPPs for lunar development. In recent years a number of firms has proposed commercial lunar ventures. One major barrier to commercial lunar missions is the inability of firms to raise the venture capital needed for implementation of business plans. Important factors related to this barrier are the lack of credible near-term revenue markets for commercial lunar activities, and political and legal uncertainties associated with commercial lunar ventures [1]. The private sector cannot be confident that it will get an acceptable ROI. This sector often looks to the government to share the technological and capital risks. Fig. 1 shows how this public–private relationship is possible.

An important role for the government in the PPP equation is to reduce as many of the risks as possible. This can be accomplished through policy actions that make sure that governmental actions do not adversely affect the development of the private space industry, through a role for government in capital formation for developing space technology, or by offloading governmental activities in space to the private sector. These actions can reduce risk and enhance the possibilities of ROI for private entities that can then commercialize the technologies. An acceptable region for this commercialization exists when there is a favorable benefit-to-cost ratio implying that ROI is greater than risk. PPPs of this nature characterize how space commerce has evolved in other areas, such as telecommunications, commercial launch vehicles and remote sensing. This is likely to characterize PPPs directed at lunar development.

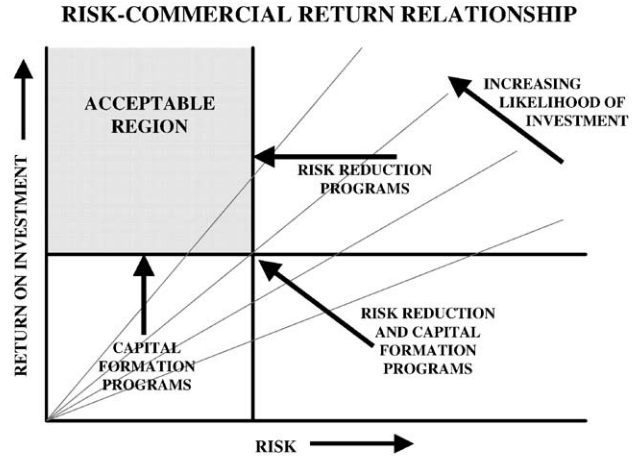


Fig. 1. Risk-commercial return relationship. *Source*: Sadeh E, editor. Space politics and policy: an evolutionary perspective. The Netherlands: Kluwer Academic Publishers; 2003.

The traditional approach of government contracting of R&D deals with risks inherent in the development of new and innovative technologies. This approach has been augmented with transfers of the technology for commercial use. The PPP equation implies that the government not only contracts for R&D and facilitates the transfer of the developed technologies, but also then addresses additional political, legal and market risks. The viability of PPPs depends upon the extent to which the government reduces all these risks for the private sector. For example, the successful commercialization of telecommunication satellites, space launch vehicles and remote sensing satellites in the USA became possible because the government not only contracted for the R&D of these technologies, for its civil and military space use, but then also facilitated the transfer of these technologies to the private sector, established policies and laws that provided a licensing and regulatory regime, and promoted the development of markets that could sustain these areas of space commercialization [2].

Concomitantly, a failure to address the non-technical risks can lead to failure of PPP initiatives. This is no better illustrated in the space commercial sector then by the failure of the Earth Observation Satellite Company (EOSAT) during the 1980s. In the EOSAT case, legal, financial and market risks were not adequately considered [3]. EOSAT was established as a result of congressional legislation and was formulated as a PPP, where the federal government transferred remote sensing satellite technology (i.e., the Land Remote Sensing Satellite System or Landsat) to EOSAT. The government mandate for EOSAT was to commercialize Landsat data and to generate profits from the sale of that data. Technology transfer did not in this case foster the success of EOSAT. Even though the government provided EOSAT with operational subsidies, these subsidies were insufficient, and there was an inadequate legal regime in place and a lack of financial mechanisms to encourage the development of a market for Landsat data.

The lessons of EOSAT show that PPP viability rests on the extent to which market barriers, such as a lack of proven markets, to commercial lunar ventures can be overcome. The US Congress Commercial Space Act 1998 addresses this barrier by calling for NASA and other US federal agencies and scientific researchers to acquire space science and Earth science data from commercial providers [4]. Early market products from lunar missions will probably comprise information, experimental data and samples. The logical market for these products is the scientific community. The scientific community currently has no way of purchasing these products, being dependent on NASA missions for gathering such data. A viable scientific market created through a federal grant program to fund the purchases by university and non-profit research groups of data and samples from commercial lunar ventures is one plausible option. It is important that the government foster an 'anchor' market for science data. A government sponsored purchase grant program provides such an anchor tenant market for commercial lunar ventures by allowing existing lunar researchers to purchase products from the commercial sector. This allows the private sector to establish a market and achieve revenue streams necessary for implementation of business plans.

### 2.1. Legal uncertainty

When the Outer Space Treaty (OST) regime[1] was codified, the focus was on government, not commercial, space activities. As a result, a number of legal questions exist about conducting commercial operations on the Moon. These questions include the rights to sell for profit samples recovered from the lunar surface, intellectual property rights to knowledge about lunar resources, and real property rights and the appropriation of lunar resources by establishing a mining facility [5].

The impact of these questions varies based on the business model of the commercial ventures. To date only a single firm, Transorbital, has succeeded in getting the necessary clearances and licenses for a commercial lunar flight [6]. Since Transorbital's planned lunar mission will only map the lunar surface from space, followed by a controlled crash to the surface to eliminate navigation risks, the legal issues it raised were minimal and could be accommodated within the existing space law framework. The licenses Transorbital needed involved getting clearance from two US government agencies. The State Department, under International Traffic in Arms Reduction (ITAR) regulations granted Transorbital a license to launch aboard a Russian booster. A second license was from the National Oceanic and Atmospheric Administration's (NOAA's) Licensing for Commercial Remote Sensing Systems legislated with the US Congress Land Remote Sensing Policy Act of 1992[2] to cover any images of Earth the spacecraft might take from lunar orbit [7].

In contrast to this case, more ambitious commercial lunar ventures, such as exploring Apollo landing sites and returning samples for sale to collectors, are not likely to be accommodated within the existing legal regimes. These ventures raise legal concerns about property rights issues under the existing OST regime. Such legal uncertainty not only raises the issue of costly legal delays, but also affects the viability of business models. A business model built around selling lunar samples to the general public, for example, hinges on legal ownership of the samples. Other commercial ventures focusing on mining lunar water or other lunar materials are even more sensitive to resolution of the legal issues of ownership and intellectual property rights about lunar surface conditions and resources.

One means to address the legal issue of commercial lunar ventures proactively is through government legislation based on the model of the US Deep Seabed Hard Mineral Resources Act of 1980.[3] This Act established a national regime to regulate the activities of US nationals and firms who wish to engage in deep seabed mining activities in international waters. It provides legal protection to US firms pending the creation of an international agreement on deep-sea mining acceptable to the US. The Act spelled out the legal rights US firms had to resources recovered from the ocean floor and ensured federal protection of these rights. Although it did not lead to any major deep-sea mining boom, as market economics did not justify recovery of sea floor minerals at the time, it did eliminate the legal uncertainty associated with deep-sea ventures. Creating a legal regime of this nature to protect commercial firms seeking to conduct lunar operations would similarly eliminate legal risk.

The model of the Deep Seabed Hard Mineral Resources Act is especially applicable to lunar development given the problems encountered with the Agreement Governing the Activities of States on the Moon and Other Celestial Bodies (Moon Agreement), and its call for an international regime to govern the resources of the Moon [8]. To date, no spacefaring powers have ratified the Moon Agreement.[4] The view of the US government on this is that commercial

[1]The Outer Space Treaty Regime as used herein includes: Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies (Outer Space Treaty); Agreement on the Rescue of Astronauts, the Return of Astronauts and the Return of Objects Launched into Outer Space (Rescue Agreement); Convention on International Liability for Damage Caused by Space Objects (Liability Convention); Convention on Registration of Objects Launched into Outer Space (Registration Convention). For a text of these treaties see *United Nations treaties and principles on outer space* (United Nations, Vienna, 1999).

[2]Public Law 102–555, US Congress.

[3]Public Law 96–283, US Congress.

[4]The Moon Agreement to date has been ratified by Australia, Austria, Chile, Mexico, Morocco, Netherlands, Pakistan, Philippines, and Uruguay.

firms need to be certain that their investments are protected and not governed through an international regime or organization that is more concerned with equity and benefit sharing than ROI. The idea of a 'Lunar Resources Act' akin to the Deep Seabed Hard Mineral Resources Act provides one possible way to provide legal protection, and thus to reduce the legal risks that will hinder the development of a commercial lunar industry.

The counter argument to the USA, in terms of the property rights issue, lies with the example of the International Seabed Authority (ISA), which was established as part of the United Nations Convention on the Law of the Sea (UNCLOS). While the USA has not ratified UNCLOS because of objections to the ISA,[5] the Seabed Authority has created a global common property resource regime embodying concepts of equity and international community interests into the arrangements for exploitation of the deep seabed as a commons resource [9]. The ISA is regulatory body that allocates companies permits to recover minerals from the seabed within a specified time period, requires all mining operators to contribute a portion of their revenues to the ISA, and obligates those companies receiving permits to sell to ISA mining technologies that cannot be obtained on the open market. With this approach there is no actual ownership or 'real' property rights to the seabed, but a right of use. Such a right of use approach is another way to reduce legal risks for lunar development, while ensuring that no one state can unilaterally impose its version of international law and equity on the rest of the world.

### 2.2. Laws and markets

There are several approaches that governments can pursue in relation to PPPs and lunar development. These approaches are highlighted in Fig. 2 below. One approach is market-based, where both access to and use of lunar resources are treated as private goods. This is essentially an extension of the capitalist economy to lunar development. Access is based on real property rights and use is determined by the marketplace, and laws of supply and demand. This approach privatizes the development of lunar resources through political and legal regimes. Proponents of this approach commonly believe that because a venture has private financing, or a company manages to land on a planetary body, such as the Moon, the business has an automatic right to all resources it finds [10]. Since private, 'real' property rights are fundamental to a capitalist economic system, it is natural to assume that they must be equally fundamental to lunar development. In order for space to be economically developed and for individuals to make the necessary investments, property rights must be available to those engaged in lunar businesses and companies.

| | Divisible | In Joint Supply |
|---|---|---|
| Exclusion<br>Appropriability | <u>Private Goods</u><br>-Assign property rights and ownership<br>-Costs determined by supply and demand | <u>Extension of Goods</u><br>Goods extended to others even though others can be excluded or charged<br>-Earth Observation data |
| Non-exclusion<br>Non-appropriability | <u>Divisibility</u><br>-Orbital slot designations<br>-Electromagnetic spectrum allocations | <u>Commons Resources</u><br>-Outer Space<br>-Space resources<br>-Celestial bodies |

Fig. 2. Approaches to the development of public–private partnerships. *Source*: Sadeh E, author.

A second approach is based on the current OST regime, which codifies space as a commons resource based on the 'province of all mankind' principle that entails free access and free use. Free access implies non-appropriation and free use implies a public good that is available to all users with no political, legal or market restrictions. This represents a 'benefit-sharing' approach to space development that takes into account the fact that developing states lack the means of competing in lunar development. The approach to 'collectivizing' space lacks any definition of real property rights, however, and it fails to address the political and legal risks inherent in any lunar development scenario. The result is a regime that is counter to the goal of encouraging the development of outer space [11].

Having said this, the Outer Space Treaty regime is permissive of commercial activities in space in that it establishes principles important to commercial development and allows for the private appropriation of resources. The regime allows all peaceful activities in space, which includes all commercial activities, and it deals with important issues of registration, liability and non-interference that would all doubtless reduce the legal risks of any PPP development. In regard to space resource utilization, the private appropriation of extracted resources is permissible under the terms of the Outer Space Treaty [12]. The OST regime also defaults to national entities or governments to regulate commercial activities in space. This is congruent with the argument that the government must play a critical role in enabling PPPs for lunar development.

[5]The US Senate has refused to formally ratify the United Nations Convention on the Law of Sea due in part to the establishment therein of an International Seabed Authority that applies ides of 'benefit-sharing' to the mining of the deep seabed. For the International Deep Seabed Authority, see http://www.isa.org.jm/en/default.htm (accessed 11 May 2005). Note that all the US presidential administrations, since the opening of the Convention for signature and ratification in 1982, have viewed the treaty as being in the interest of the US. As such, the US has abided by all of its provisions other than the deep seabed mining ones.

A third possibility is to allow for free access, but to restrict use through divisibility of lunar resources. This is the approach that is used for the governance of geostationary (GEO) orbital slot designations and electromagnetic spectrum allocations for the telecommunications sector. Governance of these resources takes place through an international organization, the International Telecommunication Union (ITU). Free access in this case is evident with the guaranteed use of these resources through international and national laws, but use is distributed with market considerations in mind and with no property rights. When applied to lunar development, this possibility would allow for a market to develop, while maintaining the non-appropriation legal principle of space codified by the OST regime. The market, in such a scenario, is restricted to those commercial activities that would not require property rights, such as scientific activities and tourism.

The fourth approach allows for an extension of goods or resources based on free use, but restricts access. This is the approach that has been applied to government-sponsored remote sensing activities [13]. Free use implies that you make the data products available as a public good to the address public interest, such as natural disaster mitigation, or weather forecasting. At the same time, access is restricted through appropriation or exclusive rights by providing the data on a proprietary basis for commercial development, e.g. developing and selling valued-added data products. In the lunar development case, this implies exploration and science activities directed at public benefits with an accompanying regime of property rights for commercial development activities. These activities entail value adding the public good resources, and making use of these resources to enable the proposed commercial activities.

### 2.3. PPP types and scenarios

Several PPP types can be identified. These types include partnerships in the form of public–private entities that are created through subsidies or ownership models, governmental relations with the private sector through contracting for hardware or services, and policies and laws formulated and implemented by the government that foster private sector development. The following government roles are identified: (1) R&D contacting of technology; (2) technology transfer; (3) diffusion of technical knowledge; (4) intellectual property rights and patent protection; (5) contractual rewards; (6) prizes for technology innovation; (7) subsidies; (8) corporate ownership; (9) loans; (10) government procurement or purchasing of commercial services; and (11) tax benefits and credits [14].

These government roles are important to consider for the development of PPPs that can establish an economically sustainable infrastructure in outer space and thereby support development scenarios on the Moon. One scenario is US government contracting to private vendors for services and hardware. This includes contacting examples from NASA, the Defense Advanced Research Projects Agency (DARPA), the US Air Force (USAF) and other parts of the US military, and US Federally Funded Research and Development Centers (FFRDCs). In this scenario, technology transfer, diffusion of technical knowledge, patent protection, rewards and prizes are taken into account.

A second scenario is based on the creation of an independent US corporate entity that owns and manages the space development infrastructure. Such a corporation acts as the systems manager for design and construction, and contracting with private firms to undertake the work. An important factor is that of government subsidies that have engendered the commercialization of telecommunications, space launch, and remote sensing. The idea of the Lunar Resource Development Corporation discussed below is indicative of this scenario.

Cases that characterize this scenario include the Communications Satellite Corporation (Comsat); and the French ownership of Arianespace and Spotimage. Comsat, for example, was formed as a result of the US Communications Satellite Act of 1962. This act authorized the formation of a federal corporation to administer satellite communications for the US, which led to the successful commercialization of space-based telecommunications. Comsat was given responsibility for developing a global satellite communications system and new satellite technologies, as well as acquiring and maintaining satellite ground stations around the world. Lockheed-Martin Corporation (LMC) began to acquire Comsat in 1998, and today Comsat is a wholly owned subsidy of LMC.

A third scenario involves the government providing competitive low interest loans for private firms to build specific space infrastructures whereupon the government serves as a customer. This involves the possibility of the government acting as an ‘anchor tenant’ by purchasing commercial services from the private firms at a specified price after the infrastructure is operational. Cash and non-cash tax benefits on revenues and tax credits provided to the private sector are other possibilities within this scenario.

## 3. Technology

The development of dual-use technologies is a viable approach for the financing of a lunar base [15]. A defining issue for the applicability of this deals with how to finance projects and technological developments that are so expensive, and require such long time-scales, that private sector investors will not support them. This issue applies to many large-scale, expensive endeavors deemed to be in the public interest (e.g. airports, highways, environmental clean-up facilities, the military, and the space exploration of the 1960s). Compared with these generally closed-ended projects, with understood economic and social benefits, lunar development is open-ended.

This fact makes it difficult to detail lunar economic benefits because of the vastness of the enterprise. How would one begin to justify the multi-generation benefits of colonizing a planet over a period of centuries? Such a venture is also very expensive when viewed as an individual project. Attempts by proponents at justification by using cost comparisons with other national expenditures do not enhance public desire for funding lunar development. Therefore, it is necessary to identify segments of the larger endeavor that can be justified independently as viable economic activities. This allows for a realistic ROI.

The dual-use technology model for lunar development is based on a sub-structuring of the venture into smaller independent and profitable units. The path to development of the Moon will thus be supported by scores of existing and newly created independent businesses. These businesses will be such that the whole is larger than the sum of its units. The whole will get us to the Moon, and private sector investors can support any or all of the units.

While this may seem to be an obvious solution to the problem, there are difficulties in such an approach. One needs to be certain that the whole project is not held together by a weak unit, or a series of weak units. For robustness and reliability, parallel technological capabilities are necessary. In addition, an independent entity must be created that can pull together all the units important for developing the Moon. At this point, it is reasonable to stipulate that R&D efforts in propulsion and rocketry will require government involvement, as shown in Fig. 1. Other lunar development efforts can be justified to investors.

How to coordinate such a disparate group of business enterprises and, at the appropriate time, embark to the Moon with robots and humans is an important question as well. Ideally, a leadership group must be in place to properly coordinate the design and development efforts of the various organizations supporting lunar development. While it is not necessary to own or acquire these businesses for this model to be effective, it is important that a central organization has the big picture in mind and has the resources, intellectual and otherwise, to ensure the development of the necessary technologies to support lunar development. These resources can only be developed in a financially viable sense, meaning that private investor interest is essential. As was discussed above à propos the government model, the government can act to foster investment interests and even become a customer of any lunar enterprise.

### 3.1. Lunar development corporation

One scenario based on the dual-use technology model would involve the creation of a lunar development corporation based on public–private partnerships [16]. Such a PPP would include management, science and engineering, financial and legal teams. These teams would act as venture capitalists, coordinating activities around each technology, attracting capital for start-up endeavors that cannot be accomplished by existing industries, and generating investor interest for existing companies that have a role in lunar development. All these activities would be viewed as for-profit. Part of the profits would be used to repay investors and the remaining funds used to create the financial strength needed to initiate and support a return to the Moon. As a lunar development corporation grows, it is appropriate to include debt financing with bank loans, in addition to equity financing through venture capital.

Business plans for the creation of a lunar development corporation must identify preliminary activities that will be used to attract investors. Investors providing start-up funds are expected to receive reasonable rates of return for these activities. Given the magnitude of the proposed venture of lunar development and the long time scales involved, such a "bootstrapping" method, as represented by the dual-use technology model, is essential.

The primary goal of a lunar development corporation is to ensure that the right technologies are available when needed. This is accomplished through the development and use of dual-use technologies that are profitable for Earth applications and lunar development needs. In this fashion, financing and ROI can reasonably be expected.

### 3.2. Dual-use technologies

Existing industries will have a significant role in lunar development. Indeed, these industries will be the backbone of early development. Although the technological issues of lunar development are relatively well understood, there are debates on technical options. For example, should the prototypical lunar structure be inflatable, a truss or within a lava tube? Nevertheless, once a choice is made, the technical issues can be addressed, even if this means that new technologies need to be developed. The long-term biomedical issues are less well understood and require continued investigation. In order for the proposed technology model to be successful, a significant percentage of the technologies must be dual-use, meaning that they not only have a role in lunar development, but also have a more immediate civilian or other Earth-based application. Table 1 lists promising dual-use technological areas for investment.

Table 1 represents only a sample of possibilities and technological options. Once very focused and specific studies are initiated, the list will grow by orders of magnitude and it will become clear which technologies have the highest potential for dual-use and therefore, ROI. These technologies will form the backbone of technology development. Some of these profits will help support the less profitable, but necessary, technologies that must also be developed. In this way, the necessary resources can be accumulated for lunar development.

## 4. Private sector

The private sector is concerned with the development of business plans that address ROI. To date, plausible

Table 1
Dual-use technological areas for lunar development

| |
|---|
| *Self-repairing systems* can be used to help safeguard systems that are hit by micrometeorites in space and on the Moon. Such systems can also be utilized in monitoring and repairing micro-cracks in aircraft fuselages and other mechanical components. |
| *Materials development and processing* are amongst the most economically valuable scientific and engineering activities because of the importance of new materials in our world. The same is true for technology developments for space application. |
| *Low gravity and microgravity technology* will be developing as a result of our experience with the International Space Station. Such capabilities, whether for fluid mechanical applications or materials processing and handling in such conditions, will become extremely important for the practicalities of space faring. |
| *Robotic manipulators* have very broad applications. In space and on the Moon they could be extremely useful in minimizing the workload of the astronaut construction corps. They also can be used in delicate manipulations such as medical procedures and hazardous material handling. |
| *Instrumentation* is an industry with broad application. Two possible areas for investment are the monitoring of material integrity and fluid flow control. Both have significant dual-use possibilities. |
| *Micro and nano devices* are those of a size that approach the smallest of scales, even the molecular and atomic scales. Potential applications include the tiniest computers, and the strongest and lightest materials. Such devices would revolutionize manufacturing, electronics, materials, and medical procedures. The applications to the space and terrestrial economies would be immense. |

Source: [18].

business plans providing competitive and realistic ROI are lacking, as is an available and cost-effective way to access space and return to the Moon. The business case has yet to be made by the fledgling lunar industry for the purpose of returning to the Moon for any reason.

Space business companies, including the companies proposing lunar commerce, must show they are capable of mitigating risks, capitalizing on the right timing, and working within present political and legal regimes. While modifying or changing regimes to enhance space business opportunities and lunar ventures is important, as discussed in the first section of this paper on government roles, doing so will be costly and time consuming. Given the uncertainties of any final political and legal regime, it will be difficult to design commercial ventures with risk-to-ROI considerations that are realistic. Thus, lunar ventures should be competitive on the basis of the existing regimes, which are known and understood. Establishing a partnership between the public and the private sectors for lunar commerce is the most rewarding path for these sectors to pursue at this time.

An important part of this partnership is for the commercial sector to understand that business plans and concepts must compete with terrestrial businesses [10]. While this places added burdens on the lunar venture to perform competitively, mainly because the associated risks of the lunar venture are likely to be higher than those of similar terrestrial ventures, it also demonstrates to financiers and investors that the lunar venture management team understands the financial and risk issues of the market place.

Important qualities are absent in both the public and private sectors that would allow for the development of a joint partnership for lunar commerce. Some of the desired qualities overlap the two sectors, such as the need for leadership, vision, organization, planning, and the ability to measure results. Both sectors require financing and must demonstrate a willingness to incur risk. In addition, both sectors need to recognize the potential benefits of joining forces to build wealth and to see future value created for their businesses.

### 4.1. Business case

Regarding the business case for returning to the Moon, private industry has not put forth compelling business reasons for establishing commerce on the Moon. In the USA, the discussion seems stuck on the Space Shuttle, the International Space Station (ISS), a proposed Crew Exploration Vehicle (CEV) for low Earth orbit, and military uses of space. Lunar development requires effective national and business leadership working together to help ascertain why it is important.

The case for private-sector investments in lunar commerce must be made by the business leaders, investors, shareholders and financiers who are the architects of business and economic growth. Such investments assure industry leadership, product development, ROI, quality employees at all levels, and strong competitive businesses. So far the private sector has been conditioned to believe that the space program is the responsibility of government and a few of its large-scale contractors. This is to be expected since today's commercial space industry, while highly profitable and successful, was initiated by government policy and acts of the US Congress, and is heavily supported by lucrative, incentive-based and cost plus government contracts for both hardware projects and R&D. This perception needs to change before the private sector will be able to act as partner to the public sector in developing commercial lunar ventures.

### 4.2. Lunar business

Commercial lunar business ventures must be based on standards that are used for terrestrial investments of similar risk and character. There will be stringent requirements for any company to earn an acceptable ROI. Businesses need to show that investing in a lunar venture has, at the minimum, a similar economic potential to a terrestrial investment of a similar kind and risk. A suitable exit strategy is also important for, without a way for investors to realize profits from the venture, the investment will not be made. Potential delays resulting from political, legal and capital issues, and realistic contingency factors to manage these delays must be part of the financial analysis. Realistic business plans will facilitate the public endorsement of and participation in the project, which will add significant credibility to the venture for those financially backing the lunar development program.

Some suggested guidelines for the PPPs being discussed are offered below and apply equally to both the public and the private sectors. These guidelines, among others to be decided upon by the participants, are fundamental to having a successful partnership for returning to the Moon for commerce. Essential to PPPs is the necessity for both the sides, public and private, to understand and appreciate the unique qualities that each brings to the venture. Together they must be able to explain these qualities and the benefits to their respective constituencies, something quite different from simply explaining the venture's business and financial benefits. The two partners must be synergetic in their relationship.

The partnership also requires that both the public and private sectors work together in financing the project. However the partnership structures the financial parameters of its lunar ventures, both partners need to be financially committed and involved in the project. The model for this was shown in Fig. 1. On the public side, providing specific government incentives for private-sector involvement is important, but there must be more. The public sector must also invest in the venture. This also holds true for private-sector participants. Investing because of government incentives is insufficient. The private-sector participants must also share in the risk and equity of the venture.

### 4.3. Business models and ethical challenges

There are three distinct models for off-Earth development and settlement: (1) the American frontier model; (2) the imperialistic model; and (3) the PPP model for commercial space development, such as a lunar development corporation discussed earlier.

The first model is based upon the manner in which the USA settled its frontier. This model would include the 'boomtown or bust' mentality resulting in a sometimes lawless and violent settlement pervasive of high risk for any business endeavors. The second choice is to model lunar development after the imperialist powers of previous centuries, wherein wealth was created by using colonies, war, sweat shops and political control. Although imperialism also produced a high-risk environment for business, as exemplified by riots and wars of independence, it did foster some legal order in the form of unions to protect the work force and laws to bring order and decency to the business communities.

The PPP model calls for an entirely new 21st century vision, drawing upon the successes and failures of the past. This new model could be useful in lunar development in a manner reflective of the tremendous advances evident in today's society as it avoids the costly consequences that burdened businesses in both the American frontier and the imperialistic models. Concomitantly, there are ethical challenges to the PPP approach that involve political and legal issues.

Two areas in critical need of an ethical approach to future lunar commercial development concern the lunar surface and the benefit sharing of lunar resources [17]. In considering lunar economic development, some areas on the surface of the Moon may undergo change that could be permanent. To many critics, this is unacceptable. Furthermore, when lunar-development advocates mention setting aside portions of the Moon for public parks or protected areas, opponents are quick to point out the fact that their activities will forever damage the virgin surface of the Moon. While some critics are focused on lunar development issues, others are focused on making sure that all nations and people have access to lunar resources, a concept that is strengthened by the Moon Agreement.

The Moon Agreement addresses the highly controversial concept of benefit sharing of lunar resources. Although it has not been ratified by the world's space powers, because its controversial nature, the ideas contained therein have a legal standing thanks to the 'commons' approach to space established by the Outer Space Treaty regime. Consequently, because of this attitude, many states, especially developing ones, could mount costly legal challenges to lunar development projects as the development of space resources gradually evolves. This is a risk that would not be conducive to an acceptable ROI for the private sector. If lunar commerce is to proceed unfettered by governmental barriers, such as direct legal challenges, then the actions undertaken by the commercial space industry to minimize the problems over benefit sharing is important. Ignoring this issue will only build future barriers enhancing risk and reducing any potential ROI.

## 5. Conclusion

The roles of the governmental, technical and business factors presented in this paper offer approaches to lunar development on the basis of PPPs. The factors address the critical issue of risk and ROI. Ultimately, the realization of PPPs for lunar development and future long-term settlement of the Moon depends on the extent to which ROI is greater than the risk.

The risks identified herein include: political and legal risks; technological risks; and financial and market risks. The nature of the risks has been identified and plausible solutions for a mitigation of risk are offered. Neither the public nor the private sector is likely to sustain lunar development independent of one another. To realize this goal will take the combined efforts of both sectors. The more these efforts are synergistic, the more the risks can be alleviated and lunar development and commerce can begin.

The US national space exploration policy, announced by President Bush on 14 January 2004 to advance robotic and human exploration of the Moon and Mars, created a presidential commission to examine and make recommendations on implementing the policy. The commission recognized that one of the major challenges of the space policy would be to create an organizational structure that would sustain the vision through 5 presidential administrations and 10 sessions of Congress. The commission formulated a final report entitled *A Journey to Inspire, Innovate, and Discover* [17]. The report recommends that the federal government, in particular NASA and the US Congress, recognize and implement a far larger presence of the private industry.

The report made two proposals for achieving this end. First, that "…NASA aggressively use its contractual authority to reach broadly into the commercial… communities;" and second, "…that Congress increase the potential for commercial opportunities… by providing incentives for entrepreneurial investment in space, by creating… monetary prizes for the accomplishment of space missions and/or technology developments…"[6]

This article has assessed how the federal government can best implement these recommendations. An obvious assumption is that the federal government must collaborate with private industry to enable successful implementation of the national space exploration policy. It explored and described the relationships and issues between the government and the private sector needed for effective collaboration.

Historically, the space industry has been a major driver of new technology development and one source of its competitive advantage in global markets. In 2002, the US Commission on the Future of the Aerospace Industry recognized the key role of the space industry and how its decline over the past decade has affected US competitiveness in global markets. The Commission called in its report for the development of new business models for government–industry interaction [18]. The understanding, insights, and lessons derived from our study should be useful for governmental policy makers when crafting the new business models needed to reinvigorate the space industry and restore US competitiveness in global markets.

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