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THE LUNAR BASE: LIABILITY IN PERSPECTIVE

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ABSTRACT

Continuing exploration of the Moon will include the eventual construction of a lunar base for scientific research, solar power development and mining of surface and subsurface mineral resources. To embark on a major, long-term commercial enterprise, the private international consortium must first address its probably liability for acts of negligence committed by its employees against co-workers and others. Until appropriate commercial liability insurance is secured, the private consortium will be effectively unable to conduct business in this most challenging enterprise. This paper briefly discusses the most significant liability problems with which the consortium will have to deal as interpreted under the provisions of the Outer Space Treaty of 1967, the Moon Treaty, the Commercial Space Launch Activities, as amended, and the regluations promulgated by the U.S. Department of Transportation, enforced by the Federal Aviation Administration relating to the: (1) launch of space vehicles from the Earth destined for the Moon; (2) the robotic surface rover exploration of the lunar surface for sample return and lunar base site selection; (3) the initial human exploration of the lunar surface for lunar base site preparation and temporary occupancy; and (4) the construction of the first lunar base facility.

Finally, we explore the need for a new international treaty that clarifies the significant liability challenges faced by the future private international consortium when planning, organizing and financing the long duration program leading to lunar base development. A strong recommendation is made for limiting the liability of the private consortium to assure completion of the long-term development program. Absent clear, definitive guidance, scientific research and commercial development of lunar resources will prove exceedingly difficult and too costly.

INTRODUCTION

The private international consortium undertaking the long-term lunar base development project must fully examine and deal with both personal and property liability issues.

To address the significant, foreseeable liability issues, it is first necessary to outline a realistic prototype lunar base development project – describing its phases and what is to be accomplished during each phase. We will then separately examine each phase of the overall project addressing some of the significant liability issues that may affect the private consortium, its contractors,

subcontractors, and others associated with the project.

In addressing these issues, we will assume that the launch location is within the jurisdiction of the United States of America; therefore, we will discuss the liability issues as they relate to extant international treaties, and statutes and regulations of the United States of America. The consortium would, however, fully examine the benefits and drawbacks of launching from another state offering comparable launch facilities and infrastructure to those found in the United States.

The phases of the lunar base development project described below are based on certain assumptions that we now have sufficient engineering skills and hardware available with which to undertake and complete the project. Given the many lessons learned from Project Apollo and numerous NASA projects and studies undertaken since 1968 on lunar base development, this is a project that can be accomplished.

THE PROTOTYPE LUNAR BASE DEVELOPMENT PROJECT

The phases of the lunar base development project are set forth below. After a brief outline of each of the four phases, we will examine each of them with respect to liability concerns to determine whether current laws, regulations and insurance industry practices now provide adequate protection. There are numerous management and engineering liability concerns not mentioned below in the four phases; they are intentionally omitted due to limitations on the size and scope of this paper. However, they must all be addressed and resolved by the consortium. Unanticipated liability concerns will arise throughout the project and will have to be resolved to insure completion of the lunar base.

PHASE I. DEVELOPMENT AND PLANNING THE MISSION

The goal of this phase is to accomplish the following objectives: formation of the private international consortium; planning the overall project; determining the launch site location; securing funding for the long-term project; determining the need for further mapping of the lunar surface to locate a base site; deciding whether to use robotic lunar rovers to explore a few potential base sites; determining liability exposure and then securing liability insurance coverage for Phases I, II and III and planning for insurance coverage for the missions to follow; determining the contractors and subcontractors that will provide the management, engineering and scientific services throughout the project; determining the hardware that will be required, such as, the rockets and launch systems and lunar base construction materials, construction machinery and equipment; training pilots, flight engineers and lunar base construction contractors; securing regulatory approvals to move forward with the mapping mission, the robotic, cargo and human missions to the Moon.

The only successful lunar transportation system to date was the Apollo system. It is no longer available. A new transportation system must be developed before the installation of a lunar base can occur. The concept selected for lunar base development will depend strongly on the size of the lunar base envisioned, on the length of the life cycle chosen, and on the mission profile selected.[1] Various lunar missions modes are available; for example, for cargo delivery

[1] PETER ECKART, ed., THE LUNAR BASE HANDBOOK 190 (1999)

missions, a direct one-way mission can be selected; or a one-way mission with lunar orbit staging.[2] The mission profiles will vary depending upon the launch vehicles used and the goal of each mission. For the purpose of examining the liability that a consortium might incur, a familiar crewed mission profile used in the Apollo program has been chosen. It involves: A launch from Earth into an Earth parking orbit; trans-lunar injection (TLI); establishment of a lunar parking orbit; Earth return vehicle remains in lunar orbit; landing vehicle desends to the lunar surface; landing vehicle ascends from the lunar surface; lunar orbit rendzvous (LOR) with the Earth return vehicle; trans-Earth injection (TEI); reentry of crew and cargo directly from a trans-Earth trajectory.[3]

PHASE II. LAUNCH MAPPING AND ROBOTIC MISSIONS

A lunar base site must be located during this phase. At least one mapping mission may be required to provide topographical and compositional data of the potential base site. One and possibly two robotic lunar rover missions, including a lunar sample mission, will provide considerable scientific data concerning the sites, such as the composition of the lunar soil for mining purposes and base construction. This phase does not include a human mission.

PHASE III. CARGO DELIVERY MISSIONS TO BASE SITE

With a base site located, construction materials and equipment must be safely delivered to the site. This phase does not involve a human mission.

PHASE IV. EARLY HUMAN MISSIONS TO BASE SITE

Construction engineers trained to work in the lunar environment must now be delivered to the base site to promptly assemble the first lunar base from the components using the machinery previously delivered to the site. The engineering specialists must assemble the primary base components – prepare living quarters, the water and oxygen generating facilities, communications facilities, activate the nuclear or solar power plant, prepare the protective shielding of all facilities, activate scientific equipment providing data needed at this early stage of base development and conduct necessary studies for future mining operations, undertake scientific studies and monitor scientific equipment for private industry and governments. During this phase, there is concern with problems that could develop involving the operation of a nuclear power plant providing electricity for the base, as well as protection and shielding for the base occupants from solar flares and meteoroids as well as damage to the equipment and scientific instruments. The missions anticipated during this phase are of a short-term nature. More than one human mission is anticipated to accomplish the base assembly work.

LIABILITY CONCERNS – PHASE I. DEVELOPMENT AND PLANNING THE MISSIONS

During this phase of development, liability concerns are determined by state and federal laws and regulations and certain international treaties entered into by the United States applicable to international business entities entering outer space.

The first concerns relate to the creation and financing of the private international

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[2] *Id.* at 180-189
[3] *Id.* at 182

consortium. The consortium will be composed of private companies and persons joining together for the common purpose of returning to the Moon motivated by commercial opportunities, particularly for the extraction of Helium-3 and other resources. Those forming the consortium must demonstrate to others that the opportunities for a return on investment are realistic, capable of being achieved. The consortium partners must be convinced that the legal regime under which they will operate – both on Earth, in orbit and on the lunar surface – will be beneficial to them. They will want to know the extent of their potential singular and collective liability throughout the duration of the long-term lunar base development project. Next, they will need to know whether there exists adequate insurance coverage to protect themselves and their companies in the likely event of death, injury and destruction or damage to property.

Some of the consortium partners will directly contribute hardware and engineering services to the project. As such, they will be governed by liability laws in force in their states. Consequently, the consortium will be compelled to consider potential liability in those states in which their consortium partners conduct business. Broad liability insurance coverage must be provided by a consortium of insurance companies. Given the high coverage limits and potential exposure of the partners, insurance companies must join together to provide coverage for death, injury, workers' compensation and damage to and destruction of property.

Phase I includes development of the business plan and securing regulatory approvals before going forward with the remainder of the ambitious project. Projects involving citizens of the United States or if the launch site is within its jurisdiction, the consortium will be required to work closely with the United States Department of Transportation ("DOT") and particularly with the Federal Aviation Administration (the "FAA"). Consortium partners not citizens of the United States may be supervised by their governments, perhaps under an intergovernmental agreement. International treaty law plays an important role in the affairs of the consortium.

The provisions of the Treaty on Principals Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies, known as the Outer Space Treaty of 1967, become important in that they require specific actions by each State Party signing the treaty. Article VI requires that a State Party "shall require authorization and continuing supervision by the appropriate State Party to the Treaty." Therefore, the United States, in compliance with its international duties, must both authorize (by issuing and controlling launch licenses) and continually supervise the activities of the consortium (a "non-governmental entity"). Failure or negligence in complying with these duties subjects the United States to "international liability for damage to another State Party to the Treaty or to its natural or juridical persons by such object or its components on the Earth, in air space or in outer space...including the Moon...."[4] The Treaty goes on to state in Article VIII that the State Party retains jurisdiction and control over the "object and over any personnel thereof, while in outer space or on a celestial body." Given the foregoing mandates, the United States must exercise some control and oversight of the consortium from the outset of the project. Legislation to accomplish some of this task has been in force since the enactment of the former Commercial Space Launch Act of 1984.

[4] Outer Space Treaty, Article VII, 18 U.S.T. 2410, 610 U.N.T.S. 205, T.I.A.S. No. 6347 (entered into force October 10, 1967).

The consortium partners must be mindful of the requirements of 49 U.S.C. Subtitle IX, Chapter 701 – Commercial Space Launch Activities, formerly the Commercial Space Launch Act of 1984, as amended (the "CSLA") and the regulations promulgated by DOT.

REGULATORY COMPLIANCE ISSUES

Under the CSLA, the Secretary of Transportation is, among other things, to "oversee and coordinate the conduct of commercial launch and reentry operations, issue and transfer commercial launch licenses authorizing those operations, and protect the public health and safety, safety of property, and national security and foreign policy interests of the United States."[5] The Secretary is required to encourage, facilitate and promote commercial space launches and reentries by the private sector[6] as well as issue procedures for requesting launch and reentry licenses.[7]

The consortium will have to address numerous liability concerns of the FAA from the inception of its work. The jurisdiction of the FAA extends to "Earth orbit in outer space; or otherwise in outer space."[8] The author has been advised by a FAA legal representative that currently jurisdiction extends to Earth orbit only. Nevertheless, the consortium must be prepared to address safety and liability concerns of the FAA outside of Earth orbit due to the provision "...otherwise in outer space"[9] and the jurisdiction and control provisions in Article VIII of the Outer Space Treaty. It must be anticipated that the FAA will exert its jurisdiction past Earth orbit – indeed, onto the lunar surface - when it becomes expedient to do so. Continued FAA involvement and oversight may be a welcome development by the insurance carriers.

The Secretary is authorized to issue a launch license for launch and reentry[10] but may "...prevent the launch if the Secretary decides the launch would jeopardize the public health and safety, safety of property...."[11] To satisfy the regulations, the consortium must submit a completed application for launch license to the Secretary of Transportation. The FAA staff and other departments that have safety and political concerns (the most apparent being NASA, Department of State and Defense Department) must carefully examine it.[12] The Department of Transportation must carry out its duties consistent with international treaty obligations as well as take into account applicable foreign laws and regulations.[13] To ensure safety and reduce liability concerns, the FAA must assess the flight risk through orbital insertion as well as identify hazards.[14] The consortium must prepare an analysis that identifies "hazards and assesses risks to public health and safety...."[15] An accident plan will have to be prepared and submitted to the FAA.[16] Next, a payload review will be conducted by the FAA.[17] Since the FAA must comply with Article IV of the 1975 Convention on Registration of Objects Launched into Outer Space, the consortium

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5 49 U.S.C. Section 70101(b)(3) and 14 CFR Parts 413 and 415
6 *Id.* at Section 70103 (b)
7 *Id.* at Section 70120
8 *Id.* at Section 70102(3)
9 *Id.* at Section 70102(3)(C)
10 *Id.* at Section 70104(a)(1), 14 CFR Parts 413 and 415
11 *Id.* at Section 70104(c)
12 *Id.* at Sections 70105(a) and 70109(b), 14 CFR 415.23 and 415.31
13 *Id.* at Section 70117(e)
14 14 CFR 415.35
15 *Id.* at 415.35
16 *Id.* at 415.41
17 *Id.* at 415.51

must provide the requested information.[18] Finally, the environmental impact associated with the proposed launches is also reviewed by the FAA.[19] The environmental impact of base construction and resource extraction may also be reviewed by the FAA although such a review process does not now exist.

During the early stages of launch vehicle construction, launch site selection and planning, United States Government employees or officers may act as observers (monitors) at the production facilities or at the assembly site a contractor of the consortium uses to produce or assemble the launch vehicles.[20] The observer will monitor the activity of the consortium or its contractors to the extent deemed necessary by the Secretary. The consortium will be required to cooperate with the observer. [21] Suspension or revocation of the launch license may occur if the consortium fails to "comply substantially" with the requirements of the launch license or the requirements of applicable law.[22] Public health and safety concerns are of primary importance – in addition to political concerns voiced by the international community and domestic government agencies.[23]

If a reusable launch vehicle is used, it must comply with additional regulations.[24] There exists a strong possibility that the consortium will use a non-reuseable reentry vehicle for the robotic (sample return) mission and may do so for the crewed missions. Therefore, close attention must be paid to the regulations governing the issuance of a license to reenter a reentry vehicle other than a reusable launch vehicle.[25] Special attention must be given to the FAA-conducted payload reentry determination.

Of great importance to the consortium is the setting of insurance coverage limits by the FAA. The Secretary of Transportation must determine the maximum probable loss to third parties and the United States Government associated with the consortium's lunar base development plans.[26] After the launch and reentry license is issued, the consortium must obtain liability insurance coverage or demonstrate financial responsibility in amounts to compensate for the "maximum probable loss" (defined as "the greatest dollar amount of loss for bodily injury or property damage that is reasonably expected to result from licensed launch activities.")[27] from claims by a third party for death, bodily injury or property damage or filed by the United States Government.[28] The coverage limits are set by the Secretary. The CSLA provides that for one launch, the consortium will not be required to obtain insurance of more than $500,000,000 for liability to third parties and no more than $100,000,000 for liability to the United States Government; and, if the world insurance market cannot support such limits, then the consortium must obtain the "maximum liability insurance coverage available on the world market at reasonable cost if the amount is less than $500,000,000."[29] The limits are subject, however, to adjustment on an annual basis.[30] If adequate coverage is unavailable on the world market, the consortium may request a waiver of the license terms or petition for rulemaking if market conditions make compliance impossible.[31]

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18 *Id.* at 415.81
19 *Id.* at 415.101 and 103
20 49 U.S.C. at Section 70106
21 *Id.* at Section 70106(a)
22 *Id.* at Sections 70107(c) and 70108(a)
23 *Id.* at Section 70107(c)(2)
24 14 CFR Part 431
25 *Id.* at 435.1-435.43
26 49 U.S.C. Section 70112(c)
27 14 CFR 440.3(11)
28 49 U.S.C. Section 70112(a)(1)
29 49 U.S.C. Section 70112(a)(3), 14 CFR 440.9
30 49 U.S.C. Section (d)(2)
31 Department of Transportation: Responsibility Requirements for Licensed

Insurance coverage must remain in full force and effect for the period of time specified by the FAA.[32]

The contractors, subcontractors and customers of the consortium must also have insurance coverage.[33]

Finally, the FAA will require the consortium to "make a reciprocal waiver of claims with its contractors, subcontractors and customers... involved in launch services under which each party to the waiver agrees to be responsible for property damage or loss it sustains or for personal injury to, death of, or property damage or loss sustained by its own employees resulting from activity carried out by the licensee."[34] The intent of requiring reciprocal waivers is to limit the cost of managing launch risks by restricting litigation among launch participants and to protect the commercial launch industry from the risk of catastrophic losses from third party liability claims.[35]

Close adherence to the license requirements is demanded by the FAA. Civil and possible criminal penalties await those who violate the terms of the license and the regulations promulgated by the Secretary of Transportation.[36]

Insurance purchased by the consortium will have to provide broad coverage for the mapping and robotic rover missions from launch sites outside the United States. However, for crewed missions, they will launch from selected United States Government facilities that have the necessary launch infrastructure unless they prove to be unavailable or cost prohibitive.

Liability insurance coverage for contractor employees will be a paramount concern throughout the entire project starting with the construction and static testing of the launch vehicles and their innumerable components. Workers' compensation insurance will cover domestic work related bodily injury claims. With the construction of many components occurring outside the United States, appropriate insurance coverage for the foreign workers must be in place. Despite the reciprocal waivers, the consortium must be assured that the suppliers and aerospace workers are protected by their respective employers who may be consortium partners or investors.

Training must be provided for the crews and construction contractors that will travel to the Moon to assemble the first lunar base. Special insurance coverage must be provided for the crew members, contractors and their families for what will initially be deemed a hazardous undertaking. The FAA and other regulatory bodies will monitor all crew training that occurs at existing United States Government training facilities that are being leased by the consortium; it is expected that constructing new training facilities will be cost prohibitive.

The development of the first lunar base has been a matter of considerable discussion over the past 30 years with numerous suggestions for the design of the lunar base or outpost.[37]

Launch Activities; Final Rule, effective October 16, 1998, at http://ast.faa.gov/licensing/regulations/14cfr-440.html, page 51 of 80

[32] 14 CFR 440.11

[33] 49 U.S.C. Section 70112(4)(C)

[34] 49 U.S.C. Section 70112(b), 14 CFR 440.17

[35] *Supra*, Responsibility Requirements for Licensed Launch Activities, 8 of 80 and 55 of 80

[36] 49 U.S.C. Section 70115

[37] PETER ECKART, ed., THE LUNAR BASE HANDBOOK 203-422 (1999) and W.W. MENDELL, ed., LUNAR BASES AND SPACE

The first lunar outpost will be assembled with construction tools and equipment and component parts that have previously been placed at the base site by a lunar lander. Given the potential liability involved with malfunctioning base components, the so-called "construction shack"[38] or habitation module, power plant, communications facility and oxygen generating facility (the major base components) will come under intense scrutiny by the FAA and other domestic regulatory bodies and by those nations from which the consortium partners originate. Well-formulated backup plans must be in place in the event any of the base components are damaged on landing or later prove inoperable.

With property damage possible due to a faulty landing by the lunar lander and the harsh lunar environment, including the invasive lunar soil, property damage insurance coverage limits must be considerable. Given the possibility of damage to its precious base cargo, the consortium will have to devise a means by which to evaluate or monitor the physical condition of the cargo upon landing on the Moon. Careful monitoring is essential before launching a crew to the Moon.

Since no previous lunar missions have involved permanent habitation and construction activity on the Moon, the consortium should anticipate strong liability concerns by the insurance consortium. The first lunar base construction plans will include the layout of the habitation module that uses lunar regolith or lunar soil as shielding against meteorites, and radiation such as galactic and solar cosmic rays.[39]

During Phase I, the consortium partners will address numerous liability concerns not the least of which relates to the series of launch vehicles that will be used to accomplish the long-term mission goals. The mapping mission can be completed by utilizing existing launch systems. The robotic mission or missions will require new technology with more sophisticated orbital and lunar landing systems. The cargo delivery missions will demand heavy-lift launch vehicles and landers to deliver the necessary base components and equipment safely to the lunar surface. Finally, the early human or crewed missions will demand launch vehicles and systems not now available. A new lunar transportation system must be developed by the consortium before the installation of a lunar base.[40] However, some of the early missions can be undertaken with presently available launch vehicles, especially for the mapping and robotic missions. In the immediate future they may prove to be the easiest way to return to the Moon. However, commercial crewed missions to the Moon will require more sophisticated propulsion and cargo delivery systems than those now available; major changes are needed.

It has been suggested that an updated Saturn V heavy-lift booster (including use of the F-I rocket engines) could be used for early crewed missions since no better system has yet to be designed and built. "Updating the Saturn 5 with new materials for fuel tanks and advanced flight electronics technology would produce a launch vehicle that could put 150 – 200 tons into Earth orbit for perhaps less than a few hundred dollars per pound. Such a vehicle could put us back on the Moon with only two launches within five to seven years of the program's initiation."[41]

ACTIVITIES OF THE 21st CENTURY 57-68, 363-373 (1985).

[38] ECKART, *supra* at 277

[39] *Id.* at 220, 253

[40] *Id.* at 190

[41] PAUL D. SPUDIS, THE ONCE AND FUTURE MOON 242 (1996).

Despite the possibility of using an improved version of the Saturn V booster with updated technology to meet the crewed mission goals, considerable liability would remain necessitating the purchase of comprehensive liability insurance coverage. However, no coverage will be sufficient to protect the consortium partners against all the potential risks inherent in the lunar base development project.

Given the technological limitations still inhibiting lunar flights, it will be essential that a reliable, safe transportation system be devised, built, tested and utilized to assure the consortium partners and their investors that the commercial goals are being advanced and met. New or even updated launch systems entail major expense and substantial liability. Untried systems enhance the possibility of system failure with loss of equipment, cargo and crews. Only by means of thorough engineering, quality control and testing programs reminiscent of the Apollo program will reliable launch vehicles be available to crews.

The FAA must be satisfied that the launch vehicles are safe and reliable for the uses intended. Therefore, a primary goal during Phase I is for the consortium and its contractors to design and begin testing the new and updated launch vehicles, lunar landers, and base components needed for installation of the early lunar base.

The consortium planners will agree upon a lunar mission mode for each phase of the project. Each mission mode must be carefully devised to accomplish the mission's goal; various mission modes are familiar and will provide some degree of comfort.[42] Each mode is subject to scrutiny by the FAA and the insurance carriers' experts and may have to be revised to comply with their reasonable demands.

[42] ECKART, *supra* at 180-189

INTERNATIONAL TREATY COMPLIANCE ISSUES

Presently, no international treaty addresses all of the concerns of a private, commercial consortium intent on constructing a lunar base. The consortium is left to piece together a multitude of treaty provisions devised for an earlier time when commercial development activity on the Moon was not a reality. The primary international treaties that must be consulted when devising the lunar base development plan are: (1) the Outer Space Treaty of 1967; (2) the Moon Treaty of 1979; (3) the Convention On International Liability For Damage Caused By Space Objects of 1972; (4) the Convention On Registration of Objects Launched Into Outer Space of 1975; and (5) the Principles Relevant to The Use of Nuclear Power Sources In Outer Space.

In preparation for lunar base development, the consortium will scrutinize international treaty law that could expose it to legal liability for breach of treaty provisions. Special attention will be given to the terms of the Moon Treaty of 1979; it adheres to the property law doctrine of *res communis* – that outer space resources are the "common heritage of mankind" and may only be exploited through the auspices of an international authority acting on behalf of all nations.[43] The Moon Treaty represented a new generation of space legislation, creating legal concepts which extended beyond the 1967 Principles Treaty.[44] Eight nations have ratified the Treaty; consequently, the treaty provisions apply to those nations only. The consortium must determine whether it intends

[43] I. BROWNLEE, PRINCIPLES OF PUBLIC INTERNATIONAL LAW 222-32 (3rd ed. 1979)
[44] NATHAN C. GOLDMAN, AMERICAN SPACE LAW: INTERNATIONAL AND DOMESTIC 90 (2nd ed. 1996)

to accept partners or investors from the eight nations bound by the treaty terms. If partners and investors are subject to the treaty provisions, they will be exposed to potential liability by their respective governments. To abate a possible international dispute, the consortium will want to consult with representatives of the eight nations to determine the extent they intend to enforce the treaty provisions against their citizens.

The United States does not support the *res communis* doctrine of property rights and was not a signatory to the Moon Treaty. The property rights doctrine supported by the United States and other developed nations is based upon the concept of Freedom of the High Seas/Outer Space – meaning that no state may claim or acquire exclusive sovereign rights to an area of pristine space; therefore, unless a state agrees to be bound in another manner, it may engage in or authorize the use and exploitation of space resources. The property rights concept of the United States must be the prevailing doctrine of the consortium; private commercial development on the lunar surface will not occur applying the *res communis* doctrine – even though the work performed on the Moon will ultimately be for the betterment of mankind. Nevertheless, the partners must conduct the lunar base activities giving reasonable regard for the rights of other nations and persons. To do otherwise would most certainly create a continuing source of liability for the consortium and its international investors.

In summary, the planning and regulatory compliance work completed during Phase I is critical to the overall health of the project. Dealing forthrightly with potential liability concerns will in some measure abate those concerns. The ability of the consortium partners to manage risk, however, will keep the project moving forward reducing the prospect of major time-consuming litigation or governmental intervention for safety reasons. Finally, the consortium legal advisors will seek the enactment of new legislation providing more protection from liability concerns than now exists in the United States; considerable attention must be given to this matter if the project is to avoid excessively expensive insurance coverage given the great number of risks inherent in the lunar base project.

LIABILITY CONCERNS - PHASE II. LAUNCH MAPPING AND ROBOTIC MISSIONS

The primary goals of Phase II are to (a) determine the final location of the lunar base site, and (b) if necessary, launch a lunar orbiter to complete topographic and compositional mapping to better examine the potential site and (c) after examining the data, launch a robotic lander mission to gather and examine or return resource samples from the vicinity of the site.

Let us first discuss the mapping mission that precedes the robotic lunar rover mission. More data about the lunar surface, especially a detailed site survey will be required to make sound scientific and operational judgments concerning lunar base siting.[45] Data, such as the regolith thickness, is required to determine whether or not proposed operations at a site are feasible.[46] The *in-situ* knowledge of the lunar surface and geology is restricted to the Apollo, Lunokhod, Luna and Surveyor landing sites and many questions remain to be answered.[47] It is also noted that "...a lunar base must be in a safe area for landing and launching spacecraft. Approaching

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[45] ECKART, *supra* at 212.
[46] *Id.*
[47] *Id.*

spacecraft must have acceptable clear area to land safely and the lunar base must not be located too close to steep slopes or near fresh craters where large rocks are common around the perimeter."[48]

MAPPING MISSION

Having established the mission plans, secured launch licenses for the early phases of the lunar base project, the consortium must make a final determination where the base site is to be located. Site characteristics are of great importance as previously noted. In Phase I, the consortium will have extensively discussed the matter and may have reached a tentative agreement on the base site. A determination would then be made whether existing topographical site data is available. If not, a mapping mission must be scheduled. Available topographical photographs of the lunar surface taken by spacecraft since the Lunar Orbiter series between August 1966 and August 1967 and the Clementine mission (taking topographical and compositional imagery) in February 20,1994 to May 3,1994 (taking 2.5 million pictures and making 330 orbits of the Moon)[49] would have been thoroughly examined to determine the need for further detailed photographs of potential base sites. However, it is believed that overall knowledge of the lunar surface is still patchy and incomplete – therefore, it is important to have detailed topographical and compositional maps of the sites, both with relatively high resolution imagery and remote sensing measurements to determine the chemical variability of lunar soil and by using an orbiting laser altimeter.[50] Given the additional cost and time expended in scheduling a mapping mission, the consortium will exert every possible effort to obtain and examine recent topographical photographs of the lunar surface especially those from the Clementine Mission. It may prove unnecessary to schedule a mapping mission provided that governmental agencies in the meantime map the potential lunar base sites under consideration. However, for the purposes of this paper, we will consider such a mission necessary.

The consortium will give careful consideration to selecting a polar site. "A major advantage of a polar site, from the stand-point of habitat design, is the almost constant thermal and illumination environment. Anywhere else on the Moon, the base design must cope with two-week day and night cycles."[51] And the possibility of water in the craters of the lunar south pole allowing the manufacture of hydrogen and oxygen for propulsion and life support must be considered when selecting a site. The Clementine Mission located a potential base site near the lunar south pole with a landing site in a nearby crater.[52] One possible disadvantage of a polar base site is that Earth-Moon communication will have to be by means of orbital or surface relays; and it is surmised that lunar surface resources are more suitably located near the equator and lunar limb (particularly a rare gas called Helium-3, to be used in future fusion reactors).[53] The prime motivation for the lunar base is resource extraction – therefore, it is believed that mature mare regolith offers the greatest flexibility, given present technology.[54] Given the foregoing, a follow-up lunar rover mission will prove helpful in determining the optimal location for mineral extraction.

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[48] *Id.*
[49] SPUDIS, *supra* at 61, 185-186
[50] ECKART, *supra* at 228, 230
[51] *Id.* at 217
[52] SPUDIS, *supra* at 187, 189
[53] See: ECKART, Table 7.4, Summary of Some Advantages and Disadvantages of Potential Lunar Base Sites, *supra* at 220
[54] *Id.* at 219

In an effort to conserve money, the consortium will learn from the experiences of the team that launched the Clementine Mission. Furthermore, it may be possible to secure funds from governmental agencies and private companies in need to high resolution lunar surface data. By using available technology and a familiar launch vehicle, costs can be contained and the liability reasonably predicted. Given the familiar technology to be used and the fact that the topographical and compositional data may be made generally available at a later time (although it would be deemed proprietary in nature), the FAA and other regulatory bodies should provide the necessary launch license. The insurance industry is familiar with liability concerns that pertain to the lunar mapping mission; therefore, insurance coverage for damage to and loss of property should be available.

With a successful mission, the consortium will have high resolution imagery and resource data pertaining to potential lunar base sites. Additional data obtained can be provided to those governmental bodies or private companies that contributed by paying a portion of the cost of the mission. After locating the lunar base site, the next resource discovery mission of the project will commence.

ROBOTIC LUNAR ROVER MISSION

We next proceed with the robotic lunar rover mission. The consortium will have already determined that such a mission is necessary. Alternatively, a decision could be made to proceed with the next phase of the project (Phase III) to reduce time delays and extra cost in developing a robotic lunar rover and lander if it is believed that sufficient resource data was acquired through the mapping mission. A robotic lander mission with lunar sample return may be planned for geological reconnaissance of the lunar surface in a selected area.[55] It is anticipate that the consortium will have earlier investigated whether a robotic lunar rover using an automation technique known as telerobotics (defined as the remote computer-assisted manipulation of equipment and materials) is available for use on the lunar surface. The consortium would seek a robot with telepresence features (allowing near simultaneous interaction with the field work being performed) so that it could be controlled by an operator from the Earth. It is reported that mobile lunar rovers are still in development but that their importance cannot be overestimated since they can, among other things, be used to traverse long distances on the Moon, performing chemical analyses and mapping the mineralogy of rock exposures.[56] To reduce potential liability resulting from human exposure to the extremes of space and conditions on the lunar surface, alternative means must be utilized to gather necessary resources data.

The increased technical complexity and cost of the robotic lunar rover mission will be justified only if the data obtained proves useful to the consortium. The likelihood of property damage or loss will be much greater since the lunar lander must perform as planned and deploy the robotic rover upon the lunar surface in the area to be mapped and examined. With no human involvement on this mission, except through robot telepresence, liability will be reduced. However, the insurance carriers will require that the mission be controlled by a fully trained and experienced team to increase the possibility of success. A successful mission will assure the consortium that the desired resources are readily available at the selected base site. Due to cost constraints and mission complexity, a sample return vehicle may be used but only if an *in-situ* examination of the

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[55] ECKART, *supra* at 232-235
[56] *Id.* at 233

mineral resources cannot be successfully accomplished.

The ever-present concern about real property rights to a lunar base site and future mining activity in the vicinity will have been fully addressed for it may be a source of substantial liability for the consortium partners. Given the need to satisfy the concerns of the FAA and other governments overseeing the lunar base project[57], the insurance carriers will undoubtedly adopt a conservative stance with regard to international treaty compliance despite the property law doctrine of the United States, earlier set forth. For partners who come from nations that signed the Moon Treaty, they could be compelled (barring a waiver) by their governments to reveal what would otherwise be considered consortium proprietary information – such as "...the results of each mission, including scientific results" that would have to be furnished upon completion of the mission.[58] The consortium will be aware that under Article VI of the Moon Treaty, it does have "...the right to collect on and remove from the moon samples of its mineral and other substances." The consortium would have full control over the collected samples but could be compelled to share samples with other states and the international scientific community for scientific investigation. In the event the consortium wishes to use lunar resources to support its base project, for example, generating hydrogen and oxygen from lunar water and mineral resources, it is helpful to know that "State parties may in the course of scientific investigations also use mineral and other substances of the moon in quantities appropriate for the support of their mission."[59]

Given the international scope of the consortium partners and investors, the exchange of scientific information that will invariably result and the direct involvement of personnel from many nations who participate on the missions, there will be compliance with the spirit and, in most cases, the provisions of the Moon Treaty.[60]

The Moon Treaty provisions allow the installation of manned or unmanned "stations and installations anywhere on or below the surface of the moon."[61]

Questions concerning compliance with Article XI of the Moon Treaty will generate the most controversy. It provides generally that the natural resources of the Moon are the common heritage of mankind not subject to national appropriation by any claim of sovereignty, by means of occupation, or by any other means. To the consortium, a for-profit business entity, it is troubling that the Treaty, Article XI, 3., does not permit the natural resources in place to become the property of the consortium. The fact that no "international regime" has yet been established to "govern the exploitation of the natural resources of the moon as such exploitation is about to become feasible"[62] will give the consortium partners concern; such a regime may be established by those eight nations (and possibly others as well may accede to the Agreement at any time)[63] when it is determined that the consortium's lunar base site for resource exploitation is a reality. The uncertainty engendered by this possible political development must be addressed

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[57] See: Moon Treaty, Article XII, 1. regarding retention of jurisdiction and control over personnel, vehicles, equipment, facilities, stations and installations of State Parties

[58] Moon Treaty, Article V, 1.

[59] Moon Treaty, Article VI, 2.

[60] Moon Treaty, Article VI, 3.

[61] Moon Treaty, Article VIII, 2. (b), Article IX.

[62] Moon Treaty, Article XI, 5. and Article XVIII.

[63] Moon Treaty, Article XIX, 2.

during Phase I of the base project. In addressing this possible development, it will prove helpful for the consortium to seek written confirmation from each signatory nation and the United Nations that they will not later intercede when, on a limited scale, resource exploitation commences.

With a base site located, a site development plan ready, and a decision made to proceed with delivery of the construction materials and equipment, Phase III is ready to commence. In the meantime, crews will have already been trained to assemble the habitat from modular components and other critical life-support facilities with the specially designed equipment. Final plans will have been completed regarding the number of crew members and construction specialists required to complete assembly; the stay time at the lunar base to accomplish the preliminary habitat assembly work and geological site evaluation; and the number and frequency of resupply missions needed to complete base assembly and readiness for full-time occupancy. The phases of base growth for the purposes of mining operations will have been settled upon by the consortium during Phase I.[64]

Thorough crew training in leased government training facilities will have commenced many months prior; such training must meet with the approval of the FAA and, if successful, will reduce liability concerns. To further reduce liability concerns, the direct one-way mission mode[65] selected for the lunar lander missions will neither employ human crews nor involve assent or departure stages from the lunar surface because the component parts of the lander will be partially utilized in constructing the base facilities. With the basic plan decided, Phase III is ready to proceed.

LIABILITY CONCERNS – PHASE III. CARGO DELIVERY MISSIONS TO BASE SITE

The goal of the third phase is to safely deliver in one or more direct one-way missions the base components and support equipment to the base site. The contents of the cargo missions will have been earlier determined premised upon the base design selected by the consortium that best accommodates the mission goals. Since no human crews will be involved with the cargo missions, liability will be less of a concern. However, concerns will be expressed by the insurance carriers as to the reliability of the launch and propulsion systems used to soft-land the base components during one and possibly two or more landings on the Moon. Reliable launch systems and trained teams will abate some of the concerns. It will be useful to recall that there is a brief history of computer controlled lunar landers (such as Luna 16) successfully landing on the surface. However, there exists no prior experience with successfully landing heavy, bulky construction components and construction equipment.

Living and working on the lunar surface entails substantial risks. Therefore, every aspect of the design and fabrication of the lunar base will be carefully reviewed by both government engineers and insurance engineering experts. The base design will have been completed during Phase I to insure base component fabrication, testing and availability. A careful quality control program will again reduce chances of lunar site component failure and, thus, will assist in reducing the otherwise astronomical insurance premiums. At the outset, the lunar base will essentially be comprised of a power plant, a habitat, a laboratory, and construction

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[64] MENDELL, *supra* at 65, 70

[65] ECKART, *supra* at 180; MENDELL, *supra* at 120

and transportation vehicles.[66] The site will have been developed taking into account the needs of the early crews and should minimize extra-vehicular activity, crew time requirements, transportation times, power transfer losses, and material handling requirements.[67]

The base components must be capable of fitting inside the cargo bay of the launch vehicles, not exceeding payload limits; and be able to survive loads during launch, flight and landing; numerous other design requirements and constraints must be fully considered.[68]

The anticipated nuclear power facility will be a ready source of liability concern both on Earth prior to and during launch (from the re-entry of radioactive space debris) as well as while being assembled on the Moon. Such a launch will be given extra scrutiny by the FAA and other involved governments that could be affected if the rocket must be destroyed prior to achieving Earth orbit. The insurance carriers may insist that the consortium comply with Principle 4 of the Principles Relevant To The Use of Nuclear Power Sources In Outer Space[69] requiring that a safety assessment be made by the launching state, or the United States, with results being made available to the public and the United Nations. From an insurance standpoint, it would prove less costly to employ the use of solar panels on the Moon to generate power; however, given the numerous heavy components that must be delivered, there will be insufficient space to accommodate the solar panels that would be needed to generate even a small portion of the power that would otherwise be generated by a compact nuclear reactor. That is not to say, however, that solar energy will not be utilized; indeed, it must be used to power certain station components outside of the base site area and act as a backup power source in the event of reactor repair, shutdown or failure.

The layout of the early base site has been a source of much interest by experts.[70] The manner in which the base is to be constructed will have a bearing on liability. Protection of the crew members is a paramount concern; therefore, the habitat, power source and oxygen generating facility will have to be promptly assembled, tested and made operational. While assembling the habitat, the crew will continue to return to the lander.

Safe delivery of the cargo will assure overall mission success. Close monitoring of every aspect of the missions will be required. An onboard monitoring system must be installed on the landers delivering the nuclear reactor to assure that the radiation level is acceptable and will not endanger the crew that later installs the reactor components nearby the base site.

The one-way mission mode selected would insure that the launch vehicles delivering the cargo spend more time getting to the Moon but will expend less propellant doing so. Speed is not a significant factor when delivering base components since no crew will be awaiting the arrival of the cargo. However, due to possible exposure damage to the components, it is important that the next phase of the project move forward promptly. It is time for the first crewed mission.

With successful completion of the cargo missions, Phase IV is ready to commence. The crews have been trained; the launch vehicles have been constructed, flight tested

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66 ECKERT, *supra* at 245
67 *Id.*at 248
68 *Id.* at 258
69 See GOLDMAN, *supra* at 116

70 ECKART, *supra* at 241-262 and 747-772 – providing two significant examples of lunar base modeling and development

and are ready to take the crews back to the Moon.

LIABILITY CONCERNS – PHASE IV. EARLY HUMAN MISSIONS TO BASE SITE

The groundwork has been laid for humans to return to the Moon to establish a permanent settlement.

Concerns for the safety of the crews who will pilot the spacecraft and the construction engineers who will assemble the base facilities will be of paramount concern. In evaluating liability concerns, we must first consider the mission mode to be used for return to the lunar surface. The mode that will generate the least liability and is familiar from the Apollo program: Launch from Earth into Earth parking orbit; TLI (trans-lunar injection); establishment of a lunar parking orbit; Earth return vehicle remains in lunar orbit; landing vehicle descends to the lunar surface; upon completion of work on the lunar surface, landing vehicle ascends from the lunar surface; LOR (lunar orbit rendezvous) with the Earth return vehicle; TEI (trans-Earth injection); reentry of crew and cargo directly from a trans-Earth trajectory.[71] This mission mode would employ expendable stages and be suitable for crew exchange and resupply of a lunar base.[72] Although there are deficits inherent in using this mission mode, such as the need to establish a lunar parking orbit and for a vehicle to remain in lunar orbit until the landing vehicle returns as well as the increased developmental and hardware expenses, it may still prove to be the safest mode for the early crews. The consortium may wish to reconsider the mode involving Earth Orbit Rendezvous instead of Lunar Orbit Rendezvous[73] should it prove useful for the lunar missions. It is important that there be no accidents during the early missions for fear that it will dampen the enthusiasm of investors, consortium partners and governmental regulators. A major property loss or loss of life would undoubtedly trigger an investigation by the FAA and agencies of other involved nations. The insurance carriers providing coverage for the missions would also investigate to determine the extent of their liability and whether to revise or continue coverage for future missions. Given the foregoing, a familiar mission mode for the early crewed missions is of utmost importance.

Another equally important consideration involves the launch vehicles chosen to fly the crews to the lunar surface. At present, there is no launch vehicle available to complete the task. It was earlier suggested that the Project Apollo launch vehicles, configured as the Saturn V, could be constructed with new materials, electronics, computers and updated rocket motors. The early crewed missions could use similar vehicles to accomplish the base assembly although it would prove difficult to deliver the necessary crews given the size and weight limitations involved in using the former lunar lander (LEM). The consortium will undoubtedly give careful consideration to the choice of launch vehicle to be used to bring the crews to the lunar surface during Phase I; in so doing, it may elect to develop a new launch vehicle, lander and internal systems despite the substantial cost and time expenditure to test and qualify the new vehicles. With the need for at least four crew members to be available to assemble the base components, plus the added weight and subsistence requirements, it is almost certain that a new or substantially revised current or former (Saturn V) launch

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[71] ECKART, *supra* at 182

[72] *Id.*

[73] ROGER E. BILSTEIN, STAGES TO SATURN 60-67 (1996)

vehicle will have to be employed. If a new launch vehicle is to be developed, it involves added risk; consequently, enhanced liability is a factor to be considered by the insurance carriers and the consortium.

To complete base assembly it is believed that more than two missions will be required; crew members will be limited in the amount of time they can spend on the EVA's required to assemble the components. Safety and human needs considerations will compel the crews to periodically return to their lunar outpost or lander.[74] With limited space, oxygen and food in the lander, the first crews will be compelled to efficiently complete their assigned assembly work and then depart for Earth. The next crew will arrive shortly thereafter and continue the next phase of the assembly work continuing to make use of the lunar outpost or lander.

In Phase I, brief reference was made to the impact of the Outer Space Treaty and the Moon Treaty upon base development activity on the Moon as well as later mineral exploitation. Given the governmental "continuing supervision" requirements of Article VI of the Outer Space Treaty, the FAA or another agency will play a significant role in early base development. It has been the practice of the FAA to send a representative to oversee launches involving United States citizens or launches within its jurisdiction. With strict crew size requirements in place, it is doubtful that the FAA will be able to send along a representative; however, by overseeing the project as a whole and with post-mission reporting demands, the FAA will be advised of mission problems with which it must be involved. The insurance carriers will likewise be the recipients of ongoing and post-mission reports to better evaluate the need for oversight before future missions and for adjustments in the coverage limits.

Given the potential dangers of traveling to and from the Moon and working upon its surface, the consortium must provide appropriate insurance coverage for injury to or death of crew members and for their families. Retaining the loyalty of crews and their families will depend upon generous compensation and a comprehensive benefits package.

Liability problems may arise from hasty or improper selection of crew members who are unable to perform as required or who develop medical/psychological problems while in the line of duty. The consortium must determine early whether the workers' compensation laws are applicable to crew members or whether they are exempt given the nature of their duties and the place where those duties are performed. Although coverage for on-the-job injuries must be in place during the crews' training phase (in the state in which they are located), it is doubtful whether coverage is available or required while they are in orbit, in transit to the Moon or working on the lunar surface.

Additional liability concerns relate to operation of equipment and mobile devices (similar to the lunar rover vehicle) while performing work outside the lander or habitat. Careful attention must be given by the crews to provide adequate shielding of the habitat and other critical facilities from solar radiation. The early concern expressed in Phase I about the dangers to the crews and their equipment from meteoroids and radiation such as galactic and solar cosmic rays is now a reality. It is anticipated that the lunar regolith will be utilized as shielding in addition to other materials that can provide a high degree of protection. To accomplish the task of burying the habitation modules with

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[74] *Id.* at 278-279

regolith and rocks, large amounts of lunar soil and rock must be excavated and moved to the base site.[75] To move the soil and rock, transportation vehicles must be sent to the Moon during Phase III and assembled by the first crew and will probably be terrestrial based equipment with track-type/dozer excavators.[76] In an effort at reducing the liability related with operating such large equipment on the lunar surface, the consortium must consider using robotic machines with various mechanical attachments to accomplish some of the heavy-lifting and moving tasks. Even with the reduced gravity on the Moon, heavy lifting and pushing will quickly tire the crews leading to shortened EVA's and possible injury.

One of the critical jobs for the first crew is to create a landing site to be used by future crews. It is anticipated that in the initial stages, a launch and landing facility will consist of not much more than a level area and, possibly, a navigational aid on the lunar surface.[77] The most important aspects of lunar launch/landing facility design include the effects of lunar lander engine exhaust blasting the lunar soil and chemical contamination from rocket plumes. This matter will affect virtually the entire lunar surface base layout.[78] It is expected that the early landing pads will be close to the habitat but in later, more developed bases, the landing pad will be considerably farther away accessible by motorized vehicle.

Next, we address the need for a nuclear power plant. "Due to the Moon experiencing long diurnal cycles, solar energy becomes an awkward energy source to rely on in a continuously inhabited and operated lunar settlement. This is mainly because massive energy storage devices would be needed for power in the night cycle. Nuclear energy offers a relatively compact power source that is not affected by the diurnal day/night cycle, and the technology should be available...."[79] Radioisotope generators have been used where long life, high reliability, solar independence, and operation in severe environments are critical.[80] The consortium will initially rely upon a compact nuclear reactor-based electric power plant for the early base. Given the work to be performed and the energy needs of the crews, they must be provided with a reliable source of electric energy. Despite the fact that liability concerns are raised by use of a nuclear power source, the alternatives (such as solar power or battery power) for providing the crews with sufficient power to complete their work and power their lander or outpost and other vehicles are inadequate. Since the nuclear power plant will have already been delivered to the base site in one of the cargo landers, there is minimal risk for the crew unless the reactor has sustained damage or becomes inoperable. In such event, given the critical need for power, the consortium will have devised backup plans for a redundant power plant that will have been delivered in another cargo lander.

Shielding the crews and their equipment against excessive radiation will be critically important. The shielding design approach consists of two steps: (1) predication of the astronaut risk and (2) evaluation of mission costs, before a mission is approved.[81] "No specific radiation exposure limits exist for crew members of exploratory-class space missions, including lunar base missions. However, radiation protection has to ensure that crew dose rates are kept as low as

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[75] *Id.* at 253
[76] *Id.* at 254
[77] ECKART, *supra* at 250
[78] *Id.* at 250

[79] MENDELL, *supra* at 91
[80] *Id.* at 91
[81] ECKART, *supra* at 526

reasonably achievable."[82] "Crew members on missions to the Moon will be unavoidably exposed to ionizing radiation ... and there is the possibility for exposure radiation from *Solar Particle Events*."[83] Great care will have early been given by the consortium and their contractors to the shielding design process for the habitat and support facilities to insure that the selected materials will enhance the degree of protection. The manufacturer of the component parts of the habitat will be aware that "[A]s high-energy radiation traverses bulk matter, their radiation field changes composition through interactions with the materials in their path. As a result of these interactions, the internal radiation environment within the lunar habitat or a spacecraft can differ appreciably from the incident external environment."[84] In addition to sufficient shielding for the habitat and support facilities, it is suggested that crew members working on the lunar surface (during EVA) be provided with dedicated shelters so that they can rush to the shelter in case of a large solar particle event; the EVA suits now available do not provide sufficient shielding.[85] It will be important for the consortium to undertake studies of solar particle events in an effort to improve the rudimentary forecasting methods now used; the welfare of the crews may depend upon a timely warning of a solar particle event allowing the crews time to seek shelter. With the risk of radiation sickness and death a distinct possibility for all crew members, appropriate insurance coverage must be obtained by the consortium.

Protection for the crews can be enhanced by developing an EVA suit that provides better radiation shielding and by providing a readily accessible radiation shelter for the crews in the event of a large solar particle event or meteoroid impacts. "The actual risk of a meteoroid impact to an object on the lunar surface is difficult to estimate" and for a large but inert structure, like a regolith-shielded lunar base, the consequences of such an impact may be very small; but for a small but vital life support package, the consequences may be disastrous.[86] No means has yet been devised of protecting exposed crew members on EVA to the potential threat of meteoroids; a new space suit assembly and accompanying portable life support system will be required to provide some of the necessary protection. The welfare of the crews will depend upon a concerted research effort in finding new materials to improve shielding but give the crew member apparel flexibility to conduct EVA work.

Shielding the habitat and other vital facilities should prove easier. Use of regolith to shield the habitat has been a matter of scientific and engineering concern for some years and is considered useful but must be fully researched by the consortium and its contractors before designing the base.[87] Through careful research on the lunar surface the consortium's crews will be able to better devise ways in which to reduce their continuing exposure to radiation.

In addition to the hazards mentioned above, the consortium planners must consider other factors relating to the impact of the lunar environment while the crews are on EVA. These factors include: (1) the effects of working in microgravity conditions; (2) the abrasive effects of lunar dust on the space suits, rovers, tools and equipment; (3) lighting conditions that may inhibit EVA activity; (4) thermal and atmospheric conditions that require materials and equipment that can withstand the wide variations of temperature;

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[82] *Id.* at 514
[83] *Id.* at 516
[84] *Id.* at 518
[85] *Id.* at 520

[86] *Id.* at 536
[87] *Id.* at 530-536

(5) lunar surface curvature that permits only line-of-sight communications without the aid of relay antennas or a communications satellite system.[88] By addressing each of the foregoing concerns, the consortium will reduce the hazards to its crews and, thus, reduce its liability exposure.

Plans to provide for crew member health care while on the lunar surface must also be implemented. Failing to provide for emergency medical problems will most assuredly be a source of liability for the consortium. Each of the crew members must receive sufficient health care training to provide for the basic medical needs of the others. When medical problems cannot be diagnosed by crew members, they must be provided with communications facilities to contact the assigned physicians on Earth who can diagnose the medical problem, monitor the crew member and advise what medical action must be taken. In certain critical situations where trained on-site medical attention (for complex surgical procedures) is unavailable, the crew member may die unless returned to Earth in a timely manner. Such an emergency return flight is unlikely with the lunar lander/return vehicle needed for the entire crew's return to Earth. Consequently, each crew member must be thoroughly examined on a routine basis, especially prior to each launch, to determine if they present a medical risk. Despite the most thorough examinations beforehand, medical emergencies on the lunar surface must be expected. Only by anticipating and providing for the medical needs of the crew will the consortium be able to reduce its continuing liability for injury and death.

Finally, we come to the lunar mining equipment that will be used initially to move the regolith and rock to shield the habitat and later be used to conduct mineral exploitation.

[88] *Id.* at 549-552

One of the primary motivations for the consortium undertaking development of the lunar base is to make a profit from the lunar resources (such as Helium - 3) that will be used upon the Earth and to sustain (extracting oxygen and hydrogen from the lunar regolith) the lunar base. Substantial monetary losses will be sustained if the mining equipment is damaged or destroyed in the cargo landers. Given the unique, one-of-a-kind nature of the mining equipment, the insurance carriers involved will be required to pay out large sums of money to the consortium in the event of damage or total loss.

In order to conduct mining activity, special equipment will be required. "Designing lunar mining equipment will be an extremely challenging undertaking. Most mining and processing equipment and techniques used on Earth will not work on the Moon without significant modifications. Like all facilities and elements of a lunar base, mining and processing equipment must be designed to withstand the lunar vacuum, temperature extremes, low gravity, radiation, and the adherence of abrasive dust particles."[89] It is anticipated that early lunar surface mining/excavation activities will feature small, simple machines suitable for excavating lunar regolith.[90] But later mining activities will require dozers, scrapers, front-end loaders, hydraulic excavators and some form of truck or motorized vehicle to transport the lunar regolith. To continue its long-term mining plans, the consortium will have to provide the heavy mining equipment to enhance the efficiency of the extraction process. However, the liability associated with such activity is not considered within the scope of this paper.

Since mining and the extraction of minerals is the primary focus of the consortium in its

[89] *Id.* at 617

[90] *Id.*

efforts at generating revenue for its investors, and since standard Earth mining equipment cannot be used on the Moon, a major investment must be made by the consortium in developing specialized mining equipment. Appropriate insurance coverage must be made available to the consortium to protect its investment in the unique equipment. Thorough equipment design, testing, evaluation and the training of crews to operate it will assure investors and government regulators of the future success of the lunar base development project.

CONCLUSION

The purpose of this paper has been to discuss some of the sources of liability that a private, for-profit business entity will face when undertaking missions to the Moon to construct a lunar base for mineral exploitation.

Numerous liability issues must be addressed by the consortium planners in an effort to realize a successful project. Some of those issues have been briefly addressed in this paper. Apart from design, testing and evaluation of equipment, launch systems, launch vehicles and crew members, the consortium must address the critical need for both international and national legislation further limiting its liability; the current national (United States of America) legislation is inadequate to the task and still exposes the consortium to crippling monetary expenses in the event of major equipment losses or death. Furthermore, real property rights, especially relating to ownership of the permanent lunar base, the minerals and the mining rights upon and under the lunar surface must be dealt with promptly. The legislation must prove beneficial for commercial development activity upon the Moon before a private consortium undertakes financing a multi-billion dollar project that will involve thousands of worldwide citizens over a period of at least fifteen years.

The minerals and other resources obtained from the Moon will be of benefit to all the people of Earth. They will be used to fashion new materials for our use and provide relatively inexpensive, clean fusion energy to generate electric power on Earth. Given the long-term benefits to be derived from such a project, some of which we can only imagine now, it is well worth the investment by the consortium, its worldwide investors and contractors. Paving the way for a successful project will be those creating and enacting new laws and regulations controlling the project. Beneficial legislation and regulations will ensure a safe and profitable project for all involved and bring to people of all nations a wealth of new products and scientific discoveries while setting the groundwork for the future exploration of Mars and beyond.