## Case

Don’t buy any of their responses extend my roach ev they literally have no solvency - -just because an agreement exists doesn’t mean it will work

Have no actual defense on case don’t buy this multilateral stuff they don’t actually have any solvency

#### International mining regimes are inefficient, corrupt, and enable exploitation/private development as much as they claim to prevent it

Roach 11-8-21

Anna Bianca Roach (she/they, degree in conflict studies from munk school of global affairs), 11-8-2021, "The Obscure Organization Powering a Race to Mine the Bottom of the Seas," PassBlue, https://www.passblue.com/2021/11/08/the-obscure-organization-powering-a-race-to-mine-the-bottom-of-the-seas/, // HW AW

On the seafloor, anemones with eight-foot-long tentacles live alongside [blind crabs](https://www.mbari.org/discovery-of-yeti-crab/) that cultivate food in their arm hair, sharks with glow-in-the-dark bellies and [glass sponges](https://www.mpg.de/5595233/climate_archive_deep-sea_sponge#:~:text=Researchers%20at%20the%20Max%20Planck,living%20animal%20species%20existing%20today.) that have been thriving since before the invention of the wheel. “Because of the lack of light and the fact that creatures do need to see each other to eat each other, you get these amazing photoluminescent animals down there,” said Helen Rosenbaum, the coordinator of the [Deep Sea Mining Campaign,](http://www.deepseaminingoutofourdepth.org/) an association of nongovernmental organizations located in Australia, Canada, the United States and the Pacific Islands. “We’re just starting to discover them!” The emerging industry of deep-sea mining is eyeing these otherworldly creatures’ home with keen financial interest: the potato-shaped rocks that provide a foothold for many of these animals in the otherwise silty, slippery environment of the ocean floor contain myriad metals that miners say are needed for a global eco-transition. At the heart of primary decision-making on deep-sea mining ventures is the [International Seabed Authority](https://www.isa.org.jm/), an autonomous organization based in Jamaica that critics say has little public oversight. “Our journey is to drive humankind through a wonderful adventure, which is to go very deep in the ocean to extract some minerals that are necessary for human activity on earth,” says Marie Bourrel-McKinnon, a special assistant to the secretary-general of the Authority, in one of its promotional [videos](https://www.youtube.com/watch?v=tzP-WqTJR_w&t=55s). The ISA, which was established through the 1982 [United Nations Convention on the Law of the Sea](https://www.un.org/depts/los/convention_agreements/convention_overview_convention.htm#:~:text=by%20%22*%22.-,The%20United%20Nations%20Convention%20on%20the%20Law%20of%20the%20Sea,the%20oceans%20and%20their%20resources.&text=The%20Convention%20also%20provided%20the,the%20law%20of%20the%20sea.), is led by the idea of a “common heritage of mankind,” a phrase that is used to explain that the wealth of the ocean floor should belong to all of humanity. Michael Lodge, the Authority’s secretary-general, says in the same video that the ISA’s focus on equity and common resources is what makes the organization special. “This is something that has never been done before,” he says. “It’s actually a unique experiment in human civilization.” **Critics balk at the organization’s lack of transparency and worry that the humanitarian intentions behind the Law of the Sea treaty aren’t enough to ensure that the monetary benefits of the minerals on the seafloor will reach everyone**. Some critics see an inherent contradiction in the Authority’s dual mandate to promote the development of deep-sea minerals while also protecting the environment. King among the coveted metals is cobalt, a mineral used for batteries in phones, electric cars and other electronics. Other minerals include nickel, manganese and copper. On land, these minerals — particularly cobalt — are shrouded in [controversy](https://www.youtube.com/watch?v=tzP-WqTJR_w&t=55s) related to child slavery and the environmental impacts of terrestrial mining, but they’re also in high demand. Large companies like the Canadian-based Metals Company and the American-based Lockheed Martin see these metals as the key to transitioning away from fossil fuels and contend that procuring these metals from the deep sea is a cleaner, more ethical alternative to digging them on land. “We’re on a quest for a more sustainable future, and we need metals to get there,” says [Gerard Barron](https://www.linkedin.com/in/gerardbarron), chief executive of the Metals Company, in an [advertisement](https://vimeo.com/286936275) for what was then called DeepGreen. “I don’t want to see more deforestation. I don’t want to see child labor. And I want to see us access the most sustainable supply of these important metals.” But scientists warn that disturbing these slow-moving ecosystems could hurt the biological pump — a process through which the ocean sequesters a substantial amount of carbon — in ways that can’t be remedied within generations. With the COP26 climate conference underway in Glasgow, Scotland, until Nov. 12, and the UN classifying the 2020s as the “Decade of Oceans,” leaders have been turning their eyes to the health of the seas and to the human activities that damage them. Peter Thomson, a Fijian diplomat and former president of the UN General Assembly who was president of the International Seabed Authority’s decision-making body twice, wrote an [open letter](https://ocean.economist.com/governance/articles/cop26-and-the-ocean-climate-nexus) calling for COP26 to devote attention to sustainability in the blue economy. “What the ocean gives, it can take away,” Thomson writes. “While our understanding of the ocean’s properties is still limited, we know it is the planet’s largest carbon sink, so that closely protecting the special places within it has become urgent work at hand.” Thomson is also the [UN’s envoy for the ocean.](https://sdgs.un.org/topics/oceans-and-seas/SpecialEnvoy) Other diplomats and advocates have spoken to similar concerns, including Monaco’s Prince Albert II. “We still need to avoid overexploitation of the ocean’s natural resources and the ocean floor,” he says in an [interview](https://people.com/royals/prince-albert-urges-bold-action-cop26-united-nations-climate-change-conference/) right before launching the most recent [Because the Ocean initiative](https://www.fpa2.org/en/initiatives/because-the-ocean-005) at COP26. “We cannot allow countries or large corporations to jump on every opportunity they see to exploit oil, gas or precious metal nodules protruding from the seabed without strict regulation.” Some experts and scientists who have worked with the ISA warn that harvesting metals from the mostly untouched ecosystems in the seafloor holds as much potential for global ecological devastation as it does for profit. The Authority has so far sold 31 licenses for companies and governments to explore the bottom of the high seas and is being [pressured](https://news.mongabay.com/2021/07/canadian-miner-looms-large-as-nauru-expedites-key-deep-sea-mining-rules/#:~:text=Nauru%2C%20which%20sponsors%20a%20company,whether%20regulations%20have%20been%20written.) by the small Pacific island nation of Nauru to authorize the beginning of mining operations within two years. Observers, civil society members and former employees of the ISA are raising alarms about **potential conflicts of interest in the organization and a lack of transparency surrounding funding for and profits from mining**. PassBlue’s investigation into the ISA’s operations has involved interviewing eight scientists, researchers and lawyers familiar with deep-sea mining as well as four former ISA employees and scouring documents from the Authority, embassy cables, civil society reports, academic papers and from the UN Appeals Tribunal, which is hearing [disputes](https://www.un.org/en/internaljustice/files/unat/orders/order-unat-2018-328.pdf) from employees who have left the organization. **The portrait that emerges is of an organization with a vested interest in promoting the work of the underwater mining industry, a consistent habit of alienating international marine scientists whose findings favor a more cautious approach to exploiting the ocean floor and a lack of good-faith engagement with civil society.** “If you guys are the first to mine, the first to extract nodules from international waters, it’s opening oceans earthwide,” Adrian Hellman, an Australian environmental scientist, says in an [ad](https://vimeo.com/user79094991) for the Metals Company. “What happens initially is going to affect everything down the track.” Although the push to speed up the start of undersea mining has been triggered by a two-year clause initiated by Nauru, it doesn’t mean that the Authority has to finalize the necessary legislation within two years, Duncan Currie of the [Deep Sea Conservation Coalition](http://www.savethehighseas.org/) says. The group consists of more than 80 international organizations that promote the conservation of biodiversity in the high seas. “**Once regulations are adopted, the voting requirements make it extremely difficult to disapprove a mining application, so it’s likely numerous 30 year contracts will be approved,**” Currie added in an email, noting that the contracts cannot be amended or canceled without the consent of the mining contractor. “Under the two-year rule, contracts can even be approved without regulations being in place. And it is likely they cannot be cancelled or amended without the contractor’s agreement.” PassBlue [published the first of its two-part investigation](https://www.passblue.com/2021/09/29/pressure-builds-to-mine-international-waters-amid-questions-about-ecosystems-and-profit-sharing/) on the ISA on Sept. 29, focusing on the efforts by Nauru to trigger deep-sea mining licenses. A spokesperson for the ISA declined an interview on the topic after repeated requests from PassBlue. A delegate of Nauru, Margo Deiye, attending the 26th session of the ISA, Feb. 18, 2020. The small Pacific island nation has triggered a clause at the ISA giving its member states the ability to demand that the process of granting mining permits to begin soon, possibly jeopardizing the delicate ecosystems of the oceans. ISA Navigating with good intentions? “A lot of idealists go into the International Seabed Authority thinking, ‘Oh wow, this is a place where there’s actually a statement about ensuring effective protection of the marine environment from harmful effects of seabed mining, and making sure that all states can participate in these activities,'” says Kristina Gjerde, who represents the [International Union for Conservation of Nature](https://www.iucn.org/) at ISA meetings. But she says that **the Authority is led more by corporate interests** than for “the benefit of all mankind,” the Authority’s stated goal. “It’s difficult for states to put on their hats as representing the global community interests, as opposed to one particular economic sector or another,” Gjerde told PassBlue. “Now that interest in seabed minerals is rising, this gives rise to very serious concerns about potential conflicts of interest.” The members of the ISA consist of 167 countries and the European Union. Formally, the organization is made up of five bodies: the Secretariat; the Assembly, where member countries are represented; the Council, elected by the Assembly; the Finance Committee; and the Legal and Technical Committee. The latter is tasked with making recommendations to the Council about approving legislation; together with the Secretariat, this committee is the most influential of the Authority’s organs. Longtime observers say that the Legal and Technical Committee has also never turned down an application for an exploration license. Critics of the ISA, including former employees who spoke to PassBlue confidentially, point to its leadership and revenue structure as the source of many of its problems. When deep-sea mining may actually begin, the ISA plans to receive a cut of the profits from the mining operations to cover its operating expenses. Until then, the organization receives money in two ways: through sales of exploration licenses and member states’ voluntary donations or assessed contributions. The ISA collects a $500,000 application fee for each exploration license that it grants as well as a yearly administrative fee of $47,000 per contractor doing the exploring, according to a 2019 [presentation](https://isa.org.jm/files/files/documents/dec-analysis_0.pdf) on the ISA’s payment regime. A [2020 report](https://isa.org.jm/files/files/documents/ISBA_26_FC_4-2006697E.pdf) by the Finance Committee to the Authority’s Secretary-General Lodge expressed concern that many member states haven’t been paying their assessed contributions. Outstanding contributions currently total just over $1.1 million, representing more than a month of the organization’s yearly budget. According to a former finance officer, who spoke to PassBlue but asked to remain anonymous because of the sensitivity of the information, the ISA depends heavily on the exploration license fees for its roughly $10 million annual operating budget. PassBlue has been unable to verify how much of the budget comes from contractor fees, as the Authority did not share audited financial statements after repeated requests to do so. The ISA also has a track record of dismissing scientists or employees who raise concerns about the speed at which decisions surrounding deep-sea mining are being taken, several former employees and longtime observers to the organization said. “I decided to speak out about the fact that, you know, we didn’t have enough science to be making informed decisions about how to manage this activity, unless the decision was not to proceed,” says Diva Amon, a marine biologist who [received](https://www.isa.org.jm/news/isa-secretary-general-presents-inaugural-edition-award-excellence-deep-sea-research-dr-diva) the ISA’s Award for Excellence in Deep Sea Research in 2018, referring to the writing of the Authority’s regulations around deep-sea mining. “That was when the relationship [with the Authority] switched.” Amon says she no longer gets invitations to the workshops that the ISA hosts on environmental management. The workshops are one way that the ISA consults scientists to inform members of the Legal and Technical Committee on policy decision-making. But some scientists who attend the workshops question whether their advice is being heeded. [Pradeep Singh](https://de.linkedin.com/in/pradeeparjansingh), a researcher at the University of Bremen, in Germany, who specializes in the Law of the Sea treaty, said that the reports on the workshops have gotten less substantive and sometimes fail to include the recommendations made by scientists at the gatherings. “If all this scientific input is not included in the workshop report,” he told PassBlue, “it won’t come to the attention of the Legal and Technical Committee.” Singh also said the organization’s selection of scientists attending the meetings isn’t transparent. Sabine Christiansen, a senior researcher at the German-based Potsdam Institute for Advanced Sustainability Studies, agreed. She has been studying the ISA since 2001 and attending the organization’s meetings since 2009, and says that it has a tendency to invite mostly “like-minded” scientists, a sentiment that other observers have also echoed. Who’s steering the ship? The relationship between Lodge, the secretary-general of the Authority, and the Metals Company, the Canadian company that holds three of the 31 current exploration licenses, especially concerns critics of the ISA. Lodge sparked controversy when he [tweeted](https://twitter.com/mwlodge/status/984626856384221185) a photo of himself in 2018, wearing a hard-hat branded DeepGreen, the previous name of the Metals Company, on one of its exploration cruises. Lodge also represented the ISA in an [ad](https://vimeo.com/286936275) for DeepGreen, where he said that mineral resources on Earth are dwindling and becoming more expensive and environmentally damaging to mine. [Baron Divavesi Waqa,](https://en.wikipedia.org/wiki/Baron_Waqa) the president of Nauru from 2013 until 2019, is also featured in the ad as well as in Lodge’s tweeted photos of the deep-sea cruise. [Lodge](https://www.isa.org.jm/secretary-general) is a British lawyer with a background in ocean law and fisheries management and has worked extensively in the South Pacific, where he was a lead negotiator for the 1995 [Fish Stocks Agreement](https://www.un.org/depts/los/convention_agreements/convention_overview_fish_stocks.htm), part of the Law of the Sea treaty. He has been with the ISA as a legal counsel since 1996 and was elected secretary-general in 2016. He did not respond to repeated requests for an interview from PassBlue. Christiansen of the Potsdam Institute says the climate at the ISA has become “less open” since Lodge’s election, citing less-thorough public reports. The Metals Company has been the most active corporation pushing for deep-sea mining to begin. It holds an exploration contract sponsored by Nauru through a local subsidiary. Gerard Barron, chief executive of DeepGreen (and now heading its renamed Metals Company), [represented](https://enb.iisd.org/events/1st-part-25th-annual-session-international-seabed-authority-isa/highlights-and-images-main-1) Nauru at the ISA’s Assembly meeting in 2019. In March 2021, the Metals Company [released](https://metals.co/deepgreen-combines-to-form-the-metals-company/) a $2.9 billion initial public offering stating that it would begin producing metals — and mining the ocean — as soon as 2024. Today, the company appears to be struggling, however, with one major investor [suddenly pulling out](https://www.ft.com/content/6675ac1e-a9a0-48d8-b4e9-aee2ef27c7be) his capital and a [class-action lawsuit](https://www.businesswire.com/news/home/20211028005874/en/EQUITY-ALERT-Rosen-Law-Firm-Files-Securities-Class-Action-Lawsuit-Against-TMC-the-metals-company-Inc.-fka-Sustainable-Opportunities-Acquisition-Corp.-%E2%80%93-TMC-TMCWW-SOAC-SOAC.U-SOACWS) accusing the company of misleading information in documents for investors. Lodge’s public statements on mining also raise questions about his commitment to protecting the environment when that work contradicts the interests of mining companies. Scientists, including the ISA awardee Diva Amon, have for years been calling for a moratorium on deep-sea mining to give scientists and miners more time to understand its potential consequences and devise mitigation strategies. During a [June 2020 hearing](http://www.dekamer.be/media/index.html?sid=55U0739) in Belgium’s parliament, Lodge said he had not heard a “powerful” call for a moratorium and called such an initiative “anti-science, anti-knowledge, anti-development and anti-international law.” In September 2021, 81 governments, more than 500 civil society organizations and several multinational companies, including Google, [jointly called](https://www.iucncongress2020.org/motion/069) for the moratorium. They also called on the ISA to improve its transparency and accountability. A deep-sea jellyfish collected by a remotely operated vehicle from a depth of at least 4,920 feet in the Celebes Sea of the western Pacific Ocean. The red color is common among deep-sea medusas, as it is invisible in the perpetual darkness and at the same time masks any bioluminescence of prey in the jelly’s gut. NOAA-OFFICE OF OCEAN EXPLORATION AND RESEARCH Sharing the profits The ISA was established “with this amazing principle as its fundamental legal basis to act on behalf of humankind,” Gjerde of the International Union for the Conservation of Nature says. The ISA contends that it is committed to prioritizing the interests of developing nations through the financial and economic frameworks that it writes for the exploitation of the riches that lie at the ocean floor. Though the US is not a party to the Law of the Sea treaty, American organizations still have influence over the ISA. Through subsidiaries, the weapons manufacturer Lockheed Martin holds two exploration contracts. The ISA also relies heavily on research by the Massachusetts Institute of Technology for its economic predictions. A [leaked US embassy cable](https://wikileaks.org/plusd/cables/05KINGSTON2220_a.html) from 2005 describes the involvement of the US in the Authority’s meetings, noting that the choice of an “acceptable” candidate to succeed then-secretary-general Satya Nandan would be an issue that the US would “want to address in the near future.” The 31 exploration licenses that the Authority has sold so far are held by a total of 23 governments, nationally owned entities and private companies. Seven of the contracts are set aside as “reserved areas,” which are donated by wealthy countries and meant to benefit developing countries. A closer look at the complex web of the parties involved with the exploration licenses, however, raises questions as to whether the mechanism is working as intended. “Sponsoring states need to think carefully, because if they fail to exercise due diligence and the company causes environmental damage because of that, they can be held liable,” Gjerde says, paraphrasing an [advisory opinion](https://www.asil.org/insights/volume/15/issue/7/advisory-opinion-seabed-disputes-chamber-international-tribunal-law-sea-) of the International Tribunal for the Law of the Sea. Of the contracts reserved for developing countries, three are owned by the Metals Company; one is a Chinese state company; one is a joint venture among Lockheed Martin, the Singaporean conglomerate Keppel and an investment company whose ownership is unknown; one is a joint venture between the Cooks Islands government and the Belgian dredging company DEME; and one is Blue Minerals Jamaica, of which little is known except its association with Peter Henrik Jantzen, a Dane. Indeed, as pressure increases for the Authority to speed up the process of allowing the mining of the deep sea, it remains an obscure body with little public oversight. The next meetings for the ISA Council and the Assembly, postponed last year due to the Covid crisis, are planned for December. “We have all these other activities in the high seas,” Christiansen of the Potsdam institute says. “The ISA is adding new pressures on the ocean, and nobody’s looking.”

## Moon Mines CP

Competitive look at pelton or beard

#### CP text: Governments ought to

#### collaborate with private entities in lunar plant research and appropriation

#### institute law for property ownership in outer space

#### implement a phased approach to mining

#### Healthy competition between companies is a necessity for lunar research and new property ownership laws ensure sustainable and safe mining

Kornuta et. al 19

David Kornuta (project coordinator at United Launch Alliance) et. al (see [the publication](https://www.sciencedirect.com/science/article/abs/pii/S2352309318300099#!)); “Recommendations”, *Commercial lunar propellant architecture: A collaborative study of lunar propellant production*; *Aerospace Engineering*, University of Illinois; 2019; <https://experts.illinois.edu/en/publications/commercial-lunar-propellant-architecture-a-collaborative-study-of>; HW-EMJ

Recommendations146 For Government230 In order to establish a successful lunar propellant plant and fully realize all of its associated benefits requires private and government collaboration. The combined strengths of these players can be leveraged to create the healthiest and most sustainable space endeavor ever undertaken. A freely competed commercial propellant plant employing the US industrial base supported by PPP with Congress, NASA, DARPA, and other US government agencies represents humanities most capable partnership for propelling Earth based economies into the expanses of space. The following section will outline some of the fundamental roles that the US government should take to create this lasting space capability. The challenge is finding ways for the USG to encourage and stimulate the development of a commercial economy without managing it as a common economy. The role of NASA should include providing scientific exploration of the Permanently Shadowed Regions (PSR) of the Moon, assisting in developing early stage technologies and serving as an anchor customer of in-space propellant by proposing a price, quantity, and location of use. US government laboratories should assist in the development of required technology by providing support to commercial companies. Both NASA and other US government laboratories can also help facilitate demonstrations including fully Integrated System Tests (IST)s of a pilot plant. Finally, Congress should play a pivotal role in the creation of regulation and law that is enabling for a Commercial Lunar Propellant Architecture. All of these recommendations are discussed in more detail in the following sub-sections. Develop Precursor “Prospecting” Missions231 Prospecting (or scientific exploration) of the lunar polar regions is critical to building the foundation for a commercial lunar propellant plant. In addition to quantifying the abundance and concentration of the water ice deposits, there is a need to understand the environment as well. The designs of the extraction and transport systems are highly dependent on knowing what conditions actually exist at the mining site. The focal areas for precursor prospecting missions to explore should be: 1. Resource-related properties. We know from the Clementine, LCROSS, Chandrayaan-1, and LRO data232 that there is water ice in significant quantities in lunar polar craters. What is unknown is the distribution of water there, how deep it goes, and how well the regolith conducts heat (which would help with getting heat down to ice deeper in the regolith). 2. The surface environment. In order to transport equipment around to build the site, as well as transporting the product around, it is important to get more details on surface conditions, such as: how firm or soft is the surface; how easily is dust stirred up; what sizes of obstacles are likely to be encountered. 3. Stability. The surface of the Moon is not static. Micrometeorite impacts are frequent enough to create a small but measurable dust content233. Regolith on the sloping crater walls might collapse periodically similar to avalanches—especially with the increased vibrations coming from construction and transport activities. These conditions need to be assessed to design a safe facility, manage the dust problem, and include adequate protection from micrometeorite impact. The detailed recommendations for lunar volatile prospecting have been addressed in the CSM publication that was developed during the 2018 Space Resources Roundtable workshop. These recommendations can be found in the Lunar Polar Prospecting Workshop: Findings and Recommendations [172]234. Develop Prototype Pilot Plant on Earth235 The commercial lunar propellant plant will require a multi-billion-dollar capital investment. One-step in attracting this level of investment and proving the technology might be a smaller, lower-cost pilot plant on Earth. Given how a plant would have to be customized for lunar operations (modularization, weight reduction, safety, redundancy, and sparing, robotic assembly) a pilot plant would have a very positive impact on risk reduction and investor confidence. Most of the robotic operations could be demonstrated on Earth. Once the properties of the resource on the Moon were measured, extraction operations could be performed separately in a cryogenic vacuum chamber. It might also be desirable to install a pilot plant on the Moon itself, prior to starting construction of the industrial-scale commercial production facility. Institute Public Private Partnership236 We believe the establishment of a lunar ice mining operation is a great opportunity for a PPP. As was the case with NASA’s Commercial Orbital Transportation Services (COTS) program, all the elements for success are present. "Significant cost reductions from the norm of cost-plus contracting are possible for new space system elements in NASA’s exploration scenarios. ... There is no basis to conclude that public private partnerships end at low Earth orbit, prohibited or incapable of going beyond that point to deep space, the Moon or Mars." [173]237 First is a legitimate government need for the service. As stated earlier, NASA’s program to return to the Moon as well as operate in cislunar space assembling Mars exploration vehicles will benefit tremendously by the availability of low cost propellant on the Moon. As described in the Demand section, propellant purchased on the lunar surface represents a tremendous savings compared to bringing it from Earth. In addition, NASA will need oxygen and purified water, both products of the mining operation. Second is a defined commercial market for the product. As shown earlier, the commercial GEO satellite industry may drive the purchase of large quantities of propellant in LEO. If this demand is successfully met, other demands will emerge. For example, SpaceX has baselined refueling for its Big Falcon Rocket (BFR) rocket. Though the BFR uses methane fuel, LO2 represents a large fraction of its propellant mass. Blue Origin is also interested in refueling both its third stage and Blue Moon lander use LO2/LH2 propellants. With these two ingredients, the PPP can be structured as a fixed NASA investment into a commercially led mining operation development with a NASA commitment to purchase commodities in some amount. By specifying a price and quantity guaranteeing propellant purchases on the lunar surface, the wheels of American innovation and creativity can be set in motion to create capabilities NASA could not afford on its own. Capabilities that will underwrite a massive expansion of the human species into an entirely new environment. Annually increasing the price until the market responds with the needed capability is one method that could be used to overcome unseen difficulties along the way. To avoid picking winners and let the free market work more efficiently, it might be sufficient for NASA to commit to buy commodities (without investment) to stimulate the private sector to make the investment on its own. Many of these ideas have been discussed extensively. See, for example, the Lunar COTS proposal from [174]238 Promote Healthy Competition239 Though there are many positive impacts to the efficiency, cost reduction, and growth of a freely competed market, there can also be destructive effects depending on the diversity and abundance of customers. Historically, in cases where there is a single high stakes, high value customer to be won, fierce competition can evolve that sometimes hinders the growth of an economic ecosystem. Table 25 [152] depicts the differences between healthy competition (cooperative challenges) and cutthroat competition (competitive challenges). Although either of these approaches can be pursued within a privately competed lunar mine, healthy competition can be encouraged and established early on if the initial government customer strategically structures their propellant procurement process. Examples from other industries show the benefits of openness and information sharing. One positive example is the microwave communications industry. Microwave conferences began to be held in 1953, with competitors sharing the results of their research and collaborative discussions of new trends and developments. As a result, microwave transmission was the dominant form of high-data-rate communications for decades. For lunar propellant production, it is also true that the benefits of a collaborative and healthily competed commercial capability substantially outweighs an approach that is dominated by a single “winner”. Multiple vendors can increase the likelihood of a robust and reliable future supply chain that funds continuous innovation and capacity enhancement. Technological and operational capabilities can also benefit from the diversity of approaches a competitive ecosystem can draw. “Jeff Bezos, founder of Blue Origin and Amazon, comments that…competition should not be cutthroat to determine future monopoly…but creating an ecosystem for other entrepreneurs to thrive upon.” [142]240 Early on, healthy competition can be promoted through the purchasing strategy of the government customers described in the Lunar Surface and EML1 Customers section. The total demand proposed by these initial government customers should be divided among multiple commercial providers. Although this may make it more challenging to close the business case for these early companies, it will encourage them to develop even more lightweight, efficient, and creative solutions. In addition, it will stimulate the establishment of multiple providers that will pursue and cultivate new customers and uses for their products. Once additional customers, both government and commercial, are established, free market competition will continue to evolve with the lunar propellant industry. Facilitate Technology Development241 Various US Government laboratories have technologies that would be very useful in the commercial lunar propellant plant. These technologies could augment the development efforts within US aerospace companies. Partnerships with the US Government or its departments could accelerate the plant design. Some examples of applicable efforts: Air Force Research Laboratory: modular and “plug-and-play” satellite design Naval Research Laboratory: automated space robotic operations Jet Propulsion Laboratory: mobility on planetary surfaces Langley Research Center: in-space assembly techniques and hardware Marshall Space Flight Center: in-space manufacturing Some cooperative efforts between government and industry have resulted in additional capabilities that could be used. NASA’s Tipping Point program has invested in three efforts that could provide robotic assembly and construction capabilities (see the Lunar Surface Construction, Maintenance, and Repair section of this paper). DARPA’s RSGS program242 is developing autonomous failure response algorithms that could be adapted for use during facility construction and operation. In addition, the following technology areas identified in this paper would greatly benefit from government support: Volatile sublimation and capture in a vacuum High efficiency electrolysis Improved cryogenic management systems for in-space storage Ultralight, high efficiency solar panel masts Ultralight deployable solar reflectors Microwave and laser power beaming MW class space rated fission reactors Extreme cold and dust tolerant robotic actuators/components Autonomous control systems and machine learning In-space rendezvous, grappling, and propellant transfer Lunar communications architecture Refuelable, large, LO2/LH2 autonomous lunar landers Refuelable LO2/LH2 in-space transport Propellantless ascent options from the lunar surface Aerobraking and aerocapture in Earth’s atmosphere Institute Law for Property Ownership243 Because legal certainty allows a private entity the ability to know its costs and its potential return on investment, to attract investors, and to plan, U.S. recognition of a private entity’s property interests would advance exploration, investment, and U.S. leadership. Congress should consider codifying the principles of adverse possession as a means of ensuring legal certainty. Typically, adverse possession principles provide an analytical tool for figuring out if a person occupying someone else’s land should be allowed to take it from the original owner. However, some of the elements may be useful for robotic lunar mining as well. For example, Congress could enact legislation recognizing that a company’s human or robotic presence and control over a particular portion of terrain if the presence and control was continuous, open and notorious, actual, and exclusive for three years (or some other number), meant the company was recognized as the owner of the land. This particular proposal would require more analysis to flesh it out fully, and to review such historical analogs at the U.S. 19th century Homesteading and Mining Acts. For Private Sector244 The US industrial base is fully capable of tackling the technical challenges of a lunar propellant plant. In addition, a free market strategy for implementing this capability is critical to its longevity. Private organizations need to establish sustainable business models in order to maintain operations. Costs and commodity prices are bound by investors’ and customers’ availability and willingness to pay. Stakeholders in private enterprise hold companies accountable to generate revenue and produce returns while maintaining competitive edge. Therefore, it is recommended that this effort have significant private sector involvement and investment to ensure the sustained interest and active business development required at the foundation of an entirely new industry with government creating the environment where commercial entities can flourish. The following sections will outline recommendations to the private sector concerning leadership, competition, investment, and participation in the development of space law. Establish Leadership within the Private Sector245 The development and implementation of a commercial lunar propellant plant is a long-term investment strategy with incredible growth potential. As described throughout this study, the hardware solutions are well on their way to maturity. However, these hardware solutions are being developed by a multitude of companies for a variety of applications. It is only through the vision of the commercial lunar propellant plant that they are currently stitched together. To ensure that the development and implementation of this system is successful, it is necessary for leadership and organization of the many constituent parts of the architecture. It is highly recommended that this leadership be established within the private sector to maintain competitive, innovative, profit generating solutions throughout all phases of development. To reap the benefits of free market competition, multiple companies should be encouraged to take on the role of system integrators for competing lunar propellant mines. These private entities may or may not exist today but are necessary to administrate the many subcontractors similar to those identified in this study. In addition, the administrating companies would interface with investment firms, government agencies, and international organizations to generate funding, facilitate technology development, and establish the customer base required to close the business case. In order for these “Commercial Lunar Propellant Companies” to be successful, government support would also be crucial. To encourage and stimulate these privatized activities, the government should incorporate the operation into future space architectures, continue to fund development of applicable technologies, implement the legal framework to support commercial lunar activity, and establish a baseline lunar propellant demand and price as the anchor customer. This relationship was described in detail in the For Government section above. With a foundation in the free market, and with continued support from NASA and the US government, the commercial lunar propellant plants will establish the first permanent foothold for US economic opportunities on the Moon. Strategize for Investment Appeal246 The following sections discusses several strategic recommendations that an emerging commercial lunar mining company should utilize to better posture themselves for investment appeal. These strategies include high fidelity financial modeling, establishing insurability, diversifying applications, and incremental deployment. In addition to promoting investment appeal, these strategies are critical steps towards the realization of this emergent industry. A third party economic study of the commercial lunar propellant plant is essential to proving financial feasibility to the investment community and should be created. A high fidelity financial model contracted to an unbiased, reputable institution would be ideal. Within the high fidelity model, detailed inputs from the constituent companies should be stitched together. This data should include detailed cost, scheduling, and financial information provided for unbiased review and incorporation into the model. The model should treat each element of the lunar propellant plant as a subcontracted item that would be provided by the most capable companies. This high fidelity economic model will be a major element in communicating the investment value of the commercial lunar propellant plant as an integrated system. There is a close relationship between the willingness of investors to contribute to product development and the assessments of insurance underwriters. Investors will generally favor opportunities that are judged insurable. An early dialogue with the insurance underwriting community will be beneficial in the system design process. For example, understanding what are considered the highest consequence failures by the insurers will assist the designers in including the appropriate amounts of redundancy and the selection of components that meet the required standards. It is easier to attract investment to technology development for a mining enterprise if those technologies are not unique to that enterprise. The development program should emphasize the use of technologies that will have multiple applications. For example, space robotics can be used in markets other than lunar propellant—servicing of orbiting satellites, construction of large space structures, and in-space manufacturing. Developing technologies that can also be applied to terrestrial operations opens up an even greater variety of markets. Examples of applicable terrestrial markets include uses in deep-sea resource exploration, remote research, mining, and military operations, as well as the automation of complex industrial processes. Investors are more willing to fund technology development if they can see multiple avenues for return on their investment. Investment is likely to be attracted incrementally as the production capability gains in maturity. A terrestrial demonstration facility will show that the selected technologies can work together. Building and operating a demonstration or pilot plant (as describe in the Develop Prototype Pilot Plant section), will be key to raising confidence by proofing the system. A pilot plant on the Moon could also be important to attract investment, with the additional attraction that it would have some revenue generation capability, although less than the full-scale plant. Promote Investment Opportunities247 Akin to early investments in internet startups in the 1990’s, the emerging space economy offers high reward investments. With a multitude of different systems and services necessary for the lunar propellant production plant, there is substantial opportunity for investment. Dependent on investment timeline, acceptable risk, and desired company profile, an investor can choose the type of venture that will best suit them in this emerging space operation. Among the potential suppliers of the hardware required for the lunar propellant architecture, there is a wide variety of company maturity, size, and ambition. To simplify, these variations can be classified into four categories of investment opportunity. These categories are described below in order of least risk to highest risk. The first category consists of the legacy companies with current operations and mature technologies in the space sector. These companies have been established for over 20 years and usually have business operations in a variety of different fields. Companies in this stage are relatively low risk investments, but many are publicly traded companies with lower potential rewards from the growth of the space economy on a per shareholder basis. The second category consists of space companies recently founded yet mature with focused operations solely on the space economy, such as ULA, SpaceX or Blue Origin. These companies have established their technologies and have proven flight systems which lowers the potential risk for investors, while still allowing for larger potential rewards in the future than legacy companies. The third category is established startups. Companies that fall into this category usually have some established space technologies developed, well-defined business plans, and a strong core team in place. Not all of these companies have substantial investment yet. These companies are usually looking to move past the design phase, develop or further prototypes, or develop complementary technologies. This is a higher risk investment opportunity than the first two, but there are substantially large potential rewards for successful investments. Companies in this stage include Made In Space, Ispace, Astrobotic, NanoRacks, Masten Space Systems, and Lunar Outpost. The fourth opportunity to invest is in seed stage companies. There are many companies in this category and differentiating the good investments from the bad can take some work. Investors should look for the companies that have technically feasible ideas, strong teams to develop the needed technology, and fleshed out business plans. While not always the case, successful investments in early stage companies can reap higher rewards in the future. In an effort to provide a survey of how feasible ISRU on the Moon is, the CisLunar Marketplace Workshops have compiled a substantial database of enabling technologies and their current TRL. Augmented by industry and expert input, that database is the foundation of this study and ongoing discussions. As described in this study, the technologies necessary for lunar propellant production are currently developed or in development. This bolsters the investment prospects for all four stages of space companies. Today, the technologies needed for space resource utilization with low TRL provide excellent opportunity for investment. Given the high maturity of complementary technologies, the support of visionary investors, focus from established and well-respected companies, and talented young startups, it is our recommendation that investment opportunities into space resources and supporting infrastructure be viewed as promising and worth the risk. Because lunar propellant production is equally valuable as a monetary or capability investment, it is equally valuable to private or government investors as well. The companies that succeed in this venture will not only help shape the space economy but also advance space exploration while improving life here on Earth for generations to come, and potentially reap substantial returns. Active Role in Space Law248 Companies intending to extract space resources from the Moon or any other celestial body will need legal certainty that: They will have exclusive rights over a certain surface area of a celestial body where the resources extraction will take place Their operations will be protected from interference from competing companies They will have ownership rights over any extracted resources Since Article II of the Outer Space Treaty is broadly seen as prohibiting ownership rights (whether sovereign or private ownership rights), mining companies should be prepared to work with international organizations (such as the Hague Working Group on Space Resources). These organizations are currently seeking to formulate a method of providing companies with exclusive mining rights (which could be something less than property rights). Regarding non-interference with existing mining operations, existing international law already contains a requirement that space operators carry out their activities with “due regard” for the activity of others. However, international organizations are similarly occupied with creating a clearer international understanding of how interference can be best avoided. Industry input is critical as these details are worked out. With respect to the ownership of extracted resources, international law is rather clear that the mining company may assert such ownership rights. This interpretation of international law has been bolstered by domestic legislation in both the United States and Luxembourg. That said, companies should continue to monitor and be involved in any new legal developments on this topic. Technical249 The concept for commercial propellant production and distribution we have described in this paper is based on the adaptation of existing technologies—hardware, software, and operational concepts. The basic science of extraction, processing, transport, storage, and delivery systems exist. Their application to a low gravity, cold lunar crater environment using only robotics for maintenance is the great challenge. Technology development effort for the project should follow three tracks: Detailed modular design concepts for extraction and transport, based on information gained from precursor prospecting and environmental characterization missions Detailed modular concepts for power, processing, storage and delivery, that modify terrestrial system components for space flight and the lunar environment Algorithms and software that automate all phases of the project The “modular” requirement for system parts comes from the need to assemble, maintain and repair everything using robots. Modularity simplifies robotic hardware and software, and it makes parts storage and delivery much more flexible. Leverage Existing Systems250 The lunar propellant plant is similar in many ways to chemical plants on Earth. All such plants have chambers where the essential chemistry takes place; tanks for holding feedstock, intermediate and final products; plumbing and vehicles for moving products around the facility; power supplies and distribution; and control systems that automate most of the processes and actuate safety features. To re-engineer a terrestrial chemical plant for the lunar propellant application, major tasks will include: Modularization. Chemical plants are often highly integrated, with large components weighing several tons. A lunar plant design will need to be broken into smaller parts that can be robotically moved from the landing site to the installation site, and robotically assembled with ease. Weight reduction. Builders of terrestrial plants are relatively unconstrained by the masses of components, other than limits of available lifting gear. Because launch and space transport are highly weight-constrained, designers should consider options such as operation at lower pressures (which reduces the weight of chambers and pipes), even if some reduction in efficiency would occur. Safety in design. Some properties of the lunar environment pose hazards to which terrestrial plants are not exposed. Most important are radiation and micrometeorites. Plant systems must be tolerant to these hazard sources. Redundancy and sparing. Investors, insurers, and customers will insist on a high level of assurance that production will be continuous and reliable. Repair times will be much more dependent on redundancy and sparing than for terrestrial plants. Having to wait for component delivery from Earth to restore production after a failure will be unattractive to investors. On-site spares, redundant components, automated responses, and robotic services will be key. Apply Automation251 Robotic operations follow one of four general modes: scripted, teleoperated, supervised autonomy and full autonomy. Choice of which mode to use depends on the availability of information (e.g. positions and orientation of components) and connectivity. Design of the lunar propellant installation will assign these modes to the various robotic operations during site preparation, construction, operation, maintenance, and repair. Fully autonomous operation sounds difficult, but it has been demonstrated in space252. Other automation features that need to be included in the design will be: Fault detection, identification and response. Robots will encounter components that are not in the nominal configuration (e.g. bent connectors). They themselves will also experience failures (e.g. electrical shorts, suspension problems). If such anomalies can be resolved without involving humans on Earth, the efficiency will be greatly improved. Process monitoring and control. Terrestrial chemical plants often include human oversight, both in control centers and around the plant. Lunar plant control must be completely automated, because the facility will have only intermittent connectivity with humans on Earth or at NRHO (which will only be intermittently occupied in any event). Without fully automated operation, failures that occur at times without human oversight could propagate and have serious consequences. Establish Standards253 Each subsystem of the lunar extraction and production facility will have to interface with other systems throughout its life cycle. These interfaces should be standardized in order to reduce costs (Standards as Cost Savings) and improve efficiency. The overall complexity of this facility is comparable to that of the ISS. Even on ISS, examples such as NASA’s International Docking System (IDS) demonstrate the necessity of standardization in space. A list of interfaces that must be considered in the design of the lunar propellant plant includes:  Pre-launch interfaces with ground support equipment (mechanical and electrical)  Launch vehicle interface (launch restraints, restraint release power, telemetry)  Lunar lander interface (at least mechanical)  Interface with transport robot (at least mechanical, probably also power for survival heat)  Interfaces with other facility subsystems (mechanical, power, control, telemetry, fluids, thermal) A design challenge for most components will be the wide variety of environments that they experience—launch vibrations, landing forces, lunar day and night, abrasion from regolith, transport by robot and in some cases the extreme cold of the shadowed craters. The interface designs will be driven by the need to accommodate all of these environments. Propellant transfer interfaces need multiple fluid paths, mechanical, power, data and command interfaces as well. Any space vehicle receiving or transferring lunar propellant will need a fuel and an oxidizer interface for primary and attitude control propellants. There may also be a need to exchange ullage as well as propellant. As described in the Rendezvous and Capture section, Altius Space Machines has a Phase II SBIR to develop a cryogenic transfer interface. Implementing these types of interfaces as standards is crucial to efficient implementation of the lunar propellant architecture. The benefit of standardizing these interfaces includes simplicity of planning, reduced cost, and enhanced reliability. Relevant research is being performed by the DLR for modular design of satellites. In a project called Intelligent Building Blocks for On-Orbit Satellite Servicing and Assembly (iBOSS)254, an Intelligent Space System Interface has been developed. Potentially, generalizing such promising interface designs may be greatly beneficial in engineering the assembly of the lunar plant. However, there is a danger to overly specific interface standardization, namely the potential inability to accommodate new features. An insight may be drawn from the 120V wall plug. It is a standardized design, but does not greatly constrain the equipment that it powers. “Flexible standardization” is the ideal approach for a system of the complexity of the lunar propellant plant. Path Forward255 A commercial lunar propellant system will be a vast undertaking. A phased approach is recommended, each phase serving to increase maturity of the technologies, attract increased levels of investment, and develop markets and customers. An example of a phased development program is: Phase 0: Establish business viability. In order to secure adequate funding, the following items must be completed prior to, or in parallel with, to the subsequent phases: NASA and others propose propellant demand, price, and location of use as customer base Prospecting and science exploration of lunar polar regions Improved space law to facilitate commercial utilization of lunar resources Commercial lunar propellant companies form for managing the many subcontractors Third party high fidelity financial models Secure investment for technology development and maturity Technology applied to terrestrial markets to generate revenue Implementation of international lunar communications architecture Phase I: Individual technology demonstrations. Organizations will continue to raise the TRL of critical hardware elements through technology demonstrations. This phase can be greatly accelerated with PPP: Demonstrating sublimation from regolith simulant Robotic demonstrations of plant assembly techniques Reusable lunar lander development Hydrogen/oxygen-fueled vehicles for operations in Earth orbit, such as LEO-to-GEO tugs Additional technology demonstrations outlined within previous sections of this study Phase II: Subscale terrestrial demonstration plant. Although conducted on Earth, elements of this IST could be conducted in simulated Permanently Shadowed Regions (PSR) environments including: Assembly demonstrations of all components of the plant Robotic operations in cryogenic conditions Efficient subscale processing plant with lightweight components System interface validation Vacuum chamber IST with cold wall for end-to-end system verification Phase III: Subscale lunar production plant. The following activities will boost the TRL of the integrated lunar propellant production plant to 9: May be scaled to fit on a single launch vehicle for delivery to PSR Designed for limited operations or production Demonstrates collection, transport, processing, and storage of cryogenic propellant Propellant produced can support robotic exploration and sample return missions Becomes seed for full-scale production plant Phase IV: Full-scale commercial lunar production facility. Initiates US industrialization on another terrestrial body. Establishes sustained presence on the Moon. Technology has been fully vetted Customer base is well established Required resource mapping complete Investment has been secured The legal framework is in place All infrastructure is delivered to the lunar surface Full-scale propellant production in support of space missions underway Transport from lunar surface to space is in place Phase V: Iterative system enhancement. In the decades following the establishment of the lunar propellant plant, new technologies will be integrated into the system to improve performance, decrease operating costs, and enable effective utilization of its products. Utilization of lunar propellant to expand the facility (Bootstrapping Deployment section) Installation of tracks and roadways for robotic operations (Surface Mobility section) Propellantless ascent systems for delivery to orbit (Propellantless Ascent section) Efficient LEO delivery (Aerobraking/Aerocapture for LEO Delivery section) Unforeseen new technologies driven by healthy commercial competition to innovate Phase ∞: Well established lunar propellant industry. The Moon and its resources become a gateway to the solar system. Its resources are used for space exploration as well as to benefit life on Earth. Robust and highly scalable space economy (Enabled Industries section) Improved scientific understanding of the Moon and beyond (Science Benefits sections) Enables solutions to Earth’s energy crisis (Energy section) Supports space habitation (Supporting Human Settlement and Existential Threats sections) Is the first step in humanity’s journey through the cosmos (Grand Science and Exploration) Establishing a commercial lunar propellant plant is fundamental to the exponential growth and prosperity of humankind. This effort requires industry, government, and academic collaboration on a scale more extensive than humanity’s greatest historic engineering achievements. Like those achievements, the challenge is great but the value is even greater. Producing far more than just near term economic gains, this Commercial Lunar Propellant Architecture enables entirely new opportunities for human civilization.