# 1NC TOC R3

### 1

#### **Interpretation – appropriation requires private ownership rights**

Hobe et al 17 [Hobe, Stephan, Bernhard Schmidt-Tedd, Kai-Uwe Schrogl, Martin Reynders, and Rada Popova. 2017. Cologne Commentary on Space Law - Outer Space Treaty : Кёльнский Комментарий К Космическому Праву - Договор По Космосу. Cologne Commentary on Space Law. Berlin: Berliner Wissenschafts-Verlag. https://elibrary.bwv-verlag.de/book/99.105025/9783830522195] JPark

In sum, it is reemphasised that, according to Article II of the Outer Space Treaty, outer space (including the moon and other celestial bodies) is not capable of being appropriated and that no activities by States or Non-State entities or natural persons will ever give rise to a legitimate claim to ownership rights. In other words, the prohibition of ‘national appropriation’ means that there are no State (sovereign or public) or private ownership rights in relation to outer space, including the moon and other celestial bodies.

#### Violation:

#### Not “appropriation by ‘way of use’” – it does not give way to private ownership rights

Hobe et al 17 [Hobe, Stephan, Bernhard Schmidt-Tedd, Kai-Uwe Schrogl, Martin Reynders, and Rada Popova. 2017. Cologne Commentary on Space Law - Outer Space Treaty : Кёльнский Комментарий К Космическому Праву - Договор По Космосу. Cologne Commentary on Space Law. Berlin: Berliner Wissenschafts-Verlag. https://elibrary.bwv-verlag.de/book/99.105025/9783830522195] JPark

However, since Article II provides that outer space ‘is not subject to’ appropriation by way of use, it follows that no amount of the use of outer space will ever suffice to justify, from a legal view-point, a claim of ownership rights over the whole, or any part of outer space, including the moon and other celestial bodies. Thus, for example (as discussed further below), the exploitation of the natural resources of the moon and other celestial bodies constitutes a ‘use’ of outer space that is contemplated by the freedom principle specified in the Outer Space Treaty, subject to any other qualifications set out in the space treaties. However, for the purposes of Article II of the Outer Space Treaty, this use does not and can never be such as to constitute a ‘national appropriation’ giving rise to ownership rights.

#### 1AC Hertzfield and Pace proves the violation – also cx

Hertzfeld and Pace 13 (, H. and Pace, S., 2013. International Cooperation on Human Lunar Heritage. [online] Cpb-us-e1.wpmucdn.com. Available at: <https://cpb-us-e1.wpmucdn.com/blogs.gwu.edu/dist/7/314/files/2018/10/Hertzfeld-and-Pace-International-Cooperation-on-Human-Lunar-Heritage-t984sx.pdf> [Accessed 18 January 2022] Dr. Hertzfeld is an expert in the economic, legal, and policy issues of space and advanced technological development. Dr. Hertzfeld holds a B.A. from the University of Pennsylvania, an M.A. from Washington University, and a Ph.D. degree in economics from Temple University. He also holds a J.D. degree from the George Washington University and is a member of the Bar in Pennsylvania and the District of Columbia. Dr. Hertzfeld joined the Space Policy Institute in 1992. His research projects have included studies on the privatization of the Space Shuttle, the economic benefits of NASA R&D expenditures, and the socioeconomic impacts of earth observation technologies. He teaches a course in Space Law and a course in microeconomics through the Economics Department at G.W. Dr. Hertzfeld has served as a Senior Economist and Policy Analyst at both NASA and the National Science Foundation, and has been a consultant to many U.S. and international organizations, including a recent project on space applications with the OECD. He is the co-editor of Space Economics (AIAA 1992). Selected other publications include a study of the issues for privatizing the Space Shuttle (2000), an analysis of the value of information from better weather forecasts, an analysis of sovereignty and property rights published in the Journal of International Law (University of Chicago, 2005), and an economic analysis of the space launch vehicle industry (2005). Dr. Hertzfeld has also edited and prepared a new edition of the Study Guide and Case Book for Managerial Economics (Sixth Edition, W.W. Norton & Co.). Dr. Scott N. Pace is the Deputy Assistant to the President and Executive Secretary of the National Space Council (NSpC). He joined the NSpC in August 2017. From 2008-2017, he was the Director of the Space Policy Institute and a Professor of the Practice of International Affairs at George Washington University’s Elliott School of International Affairs. From 2005-2008, he served as the Associate Administrator for Program Analysis and Evaluation at NASA. Prior to NASA, he was the Assistant Director for Space and Aeronautics in the White House Office of Science and Technology Policy. From 1993-2000, he worked for the RAND Corporation’s Science and Technology Policy Institute, and from 1990-1993, he served as the Deputy Director and Acting Director of the Office of Space Commerce, in the Office of the Deputy Secretary of the Department of Commerce. In 1980, he received a Bachelor of Science degree in Physics from Harvey Mudd College; in 1982, Masters degrees in Aeronautics & Astronautics and Technology & Policy from the Massachusetts Institute of Technology; and in 1989, a Doctorate in Policy Analysis from the RAND Graduate School.)-rahulpenu

International Cooperation on Human Lunar Heritage The U.S. Apollo Space Program was a premier technological accomplishment of the 20th century. Preserving the six historic landing sites of the manned Apollo missions, as well as the mementos and equipment still on the Moon from those and other U.S. (e.g., Ranger and Surveyor) and Soviet Union (e.g., Luna) missions is important. Some of the instruments on the lunar surface are still active, monitored, and provide valuable scientifi c information. But recent government and private-sector plans to explore and potentially use lunar resources for commercial activity raise questions about the use of the Moon and potential accidental or purposeful threats to the historic sites and scientific equipment there.

#### Does not meet “appropriation by ‘occupation’” – the international legal definition of ‘occupation’ is not applicable to outer space

Hobe et al 17 [Hobe, Stephan, Bernhard Schmidt-Tedd, Kai-Uwe Schrogl, Martin Reynders, and Rada Popova. 2017. Cologne Commentary on Space Law - Outer Space Treaty : Кёльнский Комментарий К Космическому Праву - Договор По Космосу. Cologne Commentary on Space Law. Berlin: Berliner Wissenschafts-Verlag. https://elibrary.bwv-verlag.de/book/99.105025/9783830522195] JPark

In similar vein, it also follows that no amount of ‘occupation’ of (a part of) outer space can constitute an appropriation. The term ‘occupation’ includes one of the traditional international law modes by which States can acquire (terrestrial) territory, where a State may seek to claim a legitimate legal interest in territory originally of a terra nullius nature, if it can show that it had subsequently exercised sufficient ‘continuous and peaceful effective control’ over that territory.48Similarly, a display of continuous and peaceful effective control may lead a State to claim territory that was initially part of the sovereignty of another State, under the international law principle of ‘prescription’.49 As noted, these modes of acquisition, as well as the concept of ‘continuous and peaceful effective control’ giving rise to ownership rights, are not applicable to, or compatible with the res communis nature of outer space.

#### Legal precision’s key – anything else obviates the whole definition of appropriation

Hobe et al 17 [Hobe, Stephan, Bernhard Schmidt-Tedd, Kai-Uwe Schrogl, Martin Reynders, and Rada Popova. 2017. Cologne Commentary on Space Law - Outer Space Treaty : Кёльнский Комментарий К Космическому Праву - Договор По Космосу. Cologne Commentary on Space Law. Berlin: Berliner Wissenschafts-Verlag. https://elibrary.bwv-verlag.de/book/99.105025/9783830522195] JPark

What the Outer Space Treaty prohibits is an ‘appropriation by use’ but not the ‘use’ of outer space, which is guaranteed. Thus in practice, it may be more complex and difficult to draw a line between ‘use’ and ‘appropriation by use’, but such **complexity** must not nullify the legal principle of non-appropriatio**n**.

#### Voter for Limits --- anything that takes place in space becomes topical– tourism, mining, constellations, rockets, skydiving, lunar bases, exploration, radio waves, photography

#### And Ground --- only appropriation is controversial, not all private space activities. Guts access to core generics

#### Competing Interps – you can’t be reasonably topical, it’s a binary question and reasonability is arbitrary

### 2

#### Spacefaring nations should:

#### -fully fund and implement the Pacific Ocean Neutrino Experiment

#### - substantially increase investments into sustainable aquaculture, including funding and implementing the Lunar Hatch Program

#### Plank 1 solves neutrino research – it’s by far the consensus among astrophysicists – answers their IceCube indicts – it also answers Lee which says the barrier to research is having lots of water

Sutter 22 – PhD in Physics, astrophysicist at SUNY Stony Brook and the Flatiron Institute in New York City. Paul received his PhD in Physics from the University of Illinois at Urbana-Champaign in 2011, and spent three years at the Paris Institute of Astrophysics, followed by a research fellowship in Trieste, Italy, His research focuses on many diverse topics, from the emptiest regions of the universe to the earliest moments of the Big Bang to the hunt for the first stars [Paul, “Astronomers propose building a neutrino telescope — out of the Pacific Ocean,” 1/19/2022, <https://www.space.com/pacific-ocean-neutrino-detector-p-one-concept>, DKP]

Whispers in water

The mass of neutrinos has no explanation in the Standard Model of particle physics, our current and best theory of fundamental interactions. So physicists would really love to do two things: measure the masses of the three neutrino flavors and understand where those masses come from. That means they have to do lots of experiments.

Most neutrino detectors are pretty straightforward: You either set up a device to generate a ridiculous number of the buggers in a laboratory, or you build a gigantic array to capture some that originate off Earth.

These experiments have made a lot of progress and gotten bigger with every generation. The Kamiokande experiment in Japan, for example, famously detected the neutrinos coming from the supernova 1987A. But they needed a vat of more than 50,000 tons of water to do it.

In recent years, the IceCube Neutrino Observatory in Antarctica has upped the ante. That observatory consists of a solid cubic kilometer (0.24 cubic mile) of ice at the South Pole, with dozens of Eiffel-Tower-sized strands of receivers sunk a kilometer (0.6 mile) into the surface. After a decade of work, IceCube has discovered some of the most energetic neutrinos ever and made tentative steps toward finding their origins. (Hint: It involves really high-energy processes in the universe, like blazars.)

Why do both Kamiokande and IceCube use so much water? A large chunk of pretty much anything can serve as a neutrino detector, but pure water is ideal. When one of the trillions of passing neutrinos happens to strike a random water molecule, it gives off a brief flash of light. The observatories contain hundreds of photoreceptors, and the purity of the water allows those detectors to pinpoint the direction, angle and intensity of the flash very accurately. (If the water had impurities, then it would be difficult to reconstruct where the flash came from within the volume.)

From there, they can reconstruct the original direction of the incoming neutrino and get a handle on its energy.

The great Pacific neutrino patch

This is all well and good for normal, everyday neutrinos. But the most energetic neutrinos are extraordinarily rare. Those extremely rare neutrinos are also the most exciting and interesting, however, because they can be caused only by the most gargantuanly powerful events in the universe.

Unfortunately, the entire might of IceCube, after a decade of observation, has been able to capture a mere handful of these ultra-powerful neutrinos.

So we're gonna need a bigger boat … I mean, detector.

This is the idea behind the Pacific Ocean Neutrino Experiment (P-ONE), a new proposal described in a paper published to the preprint server arXiv in November: to turn a massive swath of the Pacific Ocean into nature's own neutrino detector.

Once again, the concept is surprisingly simple: Find a suitable, lonely part of the Pacific. Pretty easy. Construct long strands of photodetectors — and I mean long, at least a kilometer long. Sink these strands to the bottom of the ocean, preferably to a depth of over a mile (2 km). Attach floats to them so they stand upright in the water, like giant mechanical kelp.

The P-ONE design currently involves seven 10-string clusters, with each string hosting 20 optical elements. That"s a grand total of 1,400 photodetectors floating around an area of the Pacific several miles across, providing much more coverage than IceCube.

Once it's up and running, you just need to wait. Even neutrinos will strike some ocean water and give off a little flash, and the detectors will trace it.

#### Plank 2 solves substantially increase funding for the Lunar Hatch Program –1AC Przybyla that’s key to solve – Harker is Yellow

Przybyla 21, Cyrille. "Space aquaculture: prospects for raising aquatic vertebrates in a bioregenerative life-support system on a lunar base." Frontiers in Astronomy and Space Sciences 8 (2021): 107. (Studies Aquaculture Research at University of Montpellier)

Space Aquaculture: A Relevant Source of Complementary Nutrition Resupplying a base in space from Earth on a weekly basis is neither economically nor technologically feasible (a trip to the Moon takes 4–7 days, and to Mars 5–8 months). A short-term solution is to provide processed and prepackaged space food. However, lyophilized conservation is unstable, especially concerning essential nutrients such as potassium, calcium, vitamin D, and vitamin K, which is involved in muscle and bone maintenance. The micronutrients most sensitive to storage degradation are vitamins A, C, B1, and B6 after one year at ambient temperature (Cooper et al., 2017). A possible nutrition strategy for space bases could be to couple local fresh production with supplies brought by cargo spaceships. Providing fresh, nutritious and safe food is imperative for the success of a manned base on Moon or Mars. Recent studies have shown that food energy needs during a spaceflight are similar to those required on Earth. If energy intake is reduced, the human body is subjected to physiological stress causing cardiovascular deconditioning, bone demineralization, muscle atrophy and immune system deficiency. Moreover, microgravity exposure reduces the nitrogen balance in an astronaut’s body. This results in a 30% reduction in protein synthesis (Stein, 2001). A study of previous manned missions in low orbit monitored the crew’s physical performance consuming food commonly used in space missions and showed that an increase in carbohydrates (from plants) and a decrease in animal protein and fat can disturb the diet balance (Gretebeck et al., 1994). Ideally, a fresh animal-based food source should be included in the diet of space residents. Seafood is one of the healthier animal products for human nutrition. Its nutritional merits and protective benefits have been abundantly described over the last century. Like wild fish, aquaculture fish sequester digestible proteins and essential amino acids, lipids, including essential polyunsaturated fatty acids (PUFAs), essential vitamins and minerals in their muscles. Vitamins are precursors of molecules that are essential coenzymes for enzyme catalysis. When the synthesis of coenzymes is not included in an organism’s genetic heritage (this is the case for Homo sapiens), their natural synthesis must be achieved by the ingestion of living cells. These cells are provided by a diet of plants or animals. In addition to micronutrients, farmed marine, brackish and freshwater fish can sequester ALA (PUFA precursor), EPA or DHA from their diet (Tocher, 2015). Several aquaculture fish have the physiological capability to produce EPA and DHA (ALA chain elongation) and store these essential compounds (Morais et al., 2015; Gregory et al., 2016). The micronutrients commonly found in fish and their health benefits are presented in Table 1 (Tacon et al., 2020). At the beginning of the 1980s, the first study on the possibility of space aquaculture emphasized the shared points between recirculating aquaculture systems (RAS) and BLSS (Hanson, 1983). Yet although aquaculture seems to offer a relevant solution for manned long-term missions (Bluem and Paris, 2003), almost four decades later, no significant innovative solutions have been proposed for space exploration. This may be due to the international strategy of developing low orbit science over the last 30 years with the ISS program, to the detriment of more complex and ambitious projects such as trips to the Moon or Mars involving long-term stays. Why Raise Aquatic Organisms in Space? Hydrogen and oxygen are abundant in the Universe, and water molecules are everywhere in the solar system. Sub-glacial liquid water has been detected on many rocky planets such as Mars, Mercury, and Venus (Liu, 2019; McCubbin and Barnes, 2019). There is evidence of the presence of an internal ocean on icy moons such as Enceladus (Cadek et al., 2016) and Europa (Kalousova et al., 2016). Recent research has indicated the presence of water molecules on rocky exoplanets from other solar systems in our galaxy (Olson et al., 2020). Water is the main in situ resource required for a planetary mission, both for long-term human settlement or astrobiology considerations; however, most observations have revealed that this water has high mineral content or is close to brine due to geological mineralization (Orosei et al., 2018). It would need to be purified to use as a source for water of drinking quality, yet it could be primarily used for rearing marine organisms such as algae, invertebrates, or fish. Today, producing protein from farmed animals (poultry, cattle, or sheep) in low gravity does not seem feasible. A large surface area is needed for livestock rearing, which would directly compete with human space, and costly synthetized air reconditioned from precious in situ resources such as lunar or planetary water or gas produced by BLSS biotechnology would be reserved for the human residents’ artificial atmosphere. Due to their poikilothermic physiology, fish require five to twenty times less energy than mammals, and around three times less oxygen, as well as generate less carbon dioxide emissions, which is an important consideration for BLSS gas exchange management. Another issue is waste management. With terrestrial animals such as pigs, chickens, goats, or cows, feces collection is not easy to solve. However, in aquatic vertebrate production, all dissolved compounds and particulate matter are sequestered in the water and can be easily treated and removed from the system or converted by another organism. Lastly, compared to terrestrial farmed animals, aquaculture is commonly viewed as playing a major role in improving global food security on Earth because the feed conversion ratio (FCR: the feed biomass necessary to provide to a farmed organism to obtain a weight increase of 1 kg) for fish is drastically lower than for land vertebrates. The FCR for different aquaculture organisms compared to that of the main farmed land animals is shown in Figure 1. Protein and calorie retention from aquaculture production is comparable to livestock production (Fry et al., 2018). All aquatic vertebrates exhibit better feed efficiency, which implies less feed to produce in a BLSS and to manage on the Moon or Mars. Gas management in lunar or Martian bases will probably be the main challenge for engineers in the next decade. On Earth, the atmosphere sequesters a stock of oxygen, and its continuous production is provided by oceanic and terrestrial photosynthetic organisms. Before the Industrial Revolution, carbon dioxide production was balanced with oxygen consumption. Today, even with the rise in CO2 emissions, oxygen is not a limited source. In contrast, in a closed system in an extreme environment such as the Moon or Mars, oxygen is not available in its basic form and must be produced. Hence, it is a precious molecule and it is of particular interest to include low oxygen consumers–and consequently, low carbon dioxide producers–in a BLSS. Compared to animals that breathe air, fish, and more generally aquatic organisms, have the lowest oxygen requirement and are the lowest producers of carbon dioxide (Figure 2). In fish, carbon dioxide production from respiration is dissolved, concentrated and stored in the water column. Fish have been shown to maintain their oxygen consumption under conditions of elevated CO2 partial pressure (Ishimatsu et al., 2008). The dissolved CO2 from RAS effluent could be used directly by an aquatic photosynthetic organism such as algae. Collecting CO2 emitted from fish and dissolved in the water column and directing it to a secondary biological system without an additive process would be a huge advantage for BLSS gas management. In contrast to farmed poultry and mammals, aquatic organisms would also be protected from cosmic rays by the water environment, which is an intrinsic radiation shield. The first life forms on Earth developed in a brackish ocean with a salinity of around 10 mg/L (Quinton, 1912). Complex life emerged from the Earth’s oceans when the atmospheric layer had not yet been totally formed by the respiration of microorganisms (stromatolites, bacteria and microalgae) and volcanic activity. The thin atmosphere exposed the Earth’s surface to intense cosmic radiation. The hypothesis that water played a role as a radiation shield in the appearance of aquatic life is strong and plausible. In connection with the development of space aquaculture, further experiments would be needed to determine the integrity or splitting of a heavy charged particle from cosmic radiation entering the water of an aquaculture tank. Transporting any type of animal in a space mission would subject them for several minutes to hypergravity between 4 and 8 g (unit of acceleration due to gravity) depending on the space engine. But hypergravity conditions are not unknown for oceanic fish such as the bluefin tuna (Thunnus thynnus). In one stress experiment, the force required for maximal acceleration was measured in this species. The associated hypergravity applied to the tuna was around 3 g for a few seconds (Dubois et al., 1976). No experiments have been conducted on aquaculture fish, but the natural acceleration caused by an escape behavior has been recorded as between 1 and 3 g. Another argument in favor of finfish as candidates for space aquaculture is that as opposed to other reared vertebrates and humans, in the water column they can move vertically as well as horizontally. Fish use a ballast system, the swim bladder, and otolith sensitivity to move in a volume of water, experiencing gravity but also buoyancy. In the ocean, fish are already in microgravity conditions due to water density and Archimedes’ principle. Thus, altered gravity should not interfere with swimming behavior during the lifecycle of a fish. Experiments have revealed that a fish in microgravity during a space mission orients its swimming direction and body position according to the position of the light in the module without losing the ability to feed or affecting social behavior. Fish movement can also be correlated with spaceship rotation (Ibsch et al., 2000; Anken et al., 2002). Indeed, astronauts train underwater as this is the best way to imitate the weightless conditions found in space. The suits they wear in the training pool are designed to provide neutral buoyancy (like a fish’s swim bladder) to simulate the microgravity experienced during spaceflight (Otto F.Trout, 1969). Spaceflight analog missions are conducted underwater in NASA’s Extreme Environment Mission Operations (NEEMO), involving multi-hour activities at a depth of 19 m (Koutnik et al., 2021). While the hypothesis that the variation in space gravity will not drastically disturb the fish from a physical, behavioral or welfare point of view is plausible, this remains to be tested in experiments on aquaculture fish species. Ornamental Fish as a Model for Understanding Human Physiology in Space The zebrafish Danio, the medaka Oryzias, and the swordtail fish Xiphophorus have been frequently boarded on space missions as models for understanding human gravitational sensations, due to the homology with human morphological and physiological systems. These species have proved the most suited vertebrate animals for basic gravity research. The gravity-sensing system in vertebrates from fish to humans has the same basic structure. Although aquarium fish are not aquaculture fish, space missions over the last five decades have provided useful results on fish physiology, behavior and well-being in microgravity (Lychakov, 2016). The earliest spaceflight with fish occurred on July 28, 1973. Two fingerlings and fifty embryonated eggs of the mummichog (Fundulus heteroclitus) were launched by a Saturn 1B rocket. The Apollo service module joined Skylab 3 and the fish were positioned in a plastic bag filled with seawater. This American space mission preferred the mummichog, a small saltmarsh killifish, to goldfish for this experiment. This species was not well known or described at that time, but it became the first “fishonaut”. For three days, swimming in loops and circles was observed for the two fingerlings, but they gradually returned to normal swimming. The fish acclimation period was comparable to that for a human crew during a first spaceflight. This observation suggested that the vestibular function (the otolith for fish–the inner ear for humans) probably plays the same sensory role in microgravity. The Fundulus heteroclitus eggs carried aboard the Skylab station in low orbit hatched successfully during the mission with a very good hatching rate (96%). The hatched fry displayed normal swimming behavior in contrast to the first hours in microgravity for the fingerlings (Baumgarten, 1975). Fish embryos in microgravity develop a physiological strategy to compensate for the unusual environment, and the larvae formed were already adapted to microgravity, as evidenced by the lack of looping behavior. In 1975, during nine days of the manned Apollo-Soyuz MA-161 mission, a group of 21-day-old juvenile mummichogs were exposed to real microgravity, and similar irregular swimming was observed. Fish eggs were also boarded (n = 100/samples at 32 hpf [hours post-fertilization], 66 hpf, and 128 hpf stages; pre-liftoff fertilization times) and were subjected to post-flight hatching rate evaluation back on Earth. The juveniles were evaluated using light orientation tests, and no significant differences were observed in behavior, suggesting an adaption capability to the space environment. The embryo hatching rate was 75%, and hatching date monitoring showed that the three earliest stages of egg batches carried on Apollo-Soyuz hatched at 15 days (normal hatching rate is 21 days), much sooner than the latest stage batch and earlier than the control batches at 1 g. Apparently, the development of young eggs was faster under microgravity, but the embryos exhibited no abnormalities resulting from development in a zero-gravity environment. The eyes, heart, nerves, and bones were found to be the same in the flight group as in the control group. There was no evidence of calcium deficiency, except in the shorter hatching-time group (Hoffman et al., 1977). In July 1994, the 17th Columbia space shuttle mission STS-65 boarded Japanese medaka (Oryzia latipes) for 15 days of spaceflight in the second International Microgravity Laboratory (IML-2). These ornamental fish laid eggs, and normal hatching was observed in space, with the results showing that medaka fertilization and embryonic development was not significantly impaired by altered gravity (Ijiri, 1998). Probably the most impressive aquatic closed-loop experiment in low orbit and a successful demonstration of an aquatic trophic chain in space, in the 1990s, a German team from Ruhr University Bochum and the German Aerospace Centre (DLR) developed the Closed Equilibrated Biological Aquatic System (CEBAS) with fresh water, containing small aquarium fish (Xiphophorus hellerii), water snails (Biomphalaria glabata), aquatic plants (Ceratophyllum dermersum), and aquatic microorganisms. The ground-based demonstration showed that a filter system was able to keep a closed artificial aquatic ecosystem stable for several months and to eliminate waste products deriving from degraded dead fish without a decrease in oxygen concentration to less than 3.5 mg/I at 25°C (Blum et al., 1994; Blum et al., 1995). Then in January 1998, during the Endeavour space shuttle mission STS-89 to the MIR station, aquarium swordtail fish (Xiphophorus helleri) were exposed to 9 days of microgravity, with 200 juveniles and four pregnant adult fish carried in a mini CEBAS module (10 L) (Blum et al., 1994). The aim of this aquatic mini-module (Figure 3) was to record the behavior of an artificial ecological closed loop in low orbit and verify the hypothesis that aquatic life is not affected by exposure to space conditions using a complementary organism. The female fish were retrieved in good physiological condition, adult and juvenile fish had a survival rate of about 33%, and almost 97% of the snails had survived and produced more than 250 neonates in microgravity (Bluem et al., 2000). During the spaceflight, the vertebrates were video-recorded for behavioral analysis and no aberrant looping or spinning behavior was observed. Immediately after landing back on Earth, the adult fish swam vertically, head upward, to the top of their habitat, strongly beating the caudal and pectoral fins. This was due to empty swim bladders not used during the spaceflight and reuse acclimation on Earth (Anken et al., 2000; Bluem et al., 2000; Rahmann and Anken, 2002). In April 1998, another population of swordtail fish and four adult wild marine fish oyster toadfish (Opsanus tau) flew with the space shuttle STS-90 mission, hosted in the Neurolab facility. After 16 days in real microgravity, fish brain synaptic contacts were compared to a control population at 1 g on Earth. Spaceflight yielded an increase in synaptic contacts within the vestibular nucleus indicating a compensation processes for neonates swordtail fish (Ibsch et al., 2000). Results revealed a gravity compensation process and the role of the fish lateral line associated to the fish brain for appropriate swimming behavior (Anken et al., 2002). The Vestibular Function Experiment Unit (VFEU) aboard STS-95’s SpaceHab again hosted two oyster toadfish as experimental subjects. The fish were electronically monitored to determine the effect of gravitational changes on the otolith system. The freely moving fish provided physiological signals of the otolith nerves. Measurements of afferent and efferent responses were made before, during, and post-flight (Boyle et al., 2001). In January 2003, four medaka eggs laid on Earth in an artificially controlled environment were launched by the Columbia space shuttle during the STS-107 mission. For the control, four eggs in the same condition remained on the ground. No difference was observed in the time of development. In the ground experiment, the embryos were observed to rotate in the egg membrane, whereas in flight they did not rotate. One egg hatched 8 days after the mission launch in the flight unit, while four eggs hatched in the ground unit. In the flight unit, the fry was observed with its back usually to the camera and little swimming movement suggest. The results shown no appreciable difference in the time course of development between space- and ground-based embryos. (Niihori et al., 2004). The hatched medaka larva, embryos and the crew from the space mission tragically never returned to Earth alive due to the accident during the space shuttle’s reentry in the atmosphere. In 2007, dry eggs of the ornamental killifish the redtail notho (Nothobranchius guentheri) were placed into cotton-cloth bags, then into plastic Petri dishes, and fastened on the outer side of the ISS. The aim of the Biorisk-MSN mission was to expose dry incubated eggs to low orbit radiation. Unfortunately, no data is available concerning the resistance of the fish eggs as the equipment had no temperature sensor and the plastic dishes reached 95°C, deforming the plates, and the eggs died due to the high temperature and vacuum contact (Baranov et al., 2009). To study the fish response at early stage to microgravity, two missions using medaka fish were performed on ISS, in 2012 and 2014. Each time a Soyuz rocket sent 24 juveniles medaka (6 weeks after hatching, 16 mm) with the objective of rearing this population in the Aquatic Habitat (AQH) on the Kibo section of the ISS. Medaka fish in space and control fish from the same family on Earth were filmed. The movies showed that the fish became adapted to life under microgravity although despite an unusual swimming behavior. In addition, a mating behavior was observed under microgravity at day 33 and was not different from that on the Earth, indicating microgravity environment doesn’t disturb fish reproduction. The aquarium fish used for this experiment have fluorescent osteoclast cells, which makes them easier to observe. An osteoclast is a type of bone cell that breaks down bone tissue and responsible for bone loss. After 47 days in space, the fish tended to stay still in the tank. After 56 days, the mission fish group had normal growth compared to a terrestrial control. For fish in microgravity impairment of some physiological functions was accompanied by the activity of osteoclasts and a slight decrease in mineral density and vertebral bones. (Chatani et al., 2015; Murata et al., 2015; Chatani et al., 2016). Historical space missions involving ornamental fish are listed in Table 2. Missions With Aquaculture Fish in Low Orbits Very few missions involving aquaculture fish have been carried out to date (Table 3). In one of these, the common carp (Cyprinus carpio)—considered a very important aquaculture species in many countries–was chosen as a model for a sensor motor experiment by Japanese university teams and the Japan Aerospace Exploration Agency (JAXA). Two colored carp (16 months old, 26 cm and 263–270 g) were carried to the American SpaceLab in 1992. One of the two carp was given a labyrinthectomy (the otolith was removed). For both fish, swimming behavior and dorsal light response was studied and compared. As observed during the first space missions with small fish, the normal carp was unstable (associated with a kind of space motion-sickness) for the first three days, then finally recovered its Earth-based swimming behavior. The fish whose otolith was removed two months before showed a normal dorsal light response 22 h after launch, and disruption for the next two days as with the normal carp. Unfortunately, the recovery process for the fish with the removed otolith could not be evaluated due to a technical issue, but these observations provided evidence of a sensory-motor disorder during the early phase of adaption to microgravity in aquaculture fish (Mori et al., 1996). The change in body weight was monitored from two days before launch to four days after landing. Both fish recorded a weight loss around 12% in low orbit after 14 days of fasting. No conclusion can be made as a fasting replicate on the ground was not available (Mori et al., 1994). During space shuttle missions STS-55 (1993) and STS-84 (1997), tilapia Oreochromis mossambicus larvae that had not yet developed the roll-induced static vestibuloocular reflex were exposed to microgravity for 9–10 days. Young larvae (11–14 days after hatching) already exhibited the vestibuloocular reflex on the 1993 mission. Back on Earth, a vestibuloocular reflex test (fish were turned around their longitudinal axis at an angle of 15, 30, and 45°) showed that eye movement and reflex were not affected by exposure to microgravity during the two space missions (Sebastian et al., 2001). The OMEGAHAB (Aquatic Habitat) is a closed artificial ecosystem that was sent into orbit for 13 days on board the Russian satellite FOTON-M3 in 2007. The goal of the mission led by the German Space Agency was to investigate the possibility of designing a trophic chain in real microgravity using the photosynthetic flagellate Euglena gracilis as an oxygen producer and larvae of tilapia Oreochromis mossambicus as a consumer. This freshwater and brackish species is a popular aquaculture fish, with worldwide production of around 15,000 tons per year. In the 2007 experiment, 26 small larvae (approx. 12 mm in length) in the flagellate aquarium were studied in low orbit to increase knowledge about the development of the vestibular organs and enzymatic activity. The best fish survival rate (42%) ever achieved in a German experiment was recorded. Conditions of real microgravity during spaceflight induced a larger than normal otolith compared to a control maintained at 1 g. This could result in a difference in the ability to sense gravity (Anken et al., 2016). In a same ground unit, the photosynthetic producers supplied sufficient amounts of oxygen to a fish compartment with 35 larval cichlids (Hader et al., 2006). Historical space missions involving aquaculture fish are listed in Table 3. Feeding Fish in Space: Integrated Multi-Trophic Aquaculture If fish were farmed on a space base, sending aquaculture feed from Earth to Moon or Mars would make no sense from an economic or lifecycle analysis point of view. Aquatic systems contain a large diversity of species with different roles in nutrient cycles and biomass conversion that contribute to ecosystem balance. Photosynthetic organisms (algae, phytoplankton), invertebrates (crustaceans, mollusks, zooplankton), vertebrates (fish, amphibians), and microorganisms interact in a complex trophic web. By associating different complementary species such as fish, filter feeders, detritivores and primary producers, integrated multi-trophic aquaculture (IMTA) provides an innovative possibility for BLSS on the Moon or Mars. The nutritional profile of fish is closely linked to their diet quality. In aquaculture, this can be easily adjusted by ensuring a fish feed formulation that includes organisms that synthesize or sequester proteins, lipids of interest (e.g., EPA or DHA), vitamins and minerals. These aquatic organisms can be cultivated separately in a chain (from algae to invertebrates to fish) exclusively with fish waste as a fertilizer or using other available waste from human activities, such as exhaled carbon dioxide, space agriculture byproducts, or residents food waste. In the framework of sustainable aquaculture on Earth, researchers are studying trophic webs using closed or semi-closed aquatic systems that reuse fish nutrients dissolved in the water column or fish fecal matter as a fertilizer or food source for another aquatic organism. In an IMTA system, microalgae or macroalgae cultivation is easy using fish tank effluents, as the N/P ratio fits the requirements of algae: the increasing algae biomass assimilates nitrogen and phosphorus forms (Pagand et al., 2000). To return treated water back to the fish tank, it can be cleaned so it is safe for fish growth and welfare (Mladineo et al., 2010). Moreover, fish farm effluent is a suitable media for cultivating Nannochloropsis gaditana, a marine algae with a high PUFA content (Dourou et al., 2018). Several studies have reported the possibility of feeding aquaculture fish with microalgae (mostly marine) included in the fish feed formulation. Several microalgae strains have been tested successfully (they do not alter growth kinetics or organoleptic quality) with fish feed made up of 20–40% of microalgae: Crypthecodinium sp., Phaeodactylum sp. (Atalah et al., 2007) and Schizochytrium sp. (Ganuza et al., 2008; Stuart et al., 2021) have been tested for the seabream and amberjack diet; Tetraselmis sp. (Tulli et al., 2012), and Isochrysis sp. (Tibaldi et al., 2015) for European seabass; Nanofrustulum sp. for salmon, common carp and schrimps (Kiron et al., 2012); and Tetraselmis sp. and Isochrysis sp. for cod (Walker and Berlinsky, 2011). The modern feed form for aquaculture fish is dried pellets with less than 10% moisture. However, a study has shown that feeding fish using a moist formulation, such as algae or aquatic worms, with a water content around that of the natural prey profile in oceans, did not affect fish growth parameters and in fact increased resistance and immune protection (Przybyla et al., 2014). Thus, photosynthetic or invertebrate aquatic organisms produced in a Moon or Mars greenhouse could be fed directly to aquaculture fish with no transformation process. Researchers are exploring these alternatives to preserve wild fish stocks currently used for aquaculture fish feed (e.g., processed into fish meal and fish oil). Other algae sources with higher integration rates in feed formulations are the focus of future studies, while research is also investigating new types of aquatic prey compatible with fish feed, such as jellyfish (Marques et al., 2016). The algae cultivated in an IMTA system, as well as fish effluent, can also be a feed source for invertebrates, mollusks (Li et al., 2019), and sea cucumbers (Chary et al., 2020). A team from NASA is studying the possibility of using invertebrate production systems to purify water while growing protein-rich species as food/feed sources. Aquatic species such as copepods or mussels should grow rapidly, offer good protein content and have low mass for launch requirements (Brown et al., 2021). In the ocean, copepods and mussels are the favored natural prey of fish (especially seabream) and can be used as live feed for aquaculture fish. This production could also serve as food for the human crew. Thus, aquatic invertebrates and microalgae could play a key role in a trophic chain on a space base. In a recirculating aquaculture system, particulate matter is composed mainly of feces, mucus and bacterial clusters. This waste is easy to separate and remove from the RAS. Some copepods can use this media as feed, but another invertebrate is being studied for its ability to reduce this particulate matter and convert it into valuable biomass: the aquatic worm (Galasso et al., 2020). Polychaeta are detritivores and can be a feed source of interest for fish. Aquatic worms cultivated in an RAS can convert fecal matter into useful fatty acids for fish feed (Kicklighter et al., 2003; Bischoff et al., 2009; Palmer et al., 2014). Other synergies might also be possible: for example, Caenorhabditis elegans is a small terrestrial nematode already studied in space as a model for ageing in microgravity, as 35% of C. elegans genes have human homologs (Honda et al., 2014). This nematode could thus be both cultivated and observed in space in a BLSS. In wild environments on Earth, a fish’s diet is composed of its own congener, algae or invertebrates. Ground-based experiments have evaluated Nile tilapia as a bioregenerative sub-process for reducing solid waste potentially encountered in a space aquaculture system (Gonzales, 2009). The Tilapia feed formulation consisted of vegetable, bacterial, or food waste. Sulfur, nitrogen, protein, carbon and lysine content of waste residues were assimilated, sequestered and recycled in Tilapia muscle. Although Tilapia’s specific growth rate from population fed with different fibrous waste were widely inferior (1.4—89.8 mg/day−1) compared to the control population (281.6 mg/day−1), the Tilapia’s survival rate was not different. These results suggest additional research to improve feed formulation composed with fibrous residues (Gonzales and Brown, 2007). When considering formulating aquaculture fish feed on a space base using exclusively aquatic organisms cultivated in an IMTA system, it is essential to determine the digestive efficiency of the fish feed. A recent study highlighted the extreme flexibility of European seabass to feed formulations without fish meal and fish oil. In the experiment, fish were given several formulations containing 85% plant sources and 15% alternative sources (yeast, insects, and processed animal protein or Arthrospira platensis). Zootechnical results showed that three formulations resulted in a growth equal to fish fed with a traditional commercial formulation including a wild fish source. The bacterial community in the fish digestive tract adapted to the new formulation composed of alternative protein and lipid sources, and bacterial diversity was not altered (Perez-Pascual et al., 2020). This plasticity is probably common to other fish species, allowing a promising avenue to test new innovative formulations for aquaculture fish using exclusively BLSS raw matter sources such as cyanobacteria, plants, algae, and invertebrates. Applicability and Limitations of a Space Aquaculture System Like the systems for other types of food sources being studied for a future BLSS, such as those to produce microalgae and higher plants (Tikhomirov et al., 2007), the design of a space aquaculture system (SAS) is subject to various parameters, including the location in the Solar System. The size of the SAS would depend on the number of residents to feed, the other food sources necessary based on nutritionist’s recommendations, the space available on the lunar base, water availability and quality, the energy available for this activity, and the duration the BLSS will need to operate. One scenario might be to provide around 250 g of fish per person per week. The volume of the tank for rearing the fish should also be correlated to the fish growth rate and the frequency at which the fish are harvested. The diversity of fish species allows possibilities to be imagined such as using the area under the floor of the lunar base for flat fish, for example, or a tank that is not connected to the crew’s living area. On the Moon as on Earth, an aquaculture system requires water circulation. While the energy needed to pump water in an SAS with lunar gravity (one-sixth of Earth’s gravity) is yet to be defined, maintaining a set water temperature will have an energy cost. Within a window of tolerance depending on the species, fish growth directly depends on the water temperature (Handeland et al., 2008). In a context of 14 days of Sun exposure and 14 days of darkness, the latter period will require warming the water to maintain the growth rate. Thus the thermal profile of the selected species will be one of the parameters to consider. This aspect will have a direct impact on the total energy required for an acceptable growth yield in the SAS. Although fish have a low oxygen uptake compared to other vertebrates (Figure 2), a regular supply is required. Oxygen dissolution in the water from hydroxyl extraction and oxygen from the regolith and/or from photosynthesis in plants cultivated in the BLSS must be synchronized with the biological demands of the fish. This requires the capacity to regularly collect, store and dissolve oxygen in the water column. The oxygen data from the CEBAS experiment on the STS-89 and STS-90 missions was analyzed to model this concept. Results based on the experimental MINI-MODULE (8.6 L) showed different periods of oxygen accumulation and depletion in the aquatic habitat in plants (oxygen producer) and snails (oxygen consumer). Simulations from ground-based models predict the oxygen concentration and can be adapted for other species (Drayer and Howard, 2014). A trend has to be defined between the volume of oxygen instantly available or stored and the demand of aquatic consumers. This highlights the importance of an oxygen buffer tank linked to a feedback control mechanism (possibly remotely controlled from Earth) in case of a lack of oxygen. Another aspect to monitor is bacterial development inside the system. An axenic environment cannot be considered as bacteria play an essential role in all stages of a balanced ecosystem. Yet bacteria activity affects the nutrient budget and oxygen measurement and availability (Konig et al., 2001). All these parameters will drive the size of the SAS and the fish biomass allowed in an extreme environment such as the Moon. Another issue to consider is aquatic biomass extraction in the space environment. Harvesting cells such as microalgae is a current challenge, today handled using vacuum and flocculation (Barrut et al., 2012). The development of harvesting tools is required for different aquatic organisms in a limited and constrained space. Regardless of the organism, extraction is necessary when the biomass has reached its optimum growth to avoid uncontrolled water degradation and increased oxygen consumption by microorganisms that would endanger fish production. The time needed for fish management on a lunar base also depends on the size of the SAS. Current technology developed for RAS drastically reduces the time necessary to maintain the system. Most of the tasks can be automated, such as starting and cleaning the biofilter, monitoring water parameters (Konig et al., 2001), and regulating the water. Fish feeding is a time-consuming task, but this can also be automated. Fish are able to adapt to self-feeding devices (Coves et al., 1998; Di-Poi et al., 2008), which contribute to the social interaction of the population (Chen et al., 2002). As in plant production systems (Bamsey et al., 2009), several automated SAS actions could be carried out remotely from a control room on Earth. A daily routine (visual checking of the system and fish behavior and non-automated actions) could be considered to involve around 1 h every 12 h for a closed loop system composed of 16 tanks (1 m3) and 8 kg/m3 of fish biomass (based on personal experience). The energy available to power the SAS will also determine its design. A ground-based greenhouse simulation for food production with lunar constraints is necessary to study and understand gas flow management, organism interactions, and all related parameters necessary to maintain a stable and balanced ecosystem. Studying the Feasibility of Sending Aquaculture Fish Embryos to the Moon: The Lunar Hatch Program In research underway since 2019, the Lunar Hatch program is investigating the feasibility of shipping embryonated aquaculture fish eggs to space for programmed hatching in a lunar BLSS. The hatched larvae would then be fed with local resources and reared until they reached an appropriate size for human consumption. The aim of the study is proof of concept based on experimental data collected first in ground-based trials, followed by test missions in low orbit, and concluding with a real flight to space, perhaps leading to the hatching of the first vertebrate on the Moon. The program focuses on the viability of European seabass (Dicentrarchus labrax) for such a project, by analyzing the potential effects on embryos of a Moon journey and the associated environmental changes. Water found on celestial bodies in the Solar System have a saline or hypersaline profile. The choice of the European seabass in the Lunar Hatch program was based on the fact it is a marine organism with an appreciated taste, and its physiology and behavior have been abundantly described. A secondary water source for fish aquaculture could also be considered such as recycled water from a greenhouse or non-potable water from technical process or human activities. The diversity of aquaculture fish species allows the appliacation of many potential “fishonauts”, depending on the primary or secondary water resource available in situ (fresh or salt water). Other aquaculture species could equally be considered for rearing in space, such as trout, flat fish or shrimp. As mentioned, in the 1970s, spaceflight tests were carried out at the egg stage with ornamental fish (Table 2). The choice of eggs as the biological stage for space travel is relevant for several reasons. A low volume of water is required for egg incubation, so the initial launch biological payload could be less than 1 kg for around 900 future larvae. In aquaculture nurseries, European seabass egg density in the water column is around one egg per milliliter. Unlike the larval or adult stages, the embryogenesis phase is suitable for a spaceflight because embryo development does not require human intervention for several days (the duration of embryogenesis depends on the species). Although embryogenesis involves intense metabolic activity for the development of the future larva, the low biomass and the chorion limit catabolite emission as well as the self-pollution of water during the journey. This would allow either long manned spaceflights with no need for maintenance from the crew, or simply the transport of fish eggs using an automated cargo ship. Compared to normal conditions in land-based aquaculture production, during a spaceflight fish embryos would be initially subjected to atypical acoustic and mechanical vibrations caused by launcher motors and acceleration in the atmosphere. The effects of this are under study in the framework of the Lunar Hatch program (supported by the French National Institute for Ocean Science, Ifremer) using a standard qualification test commonly employed in the space industry. In a recent experiment, a vibration exciter mimicked the conditions of a SOYUZ-2/FREGAT launch on a population of fish embryos (Figure 4). In this test, two triplicates (n = 300) of embryos of aquaculture species (European seabass and meagre in two separate experiments) were submitted to the acoustic and mechanical environment of a launch for 10 min at one-third and two-thirds of their development. The hatching rate was then compared to a control triplicate (n = 300). No significant differences were observed on the hatching rate for either species whatever the stage of development when the embryos were exposed to the conditions (Figure 5). These encouraging results indicate the egg robustness of two major aquaculture species. A credible hypothesis to explain these results is that the success of the global aquaculture industry is based on the selection of aquatic species for robustness criteria to actions such as unusual and stressful handling–especially at an early lifecycle stage–such as sorting, sampling, transfer from aquarium to tank, or long transport by road or air. The aquaculture sector has selected the most biologically flexible strains with the most interesting nutritional profile for economic reasons. The resulting robustness could benefit space programs–it would not be surprising if other aquaculture species also successfully pass this qualifying test. Beyond intense vibrations, understanding the influence of hypergravity and microgravity on embryonic development is essential to evaluate the feasibility of space aquaculture. Previous studies on ornamental aquarium fish can provide some information on fish behavior and physiology in space that may be useful. Hypergravity is experienced during rocket take-off, an acceleration phase that lasts about 10 min at 4–8 g, depending on the launcher motors. This situation was tested on swordtail fish and medaka otoliths (Anken et al., 1998; Ijiri et al., 2003; Brungs et al., 2011; Anken et al., 2016) and larvae bone development (Aceto et al., 2015; Chatani et al., 2015), but its effects on early ontogeny (hatching capability) are as yet poorly described. A recent research showed that six month exposition at 5 g can induce vertebral curvatures and asysmetric otoliths (Chatani et al., 2019). However, the duration of exposure to hypergravity during a launch to the Moon or Mars will be about 10 min, the time to extract the embryos from the Earth’s attraction. Ongoing experiments are exploring the ability of aquaculture finfish embryos to develop in these conditions. It is credible to posit that hypergravity applied to a water reservoir may be less felt by a submerged embryo. In contrast to poultry eggs stored in air, the water density surrounding fish eggs may reduce the acceleration force on the chorion. Following the initial conditions of rocket vibrations and acceleration, a situation of microgravity appears beyond an altitude of 110 km. During the entire evolution of life on Earth, the development of all organisms took place under constant gravity conditions in different media (air/water). It should be noted that in the ocean, fish embryos are already in a kind of microgravity compared to terrestrial organisms due to Archimedes’ principle and other physical phenomena. This is why, to simulate partial microgravity, astronaut training exercises are carried out in a swimming pool. A study has found that embryos of Xenopus (an aquatic frog) are able to adjust to microgravity environments until hatching through an adaptation mechanism and strategy (Black et al., 1995). Might this capability be common to other aquatic organisms, including fish embryos? Supported by the French space agency (CNES), the Lunar Hatch program plans to study the embryo behavior of European seabass in hypergravity and microgravity in the Gravitational Experimental Platform for Animal Models (GEPAM), a European Space Agency platform to test different gravity environments on animals (Bonnefoy et al., 2021). Exposure to radiation during the space journey will be the last environmental change investigated in future Lunar Hatch program studies: this is probably the parameter with the most impact on fish embryo biology. Knowledge about the effects of space radiation on a variety of organisms has increased over the last decades: for bacteria (Leys et al., 2009), plant and mammalian cells (Arena et al., 2014), and amphibians (Fuma et al., 2014). A ground-based study on the influence of radiation on fish immediately post-hatching was carried out on the ornamental zebrafish (Danio rerio), in which eggs were irradiated with doses ranging from 1 to 1,000 mSv.d−1 for 20 days (Simon et al., 2011). At the stage of 3 days post-hatching, no significant difference in mortality was observed between irradiated eggs and the control. The maximum daily dose was 100 times greater than the total dose astronauts were subjected to during the Apollo 11 mission. These results are consistent with a study in which no significant difference in mortality was observed between 0.8 mGy (the threshold recommended to protect ecosystems) and 570 mGy delivered per day, but the radiation exposure induced accelerated hatching for both doses and a decrease in yolk bag diameter for the highest dose (Gagnaire et al., 2015). In contrast, another study exposing zebrafish embryos to 1, 2.5, 5, 7.5, and 10 mGy of gamma radiation at 3 hpf showed that increasing gamma radiation increased DNA damage, decreased hatching rate, increased median hatching time, decreased body length, increased mortality rate, and increased morphological deformities (Kumar et al., 2017). A higher total dose but spread over time therefore seems to be less harmful than a single high dose concentrated in the early stages of development. Gagnaire et al. also found abnormal development of the spine for individuals subjected to 570 mGy.d−1. These research results on a small fish provide useful information for countermeasures that would need to be implemented on a lunar base. Fish and crew should be protected to reduce cosmic ray damage. Fish embryos could benefit from progress in countermeasure technology developed for humans, but it would be valuable to conduct experiments on the impact of different particles and charges (separate and cumulative) from cosmic radiation on the candidate fish. Conclusion The Lunar Hatch program is investigating the prospects of lunar aquaculture based on a circular food system using a selected species at a specific stage of the lifecycle. It may be of interest to investigate other aquaculture species for other targeted planets or other lifecycle development stages. In the case of the Moon, it is so close to Earth that rearing adults for reproduction would not be worthwhile: a regular shipment of fertilized eggs for monthly generation would avoid costly fish-spawning management on the lunar base. For a more distant destination such as Mars, the embryo stage would be realistic for the first part of the mission, but the total flight would be longer than the duration of embryogenesis. In this case, larval development would need to be considered during the multi-month journey. For farther destinations, studies would need to determine the possibility of rearing broodstock to control the entire biological lifecycle in space. Space aquaculture would provide a valuable food source in addition to those already studied for long-term missions. The diversity of nutrients provided by fish and the benefits for human metabolism may help in the challenges of space medicine, in particular the prevention of cancer caused by long-term exposure to radiation. The activity of fish farming itself could have positive psychological and cognitive effects. Reports about plant-growth chambers on manned missions have described the psychological benefits of working with living organisms in space. An investigation involving social scientists could be conducted to better understand the possible positive benefits of human–animal interaction in space. Vertebrates may recall basic human activities and provide a psychological umbilical cord with the Earth. Modern recirculating aquaculture systems share many characteristics with the closed bioregenerative life-support systems planned for space. Progress in aquaculture technology on land and in space can feed into each other. For example, developments that allow space aquaculture systems to recover and convert waste molecules into edible food could be deployed on Earth to increase food availability while avoiding waste discharge in the environment and preserving biodiversity. Joint efforts to design such waste conversion systems will be applicable above all to human activities on Earth. Like other aspects of BLSS, while space aquaculture is close to being a reality, it is highly dependent on the water and energy available in situ. At the turn of the 20th century, the Russian father of astronautic science Konstantin Tsiolkovsky wrote: “Earth is the cradle of humanity, but one cannot remain in a cradle forever.” Plants and animals are part of the human biosphere and food chain. Space exploration will likely be more successful if humans leave the cradle with a part of their own biosphere and their knowledge of agricultural science, including aquaculture.

### 3

#### Space investment is at a historic high but increased risk makes the market shaky

Sheetz 1/18 [Michael Sheetz, I break news on the space industry, with stories focused on investment and companies building rockets, satellites, spacecraft and next-generation space technologies, 01-18-2022, “Investment in space companies hit record $14.5 billion in 2021, report says,” CNBC, https://www.cnbc.com/2022/01/18/space-investing-q4-report-companies-hit-record-14point5-billion-in-2021.html] simha

Private investment in space companies last year set a record, according to a report Tuesday by New York-based firm Space Capital.

Space infrastructure companies received $14.5 billion of private investment in 2021, a new annual record that was up more than 50% from 2020. That includes a record-setting fourth quarter, which brought in $4.3 billion thanks to “mega-rounds” of $250 million or more by Sierra Space, Elon Musk’s SpaceX, and Planet Labs.

The quarterly Space Capital report divides investment in the industry into three technology categories: infrastructure, distribution and application. Infrastructure includes what would be commonly considered as space companies, such as firms that build rockets and satellites.

In total, Space Capital tracks 1,694 companies which have raised $252.9 billion in cumulative global equity investments since 2012 across the three space categories.

“As we look ahead, we see tremendous opportunities to scale mass adoption of the existing infrastructure as we look for radically new approaches to build and operate space-based assets,” Space Capital managing partner Chad Anderson wrote in the report.

The report also highlighted record investment by venture capital firms across the three categories. Space-related companies received $17.1 billion in venture capital last year, which the report said made up 3% of total global venture capital investment in 2021.

Space Capital also highlighted the changing market environment for the flurry of newly-public space companies, as rising interest rates are hitting technology and growth stocks hard — especially companies where profitability is years away, as is the case with several space ventures.

“The public markets have started the year with a selloff and, if it continues, venture firms may not find it as easy to raise record-setting funds as they did last year,” Anderson wrote.

Anderson gave further warning that “not all SPACs are created equal,” saying that “much of the momentum we saw in 2021 came at the cost of deep diligence, which increases the risk for investors.”

“It’s important for investors to realize that investment in the space economy requires specialist expertise. We believe this will become more apparent in 2022 as some of these overvalued companies come back down to Earth and the quality companies rise above,” Anderson said.

#### Unpredictable shifts ruin biz con AND overall growth

Sarah Chaney Cambon 21, Reporter on The Wall Street Journal's Economics Team, BA in Business Journalism from the University of North Carolina-Chapel Hill, “Capital-Spending Surge Further Lifts Economic Recovery”, Wall Street Journal, 6/27/2021, https://www.wsj.com/articles/capital-spending-surge-further-lifts-economic-recovery-11624798800

Business investment is emerging as a powerful source of U.S. economic growth that will likely help sustain the recovery.

Companies are ramping up orders for computers, machinery and software as they grow more confident in the outlook.

Nonresidential fixed investment, a proxy for business spending, rose at a seasonally adjusted annual rate of 11.7% in the first quarter, led by growth in software and tech-equipment spending, according to the Commerce Department. Business investment also logged double-digit gains in the third and fourth quarters last year after falling during pandemic-related shutdowns. It is now higher than its pre-pandemic peak.

Orders for nondefense capital goods excluding aircraft, another measure for business investment, are near the highest levels for records tracing back to the 1990s, separate Commerce Department figures show.

“Business investment has really been an important engine powering the U.S. economic recovery,” said Robert Rosener, senior U.S. economist at Morgan Stanley. “In our outlook for the economy, it’s certainly one of the bright spots.”

Consumer spending, which accounts for about two-thirds of economic output, is driving the early stages of the recovery. Americans, flush with savings and government stimulus checks, are spending more on goods and services, which they shunned for much of the pandemic.

Robust capital investment will be key to ensuring that the recovery maintains strength after the spending boost from fiscal stimulus and business reopenings eventually fades, according to some economists.

Rising business investment helps fuel economic output. It also lifts worker productivity, or output per hour. That metric grew at a sluggish pace throughout the last economic expansion but is now showing signs of resurgence.

The recovery in business investment is shaping up to be much stronger than in the years following the 2007-09 recession. “The events especially in late ’08, early ’09 put a lot of businesses really close to the edge,” said Phil Suttle, founder of Suttle Economics. “I think a lot of them said, ‘We’ve just got to be really cautious for a long while.’”

Businesses appear to be less risk-averse now, he said.

After the financial crisis, businesses grew by adding workers, rather than investing in capital. Hiring was more attractive than capital spending because labor was abundant and relatively cheap. Now the supply of workers is tight. Companies are raising pay to lure employees. As a result, many firms have more incentive to grow by investing in capital.

Economists at Morgan Stanley predict that U.S. capital spending will rise to 116% of prerecession levels after three years. By comparison, investment took 10 years to reach those levels once the 2007-09 recession hit.

Company executives are increasingly confident in the economy’s trajectory. The Business Roundtable’s economic-outlook index—a composite of large companies’ plans for hiring and spending, as well as sales projections—increased by nine points in the second quarter to 116, just below 2018’s record high, according to a survey conducted between May 25 and June 9. In the second quarter, the share of companies planning to boost capital investment increased to 59% from 57% in the first.

“We’re seeing really strong reopening demand, and a lot of times capital investment follows that,” said Joe Song, senior U.S. economist at BofA Securities.

Mr. Song added that less uncertainty regarding trade tensions between the U.S. and China should further underpin business confidence and investment. “At the very least, businesses will understand the strategy that the Biden administration is trying to follow and will be able to plan around that,” he said.

#### Lunar’s key to commercial space industry expansion

Alex Gilbert 19, Non-Resident Fellow at the Payne Institute for Public Policy at the Colorado School of Mines, with; Morgan D. Bazilian, Professor of Public Policy and Executive Director of the Payne Institute at the Colorado School of Mines; 4/19/19, “We Need a Space Resources Institute,” https://blogs.scientificamerican.com/observations/we-need-a-space-resources-institute/

Fifty years ago this July, Apollo 11 delivered the first crewed mission to the surface of the moon. Today, the United States is on the verge of a space renaissance—returning astronauts to the moon, first on an orbiting space station and then a return to the surface. Among other objectives, NASA, its international partners and commercial companies are looking to find and mine lunar water­—the basic building block of hydrogen fuel and oxygen.

Water, or ice, located on a celestial body like the moon or an asteroid, is a type of space resource. In the last 20 years, deep space exploration has identified potential water deposits on the moon, on Mars, in the asteroid belt and even on moons orbiting Jupiter and Saturn.

Using in-situ resource utilization (ISRU) technology, such deposits could be converted to hydrogen or oxygen, enabling the refueling and supply of future space missions. In the long term, these space resources can also reduce the cost of uncrewed exploration missions to deep-space locations such as the asteroid belt, the giant planets and the Kuiper Belt.

Commercial interests are also interested in mining space resources. If water can provide (relatively) cheap refueling services in space, it could catalyze the growth of the commercial space industry. As an example, there is already interest in asteroid mining, in search of platinum or other valuable metals. The global space industry is estimated to be worth more than $400 billion in 2018. By 2030, the industry could double in size because of new technologies and commercial innovation, including space resources. The U.S. is well-situated to capture a significant share of that growth, but that is far from assured. A further focus on scientific research is needed.

#### Space is a trillion-dollar industry that impacts major sectors of the economy

Morgan Stanley 20 [Morgan Stanley, 7-24-2020, "Space: Investing in the Final Frontier," https://www.morganstanley.com/ideas/investing-in-space] simha

It’s been nearly half a century since humans left footprints on the moon and during that time, human space exploration has largely centered on manned low-Earth orbit missions and unmanned scientific exploration. But now, high levels of private funding, advances in technology and growing public-sector interest is renewing the call to look toward the stars.

The revenue generated by the global space industry may increase to more than $1 trillion by 2040.

The investment implications for a more accessible, less expensive reach into outer space could be significant, with potential opportunities in fields such as satellite broadband, high-speed product delivery and perhaps even human space travel. While the most recent space exploration efforts have been driven by handful of private companies, the establishment of a sixth branch of the U.S. military in 2019—the “Space Force”—along with growing interest from Russia and China, means public-sector investment may also increase in the coming years. To outline progress in space from both public and private companies, as well as government efforts, the Space team at Morgan Stanley Research has been examining these developments to detail the constellation of potential opportunities for investors. A single transformative technology shift often can spark new eras of modernization, followed by a flurry of complimentary innovations. In 1854, when Elisha Otis demonstrated the safety elevator, the public couldn’t foresee its impact on architecture and city design. But roughly 20 years later, every multistory building in New York, Boston, and Chicago was constructed around a central elevator shaft. Today, development of reusable rockets may provide a similar turning point. “We think of reusable rockets as an elevator to low Earth orbit (LEO),” says Morgan Stanley Equity Analyst Adam Jonas. “Just as further innovation in elevator construction was required before today's skyscrapers could dot the skyline, so too will opportunities in space mature because of access and falling launch costs.” Privately held space exploration firms have also been developing space technologies, with ambitions such as manned landings on the moon and airplane-borne rocket launchers that could launch small satellites to LEO at a far lower cost, and with far greater responsiveness, than ground-based systems.

Growing Public-Sector Interest

While private-equity projects have grabbed most of the headlines in recent years, public-sector interest has also grown. In December of 2019, the Trump Administration established a U.S. Space Command (including a Space Operations Force and a Space Development Agency) with the signing of the as part of the National Defense Authorization Act for 2020. This development will likely benefit the U.S. Defense Department—as well as the aerospace and defense industries—and help focus and accelerate investment in innovative technologies and capabilities. Then in May of 2020, NASA launched a manned flight to the International Space Station (ISS) on a commercially developed U.S. rocket. The launch represented the first time that the U.S. has flown a manned mission to the ISS since the shuttle program was retired in 2011. It also represents an important milestone for the relationship between private enterprise and the U.S. government in the space domain.

The Global Space Economy

Near term, space as an investment theme is also likely to impact a number of industries beyond Aerospace & Defense, such as IT Hardware and Telecom sectors. Morgan Stanley estimates that the global space industry could generate revenue of more than $1 trillion or more in 2040, up from $350 billion, currently. Yet, the most significant short- and medium-term opportunities may come from satellite broadband Internet access. Morgan Stanley estimates that satellite broadband will represent 50% of the projected growth of the global space economy by 2040—and as much as 70% in the most bullish scenario. Launching satellites that offer broadband Internet service will help to drive down the cost of data, just as demand for that data explodes. “The demand for data is growing at an exponential rate, while the cost of access to space (and, by extension, data) is falling by orders of magnitude," says Jonas. “We believe the largest opportunity comes from providing Internet access to under- and unserved parts of the world, but there also is going to be increased demand for bandwidth from autonomous cars, the Internet of things, artificial intelligence, virtual reality, and video." In fact, as data demand surges—a trend driven particularly by autonomous vehicles—Morgan Stanley estimates that the per-megabyte cost of wireless data will be less than 1% of today's levels. While reusable rockets will help drive those costs down, so too will the mass-production of satellites and the maturation of satellite technology. Currently, the cost to launch a satellite has declined to about $60 million, from $200 million, via reusable rockets, with a potential drop to as low as $5 million. And satellite mass production could decrease that cost from $500 million per satellite to $500,000.

To Infinity and Beyond

Beyond the opportunities generated by satellite broadband Internet, the new frontiers in rocketry offer some tantalizing possibilities. Packages today delivered by airplane or truck could be delivered more quickly by rocket. Perhaps private space travel could become commercially available. Mining equipment could be sent to asteroids to extract minerals—all possible, theoretically, with the recent breakthroughs in rocketry. Jonas cautions that “history is littered with cautionary tales" of investing in satellite and other space-related companies, noting that stocks have been volatile and several such companies failed in the 1990s. Understandably, many investors would rather think about nearer-term themes that are actionable and can impact their portfolios in 2020. However, initiatives by large public and private firms suggest that space is an area where we will see significant development, potentially enhancing U.S. technological leadership and addressing opportunities and vulnerabilities in surveillance, mission deployment, cyber, and artificial intelligence.

#### Decline cascades---nuclear war

Dr. Mathew Maavak 21, PhD in Risk Foresight from the Universiti Teknologi Malaysia, External Researcher (PLATBIDAFO) at the Kazimieras Simonavicius University, Expert and Regular Commentator on Risk-Related Geostrategic Issues at the Russian International Affairs Council, “Horizon 2030: Will Emerging Risks Unravel Our Global Systems?”, Salus Journal – The Australian Journal for Law Enforcement, Security and Intelligence Professionals, Volume 9, Number 1, p. 2-8

Various scholars and institutions regard global social instability as the greatest threat facing this decade. The catalyst has been postulated to be a Second Great Depression which, in turn, will have profound implications for global security and national integrity. This paper, written from a broad systems perspective, illustrates how emerging risks are getting more complex and intertwined; blurring boundaries between the economic, environmental, geopolitical, societal and technological taxonomy used by the World Economic Forum for its annual global risk forecasts. Tight couplings in our global systems have also enabled risks accrued in one area to snowball into a full-blown crisis elsewhere. The COVID-19 pandemic and its socioeconomic fallouts exemplify this systemic chain-reaction. Onceinexorable forces of globalization are rupturing as the current global system can no longer be sustained due to poor governance and runaway wealth fractionation. The coronavirus pandemic is also enabling Big Tech to expropriate the levers of governments and mass communications worldwide. This paper concludes by highlighting how this development poses a dilemma for security professionals.

Key Words: Global Systems, Emergence, VUCA, COVID-9, Social Instability, Big Tech, Great Reset

INTRODUCTION

The new decade is witnessing rising volatility across global systems. Pick any random “system” today and chart out its trajectory: Are our education systems becoming more robust and affordable? What about food security? Are our healthcare systems improving? Are our pension systems sound? Wherever one looks, there are dark clouds gathering on a global horizon marked by volatility, uncertainty, complexity and ambiguity (VUCA).

But what exactly is a global system? Our planet itself is an autonomous and selfsustaining mega-system, marked by periodic cycles and elemental vagaries. Human activities within however are not system isolates as our banking, utility, farming, healthcare and retail sectors etc. are increasingly entwined. Risks accrued in one system may cascade into an unforeseen crisis within and/or without (Choo, Smith & McCusker, 2007). Scholars call this phenomenon “emergence”; one where the behaviour of intersecting systems is determined by complex and largely invisible interactions at the substratum (Goldstein, 1999; Holland, 1998).

The ongoing COVID-19 pandemic is a case in point. While experts remain divided over the source and morphology of the virus, the contagion has ramified into a global health crisis and supply chain nightmare. It is also tilting the geopolitical balance. China is the largest exporter of intermediate products, and had generated nearly 20% of global imports in 2015 alone (Cousin, 2020). The pharmaceutical sector is particularly vulnerable. Nearly “85% of medicines in the U.S. strategic national stockpile” sources components from China (Owens, 2020).

An initial run on respiratory masks has now been eclipsed by rowdy queues at supermarkets and the bankruptcy of small businesses. The entire global population – save for major pockets such as Sweden, Belarus, Taiwan and Japan – have been subjected to cyclical lockdowns and quarantines. Never before in history have humans faced such a systemic, borderless calamity.

COVID-19 represents a classic emergent crisis that necessitates real-time response and adaptivity in a real-time world, particularly since the global Just-in-Time (JIT) production and delivery system serves as both an enabler and vector for transboundary risks. From a systems thinking perspective, emerging risk management should therefore address a whole spectrum of activity across the economic, environmental, geopolitical, societal and technological (EEGST) taxonomy. Every emerging threat can be slotted into this taxonomy – a reason why it is used by the World Economic Forum (WEF) for its annual global risk exercises (Maavak, 2019a). As traditional forces of globalization unravel, security professionals should take cognizance of emerging threats through a systems thinking approach.

METHODOLOGY

An EEGST sectional breakdown was adopted to illustrate a sampling of extreme risks facing the world for the 2020-2030 decade. The transcendental quality of emerging risks, as outlined on Figure 1, below, was primarily informed by the following pillars of systems thinking (Rickards, 2020):

• Diminishing diversity (or increasing homogeneity) of actors in the global system (Boli & Thomas, 1997; Meyer, 2000; Young et al, 2006);

• Interconnections in the global system (Homer-Dixon et al, 2015; Lee & Preston, 2012);

• Interactions of actors, events and components in the global system (Buldyrev et al, 2010; Bashan et al, 2013; Homer-Dixon et al, 2015); and

• Adaptive qualities in particular systems (Bodin & Norberg, 2005; Scheffer et al, 2012) Since scholastic material on this topic remains somewhat inchoate, this paper buttresses many of its contentions through secondary (i.e. news/institutional) sources.

ECONOMY

According to Professor Stanislaw Drozdz (2018) of the Polish Academy of Sciences, “a global financial crash of a previously unprecedented scale is highly probable” by the mid- 2020s. This will lead to a trickle-down meltdown, impacting all areas of human activity.

The economist John Mauldin (2018) similarly warns that the “2020s might be the worst decade in US history” and may lead to a Second Great Depression. Other forecasts are equally alarming. According to the International Institute of Finance, global debt may have surpassed $255 trillion by 2020 (IIF, 2019). Yet another study revealed that global debts and liabilities amounted to a staggering $2.5 quadrillion (Ausman, 2018). The reader should note that these figures were tabulated before the COVID-19 outbreak.

The IMF singles out widening income inequality as the trigger for the next Great Depression (Georgieva, 2020). The wealthiest 1% now own more than twice as much wealth as 6.9 billion people (Coffey et al, 2020) and this chasm is widening with each passing month. COVID-19 had, in fact, boosted global billionaire wealth to an unprecedented $10.2 trillion by July 2020 (UBS-PWC, 2020). Global GDP, worth $88 trillion in 2019, may have contracted by 5.2% in 2020 (World Bank, 2020).

As the Greek historian Plutarch warned in the 1st century AD: “An imbalance between rich and poor is the oldest and most fatal ailment of all republics” (Mauldin, 2014). The stability of a society, as Aristotle argued even earlier, depends on a robust middle element or middle class. At the rate the global middle class is facing catastrophic debt and unemployment levels, widespread social disaffection may morph into outright anarchy (Maavak, 2012; DCDC, 2007).

Economic stressors, in transcendent VUCA fashion, may also induce radical geopolitical realignments. Bullions now carry more weight than NATO’s security guarantees in Eastern Europe. After Poland repatriated 100 tons of gold from the Bank of England in 2019, Slovakia, Serbia and Hungary quickly followed suit.

According to former Slovak Premier Robert Fico, this erosion in regional trust was based on historical precedents – in particular the 1938 Munich Agreement which ceded Czechoslovakia’s Sudetenland to Nazi Germany. As Fico reiterated (Dudik & Tomek, 2019):

“You can hardly trust even the closest allies after the Munich Agreement… I guarantee that if something happens, we won’t see a single gram of this (offshore-held) gold. Let’s do it (repatriation) as quickly as possible.” (Parenthesis added by author).

President Aleksandar Vucic of Serbia (a non-NATO nation) justified his central bank’s gold-repatriation program by hinting at economic headwinds ahead: “We see in which direction the crisis in the world is moving” (Dudik & Tomek, 2019). Indeed, with two global Titanics – the United States and China – set on a collision course with a quadrillions-denominated iceberg in the middle, and a viral outbreak on its tip, the seismic ripples will be felt far, wide and for a considerable period.

A reality check is nonetheless needed here: Can additional bullions realistically circumvallate the economies of 80 million plus peoples in these Eastern European nations, worth a collective $1.8 trillion by purchasing power parity? Gold however is a potent psychological symbol as it represents national sovereignty and economic reassurance in a potentially hyperinflationary world. The portents are clear: The current global economic system will be weakened by rising nationalism and autarkic demands. Much uncertainty remains ahead. Mauldin (2018) proposes the introduction of Old Testament-style debt jubilees to facilitate gradual national recoveries. The World Economic Forum, on the other hand, has long proposed a “Great Reset” by 2030; a socialist utopia where “you’ll own nothing and you’ll be happy” (WEF, 2016).

In the final analysis, COVID-19 is not the root cause of the current global economic turmoil; it is merely an accelerant to a burning house of cards that was left smouldering since the 2008 Great Recession (Maavak, 2020a). We also see how the four main pillars of systems thinking (diversity, interconnectivity, interactivity and “adaptivity”) form the mise en scene in a VUCA decade.

ENVIRONMENTAL

What happens to the environment when our economies implode? Think of a debt-laden workforce at sensitive nuclear and chemical plants, along with a concomitant surge in industrial accidents? Economic stressors, workforce demoralization and rampant profiteering – rather than manmade climate change – arguably pose the biggest threats to the environment. In a WEF report, Buehler et al (2017) made the following pre-COVID-19 observation:

The ILO estimates that the annual cost to the global economy from accidents and work-related diseases alone is a staggering $3 trillion. Moreover, a recent report suggests the world’s 3.2 billion workers are increasingly unwell, with the vast majority facing significant economic insecurity: 77% work in part-time, temporary, “vulnerable” or unpaid jobs.

Shouldn’t this phenomenon be better categorized as a societal or economic risk rather than an environmental one? In line with the systems thinking approach, however, global risks can no longer be boxed into a taxonomical silo. Frazzled workforces may precipitate another Bhopal (1984), Chernobyl (1986), Deepwater Horizon (2010) or Flint water crisis (2014). These disasters were notably not the result of manmade climate change. Neither was the Fukushima nuclear disaster (2011) nor the Indian Ocean tsunami (2004). Indeed, the combustion of a long-overlooked cargo of 2,750 tonnes of ammonium nitrate had nearly levelled the city of Beirut, Lebanon, on Aug 4 2020. The explosion left 204 dead; 7,500 injured; US$15 billion in property damages; and an estimated 300,000 people homeless (Urbina, 2020). The environmental costs have yet to be adequately tabulated.

Environmental disasters are more attributable to Black Swan events, systems breakdowns and corporate greed rather than to mundane human activity.

Our JIT world aggravates the cascading potential of risks (Korowicz, 2012). Production and delivery delays, caused by the COVID-19 outbreak, will eventually require industrial overcompensation. This will further stress senior executives, workers, machines and a variety of computerized systems. The trickle-down effects will likely include substandard products, contaminated food and a general lowering in health and safety standards (Maavak, 2019a). Unpaid or demoralized sanitation workers may also resort to indiscriminate waste dumping. Many cities across the United States (and elsewhere in the world) are no longer recycling wastes due to prohibitive costs in the global corona-economy (Liacko, 2021).

Even in good times, strict protocols on waste disposals were routinely ignored. While Sweden championed the global climate change narrative, its clothing flagship H&M was busy covering up toxic effluences disgorged by vendors along the Citarum River in Java, Indonesia. As a result, countless children among 14 million Indonesians straddling the “world’s most polluted river” began to suffer from dermatitis, intestinal problems, developmental disorders, renal failure, chronic bronchitis and cancer (DW, 2020). It is also in cauldrons like the Citarum River where pathogens may mutate with emergent ramifications.

On an equally alarming note, depressed economic conditions have traditionally provided a waste disposal boon for organized crime elements. Throughout 1980s, the Calabriabased ‘Ndrangheta mafia – in collusion with governments in Europe and North America – began to dump radioactive wastes along the coast of Somalia. Reeling from pollution and revenue loss, Somali fisherman eventually resorted to mass piracy (Knaup, 2008).

The coast of Somalia is now a maritime hotspot, and exemplifies an entwined form of economic-environmental-geopolitical-societal emergence. In a VUCA world, indiscriminate waste dumping can unexpectedly morph into a Black Hawk Down incident. The laws of unintended consequences are governed by actors, interconnections, interactions and adaptations in a system under study – as outlined in the methodology section.

Environmentally-devastating industrial sabotages – whether by disgruntled workers, industrial competitors, ideological maniacs or terrorist groups – cannot be discounted in a VUCA world. Immiserated societies, in stark defiance of climate change diktats, may resort to dirty coal plants and wood stoves for survival. Interlinked ecosystems, particularly water resources, may be hijacked by nationalist sentiments. The environmental fallouts of critical infrastructure (CI) breakdowns loom like a Sword of Damocles over this decade.

GEOPOLITICAL

The primary catalyst behind WWII was the Great Depression. Since history often repeats itself, expect familiar bogeymen to reappear in societies roiling with impoverishment and ideological clefts. Anti-Semitism – a societal risk on its own – may reach alarming proportions in the West (Reuters, 2019), possibly forcing Israel to undertake reprisal operations inside allied nations. If that happens, how will affected nations react? Will security resources be reallocated to protect certain minorities (or the Top 1%) while larger segments of society are exposed to restive forces? Balloon effects like these present a classic VUCA problematic.

Contemporary geopolitical risks include a possible Iran-Israel war; US-China military confrontation over Taiwan or the South China Sea; North Korean proliferation of nuclear and missile technologies; an India-Pakistan nuclear war; an Iranian closure of the Straits of Hormuz; fundamentalist-driven implosion in the Islamic world; or a nuclear confrontation between NATO and Russia. Fears that the Jan 3 2020 assassination of Iranian Maj. Gen. Qasem Soleimani might lead to WWIII were grossly overblown. From a systems perspective, the killing of Soleimani did not fundamentally change the actor-interconnection-interaction adaptivity equation in the Middle East. Soleimani was simply a cog who got replaced.

### 4

#### Moon basing causes US-China war due to competing property claims

Copp 21 If China and the US Claim the Same Moon-Base Site, Who Wins? TARA COPP [SENIOR PENTAGON REPORTER, DEFENSE ONE] AUGUST 8, 2021 <https://www.defenseone.com/technology/2021/08/if-china-and-us-claim-same-moon-base-site-who-wins/184352/> SM

If China and the US Claim the Same Moon-Base Site, Who Wins?

Relatively few craters are attractive, and there’s no consensus about avoiding conflict over them.

There’s a not-so-quiet race back to the moon underway, but the two largest factions, with China and Russia on one side, and the United States and its partners on the other, are not recognizing each others’ proposed rules on what’s allowed once they get there.

Lawmakers and space policy analysts are concerned: How do you avoid conflict in space if the international laws and policies on Earth no longer apply?

“Many terrestrial military doctrines are not applicable in space, or at least not as applicable. If you get beyond 50 miles, or at least 62 miles, suddenly different rules apply. We need to start being aware of that,” says Rep. Jim Cooper, D-Tenn.

There’s already some aggressive international elbowing over the rules of satellite operations. As with the moon, there’s no consensus yet on how to respond to aggression in Earth orbit, the head of U.S. Space Command Gen. James Dickinson told attendees at last week’s Sea Air Space conference.

“The behavior of some of our adversaries in space may surprise you,” Dickinson said. “If similar actions have been taken in other domains, they'd likely be considered provocative, aggressive, or maybe even irresponsible. And in response, the U.S. government would take corresponding actions using all levers of national power, a demarche, or a sanction or something to indicate we won't tolerate that type of behavior, but we're not quite there yet in space policy.”

In 1967, the U.N. General Assembly adopted a treaty on the use of outer space that promised cooperation and banned nuclear weapons, military maneuvers, and military installations off-planet. The agreement also requires countries to take “appropriate international consultations” before making any moves that would “cause potentially harmful interference” with other space programs, and allows countries to “request consultation” if they believe such interference is likely.

This treaty “forecasted very well” the issues that that might arise as space exploration expanded, said James Lake, a senior associate at Canyon Consulting who co-wrote an article on lunar security issues in this month’s Space Force Journal. “The question remains: is that text sufficient? That’s something we are going to find out fairly soon.”

Notably, a treaty annex that prohibits military activity on the moon went unratified by Russia, China, and the United States. It’s likely both the China-Russia and U.S.-led partnerships will begin their moon bases without any sort of agreement between them in place.

In June, the China National Space Agency and Russia’s Roscosmos announced they would begin surveying locations for their International Lunar Research Station this year, and pick a site by 2025.

In 2020, NASA, together with the nations partnering with the U.S. under the Artemis Accords, outlined its Artemis Base Camp project. The Artemis nations aim to to send astronauts back to the moon by 2024.

In addition to those two major alliances, private firms such as Blue Origin are also working on private moon bases.

But there may be only a few locations on the moon where it would make economic sense to build a base, said Bleddyn Bowen, a professor at the University of Leicester and author of War in Space: Strategy, Spacepower, Geopolitics.

“Water ice, for example, might be in limited pockets, for example, making the territories around certain craters on the polar regions, perhaps more desirable,” Bowen said.

So what happens if each decides on the same crater as the best spot to begin moon operations?

“If you have a situation like that, where you're trying to do something in the exact same spot, it’s essentially who gets there first,” said Alex Gilbert, a researcher and space resources doctoral student at the Payne Institute at the Colorado School of Mines. “And if you're not first, then the only alternative is to forcibly remove the current occupant.”

The Artemis nations have endorsed the idea of “safety zones” on the moon, to require communication between two space operations that want to operate in the same area.

“Even if you set up a base and you declare a safety zone, people can still go into that safety zone. It's just something that it's really to be used as a tool to get parties to talk to each other,” he said.

But there’s already a risk those zones will instead be used as a way to rope off sites from competitors, he said.

“One thing that is really kind of important to understand about safety zones is that everyone kind of has their own definition,” Gilbert said.

“Whoever gets there first can use the resources, but no nation can ‘claim’ the territory,” said Laura Duffy, a space systems engineer with Canyon Consulting who co-wrote “Cislunar Spacepower, The New Frontier,” with Lake with Lake in this month’s Space Force Journal.

It’s not just water, but rare earth metals and helium-3 that will be up for grabs on the moon, making a treaty for its peaceful use critical, Duffy said.

“The Moon must be available for open and free use, according to the Artemis Accords and Outer Space Treaty,” she said.

But neither Russia nor China are expected to join the Artemis Accords.

Until now, U.S. space defense has largely concentrated around the objects orbiting Earth. That changed this year, when the U.S. Space Force and U.S. Space Command were tasked with protecting U.S. assets up to 272,000 miles away, a volume called “cislunar space” that extends slightly beyond the Moon’s orbit.

They have some catching up to do, said Rep. Frank Lucas, R-Okla., the ranking member of the Science, Space and Technology Committee. Lucas believes the 2019 landing of China’s Chang'e-4 spacecraft on the far side of the moon should have been this generation’s Sputnik moment.

“But with all of the chaos in the world, and COVID-19, and all of this environment we're working in, we missed it,” he said.

Those far-side moon operations meant China had developed the technology to operate and communicate with its landed rover out of line of sight—and out of view of almost all of the U.S. ability to see what they’re doing.

The achievement allows China “to accomplish scientific, military, or other endeavors without observation or repercussion,” Duffy and Lake wrote. The authors urged that the U.S. needs to speed its monitoring efforts, such as the Cislunar Highway Patrol System, or CHPS, that is being developed by the Air Force Research Laboratory.

#### Space conflicts go nuclear---both fast and probable

Laura Grego 15, a physicist in the Global Security program at UCS. She is an expert in space weapons and security; ballistic missile proliferation, and ballistic missile defense, "Preventing Space War", https://allthingsnuclear.org/lgrego/preventing-space-war

So says a very good New York Times editorial “Preventing a Space War” this week. Sounds right, if X-Wing fighters come to mind when you think space conflict. But in reality conflict in space is both more likely than one would think and less likely to be so photogenic. Space as a locus of conflict The Pentagon has known that space could be a flash point at least since the late 1990s when it began including satellites and space weapons in earnest as part of its wargames. The early games revealed some surprises. For example, attacking an adversary’s ground-based anti-satellite weapons before they were used could be the “trip wire” that starts a war: in the one of the first war games, an attack on an enemy’s ground-based lasers was meant to defuse a potential conflict and protect space assets, but instead was interpreted as an act of war and initiated hostilities. The games also revealed that disrupting space-based communication and information flow or “~~blinding~~” could rapidly escalate a war, eventually leading to nuclear weapon exchange. The war games have continued over the years with increased sophistication, but continue to find that conflicts can rapidly escalate and become global when space weapons are involved, and that even minor opponents can create big problems. The report back from the 2012 game, which included NATO partners, said these insights have become “virtually axiomatic.” Participants in the most recent Schriever war games found that when space weapons were introduced in a regional crisis, it escalated quickly and was difficult to stop from spreading. The compressed timelines, the global as well as dual-use nature of space assets, the difficulty of attribution and seeing what is happening, and the inherent vulnerability of satellites all contribute to this problem. Satellite vulnerability & solutions Satellites are valuable but, at least on an individual basis, physically vulnerable. Vulnerable in that they are relatively fragile, as launch mass is at a premium and so protective armor is too expensive, and a large number of low-earth-orbiting satellites are no farther from the earth’s surface than the distance from Boston to Washington, DC.

## Advantage

### NC – Top

#### Disruptions are inevitable and improve research

Quenelle 20 [Nicole Quenelle, 11-10-2020, "The Perils and Promise of Dust on the Moon,", NASA https://www.nasa.gov/directorates/spacetech/flightopportunities/Perils\_and\_Promise\_of\_Dust\_on\_the\_Moon/ ]

Collecting the dust

Dust on the Moon is not just a hazard – it also presents scientific opportunity. In fact, researchers want to collect some of that surface dust, called regolith, for analysis. This is the goal behind the second technology flying on the upcoming flight test: PlanetVac from Honeybee Robotics, headquartered in New York City.

Previously flown on Masten’s vehicle in 2017, PlanetVac attaches to the leg of a lander and uses gas to initiate suction, transferring a surface sample through a tube and depositing it into a container that can be sent back to Earth for analysis. The device has been selected to go to the Moon on a future flight through NASA's Commercial Lunar Payload Services (CLPS) initiative. The payload will also be part of the Japan Aerospace Exploration Agency’s Martian Moons Exploration mission in 2024.

While the 2017 testing proved the technology’s ability to successfully collect more than 300 grams of simulated regolith (about the size of an orange), the upcoming flight goes a few steps further. First, whereas the previous test involved a sample container located very close to the lander footpad, this time researchers want to demonstrate the ability to transfer the sample to a container located several feet above the device.

“This will show that the technology is capable of even more than it would likely need to do in a lunar mission,” said Luke Sanasarian, mechanical engineer and Honeybee’s project lead for the upcoming flight. “If we can show that we can deliver a sample in this scenario, then we buy down even more risk for the lunar mission.”

Second, Honeybee is taking advantage of the dust clouds created for the Ejecta STORM testing to evaluate PlanetVac’s efficacy in collecting a sample after the surface has been scoured of loose regolith – something they did not look at in the 2017 tests.

“Previously, we completely blocked the rocket plume to prevent it from disturbing the regolith, because the amount of disruption given Earth’s atmosphere is much more than what we’d see in the vacuum environment on the Moon,” explained Sanasarian. “But now we want to allow for some disturbance of the surface soil, to a degree similar to what we’d see in a lunar mission. This gets us even closer to what the device will encounter there.”

Sanasarian said that this iterative testing – where researchers are able to evaluate certain aspects of a technology, make refinements, and then fly again to validate other parameters – has proven extremely valuable in preparing PlanetVac for the commercial mission, scheduled for 2023.

“Being able to do this second test in a new configuration is not only expanding our understanding of how the technology works, but it’s also expanding the potential missions that it could be a part of,” he said.

Flying the University of Central Florida and Honeybee technologies together will also provide more data than either team would have had flying alone. In particular, the university team’s measurements may help Honeybee better understand just how much surface soil can be disturbed while still allowing for a successful sample collection.

“Having their data to help us understand how much dust is being kicked up really makes for a beneficial complement to our testing as well,” said Sanasarian. “And of course, that just adds even more value to the flight for everyone involved and for the NASA missions that will benefit.”

#### Tons of tech solves moon dust – it’s a non-factor

Rabie 21 [Passant Rabie is a space writer at Inverse, where she guides readers through the mysteries of the local universe. She covers ongoing missions to distant planets and beyond, and breaks down recent discoveries in the world of astrophysics and the latest in ongoing space news. "NASA IS TRYING TO DEAL WITH ITS MOST ANNOYING PROBLEM ON THE MOON." https://www.inverse.com/science/nasa-moon-dust-problem]

HOW DO YOU DEAL WITH DUST ON THE MOON?

In 2019, NASA created the Lunar Surface Innovation Initiative (LSII) to come up with new technologies needed for future exploration of the Moon, with dust mitigation being one of the main priorities.

The initiative came up with active and passive mitigation technologies for different kinds of equipment like rovers, power systems, spacesuits, and other types of hardware that NASA would send to the Moon.

Sharon Miller, the dust shedding material program’s principal investigator at NASA Glenn, says the combination of the passive and active techniques will allow the dust to be removed from the surface area while reducing the amount of power needed to remove it.

“The equipment that we're using is a variety of things from the different NASA centers,” Miller tells Inverse.

Some of the ideas that are currently being developed include ion-beamed deposited coating or laser patterned surfaces.

The team has started developing these materials and testing them in the lab, experimenting with different textures and combinations. NASA is then planning on testing these experimental solutions on the surface of the Moon starting in 2023.

“The solutions that we're working on are ‘leave no damage behind’ type of solutions,” Montbach says. “These are things that will only affect the equipment and prevent the equipment from being damaged by the dust, but will not do anything specifically to change what is on the Moon.”

The solutions are not only for missions like Apollo, but are designed for a longer, more sustainable stay on the Moon as NASA plans on building a lunar base on the Moon.

“A lot of what has begun this interest in this need is to try and find solutions not only for shorter missions but potentially that would work for longer missions as well,” Montbach says.

#### Moon basing is literally impossible

Whittaker 1-2 [Ian Whittaker, 1-2-2022, "Why can't we put a space station on the moon?," Space, https://www.space.com/why-cant-we-put-space-station-on-moon,Dr. Ian Whiitaker is a senior lecturer in physics at Nottingham Trent University in Nottingham, England in the United Kingdom. He earned a master's of physics with space science and technology from the University of Leicester in 2006 and earned his Ph.D. in space physics from the University of Wales, Aberystwyth in 2010 while studying the interaction of the sun with the upper atmosphere of Venus. Ian has lectured at Nottingham Trent University since 2017 and has a special interest in space science outreach. In addition to his lecturing duties, Ian is a contributor to The Conversation, where he writes about a wide range of issues on space exploration and science. ]

One reason we haven’t built a space station on the moon is that we don’t send people there very often. We have only managed to put astronauts on the moon six times so far. These moon landings took place in a three-year period between 1969 and 1972 and were part of a series of space missions called the Apollo missions. The type of rocket used to get the astronauts to the moon was an extremely powerful one called a Saturn V, which is no longer produced. This means that, at the moment, we do not have a rocket powerful enough to get people to the moon – let alone build a space station there. We are starting to build powerful rockets again. Space exploration company SpaceX is creating newer and bigger rockets which are capable of taking the weight of astronauts to the moon. NASA is also planning new missions to take astronauts to the moon. However, there is a big difference between a short trip and building a space station on the moon, which is extremely difficult. One way to do it would be to build it in pieces on Earth, take the pieces to the moon and assemble them there. This would be like how the International Space Station was built: pieces were taken into space and then put together by astronauts aboard the space shuttle. However, the International Space Station is only 250 miles (400 kilometers) from the surface of Earth. The moon is 230,000 miles (384,000 km). Each trip to the moon would take about three days and would require incredible amounts of fuel, potentially adding to climate problems on Earth. A much better idea would be to build as much of the base as possible from materials found on the moon. Lunar concrete is being tested on Earth as a possible building material. On Earth you would make concrete from gravel or sand, cement and water. We have none of those things on the moon, but what we do have is lunar dust and sulphur. These can be melted and mixed together. Once this mixture cools, it produces a solid material that is stronger than many materials we use on Earth. Food and power We also need to think about what astronauts staying at the space station would need. The most important things would be a food supply and electricity to power equipment, food production and breathable air. Scientists have been working on how to grow food in space. On board the International Space Station, astronauts are carrying out experiments to try to grow vegetables using soil pillows. Another option would be to grow plants using hydroponics, which means that the plants grow in water, not soil. Getting power on the moon would be more complicated. The best way would be to use solar energy from the sun. However, the moon rotates every 28 days. This means that a space station in a fixed position on the moon would be in the sun for 14 days and then darkness for 14 days – and without light, solar-powered equipment wouldn’t work without a big improvement in battery storage. One way to get round this problem would be to build the space station at either the north or south pole of the moon, and raise the solar panels above the surface. The panels would get constant sunlight as they can rotate and not be blocked by the planet at all. Alternatively, we might not even need a base on the surface of the moon at all. Instead, NASA is planning to build a satellite to orbit the moon. Rockets launching from the lunar surface use more fuel to escape the moon’s gravity, but this would not be so difficult from a satellite. This means it would be even better than a base on the moon; a gateway for missions heading further into the solar system.

### NC – Moon-basing Bad

#### Moon-Basing is Bad –

#### NASA DA –

#### Moon base causes existential budget tradeoffs for NASA

Easterbrook 6 [Gregg Easterbrook is a fellow at the Brookings Institution. His most recent book is The Progress Paradox: How Life Gets Better While People Feel Worse. "Moon Baseless." https://slate.com/technology/2006/12/why-do-we-need-a-moon-base.html]

Coming under a presidency whose slogan might be “No Price Too High To Accomplish Nothing,” the idea of a permanent, crewed moon base nevertheless takes the cake for preposterousness. Although, of course, the base could yield a great discovery, its scientific value is likely to be small while its price is extremely high. Worse, moon-base nonsense may for decades divert NASA resources from the agency’s legitimate missions, draining funding from real needs in order to construct human history’s silliest white elephant.

What’s it for? Good luck answering that question. There is scientific research to be done on the moon, but this could be accomplished by automatic probes or occasional astronaut visits at a minute fraction of the cost of a permanent, crewed facility. Astronauts at a moon base will spend almost all their time keeping themselves alive and monitoring automated equipment, the latter task doable from an office building in Houston. In deadpan style, the New York Times story on the NASA announcement declared, “The lunar base is part of a larger effort to develop an international exploration strategy, one that explains why and how humans are returning to the moon and what they plan to do when they get there.” Oh–so we’ll build the moon base first, and then try to figure out why we built it.

#### Plan forces spending trade-offs that crush effective Earth sciences --- risks catastrophic climate change

Haymet 7 (Tony, Director of the Scripps Institution of Oceanography – University of California, San Diego, Mark Abbott, Dean of the College of Oceanic and Atmospheric Science – Oregon State University, and Jim Luyten, Acting Director – Woods Hole Oceanographic Institution, “The Planet NASA Needs to Explore”, Washington Post, 5-10, [http://www.washingtonpost.com/wp-dyn/content/article/2007/05/09/AR2007050902451.html](http://www.lexis.com/research/retrieve))

Decades ago, a shift in NASA priorities sidelined progress in human space exploration. As momentum gathers to reinvigorate human space missions to the moon and Mars, we risk hurting ourselves, and Earth, in the long run. Our planet -- not the moon or Mars -- is under significant threat from the consequences of rapid climate change. Yet the changing NASA priorities will threaten exploration here at home.

NASA not only launches shuttles and builds space stations, it also builds and operates our nation's satellites that observe and monitor the Earth. These satellites collect crucial global data on winds, ice and oceans. They help us forecast hurricanes, track the loss of Arctic sea ice and the rise of sea levels, and understand and prepare for climate changes.

NASA's budget for science missions has declined 30 percent in the past six years, and that trend is expected to continue. As more dollars are reallocated to prepare for missions back to the moon and Mars, sophisticated new satellites to observe the Earth will be delayed, harming Earth sciences.

The National Academy of Sciences has noted that the Landsat satellite system, which takes important measurements of global vegetation, is in its fourth decade of operation and could fail without a clear plan for continuation. The same is true for the QuikSCAT satellite, which provides critical wind data used in forecasting hurricanes and El Niño effects.

In January, a partnership of university and NASA scientists demonstrated that climate change and higher ocean temperatures were reducing the growth of microscopic plants and animals at the heart of the marine food web.

Their analysis was based on nearly a decade of NASA satellite measurements of ocean color, which unfortunately are at risk of being interrupted for several years.

Sea levels are rising, and the Arctic Ocean may be ice-free in summer. The buildup of carbon dioxide in the oceans threatens to make them more acidic, which may in turn hinder the ability of some types of marine life, including corals, to build their shells and skeletons. We must learn as much as we can to assess these threats and develop solutions.

Satellites provide coverage of vast, remote regions of our planet that would otherwise remain unseen, especially the oceans, which play an important role in climate change. Without accurate data on such fundamentals as sea surface height, temperatures and biomass, as well as glacier heights and snowpack thickness, we will not be able to understand the likelihood of dangers such as more severe hurricanes along the Gulf Coast or more frequent forest fires in the Pacific Northwest.

Climate change is the most critical problem the Earth has ever faced.

Government agencies and the private sector, as well as individual citizens, need to better grasp the risks and potential paths of global climate change. Mitigating these risks and preparing for the effects of warming will require scientific understanding of how our complex planet operates, how it is changing, and how that change will affect the environment and human society.

John F. Kennedy's brilliant call to put a man on the moon by the end of the 1960s set an arbitrary deadline, but the deadline we face today is set by nature. NASA must continue to play a vital role in helping find ways to protect our planet for (and perhaps from) its intelligent life. Exploration of space is a noble quest. But we can't afford to be so starry-eyed that we overlook our own planet.

#### Warming is inevitable but adjusting government policy can address the worst effects – specifically, for sea level rise. US responses are modeled globally.

**Economist 17**, "How government policy exacerbates hurricanes like Harvey," Economist, https://www.economist.com/news/leaders/21727898-if-global-warming-were-not-enough-threat-poor-planning-and-unwise-subsidies-make-floods

THE extent of the devastation will become clear only when the floodwater recedes, leaving ruined cars, filthy mud-choked houses and the bloated corpses of the drowned. But as we went to press, with the rain pounding South Texas for the sixth day, Hurricane Harvey had already set records as America’s most severe deluge (see Briefing). In Houston it drenched Harris County in over 4.5trn litres of water in just 100 hours—enough rainfall to cover an eight-year-old child. The fate of America’s fourth-largest city holds the world’s attention, but it is hardly alone. In India, Bangladesh and Nepal, at least 1,200 people have died and millions have been left homeless by this year’s monsoon floods. Last month torrential rains caused a mudslide in Sierra Leone that killed over 1,000—though the exact toll will never be known. Around the world, governments are grappling with the threat from floods. This will ultimately be about dealing with climate change. Just as important, is correcting short-sighted government policy and the perverse incentives that make flooding worse. Judgment day The overwhelming good news is that storms and flooding have caused far fewer deaths in recent decades, thanks to better warning systems and the construction of levees, ditches and shelters. The cyclone that struck Bangladesh in 1970 killed 300,000-500,000 people; the most recent severe one, in 2007, killed 4,234. The bad news is that storms and floods still account for almost three-quarters of weather-related disasters, and they are becoming more common. According to the Munich Re, a reinsurer, their number around the world has increased from about 200 in 1980 to over 600 last year. Harvey was the third “500-year” storm to strike Houston since 1979. At the same time, floods and storms are also becoming more costly. By one estimate, three times as many people were living in houses threatened by hurricanes in 2010 as in 1970, and the number is expected to grow as still more people move to coastal cities. The UN reckons that, in the 20 years to 2015, storms and floods caused $1.7trn of destruction; the World Health Organisation estimates that, in real terms, the global cost of hurricane damage is rising by 6% a year. Flood losses in Europe are predicted to increase fivefold by 2050. One cause is global warming. The frequency and severity of hurricanes vary naturally—America has seen unusually few in the past decade. Yet the underlying global trend is what you would expect from climate change. Warmer seas evaporate faster and warmer air can hold more water vapour, which releases energy when it condenses inside a weather system, feeding the violence of storms and the intensity of deluges. Rising sea levels, predicted to be especially marked in the Gulf of Mexico, exacerbate storm surges, adding to the flooding. Harvey was unusually devastating because it suddenly gained strength before it made landfall on Friday; it then stayed put, dumping its rain on Houston before returning to the Gulf. Again, that is consistent with models of a warmer world. Poor planning bears even more blame. Houston, which has almost no restrictions on land-use, is an extreme example of what can go wrong. Although a light touch has enabled developers to cater to the city’s rapid growth—1.8m extra inhabitants since 2000—it has also led to concrete being laid over vast areas of coastal prairie that used to absorb the rain. According to the Texas Tribune and ProPublica, a charity that finances investigative journalism, since 2010 Harris County has allowed more than 8,600 buildings to be put up inside 100-year floodplains, where floods have a 1% chance of occurring in any year. Developers are supposed to build ponds to hold run-off water that would have soaked into undeveloped land, but the rules are poorly enforced. Because the maps are not kept up to date, properties supposedly outside the 100-year floodplain are being flooded repeatedly. Government failure adds to the harm. Developing countries are underinsured against natural disasters. Swiss Re, a reinsurer, says that of the $50bn or so of losses to floods, cyclones and other disasters in Asia in 2014, only 8% were covered. The Bank of International Settlements calculates that the worst natural catastrophes typically permanently lower the afflicted country’s GDP by almost 2%. America has the opposite problem—the federal government subsidises the insurance premiums of vulnerable houses. The National Flood Insurance Programme (NFIP) has been forced to borrow because it fails to charge enough to cover its risk of losses. Underpricing encourages the building of new houses and discourages existing owners from renovating or moving out. According to the Federal Emergency Management Agency, houses that repeatedly flood account for 1% of NFIP’s properties but 25-30% of its claims. Five states, Texas among them, have more than 10,000 such households and, nationwide, their number has been going up by around 5,000 each year. Insurance is meant to provide a signal about risk; in this case, it stifles it. Mend the roof while the sun shines What to do? Flooding strengthens the case for minimising climate change, which threatens to make wet places wetter and storms stormier. Even those who doubt the science would do well to see action as an insurance policy that pays out if the case is proven. However, that will not happen fast, even if all countries, including America, sign up to international agreements. More immediately, therefore, politicians can learn from Houston. Cities need to protect flood defences and catchment areas, such as the wetlands around Kolkata and the lakes in and around Pokhara in Nepal, whose value is becoming clear. Flood maps need to be up to date. Civil engineers, often starved of funds and strangled by bureaucracy, should be building and reinforcing levees and reservoirs now, before it is too late. The NFIP should start to charge market premiums and developing countries should sell catastrophe bonds. All this is a test of government, of foresight and the ability to withstand the lobbying of homeowners and developers. But politicians and officials who fail the test need to realise that, sooner or later, they will wake up to a Hurricane Harvey of their own.

#### Causes extinction – adaption key

Eric Holthaus 15, editor at rollingstone magazine citing James Hansen, former NASA climatologist, "The Point of No Return: Climate Change Nightmares Are Here," Rolling Stone, accessed 10-23-2016, http://www.rollingstone.com/politics/news/the-point-of-no-return-climate-change-nightmares-are-already-here-20150805

On July 20th, James Hansen, the former NASA climatologist who brought climate change to the public's attention in the summer of 1988, issued a bombshell: He and a team of climate scientists had identified a newly important feedback mechanism off the coast of Antarctica that suggests mean sea levels could rise 10 times faster than previously predicted: 10 feet by 2065. The authors included this chilling warning: If emissions aren't cut, "We conclude that multi-meter sea-level rise would become practically unavoidable. Social disruption and economic consequences of such large sea-level rise could be devastating. It is not difficult to imagine that conflicts arising from forced migrations and economic collapse might make the planet ungovernable, threatening the fabric of civilization."

### NC – Top vs Basing Solves Neutrinos

#### Whole scenario is a joke – no ev indicating sufficiency or establishing brink – 1AC ev is about astronomy, not research. No reason any nation would agree to it and increased research can’t facilitate detection absent a vested interest in doing so

#### Long distance tubes detection

Wright 20 [Katherine Wright, 3-12-2020, Physics, "Neutrino Detectors for National Security," https://physics.aps.org/articles/v13/36 ] \* Figures Omitted

Making these detectors also required engineering advances. Classic neutrino detectors are built around enormous tanks of liquid that are thousands of meters underground, with the overlying rock needed to shield out cosmic rays. The Super-Kamiokande detector in Japan, for example, is 1000 meters below ground and includes a tank containing 50 kilotons of water. But for nuclear security, the detector needs to be close to the source and to be mobile in order to travel between reactor sites.

Researchers recently solved these problems, demonstrating above-ground, mobile detectors that can accurately measure neutrinos at commercial reactors. The detectors work by recording the flashes of visible light (scintillation events) produced when a neutrino interacts with the detection medium (the scintillator). To make the detectors operational above ground, researchers used new scintillators and split them up into tubes or cubes, a process called segmenting. Segmentation makes reactor neutrino scintillation events distinguishable from those from sources that underground facilities never had to worry about, such as fast neutrons produced by cosmic rays. When a particle enters, the pattern of segments that light up indicates the particle’s identity.

The recently demonstrated detectors included VIDARR (1 ton), from Liverpool University, UK; PROSPECT (4 tons), based at Oak Ridge National Laboratory (ORNL), Tennessee; and the small-scale prototype detector CHANDLER (80 kg), from Virginia Tech. Each has detected neutrinos from a nuclear power plant, and each fits inside a trailer or shipping container. PROSPECT also demonstrated the high-precision energy spectrum measurements required to make an above-ground estimate of a reactor’s plutonium content.

Practical Limitations and a Hefty Price Tag

But the technology has challenges, the most significant of which is the requirement to be close to a reactor. Neutrinos easily pass through a reactor’s walls because they rarely interact with matter, but this property also leads to very few detections, says Nathaniel Bowden of Lawrence Livermore National Laboratory, California, co-spokesperson of the PROSPECT team. For example, at a distance of 9 m, PROSPECT picked up about 700 antineutrinos of the roughly 1019 emitted per day by the High Flux Isotope reactor at ORNL. This low rate, however, is still sufficient for detectors like PROSPECT to make meaningful measurements.

The distance limitation is a real issue, says Alex Glaser, who studies policy questions related to nuclear nonproliferation at Princeton University, New Jersey. Detecting undeclared facilities, rather than monitoring known ones, is the “holy grail,” and neutrino detectors don’t currently have that capability, he says. Physicists are building a neutrino detector called WATCHMAN that aims to spot a clandestine reactor in the shadow of a known facility from a distance of 26 km. But even at that distance, the detector must still be located within the country being monitored. Detectors that operate from further afield, for example, outside of a country’s borders, “would be a game changer but remain elusive for now,” Glaser says.

Calculations carried out by Huber and his colleagues indicate that a neutrino detector would need over 300 kilotons of scintillator to discern a reactor 1000 km away [1]. Even with that size, it would only detect three neutrinos per year. And then there are background signals from other reactors around the globe. A neutrino detector at Iran’s border, for example, could be within 1000 km of an undeclared reactor, but it would also sit 5000 km from Europe’s 400 gigawatts’ worth of nuclear power. “The neutrinos from those [European] reactors are going to drown out the Iranian ones,” Huber says.

#### Detectors are too complicated and rogue states circumvent them – cx

Berryrieser 12 [David Berryrieser, March 22, 2012, ' Neutrino Detectors for Anti-Proliferation', Stanford, http://large.stanford.edu/courses/2012/ph241/berryrieser2/, Full Time Atomic Physicist @ Stanford **\* Note - 15 m3 = Neutrino Detector, Pthermal = power in a reactor** ]

Problems

While possible in principle, such a device has flaws that make it ineffective as a tool for anti-proliferation. The fundamental problem is that it is far easier for a rogue state to stay one step ahead of the inspectors than the other way around. Say the IAEA had NUCIFER detectors ready for deployment. In what easy way could the rogue state make NUCIFER detectors useless? The Pthermal of the reactor could be varied with time. Or, there could just happen to be no convenient place anywhere close to the reactor to put a 15 m3. This is by no means an extensive list of foils. A creative reader could dream up many more.

Conclusion

Reactor neutrino detectors are a far less attractive tool for monitoring reactor composition than advertised. The complicated nature of the process provide many opportunities for the measurement to be contaminated or rendered impossible to make. In addition, the statistical and abstract nature of the measurement make it inaccessible to everyone without a physics degree. Any public discussion of the results could easily be devolved into jargon indecipherable by any public servant. However, there is a broader problem. A fancy measuring device is not necessary to expose nuclear weapons ambitions. One only needs to don a common sense cap and ask, would Iran build reactors for peaceful energy purposes while simultaneously burning away their stranded natural gas? No. The larger problem then is not outing reactors used for breeding fuel, but determining how to stop them. It is possible that good reliable third party measurements on the reactors in questions would aid this process. Neutrino detectors, with their fog of complications, cannot serve this role.

#### Prolif doesn’t cause nuke war or preemptive strikes – it’s overstated

* Prolif impact exaggerated – wrong about China in the 60s and wrong now
* Iran and Korea are both defensive, won’t escalate
* Cascade disproven by Israel and NoKo
* Weapons don’t get used – just ego booster for leaders and deterrence policy

Mueller 6/22/20 [Mueller 6/24/20 [John Mueller is a political scientist at Ohio State University and a senior fellow at the Cato Institute. His latest book, The Stupidity of War: American Foreign Policy and the Case for Complacency, is forthcoming from Cambridge University Press. "Nuclear Anti‐​Proliferation Policy and the Korea Conundrum: Some Policy Proposals." https://www.cato.org/publications/policy-analysis/nuclear-anti-proliferation-policy-korea-conundrum-some-policy]

Like the notion accepted in the 1950s that World War III was pretty much inevitable, the notion that nuclear weapons proliferation is a major problem has been substantially overwrought.2 At the same time, the costly impact of aggressive policies to combat proliferation has often been overlooked or ignored.

The Benign Consequences of Proliferation

When China began building a nuclear capac­ity, President John F. Kennedy seriously considered bombing Chinese nuclear facilities. He was heard to declare that “A Chinese nuclear test is likely to be historically the most significant and worst event of the 1960s,” and his director of the Central Intelligence Agency soberly prophesied that, with that event, nuclear war would become almost inevitable.3

Declamations like Kennedy’s continue to this day.4 Elected officials and foreign policy experts have repeatedly warned that if Iran or North Korea were to get a nuclear weapon, there would be a proliferation cascade, resulting in an increased risk of nuclear war or, in the words of Mohamed ElBaradei, the head of the International Atomic Energy Agency, “the beginning of the end of our civilization.”5 North Korea has now had the weapons for well over a decade, but there is little sign of the warned‐​about cascade: thus far, no country in the region has altered its commitment to remain a nuclear‐​weapons‐​free state.

Despite decades of such fears, the consequences of the nuclear‐​weapons proliferation that has taken place have been substantially benign. As it turned out, the United States did not attack or otherwise punish China for developing nuclear weapons, and a nuclear‐​armed China did not become more aggressive//

: in fact, the existence of its arsenal has proved to be of little historical consequence. In retrospect, “historically the most significant and worst event of the 1960s” stemmed not from China’s nuclear weapons, but from Kennedy’s tragically misguided decision to begin sending American troops in substantial numbers to Vietnam — largely to confront the Chinese threat that he believed lurked there.6

In general, regimes that have acquired the weapons have used them to stoke their egos or to deter real or imagined threats. They have quietly kept the weapons in storage (or even denied their existence) and haven’t even found much benefit in rattling them from time to time.

### NC – Top vs Basing Solves Aquaculture

#### No ev says that the aff is sufficient to overcome the problems with global aquaculture now, and no UQ argument about aquaculture declining now.

#### Not Sustainable

\* in the above header as well

Richens 20 [James Richens, 8-26-2020, "Can sustainable aquaculture feed the world?," Reuters, https://www.reutersevents.com/sustainability/can-sustainable-aquaculture-feed-world ]

The aquaculture industry has greatly reduced the proportion of feed derived from wild-caught fish by switching to fish by-products as well as plant-based alternatives. For example, fishmeal and fish oil inclusion rates in the diets of salmon farmed in Norway have dropped from 29% and 24% respectively in 2000 to 15% and 8% respectively in 2018, according to data from the Marine Ingredients Organisation (IFFO).

However, switching to alternative feeds may not be sustainable if they come from sources such as soy, which can contribute to other environmental problems such as deforestation. It is also important that they provide the nutrients that farmed fish need. Some companies are looking at innovative options such as industrial fermentation.

Veramaris is a joint venture formed in 2018 by Dutch-based biotechnology company DSM and German chemicals firm Evonik. In July 2019, the partnership opened a $200m manufacturing site in the US state of Nebraska, which will supply 15% of the global omega-3 fatty acid demand for salmon aquaculture, the equivalent of over one million tonnes of wild-caught fish.

We would like to go offshore because that is the natural habitat of the salmon

The process works by fermenting marine micro-algae with sugar from beet, wheat or corn to make an oil that contains omega-3 fatty acids at a 50% concentration.

Consumer-facing businesses with reputations at risk have an important role in driving the switch to sustainably farmed fish. UK supermarket chain Tesco has been working with its key salmon suppliers to scale up the use of more sustainable feed ingredients. One of its suppliers in Norway has started to supply salmon that was partially fed with omega-3 algal oil.

Mariculture faces other sustainability challenges that it must overcome to realise its potential to help feed the world. Most is done close to the coast for ease of access, but this means that fish farms can cause water pollution and degrade local ecosystems. Disease and parasite transmission between farmed and wild fish is also a major problem, as well as a commercial cost through fish mortality.

#### Aquaculture is hype and alts fill in

Bethune 18 (Claudette, Ph.D., pharmaceutics and pharmacokinetics, is an associate director of clinical development at a pharmaceutical company in California. From 2003 – 2006, Bethune was a senior scientist at the Norwegian Institute for Nutrition and Seafood Safety in Bergen, Norway, Organic Consumers Association, "Nordic Aquafarms' Claims of 'Sustainably Produced' Farmed Salmon for a Hungry World Don't Hold Up," <https://www.organicconsumers.org/blog/farmed-salmon-unsustainable-unhealthy> MDRJ)

The developers of today’s salmon aquaculture often claim that their industry is “sustainable.” In response to concerns regarding the dangers of open-net salmon pens—where feces, chemicals, parasites and disease are directly transmitted into the bodies of water in which they are located—certain companies are moving their salmon farms on land to “closed-containment” models. But are these farmed Atlantic salmon any more nutritious or sustainable than farmed land-animals? Is salmon farming really helping to feed a hungry world? Nordic Aquafarms (NAF), a Norway-based company that proposes to build a mega-sized closed-containment salmon farm in Maine, claims that “the world has a growing need for protein sources produced in a sustainable way” and that “farmed Atlantic salmon has proven to be a more sustainable product than most other comparable protein sources." However, reviewing the actual analysis and results in the scientific literature to date, it is clear that the results related to fish feed do not support the typical claims that closed-containment salmon farming operations can produce sustainable or more nutritious products than conventional salmon aquaculture. Currently, NAF has not yet stated unequivocally or publicly what the company intends to feed the salmon at its proposed Belfast, Maine facility, which is described as “one of the largest [salmon farms] in the world.” However, a review of what is currently used or available for use as feed for farm-raised salmon shows that none of the options pass the sustainability test, nor do they result in a more “nutritious” product for consumption. Misconceptions around the use of fish meal and fish oils in farmed-fish feed One of the key concerns about farming carnivorous and omnivorous fish such as Atlantic salmon is the use of fish meal and fish oils as ingredients in feed for farmed salmon. That’s because the production of fish meal and fish oils requires raising or catching vast quantities of other fish to produce—fish that could be directly used for human consumption. From a food security, safety, and sustainability perspective, it is highly questionable that farms that consume more fish in feed than they produce could rival the best available protein alternatives.

#### No food wars – best models.

**Buhaug et al, PhDs, ’15**

(Halvard, PoliSci@NTNU, Tor A Benjaminsen, HumanGeo@Roskilde, Espen Sjaastad, ResourceEcon@NMBU, and Ole Magnus Theisen, PoliSci@NTNU, “Climate variability, food production shocks, and violent conflict in Sub-Saharan Africa,” Environmental Research Letters, Volume 10, Number 12) BW

**Across all models,** we find relatively **weak and** **insignificant effects** for domestic food production and we also note that the sign of the coefficients shifts between outcome types. In this sense, table 1 implicitly contrasts both claims that political violence is more prevalent when basic needs are met (Salehyan and Hendrix 2014) and claims that agricultural income shocks increase civil conflict risk (von Uexkull 2014). The results are consistent with Koubi et al (2012) and van Weezel (2015), however, who conclude that rainfall—a significant determinant of yields in SSA—has little impact on conflict either directly or through economic performance. The covariate that best and most consistently explains temporal variation in political violence is the time-lagged conflict incidence indicator. Models 1–2 show that a new civil conflict is unlikely to break out if another one is already ongoing in the same country whereas Models 3–6, which capture the occurrence of less organized conflict, demonstrate that violence begets violence. Coups d’état (Models 7–8) exhibit a comparatively weak temporal correlation pattern in our data and are generally regarded as a highly unpredictable phenomenon (Luttwak 1979). Next, we estimate the same set of models on a subsample of 14 countries in SSA where rainfall has a large and significant positive effect on food production (figure 2(b); see supplementary information, section B for details). To better capture the influence of climate variability and reduce concerns with endogeneity, we further replace the standard OLS model with twostage instrumental variable regression. The first stage in this model estimates the joint influence of annual rainfall (linear and squared terms) and temperature (linear) on contemporaneous food production. This effect then constitutes the exogenous instrument for food production in the second stage. The results are reported in table 2. Mirroring the results presented above, we fail to uncover a robust signal for agricultural performance, although the sign of the coefficient for food production now remains negative in seven of the eight specifications. Food production shocks may have different consequences depending on the socioeconomic context, so next we consider a series of interactive relationships. Specifically, we investigate the joint effect of food production and (i) low level of development, (ii) extent of discriminatory political system, and (iii) economic dependence on agriculture; three conditions whereby loss of income from agriculture might constitute a particular challenge to society. To model these interactions, we include time-varying regressors instead of country-fixed effects where (i) is represented by infant mortality rate (IMR; World Bank 2014), (ii) is captured using the Ethnic Power Relations v.1.1 data (Cederman et al 2010), while (iii) uses an index of agricultural contribution to GDP (World Bank 2014). Moreover, to preserve focus on temporal dynamics, food production is now operationalized as yearly deviation from the country mean, 1961–2009. We use additive inverse deviation values to ensure theoretical consistency among the components in the interaction terms. All models control for (ln) population size, conflict history, and a common time trend, and models without IMR and agricultural dependence additionally control for (ln) GDP per capita. The results are presented in table 3. Again, **we are unsuccessful in establishing a** **consistent covariation** **pattern between agricultural performance** **and** **political** **violence.** Interpreting the combined effect of interaction terms with continuous parameters is inherently difficult but figure 4 shows that food production is insignificantly related to all conflict outcomes across levels of socioeconomic development for all three interaction terms. The sole exception is the result in Model 24, where lower food production in highly discriminatory societies is negatively associated with non-state conflict. This result would seem to **contradict the** **standard** **scarcity thesis** (Homer-Dixon 1999) although it is consistent with observations that conflict is more prevalent during surplus years (Witsenburg and Adano 2009, Salehyan and Hendrix 2014). Mirroring earlier research, ethnopolitical exclusion is strongly related to higher civil conflict risk, but not necessarily to other forms of political violence. Infant mortality rate and economic dependence on agriculture appear largely irrelevant. While this may come as a surprise, recall that most countries in SSA are characterized by underdevelopment and a large agricultural sector, implying that the variation in values on these indicators is modest. Large parameter uncertainties and p-values above the conventional significance threshold (5%) may disguise substantively important effects (Ward et al 2010). Accordingly, as a final assessment, we conduct a set of out-of-sample simulations and compare predictions for models with and without food production. The models are estimated on a subset of the full sample, in this case all years before 2000, and the estimated effects are then used to predict conflict outcomes out of sample, i.e., the 2000–09 period. Figure 5 shows the predicted values from four pairs of models that are specified similarly to Models 17, 20, 23, and 26, except for the shorter time period and the fact that one model in each pair drops the food production deviation variable. For civil conflict and social unrest, the models generate very similar predictions, signaling that **agricultural performance** **adds little** **to the models’ predictive power.** There is more spread in the predictions for the remaining two outcome categories. Puzzlingly, **the model without food production performs better** in both cases—i.e., the Receiver Operating Characteristics curves have higher ‘Area Under the Curve’ scores. We hesitate to put too much emphasis on the ROC tests, given the rareness of the outcomes(notably Models 17 and 26) and the relatively small training samples (Models 20 and 23), but nonetheless the patterns observed in the out-of-sample simulations substantiate the regression results reported above; fluctuations in agricultural output **explain little** of the observed variation in political violence in post-colonial Sub-Saharan Africa. 5. Concluding remarks Emerging evidence suggests that food price shocks are associated with an increase in social unrest (Smith 2014, Bellemare 2015, Hendrix and Haggard 2015, Weinberg and Bakker 2015). Yet, the robust ‘non-finding’ presented here implies that so-called ‘food riots’ play out **largely isolated** from climate-sensitive production dynamics in the affected countries. Likewise, claims that adverse weather and harvest failure drive contemporary violence in Africa (e.g., Hsiang et al 2013, IFPRI 2015) are **not supported** by our analysis. Instead, social protest and rebellion during times of food price spikes may be better understood as reactions to poor and unjust government policies, corruption, repression, and market failure (e.g., Bush 2010, Buhaug and Urdal 2013, Sneyd et al 2013, Chenoweth and Ulfelder 2015).