## OFF

### NC – Long

#### The call to space fuels strategies of technocratic managerialism that position the American transcendental state as supreme---transcendence of limits enables imperialistic violence through intervention, war, circumvention of norms, preemption, and tactics of control

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In the preceding eight chapters I have argued that some of the unique qualities of outer space—vastness, Otherness, sublimity, timelessness, spacelessness—are just as integral to extra-terrestrial projections of US geopower, as its well-known capacity (Arendt, 1963; Cosgrove, 2001; Dickens and Ormrod, 2007; Dolman, 2001; Macdonald, 2007) to function as an Archimedean high point to monitor and control the surface, and atmosphere, of the Earth. While the focus of my study has been the United States, and more specifically NASA, the implications of this cosmic projection of geopower—the American transcendental state—are global in reach, from enabling and shaping imperialistic ideologies (Chapters 1-3 and 7) to fuelling the extension of technocratic managerialism (Chapter 4-6 and 8). What is more, messianic hope in America remains a global commodity, consumed, for example, through the internationally franchised Star Trek television episodes and films (Penley, 1997: 98-99), multinational ‘Space 2.0’ corporations, like SpaceX (Chapter 6), worldwide audiences to the addresses of American presidents (Chapter 6) and global tourist attractions like the National Air and Space Museum and Kennedy Space Center Visitor Complex (Chapter 7). These global circulations suggest that while my empirical focus in this study has been on the extra-terrestrial assemblage of the American transcendental state, as viewed from within the borders of the US, the salience of my analysis is geo-political.

The development of the American transcendental state through space exploration must also be viewed as an integral component of a far older geopolitical project—the production of an American identity defined in terms of the transcendence of limits, whether technological, economic, spiritual or territorial, enabling the moral aggrandizement of the past, present and future of a horizontal strata of sovereign territory and its peoples (McDougall, 1997; Noble, 2002; Nye, 1994; O’Brien, 1988; Ricard, 1999; Stephanson, 1995). Over the last decade or so, a growing number of scholars, including geographers, have turned their attention to how messianic-exceptionalist visions of America as the ‘Promised Land’ of ‘Chosen People’ have inflected various imperialistic projects including: the pursuit of democracy through military intervention in the ‘global south’ (Anthony, 2008); the technocratic ‘greening’ of Western global capitalism (Singer, 2010); the building of a ‘culture of war’ in foreign policy (Marsella, 2011), the circumvention of international institutions (Agnew, 2006); and most prominently perhaps, George W. Bush’s ‘war on terror’ where invasions of Afghanistan and Iraq became justified as a ‘cosmic struggle between good and evil’ (Agnew, 2006: 183; see also Barkun, 2010; Dijink, 2006; Strum, 2010; Wallace, 2006). All of this work indicates two points: first, the enduring Apocalyptic influence of dispensational pre-millennialism on both interventionist and isolationist currents within American (geo)politics (Strum and Dittmer, 2010: 18); and secondly, the rise of a religious cosmology that positions America at the moral, geographical, and spiritual, centre of the universe (Strum, 2010: 150).

My analysis of American spaceflight adds to this body of work on religion and geopolitics by drawing attention to five less discussed conduits of this pious vision of American geopower: (i) the secular—museums, family theme parks, systems management; (ii) the sublime—astronomical artwork, Moon landings and distant Nebula; (iii); the profane—Nazi slave labor camps, technocratic patriarchy, and dead astronauts; the technological (iv)—rocket production lines, O-rings, electrical wiring; and (v) the revolutionary—female astronauts, May 1968, and Richard Feynman. Analytically, these diverse registers suggest the utility of working with a broader, less explicitly spiritual, set of theoretical assumptions, to address the cosmological aspects of American geopolitics. This is why I mobilized the concept of the ‘American transcendental state’, rather than ‘deified nation’ (O’Brien, 1988: 41) within this study. This deliberately hallucinogenic sounding term captures some sense that the messianic-exceptionalistic projection of American geopower is a more diffusive, experimental, fantasmic, embodied, and ostensibly secular, affair, than conveyed within much discursive analysis of the religious undercurrents inflecting American geopolitics (for example Agnew, 2006; Dijink, 2006; Strum, 2010; Wallace, 2006).

I would like to suggest now that there is another benefit in bringing together these diverse practices under a broader analysis of the American transcendental state: their common geography becomes all the more obvious. That is, all these practices involve thinking, doing or resisting, celestial transcendence as an apparatus of American geopower; hence they can all be rightly considered ‘vertical geopolitics’ (Elden, 2013; Graham, 2004; Graham and Hewitt, 2013). This label has developed to identify a body of work addressing how the circulation of American geopower involves more than two-dimensional geographies of area. It currently includes analyses of; drone warfare (Gregory, 2011); aerial bombardment (Graham, 2004); police helicopters (Adey, 2010); satellite surveillance (Macdonald, 2007) and satellite drone navigation and targeting (Gregory, 2011). Elden (2013: 40) explains that ‘vertical geopolitics’ is mostly focussed upon how state political technologies allow diverse populations to be measured, calculated, controlled and killed, ‘from above’, and occasionally ‘from below’ (for example Elden, 2013; Graham and Hewitt, 2013). By contrast, the vertical orientation I have adopted here, while related, is different. Specifically, I have described how aspects of the projection of American identity, geopower, and territory, also involve a vertical spacelessness—a deterritorialization—a potential collapse into sublime, cosmic, insignificance; in short, rather than the ‘view from above’, the perspective I have traced has been a ‘view into the above’ (and back). In part, therefore, my study can be considered a response to Elden’s (2013) recent question: ‘How would our thinking of geo-power, geo-politics and geo-metrics work if we took the earth; the air and the subsoil; questions of land, terrain, territory; earth processes and understandings of the world as the central terms at stake, rather than a looser sense of the ‘global?’ (p49)

I propose we add to this list celestial entities, including the Moon (Chapter 3), the Martian surface (Chapter 6) and the Eagle Nebula (Chapter 7), as well as God (Agnew, 2006; Dittmer and Strum, 2010; Strum, 2013). Thus, perhaps we should be cautious of Elden’s (2013b) rather geocentric call ‘about how geopolitics might be thought as earth-politics rather than simply a synonym for global politics’ (p59). Instead, it might be more useful to bear in mind Deleuze and Guattari’s (1988: 101) argument that even absolute deterritorialization—something akin perhaps to the mathematical cosmic sublime of Kant (Nye, 1994: 7-8)—always involves reterritorialization(s). Recall how Charles Bonestell (Chapter 2), William Clancey (Chapter 6) and the National Air and Space Museum (Chapter 7), respectively, and persuasively, associated vistas of the Moon, Mars and the Eagle Nebula with the American West, and by extension locate America at the centre of God’s universe (Boime, 1991; Stephanson, 1995).

This analysis of American spaceflight also sheds light on seldom acknowledged connections between religious and vertical geopolitics and technocracy. The relation between critical analysis of geopolitics (O Tuathail, 1996) and technocratic management (Alvesson, 1987), remains remarkably undeveloped. Arguably this lacuna says more about the disciplinary separation between critical security studies and organization studies (Grey, 2009) than the various intellectual crossfertilizations between organization studies and human geography (Clegg and Kornberger, 2006; Dale and Burrell, 2008; Parker, 2013). Nevertheless, there are, as Grey (2009) maintains, clear resonances:

Indeed it could said that, in the same way that the development of security studies in particular, and organization studies to an extent, was shaped by geopolitics of wars both hot and cold, so too many current and future directions be in part a reflection of developments in contemporary geo-politics (p31).

Some organizational practices are of course, very much on the ‘front line’ of practical geopolitics; that is, they comprise the ‘the foreign policy bureaucracy’ (Ó Tuathail and Dalby, 1998: 4) through which geographical concepts are deployed to aid ‘conceptualization and decision making’ in ‘everyday foreign policy’ (O Tuathail, 1999: 110). Examples here include the work of the US Air Force, the CIA (Central Intelligence Agency) and the UK’s Foreign and Common Wealth Office. There are also a host of other organizations that no doubt influence how practical geopolitics is produced, from security analysts like the RAND Corporation to global defense contractors like McDonnell Douglas. However, analysis of the relationship between organizational and geopolitical practices remains embryonic. For example, Anderson’s (2011) study of urban counterinsurgency and Gregory’s (2011) of drone warfare, do no more than merely infer that the rise of the ‘networked organization’ is reworking the projection of American geo-power. Correspondingly, two organizational studies of the military only hint that, for example, masculine discipline (Godfrey et al., 2012) and team identities (Corona and Godart, 2010) shape and are themselves shaped by grand geopolitical narratives like the ‘war on terror’.

But the imbrication of geopolitical and organizational practice can also be more subtle and much less militaristic—concerning the anticipation and cultivation of geopower through shared national identities, that is ‘popular geopolitics’ (O Tuathail, 1999: 110). Here, the connection to organizational practices is no less significant, yet invisible in the literature. NASA offers a good example: from its inception, the space agency developed increasingly refined technocratic techniques that aligned people and machines to naturalize the pursuit of a popular geopolitics wedded to American geopower. Viewed in this way, imperialistic geopower and technocratic-managerialism are interwoven forces; hence the present study suggests the richness of more sustained critical analysis of organization and geopolitics.

#### The alternative is a refusal to name and command space, a movement of transcendence to a plane focused on human experience, and an exploration of new affects that all interfere with the state’s technocratic, imperial impulses

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However, I am all too aware that in stressing the widespread application of this concept of the America transcendental state to understand American geopower— and, concomitantly, the fecundity of bringing together analyses of religion, verticality and now technocracy within critical geopolitics—I run the risk of constructing a totalizing, monstrous, edifice. The reader might rightly ask at this juncture, paraphrasing Nietzsche, have you not gazed into the cosmic abyss of American geopower for too long; are you not also reifying American geopower in the cosmos rather than challenging it? Indeed, throughout the preceding chapters I made reference to a rather singular sounding concept of the ‘American transcendental state’. But, as in the introduction, I must stress again here, that I took this decision for reasons of analytical clarity rather than to suggest I have revealed an independent, singular, definite and a priori reality (Law, 2006), some essence akin perhaps to what Agnew (2006: 184) refers to as ‘Americanism’. Instead, within each chapter I have traced the progressive assemblage of the American transcendental state—that is, nothing less than the divinely sanctioned, exceptional, and messianic, right and duty, of America, and its leaders in its name (Wallace, 2006: 225), to command cosmic space and time by evoking forces of ‘good’ and ‘evil’, ‘us’ and ‘them’ (Agnew, 2006; Strum, 2010). But the immutability of this cosmic vision (Strum and Dittmer, 2010; Wallace, 2006) belies the transformative, fragmented, heterogeneous components that sustain it, across landscape artwork, through Kennedy’s Moon Speech, to the O-rings of Space Shuttle Challenger. Throughout this study I have suggested countless relations through which this vision is not only produced (Dijink, 2006; McDougall, 1997; Noble, 2002; Nye, 1994; Ricard, 1999; Stephanson, 1995; Wallace, 2006) but circulated, maintained, resisted, repaired, transformed, and experimented with.

How then to conceptualize this heterogeneous, but obdurate, cosmic being? Latour’s actor-network theory (1987; 2005; 2012) is useful to an extent here; first, we can conceptualize the transcendental state as an ‘immutable mobile’ that ‘ends up traversing the universe’ by ‘pay[ing] for each transport with a transformation’ (Latour, 2013: 127); it is ‘not displacement without transformation but displacement through transformation (Latour, 2005: 223); second, the transcendental state can be understood as offering a prophetic, but partial, ‘panorama’ of the ‘world [cosmos] to be lived in’ (p189) which must then, in turn, be:

… carefully situated inside one of the many Omnimax theatres offering complete panoramas of society—and we now know that the more thrilling the impression, the more enclosed the room has to be. [American] Society is not the whole ‘in which’ everything is embedded, but what travels ‘through’ everything, calibrating connections and offering every entity it reaches some possibility of commensurability. (p242)

Read against Latour’s concepts of the ‘immutable mobile’ and the ‘localizable panorama’ it is easy to see why my analysis of American transcendental state has involved mapping circulations within as well as beyond our lives. And this is a political move too, because it suggests that opportunities to test and resist the American transcendental state are closer to hand than we might think. As revealed in Chapter 8, a great deal of effort is required to keep the transcendental state circulating because the heterogeneous conduits it passes through—electrical wiring, teleconferences, flight readiness reviews, budget decisions and O-ring joints—are capricious and experimental; that is, affective. Other Chapters acknowledged similar fragility accompanying the assemblage of the transcendental state, including; the partially-owned Declaration of Independence (Chapter 1), the globally unifying Earthrise photograph of Apollo 8 (Chapter 3) and the rusting rockets on display in the gardens of the Kennedy Space Center Visitor Complex (Chapter 7). Now located within this chain of heterogeneous transformations, what strategies might aid us in purposefully transforming this now confined totality? Or put differently, how might we engage outer space to resist this cosmic deification of America (O Brien, 1988)? In concluding this study, I propose three techniques but no doubt there are many more.

First, we can expose the void at the heart of this messianic-technocratic projection of geopower (Wallace, 2006). This approach was evidenced in Chapter 1 by Derrida’s (2002) deconstructive reading of Declaration of Independence. Derrida (2002) emphasizes how signing the Declaration in God’s name entails no democratic ownership over America’s future, in outer space or elsewhere. Across the development of American spaceflight, the perils of messianic, freefloating, notions of ‘Progress’, ‘Exploration,’ ‘Frontier’ and ‘The Future’ are all too apparent, not least for NASA itself. Lester and Robinson (2009) suggest the emergence of this critique within the American space policy community:

We should accept that “exploration” is a multivalent term, with many meanings, some of which are contradictory, and all of which have historical precedent. For too long we have looked at the history of exploration selectively, seeking to find the antecedents which justify our own vision of exploration: as science, as human adventure, as geopolitical statement. This is a definitional fight which cannot be won. Space policy must acknowledge the multiple visions for space exploration, developing a clear-eyed metric of value which avoids the vagaries of lofty “exploration-speak”, If the merits of human exploration of the Moon and Mars are primarily symbolic and geopolitical, what are these goals worth in terms of federal funding?

I am unconvinced by the economically instrumentalist conclusions made by Lester and Robinson (2009) about putting a value upon even NASA’s ‘softer’ geopower, but the general caution about harnessing nebulous messianic mythologies to advance American space exploration is valuable. Of course the problem is this tradition of finding our God in the cosmos is long-established as Olsson (2007) suggests via this retelling of the Babylonian creation epic, Enuma elish:

Marduk is the Lord of lords … Hail to the Chief! Fifty were his names, so numerous that if ever attacked he could always hide behind another alias. Never catchable as the specific this or that, always on the move as an ambiguous this and that … Ungraspable multiplicity. … In this mist-enveloped region of religion naming is the name of the game, an exercise in ontological transformations where earthly people appear as projections of heavenly gods, social relations as signs in the sky. … a signified meaning searching for its own coordinates (Olsson, 2007: 23).

Perhaps a more modest approach is required: we should simply resist the urge to name, and tame, the cosmos as a Whole, by naming a celestial Godhead in it that we claim for ourselves (Wallace, 2006) but cannot ever fully own. ‘Evil is the disaster of a truth when the desire to force the naming of the unnameable is unleashed . … Evil is not disrespect for the name of the other, but rather the will to name at any price’ (Badiou, 2004: 115-6; original emphasis). Challenging the cosmic aggrandization of America might therefore imply some attempt to resist naming our God/Future/Progress in the cosmos. Put simply, this all too easy act of cosmic de/reterroritalizaiton is too crude, too undemocratic, too costly.

A second, related, strategy which can be adopted to resist the American transcendental state was discussed within Chapter 3; this is the capacity to push transcendence to another plane or refuge—to follow one line of flight of cosmic deterritorialization and then re-territorialize the Earth in a panorama that starts with a common human experience, rather than those of any particular nation/ God/future. The aim of this strategy is to mobilize a cosmic imagination that can register something of the shared experience of being human.

In Chapter 3 I discussed how the Earthrise photograph from NASA’s Apollo 8 mission have stimulated new cosmic imaginations—including ‘spaceship’ Earth (Cosgrove: 2001, 257-262; Henry and Taylor, 2009; Ward, 1964), Noetic science (Benjamin, 2003: 60-61), global political ecologies (Connolly, 2002)—that defied nationalistic appropriations by inferring a human transcendence. However, as the American author Kurt Vonnegut explains such a transcendental image of humanity, emptied of territorial divisions and difference, is not itself without risk: ‘Earth is such a pretty blue and pink and white pearl in the pictures NASA sent me. It looks so clean. You can’t see all the hungry, angry earthlings down there—and the smoke and sewage and trash and sophisticated weaponry’ (Vonnegut cited in Burrows, 1998: 423). Similarly, Deleuze and Guattari (1988) suggest we should always remain sceptical that de-territorialization is a progressive act on its own: ‘Never believe that a smooth space will suffice to save us’ (p500).

A third strategy is to augment different affects amid the assemblage of the American transcendental state. As described in Chapter 8, the American transcendental state depends upon the cultivation of confidence in technocracy allied to an affective becoming hopeful—a positive openness to the future as life enhancing—orientated around the transcendence of America in cosmic space and time. But, as Anderson (2006), explains, becoming hopeful does not necessarily need to operate in this transcendental manner: hopefulness can also emerge not to ward off suffering, but through every day sorrows, through diminishment of the body’s potential to affect and be affected. Consider, for example, how Dotty Duke refused to discuss her fears and anxieties with her astronaut husband as she kept the ‘house in order and [took] out the garbage’ (Duke 1990—Chapter 5). Dotty Duke epitomizes a different kind of becoming hopeful—a capacity to remain open-ended about the future in a life enhancing manner through diminishment—devoid of discussion of a better future in Earth or in the cosmos; this is hope that challenges ‘the easy equation between transcendence and a future elsewhen or elsewhere in favor of an imminent transcendence from within vectors of diminishment’ (Anderson, 2006: 749; for more analysis of immanent transcendence related to Space see Smith, 2009: 211).

Another affect which is useful in short-circuiting the hopeful assemblage of the transcendental state is boredom. Anderson (2004) describes boredom as the moment when the ‘“forgetting” intrinsic to habit has been momentarily incapacitated. It is the unravelling of habit, a sudden realization of the again’ (p743). Boredom depresses the life enhancing capacity of ourselves to be open to the future, engendering stillness and slowness of thought-action in spacetime, where, as Anderson (2004) puts it, the capacity to experience the ‘not yet’ (p749) is suspended. The evolution of American spaceflight might appear to some the antithesis of boredom, but, as Jorgensen (2009) suggests, the American humanization of outer space has gone hand in hand with endless repetition (of middle America):

The August 1969 Life Special Issue, released to commemorate the landing, wants to produce sympathetic accounts of the astronauts. It is filled with glossy, high color photographs of the astronauts not only mastering outer space, but their domestic spaces as well. Neil Armstrong bakes pizza, Buzz Aldrin jogs through the suburbs, and Mike Collins prunes his garden. These images resonate with outer space itself, as the astronauts use tools in both terrestrial and extraterrestrial environments. The spatula and shears the astronauts use to cook lamb curry and prune roses with resemble the objects they hold while walking the moon, these being a laser reflector, seismometer and solar wind sheet (p179).

There is no hopefulness on offer in Jorgensen’s (2009) reading of American spaceflight. Instead the boredom experienced in the cosmic repetition of middle America signals despair: ‘Apollo 11 represented an America that had become unhinged by its own technocracy, its middle class lifestyle, and television’ (p188). Jorgensen (2009) is not, of course, alone in identifying aspects of spaceflight repetitive, even boring. As the emergence of the Teacher in Space program demonstrated (see Chapter 8), NASA itself has historically attempted to introduce elements of excitement, even increased risk, to engage a global audience. Yet, of course, a balance has always had to be struck, as Parker (2009) explains of Apollo: ‘Everything was supposed to be boring, because boredom meant no surprises, and hence the possibility of the adventure in some sense rested on its denial’ (p326). Although fleeting, boredom is surely an unavoidable ingredient in NASA’s technocratic confidence, but when focused and channeled, it does suspend hope in the cosmos as a better place, perhaps providing an opportunity for us to pause and register something of the sublime Otherness of Space, where we concurrently repeat and differ ourselves into infinity: ‘Media representations of space travel turn the vastness of space into the similitude of domesticity, as human familiarity comes to stand in for the infinite. At the same time, the domestic attains the dimensions of the infinite, and in turn becomes strangely unfamiliar to the television viewer’ (Jorgensen, 2009: 179).

These three techniques of cosmo-political intervention—refusal to name, human transcendence, and sensitivity to new affects—are all worthy of greater attention, especially when they can be connected up to, and interfere with, the assemblage of the American transcendental state. Clearly not all of those involved directly in the development of spaceflight will want or be able to practise these techniques. Nevertheless even among this group these techniques are intended to offer greater receptivity to new cosmographical imaginations which move beyond the cosmic aggrandization of messianic-imperialistic-technocratic impulses. If we have entered the Cosmic Age where all territorializing assemblages, all States, now derive vital energy from the Cosmos (Deleuze and Guattari (1988: 342), then the imperative becomes not to simply do cosmopolitics (Latour, 2005) but rather which cosmo-politics do we want to pursue? My favoured vision of a Geography of Space is one where this question is endlessly asked but never answered with absolute confidence.

## OFF

### NC – CP

#### 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.

## OFF

### NC – Long

#### Interpretation – affirmative teams must defend legal action by a government

John Bouvier 56 [The Free Dictionary, “Unjust”] [DS] [https://legal-dictionary.thefreedictionary.com/Unjust#:~:text=UNJUST.,test%20of%20right%20and%20wrong.]

Unjust Also found in: Dictionary, Thesaurus, Wikipedia. Related to Unjust: Unjust enrichment UNJUST. That which is done against the perfect rights of another; that which is against the established law; that which is opposed to a law which is the test of right and wrong.

#### This is clear

Black’s Law Dictionary ND [DS] [https://thelawdictionary.org/unjust/]

UNJUST Contrary to right and justice, or to the enjoyment of his rights by another, or to the standards of conduct furnished by the laws.

#### “Resolved” means enactment of a law.

Words and Phrases 64 Words and Phrases Permanent Edition (Multi-volume set of judicial definitions). “Resolved”. 1964.

Definition of the word “resolve,” given by Webster is “to express an opinion or determination by resolution or vote; as ‘it was resolved by the legislature;” It is of similar force to the word “enact,” which is defined by Bouvier as meaning “to establish by law”.

#### Violation – the aff fiats private self-restriction, which is not a method of correcting injustice nor an enactment of a law.

#### Ground – generics on this topic must be tied to the actor, not the action, because each space appropriation is unique. A topic where the unifying thesis is countries legislating restrictions on space appropriation is much better than one about private actors self-restricting – their interp skirts multilat good/bad, K’s of IR and global governance, and CP’s to reform the OST – there are no unifying DA’s to different private companies around the world signing binding internal memos to restrict a type of space appropriation.

#### Predictability and Limits – there are infinite private entities that could appropriate space but only a small amount of spacefaring nations – legal limits are necessary when the topic doesn’t have the word “substantial” in it.

#### Topicality is a voting issue of competing interpretations – it prevents arbitrary judge intervention and a race to the top that favors no one. The standards debate above also proves they aren’t reasonable.

#### No RVIs – they’re illogical, create a chilling effect on setting theory norms, and destroy substantive education.

## OFF

### NC – T

#### Interpretation: Scientifically outer space excludes celestial bodies

Science Daily ND [ScienceDaily, "Outer space," https://www.sciencedaily.com/terms/outer\_space.htm]/ISEE

Outer space, also simply called space, refers to the relatively empty regions of the universe outside the atmospheres of celestial bodies. Outer space is used to distinguish it from airspace (and terrestrial locations). Contrary to popular understanding, outer space is not completely empty (i.e. a perfect vacuum) but contains a low density of particles, predominantly hydrogen gas, as well as electromagnetic radiation.

#### Violation: they don’t; the

John Carl Villanueva, 3-19-2010, "What Is A Moon?," Universe Today, https://www.universetoday.com/60072/what-is-a-moon/]/ISEE

A moon is defined to be a celestial body that makes an orbit around a planet, including the eight major planets, dwarf planets, and minor planets. A moon may also be referred to as a natural satellite, although to differentiate it from other astronomical bodies orbiting another body, e.g. a planet orbiting a star, the term moon is used exclusively to make a reference to a planet’s natural satellite.

#### Limits: Allowing celestial bodies creates an unpredictable research burden – the neg not only has to familiarize themselves with the privatization of outer space but also every planet ever with changing conditions – this kills limits on an already large topic – ground is also completely different – skews neg generics about OUFs

#### Predictability: science concludes neg – most people define outer space as in between atmospheres– including earth guts predictability for topic lit

#### CI competing interps/no rvis/t voting isuse

## OFF

### NC – DA

#### 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.

#### Commercial space innovation stops extinction

Charles Beames 18, Chairman of the SmallSat Alliance, Executive Chairman of York Space Systems, former Principal Director of Space and Intelligence in the Office of the Undersecretary of Defense for Acquisition, Technology, and Logistics (OUSD(AT&L)), Col. (ret.) in the USAF where he served 23 years in space & intelligence leadership positions around the world, 8/8/18, “Op-ed | SmallSat Alliance is on a path toward a new space horizon,” https://spacenews.com/op-ed-smallsat-alliance-is-on-a-path-toward-a-new-space-horizon/

We find ourselves still at the dawn of a new space century, mindful of the victories and setbacks of our past, eager to pass the torch to the next generation of space visionaries, scientists, engineers, and enthusiasts. We look to the future not just to see how much bigger, faster, or higher we can reach, but also how the United States, and specifically the U.S. space community, can again inspire the nations of the world to align with us, as it did in the 20th century.

The SmallSat Alliance is an alliance of companies developing, producing, and operating in all segments of the ‘next generation’ space economy; championing renewed U.S. leadership in the burgeoning commercial space economy, and advocating for the transformation of government-led space capabilities. We are experienced space professionals who have chosen to join with others leveraging our decades of hard-won experience, to develop smarter ways to explore space in the 21st century.

A wonderful outgrowth of the legacy space program is the commercial, entrepreneurial, and job-creating commercial space business that it bequeathed. These next-generation enterprises range from multi-million-dollar startups providing rideshare opportunities or components for small satellites to multi-billion-dollar space data-analytic platforms reinventing urban car service and agricultural production. The early returns of this economic revolution are already on our doorstep: space data capabilities are exponentially growing elements of the 21st century world economy.

Beginning with the dreams and funding by successful tech entrepreneurs, enormous venture investments are already delivering wondrous benefits to the world.

Commercial Space – Profit and Non-Profit

There are really two major categories in the commercial sector, the profit driven and the non-profit. The classic for-profit companies include not only those designing, building, launching, and operating satellites but also the tech sector that is turning that raw space data into gold through machine-learning analytics. Since for-profit companies are no longer dependent upon the revenues generated by the Cold War space race culture of a bygone era, this new generation of space companies is able to more efficiently capitalize on Moore’s Law, the nonstop exponential growth in chip density, and the associated networking technology co-evolving with it. This new generation is building profitable businesses helping to clean up our oceans of garbage and debris with satellite surveillance, reconnoitering to assist in enforcing laws that protect our oceans from illegal, unregulated, unlicensed fishing, something that is rapidly depleting the world’s most valuable and essential lifeforms. It’s leading in the innovative use of low-cost satellite constellations to produce ubiquitous remote-sensing data, enabling small business owners to be more profitable and less wasteful. For example, precise timing signals from space are already optimizing transportation of people, goods, and services, with even further gains anticipated with the introduction of artificial intelligence to assist drivers, perhaps even someday replacing them entirely.

The non-profit sector is the other side of commercial space, concerned more for the general welfare of society, but every bit as integral to this new space enterprise. Much like every century before it in human history, ours is not without its unique challenges, some of which have been a consequence of the last, and all of which the space data domain can be leveraged to help solve. Examples are endless, but one challenge that this new space community is uniquely well-adapted for is to further inform worldwide resource allocation for the 21st century and beyond. These two primary resources are sustainable water and the materials needed for adequate housing for an ever-increasing human population. As cities and urbanization continue to expand, governmental planning challenges such as transportation design optimization for goods and services are only the beginning. Additionally, through using inexpensive remote sensing technologies, some members are designing space data analytics to mitigate human suffering from plagues, contain outbreaks, and combating illegal poaching. Some are connecting with other non-profits to curtail human trafficking for the sex trade or forced labor for migrant debt repayment. Still others are helping non-governmental organizations in their work to expose the use of children as soldiers. Addressing these challenges has little to do with resuscitating dreams conceived by long deceased science-fiction writers and much more to do with turning “swords back into plowshares” to solve real threats to humanity.

Other non-profit initiatives include pursuing an even more foundational understanding of who we are and how to be the best custodians of our environment. Much as exploring and monitoring the world’s oceans has advanced civilization through a better understanding of human life and the planet, so too does exploring and monitoring from space. Low Earth orbit (LEO) provides a unique vantage point to look back on the planet and understand what is happening, anticipate what might happen and prepare for the future. In addition to better understanding Earth, responsible and rapid exploitation of the low Earth orbit domain will enhance the understanding of the solar system and the rest of the universe. Small satellites already offer low-cost platforms to study and explore what lies beyond the Earth. Other members are pioneering the use of zero-carbon, hydrogen-based reusable propulsion systems to ensure we don’t worsen our atmosphere using kerosene-fueled rockets for the coming tsunami of satellite launches. Finally, a mission ensuring the general welfare and planet survival for the next thousand years is finally confronting the existential threat that asteroids and comets pose to humanity. These extra-terrestrial, deep-space threats are passing dangerously close to our planet, and today we have no solar map of them and no defense.

#### Lunar mining facilitates low-cost commercial spaceflight

Paul Spudis 17, former senior staff scientist at the Lunar and Planetary Institute in Houston, Texas, 12/14/17, “Why We Need Humans—Not Just Robots—On the Moon,” https://www.airspacemag.com/daily-planet/why-we-need-humansnot-just-robots-moon-180967547/

I have detailed in many previous posts the Moon’s richness as a source of materials and energy in space. This is (or should be) a primary motivator for human return to the Moon—to use its resources to create new spaceflight capabilities and for life support. While human space travel will never be dirt cheap, we can use cheap dirt on the Moon to lower its costs dramatically. A fueled rocket is more than 90 percent propellant by weight—why not get that propellant from a source already in orbit around Earth? Certainly, many have their eyes set on places beyond the Moon; so learning how to access and use resources on the Moon is beneficial to their getting where they want to go, and vital to remaining there.

People have a value in space beyond the calculus of dollars per kilogram or gigabits per second. We’re told about the accomplishments of the Mars Exploration Rovers, yet, for all the data they’ve collected, we still cannot draw a simple geologic cross-section of their landing sites, and we still do not know the origin of many of the rocks at the site (igneous or sedimentary). A human geologist would have obtained this information after a few hours of fieldwork. People require abundant mass and power, but people give a big return on that investment.

#### Commercial space solves disease

Dirk C. Gibson 12, Associate Professor at the University of New Mexico, Commercial Space Tourism: Impediments to Industrial Development and Strategic Communication Solutions, Bentham Books, Google Books

4. COMMERCIAL SPACE BENEFITS

Four factors might justify commercial space development: I) Manufacturing benefits, 2) Mining opportunities, 3) Medical breakthroughs and 4) Astronomy advancements. Each will be described in detail.

A. Manufacturing Benefits "The future also promises more commercial benefits. Much has been said about the potential for creating and manufacturing new materials in the microgravity environment of space," declared Edward L. Hudgins [10]. Taylor noted that "Certain manufacturing processes can be done better in the absence of gravitational fields, or in a vacuum which space offers" [23]. We will consider: I) General manufacturing, 2) Biotechnology and 3) Pharmaceutical production.

General Manufacturing The microgravity environment of space appeals to manufacturers for a variety of reasons. According to Taylor, "Materials that will not mix on earth—oil and water, certain minerals—will mix in space. This space manufacturing could lead to the production of vastly improved products, more precise manufacturing of products, and new materials-processing techniques" [23]. O'Neill referred to "the advantages of zero gravity for the handling of massive objects, for the heating of materials to very high temperatures without the contamination of containing crucible walls, for the formation of uniform production of light and heavy materials" [24].

Biotechnology Biotechnology and medical research and development in particular would benefit from space manufacturing. A study for the Office of Space Commercialization in the Department of Commerce found that "The microgravity conditions of space enable the growth of large, superior quality crystals that could be the predecessors to synthesized proteins for fighting disease. Materials have been developed without the structural flaws that often accompany their production on Earth" [3J.

Pharmaceutical Production

Medicines may be improved substantially by research and production conducted in space. It is believed that the environmental characteristics of space would

enhance pharmaceutical company operations. One study specified that because of space-based electrophesis, "New vaccines and drugs can be produced in volumes that could aid millions of people" [23]. Existing drugs could be improved and made more cheaply, including diabetes and hormone deficiency drugs, and antihemophiliac products, epidermal growth stimulants, antitrypsin products and interferon [23].

#### Extinction

Yaneer Bar-Yam 16, Founding President of the New England Complex Systems Institute, “Transition to extinction: Pandemics in a connected world,” NECSI (July 3, 2016), http://necsi.edu/research/social/pandemics/transition

Watch as one of the more aggressive—brighter red — strains rapidly expands. After a time it goes extinct leaving a black region. Why does it go extinct? The answer is that it spreads so rapidly that it kills the hosts around it. Without new hosts to infect it then dies out itself. That the rapidly spreading pathogens die out has important implications for evolutionary research which we have talked about elsewhere [1–7].¶ In the research I want to discuss here, what we were interested in is the effect of adding long range transportation [8]. This includes natural means of dispersal as well as unintentional dispersal by humans, like adding airplane routes, which is being done by real world airlines (Figure 2).¶ When we introduce long range transportation into the model, the success of more aggressive strains changes. They can use the long range transportation to find new hosts and escape local extinction. Figure 3 shows that the more transportation routes introduced into the model, the more higher aggressive pathogens are able to survive and spread.¶ As we add more long range transportation, there is a critical point at which pathogens become so aggressive that the entire host population dies. The pathogens die at the same time, but that is not exactly a consolation to the hosts. We call this the phase transition to extinction (Figure 4). With increasing levels of global transportation, human civilization may be approaching such a critical threshold.¶ In the paper we wrote in 2006 about the dangers of global transportation for pathogen evolution and pandemics [8], we mentioned the risk from Ebola. Ebola is a horrendous disease that was present only in isolated villages in Africa. It was far away from the rest of the world only because of that isolation. Since Africa was developing, it was only a matter of time before it reached population centers and airports. While the model is about evolution, it is really about which pathogens will be found in a system that is highly connected, and Ebola can spread in a highly connected world.¶ The traditional approach to public health uses historical evidence analyzed statistically to assess the potential impacts of a disease. As a result, many were surprised by the spread of Ebola through West Africa in 2014. As the connectivity of the world increases, past experience is not a good guide to future events.¶ A key point about the phase transition to extinction is its suddenness. Even a system that seems stable, can be destabilized by a few more long-range connections, and connectivity is continuing to increase.¶ So how close are we to the tipping point? We don’t know but it would be good to find out before it happens.¶ While Ebola ravaged three countries in West Africa, it only resulted in a handful of cases outside that region. One possible reason is that many of the airlines that fly to west Africa stopped or reduced flights during the epidemic [9]. In the absence of a clear connection, public health authorities who downplayed the dangers of the epidemic spreading to the West might seem to be vindicated.¶ As with the choice of airlines to stop flying to west Africa, our analysis didn’t take into consideration how people respond to epidemics. It does tell us what the outcome will be unless we respond fast enough and well enough to stop the spread of future diseases, which may not be the same as the ones we saw in the past. As the world becomes more connected, the dangers increase.¶ Are people in western countries safe because of higher quality health systems? Countries like the U.S. have highly skewed networks of social interactions with some very highly connected individuals that can be “superspreaders.” The chances of such an individual becoming infected may be low but events like a mass outbreak pose a much greater risk if they do happen. If a sick food service worker in an airport infects 100 passengers, or a contagion event happens in mass transportation, an outbreak could very well prove unstoppable.

## Case

### 1NC – Top

#### 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.

#### No moon dust – electron showers

Tomaswick 20 [ANDY TOMASWICK, Universe Today. COO at Bionymer, a biotechnology firm. "Finally! A Solution to Deal With Sticky Lunar Dust." https://www.universetoday.com/147737/finally-a-solution-to-deal-with-sticky-lunar-dust/]

The kind of dust present on the moon is even more annoying than the grains that bothered Anakin Skywalker on Tatooine. It is constantly bathed in solar radiation, smells like spent gunpowder, and can cause allergic reactions, as it did in some of the Apollo astronauts. It’s also notoriously difficult to clean off of surfaces. Now a team of scientists at the University of Colorado at Boulder think they have a solution that would remove lunar dust without harming the material it’s attached to. And they would do this by using a tool that sounds like it’s straight out of Star Wars – an electron beam.

Electron beams aren’t actually as sci-fi as they sound. They have been well understood since the 1950s, and are widely used in semiconductor manufacturing processes. They consist of a device that shoots out a low-energy (ie safe) stream of negatively charged particles.

Lunar dust itself is also negatively charged, caused by the constant solar radiation it is subjected to. This is part of the reason it’s so hard to clean – the small electrostatic buildup caused by the radiation makes the dust extremely clingy. This is similar to how a feather can stick to your hand in winter via electrostatic attraction. Or a cat can be completely surrounded by styrofoam pellets.

What Benjamin Farr and his colleagues at CU Boulder’s Laboratory for Atmospheric and Space Physics, the University of Iowa, and JPL realized was that they could use an electron beam to negatively charge a base material. Negative charges repel each other, so any negatively charged lunar dust that is present on the material should slough itself off.

In order to test this theory the team were unfortunately not able to take a prototype to the moon. However, they did manage to get their hands on a substance called “lunar simulant”, which is commercially available from NASA, and is designed to be as close as possible to actual lunar dust.

The researchers sprinkled the dust over various surfaces that could potentially be part of a future lunar mission. They then put the dust-coated material in a vacuum chamber (which obviously wouldn’t be needed on the moon) and then pointed an electron beam at them. As predicted, the dust just fell off the material. The team was able to clean about 75-85% of a dusty surface with their electron beam.

That’s still a far cry from being perfect, but it’s a lot better than the manual hand scrubbing that is currently part of any future lunar astronaut’s cleaning repertoire. And the research team still isn’t done yet. There’s still a lot of research to go before even a prototype makes a trip on any lunar mission. However, Dr. Mihály Horányi, one of the co-authors envisions a future where astronauts can simply leave their space suits in a special room, and they can then be bathed in an electron shower that flushes all the dust right off of them. Who knows, maybe that technique would work on Jedi robes too.

#### Mining solves the case, it turns the dust into a base and extracts helium in the process – GG

Jamasmie 19 [Cecilia has covered mining for more than a decade. She is particularly interested in Corporate Social Responsibility (CSR), Diamonds and Latin America. Cecilia has been interviewed by BBC News and CBC among others and has been a guest speaker at mining conventions, including MINExpo 2016 and the World’s Copper Conference 2018. She is also member of the expert panel on Social License to Operate (SLO) at the European project MIREU (Mining and Metallurgic Regions EU). She holds a Master of Journalism from the University of British Columbia, and is based in Nova Scotia. "Mining the moon ready to lift off by 2025." https://www.mining.com/mining-moon-ready-lift-off-2025/]

European scientists have announced plans to start mining the moon as early as 2025, though what they’ll be extracting is neither gold nor diamonds, but waste-free nuclear energy thought to be worth trillions of dollars.

The goal is to place a lander on the lunar surface to mine and process regolith for water, oxygen, metals and an isotope called helium-3, which may prove useful for fueling future fusion reactors.

SIGN UP FOR THE AFRICA, EUROPE & MIDDLE EAST DIGEST

Regolith, Universe Today reported, is a dust-like material that covers the lunar surface and is the result of billions of years of meteor and comet impacts. If anyone ever lives on the moon, they could use the regolith to build habitats for a base.

The mission will be in charge of the European Space Agency in partnership with ArianeGroup, Popular Mechanics reported. It will also count with the participation of Part-Time Scientists, a German group and former Google Lunar XPrize contestant.

Europe isn’t the only one getting on board of the lunar mining train. Both India and China have floated ideas about extracting Helium-3 from the Earth’s natural satellite. Beijing has already landed on the moon twice in the 21st century, with more missions to follow.

There are an estimated one million tonnes of helium-3 in the moon, though only 25% of that could be brought to Earth, Gerald Kulcinski, director of the Fusion Technology Institute at the University of Wisconsin-Madison and a former member of the NASA Advisory Council told Bloomberg last year.

But that’s enough to meet the world’s current energy demands for at least two, and maybe as many as five, centuries, said the expert said, who estimates that helium-3 is worth almost $5 billion a tonne.

No longer science fiction

After being considered mostly a science-fiction tale, governments are now rushing to implement programs and legislation that allow them to join the race for mining in space.

#### Emerging moon development is inevitable and causes accidental and intentional artifact destruction – heritage sites would be destroyed inevitably by public actors – OST allows it and overriding current OST policies would deck scientific research and space stability

Pace & Hertzfeld 13 [Dr. Henry R. Hertzfeld is a Research Professor of Space Policy and International Affairs in the Space Policy Institute at the Elliott School of International Affairs. Scott Norman Pace currently serves as the Executive Secretary of the National Space Council. Pace was formerly the Director of the Space Policy Institute at the Elliott School of International Affairs at George Washington University, where he was also a Professor of the Practice of International Affairs. “International Cooperation on Human Lunar Heritage.” <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>]

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 scientific 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. Although some steps to protect these sites have been proposed, we suggest a better way, drawing on international, not U.S. unilateral, recognition for the sites.

Less than 2 years before the fi rst footsteps on the lunar surface on 20 July 1969 (see the image) , the United Nations Outer Space Treaty (OST) was drafted, ratifi ed, and came into force ( 1). Article II of the OST reinforced and formalized the international standard that outer space, the Moon, and other celestial bodies would not be subject to claims of sovereignty from any nation by any means, including appropriation. The OST prohibits ownership of territory or its appropriation by any state party to the treaty, which includes the United States, Russia, and 126 other nations. It does not prohibit the use of the Moon and its resources. In fact, the treaty emphasizes the importance of freedom of access to space for any nation and the importance of international cooperation in space exploration. These principles of the space treaties have enabled gains in science and technology and have contributed to international stability in space.

### Aquaculture

#### Aquaculture fails – companies lie about their efficiency and they’re not any more sustainable than farm animals

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.

#### Makes pesticide use explode when scaled up for more countries

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)

Vegetables and animal byproducts in fish feed raise GMO and pesticide concerns

As stated above, to reduce the use of fish meal and fish oil, the salmon aquaculture industry has steadily increased its use of vegetable protein and oil over the last 20 years. This includes an increase in the use of soy, rapeseed, wheat, palm oil, groundnuts, and corn—and their genetically-modified counterparts. The industry has also increased its use of terrestrial animal byproducts. [6]

With the increased use of vegetables in salmon feed, there has been a concurrent increase and concern for the increase in the allowable limit for pesticides used on plants for fish feed. For example, in 2012, a 10-fold increase in the allowable limit of the pesticide endosulfan was approved for salmon feed, because the pesticide was widely present in plants sourced for feed. [7] This occurred despite the fact that in 2011, the Stockholm Convention on Persistent Organic Pollutants during their 5th meeting added endosulfan to its list of dangerous pollutants because it is known to be highly toxic to humans and wildlife.

#### More contaminants and synthetic antibiotics are bad for the environment

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)

In addition to increased levels of pesticides, such as endosulfan, in farmed salmon feeds, other pesticides and contaminants found in fish feed, including PCBs, are known to accumulate in farmed salmon at up to 10-times more than in farmed land animals. National monitoring data on commercial fish feed and farmed Atlantic salmon on the Norwegian market found persistent organic pollutants (POPs) such as PCBs up to 10-times higher than those reported for terrestrial meat products on the same feed. [8]

Compared with wild fisheries, farmed salmon feed also uses synthetic antioxidants, such as ethoxyquin, to prevent the feed going rancid. Ethoxyquin and its metabolites that are present in farmed salmon accumulate from feed at relatively high concentrations and are known to be toxic to dogs, and likely to humans as well. [9]

The use of animal byproducts (pig and chicken) in fish feed raises additional concerns about environmental contaminants and synthetic additives. This practice recycles the contaminants and antibiotic residues from farmed animals in the food chain, even when closed-containment systems themselves do not routinely use antibiotics and other contaminants known to be used in industrial poultry and hog production. [10]

#### Worse for food prices – turns insecurity over food

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)

Some have suggested that insects could be used in farmed salmon feed, which would benefit the fish and the consumer. However, the use of insects as fish feed is still unproven. As of yet, there is no evidence of the development of an insect-based compound feed that would be sufficient to supply large salmon aquaculture systems, such as the one proposed by NAF.

As we can see, feeds for livestock and farmed salmon rely largely on the same crops. We know that many of these crops, as well as the forage fish used to make fish feed, are also consumed directly by humans, and provide essential nutrition for low-income households. As salmon aquaculture grows, competition for these crops will increase, and demand for wild fish as feed inputs, will also grow. This will potentially lead to higher prices and price volatility, worsening food insecurity among the most vulnerable populations. [11]

### Neutrinos

#### They cannot solve the unraveling prolif intnl link either – their evidence Identifies that barriers to prolif and detection are unraveling incredibly quickly which means that we need a quick response which is not what neutrino research is

cx

#### Also not a complete scenario – they’ve read prolif easy and possible evidence but have not identified who will proliferate or why motive exists

#### Says the tech doesn’t exist, only works within 10 km, which doesn’t solve prolif!

1AC Lee 20 Thomas Lee "Can tiny, invisible particles help stop the spread of nuclear weapons?" <https://engineering.berkeley.edu/news/2020/03/can-tiny-invisible-particles-help-stop-the-spread-of-nuclear-weapons/> (Associate Adjunct Professor, Research Scientist Operations & IT Management.)//Elmer

The key to preventing nuclear proliferation may depend on a little bit of ghost hunting. Scientists have long been interested in a device that can detect neutrinos, ghost-like particles that have no electric charge and nearly no mass — and therefore can pass through matter. Now, researchers are closer than ever to deploying technology that can spot those elusive subatomic particles and, in doing so, alert international authorities to the illicit production of plutonium, a key fuel for nuclear bombs. The technology may provide a “way to monitor the plutonium content in a nuclear reactor in real time that we just don’t have right now,” said Bethany Goldblum (M.S.’05, Ph.D.’07 NE), a top researcher with UC Berkeley’s Department of Nuclear Engineering. Goldblum, the executive director of the Berkeley-based Nuclear Science and Security Consortium, co-wrote a study published this week in the Review of Modern Physics that examines the feasibility of neutrino detectors in nuclear nonproliferation efforts. The study’s co-authors include Adam Bernstein and Nathaniel Bowden from Lawrence Livermore National Laboratory, Patrick Huber from Virginia Tech, Igor Jovanovic from the University of Michigan and John Mattingly from North Carolina State University. The study ultimately concludes that such technology deployed outside nuclear reactors could prove effective in ensuring that countries are not making weapons-related material under the guise of peaceful civilian energy production. The report also advances the idea that researchers could one day use the technology to discover or exclude the presence of reactors at distances of a few hundred kilometers. “Over several decades, physicists have conceived many ideas for using ﬁssion neutrinos in nuclear security,” the study says. “Some ideas remain in the realm of pen and paper, constrained by basic physical and practical considerations. For other concepts, demonstrated technology is catching up with real opportunities.” The ghost particle Neutrinos are the most abundant particles in the universe, having been formed by large nuclear explosions like the Big Bang, supernovas and the fusion process that happens inside the sun. They travel near the speed of light, have little mass and carry no electric charge. Because of these attributes, neutrinos can pass through matter and are incredibly difficult to detect, which is why scientists often refer to them as “ghost particles.” For example, if 10 trillion neutrinos struck the Earth, all but one would pass through the planet without having interacted with anything at all. In 1956, Clyde Cowen and Frederick Reins, two scientists at the Los Alamos National Laboratory in New Mexico, confirmed the neutrino’s existence, work that eventually earned the Nobel Prize in Physics. The duo placed two large water tanks near a nuclear reactor, which produces electron antineutrinos in huge quantities, as part of the fission process. As it turns out, neutrinos can collide with protons in the water and produce a neutron and a positron through a process called inverse beta decay. When the positron moves through the water, it produces a flash of light that special sensors can detect. Up to this point, scientists were primarily interested in finding neutrinos because the particles might offer clues to the universe’s origin and the formation of stars and galaxies. But starting around the turn of the 21st century, the idea that neutrino detectors could be used in nuclear nonproliferation efforts started to gain real traction. In 2000, Adam Bernstein, then a postdoctoral fellow at the Sandia National Laboratory in Livermore, California, wrote a paper exploring the idea of using detectors filled with purified water to spot neutrinos produced from nuclear explosions. In many ways, water is a great medium to detect neutrinos because it is easy to purify, cheap and is transparent to light produced by neutrinos colliding with water molecules. The key would be to build detectors big enough to hold enough water to see the neutrino signal above background radiation. However, finding neutrinos in water is still pretty hard. Bernstein found that adding small amounts of gadolinium — a rare earth metal with unusual nuclear properties — to the water could significantly boost the detector’s chances of spotting neutrinos. In gadolinium-doped water, neutrino interactions produce a much stronger signal than neutrinos in water alone. Bernstein eventually abandoned the idea to monitor explosions because the cost and size of such neutrino detectors would make the technology impractical, especially compared to existing, cheaper technologies like seismic detectors, he said. Instead, Bernstein turned his attention to using the gadolinium-doped technology to catch neutrinos from nuclear reactors. “Since we’re still mostly using water, it is possible to build large detectors, up to 100 kilotons in size or more, to spot these reactor neutrinos,” said Bernstein, now a staff physicist at the Lawrence Livermore National Laboratory (LLNL) and director of the lab’s Rare Event Detection group in the Nuclear and Chemical Sciences division. “The neutrino signature would stand out much more readily above background radiation even in a big detector,” he said. LLNL is the lead laboratory for a proposed United States/United Kingdom experiment, called WATCHMAN, to demonstrate remote monitoring of nuclear reactors using a kiloton-scale antineutrino detector. This experiment has already “exceeded my expectations,” Bernstein said. “The idea that the nonproliferation community might one day be able to use this technology that until now has been the exclusive province of fundamental science is an exciting motivation for this work.” Halting the spread of nukes Since 1970, nearly 200 nations signed the landmark Treaty of the Non-Proliferation of Nuclear Weapons (NPT), which seeks to limit the spread of nuclear weapons. Through a combination of remote monitoring and on–the–ground inspections, containment and surveillance, the International Atomic Energy Agency (IAEA) commands plenty of tools to figure out if countries are using nuclear energy for peaceful purposes, Goldblum said. But what happens if the line between civilian and military use of nuclear energy is not so clear? For example, the United States has long accused Iran of trying to make nuclear weapons, but Iran says it wants to develop nuclear capabilities for civilian power generation. The knowledge to construct a nuclear bomb is actually pretty well known. The hard part is getting enough materials — either enriched uranium or plutonium — to fuel the weapon. A country can reprocess the spent fuel from a civilian nuclear reactor and extract plutonium for a weapon. And a nuclear bomb only requires about 10 kilograms of plutonium. The so-called “dual-use” capabilities of nuclear reactors presents a significant challenge to the IAEA. “None of the countries now embarking on civil nuclear power programs say they are planning to acquire reprocessing capabilities,” according to a 2017 report by the Brookings Institute think tank. “But many of them are unwilling to forswear what they consider to be their ‘right’ eventually to have dual-use capabilities.” The neutrino detection technology could offer a solution. In addition to the large systems like WATCHMAN, scientists have constructed much smaller detectors that can be deployed close to reactor cores — provided operators allow such access. Optimizing reactor power levels to produce plutonium, a telltale sign that a country is trying to build a bomb, will change the rate and energy spectrum of antineutrinos that a device parked outside of the reactor can detect. And since these particles can pass through matter, the operator can’t shield the reactor’s release of antineutrinos the same way lead blocks X-rays. So if a country wants to operate a civilian nuclear power program, an antineutrino detector could provide an effective tool to continuously verify the reactor is only producing energy for peaceful purposes. For now, a detector must stay within tens of meters of the reactor to be effective. But in the future, could such technology spot antineutrinos from longer distances and even across borders? For distances 100 kilometers or beyond, the Review of Modern Physics study shows detectors would need to be 10 to 100 times bigger than WATCHMAN. But researchers hope WATCHMAN will demonstrate the basic technology and provide a platform for study of a range of possible enhancements to improve standoff and overall sensitivity. And in any case, the mere knowledge that such technology has become a reality could prove to be a powerful deterrent to nuclear proliferation in itself.

#### Neutrino anti-prolif fails – monitoring distance and it’s so expensive nobody will even bother to build them

Wright 20 [Katherine Wright is a Senior Editor for Physics. "Neutrino Detectors for National Security." https://physics.aps.org/articles/v13/36]

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 1019emitted 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.

Cost also poses a problem. A 4-ton detector, such as PROSPECT, costs around $5 million, while the price tag on a 40-ton detector is $100 million. A 300-kiloton scintillator could easily require an outlay approaching a billion dollars, says Rachel Carr, a nuclear physicist at the Massachusetts Institute of Technology, Cambridge. It’s unclear who would pay for this upfront capital cost, she says, but new regulations could be adopted that would require host countries to foot the bill. Glaser notes that building a detector is just one part of the budget—there are personnel costs for operating the device and analyzing the data. Factor in that there are 450 reactors in 30 countries, and the costs could quickly become unmanageable, he says.

#### No prolif or it takes forever

* Prolif cascades are empirically denied
* Reputational damage and economic costs disincentivize it – cons outweigh pros
* Takes 17 years to proliferate on average – hardware, knowledge, and industrial base

Kahl 13 [Colin H. Kahl, Senior Fellow at the Center for a New American Security and an associate professor in the Security Studies Program at Georgetown University’s Edmund A. Walsh School of Foreign Service, citing Jacques Hymans, USC Associate Professor of IR. If Iran Builds the Bomb, Will Saudi Arabia Be Next? Feb 19, 2013. <http://www.cnas.org/files/documents/publications/CNAS_AtomicKingdom_Kahl.pdf>]

I I I . LESSONS FRO M HISTOR Y Concerns over “regional proliferation chains,” “falling nuclear dominos” and “nuclear tipping points” are nothing new; indeed, reactive proliferation fears date back to the dawn of the nuclear age.14 Warnings of an inevitable deluge of proliferation were commonplace from the 1950s to the 1970s, resurfaced during the discussion of “rogue states” in the 1990s and became even more ominous after 9/11.15 In 2004, for example, Mitchell Reiss warned that “in ways both fast and slow, we may very soon be approaching a nuclear ‘tipping point,’ where many countries may decide to acquire nuclear arsenals on short notice, thereby triggering a proliferation epidemic.” Given the presumed fragility of the nuclear nonproliferation regime and the ready supply of nuclear expertise, technology and material, Reiss argued, “a single new entrant into the nuclear club could catalyze similar responses by others in the region, with the Middle East and Northeast Asia the most likely candidates.”16 Nevertheless, predictions of inevitable proliferation cascades have historically proven false (see The Proliferation Cascade Myth text box). In the six decades since atomic weapons were first developed, nuclear restraint has proven far more common than nuclear proliferation, and cases of reactive proliferation have been exceedingly rare. Moreover, most countries that have started down the nuclear path have found the road more difficult than imagined, both technologically and bureaucratically, leading the majority of nuclear-weapons aspirants to reverse course. Thus, despite frequent warnings of an unstoppable “nuclear express,”17 William Potter and Gaukhar Mukhatzhanova astutely note that the “train to date has been slow to pick up steam, has made fewer stops than anticipated, and usually has arrived much later than expected.”18 None of this means that additional proliferation in response to Iran’s nuclear ambitions is inconceivable, but the empirical record does suggest that regional chain reactions are not inevitable. Instead, only certain countries are candidates for reactive proliferation. Determining the risk that any given country in the Middle East will proliferate in response to Iranian nuclearization requires an assessment of the incentives and disincentives for acquiring a nuclear deterrent, the technical and bureaucratic constraints and the available strategic alternatives. Incentives and Disincentives to Proliferate Security considerations, status and reputational concerns and the prospect of sanctions combine to shape the incentives and disincentives for states to pursue nuclear weapons. Analysts predicting proliferation cascades tend to emphasize the incentives for reactive proliferation while ignoring or downplaying the disincentives. Yet, as it turns out, instances of nuclear proliferation (including reactive proliferation) have been so rare because going down this road often risks insecurity, reputational damage and economic costs that outweigh the potential benefits.19 Security and regime survival are especially important motivations driving state decisions to proliferate. All else being equal, if a state’s leadership believes that a nuclear deterrent is required to address an acute security challenge, proliferation is more likely.20 Countries in conflict-prone neighborhoods facing an “enduring rival”– especially countries with inferior conventional military capabilities vis-à-vis their opponents or those that face an adversary that possesses or is seeking nuclear weapons – may be particularly prone to seeking a nuclear deterrent to avert aggression.21 A recent quantitative study by Philipp Bleek, for example, found that security threats, as measured by the frequency and intensity of conventional militarized disputes, were highly correlated with decisions to launch nuclear weapons programs and eventually acquire the bomb.22 The Proliferation Cascade Myth Despite repeated warnings since the dawn of the nuclear age of an inevitable deluge of nuclear proliferation, such fears have thus far proven largely unfounded. Historically, nuclear restraint is the rule, not the exception – and the degree of restraint has actually increased over time. In the first two decades of the nuclear age, five nuclear-weapons states emerged: the United States (1945), the Soviet Union (1949), the United Kingdom (1952), France (1960) and China (1964). However, in the nearly 50 years since China developed nuclear weapons, only four additional countries have entered (and remained in) the nuclear club: Israel (allegedly in 1967), India (“peaceful” nuclear test in 1974, acquisition in late-1980s, test in 1998), Pakistan (acquisition in late-1980s, test in 1998) and North Korea (test in 2006).23 This significant slowdown in the pace of proliferation occurred despite the widespread dissemination of nuclear know-how and the fact that the number of states with the technical and industrial capability to pursue nuclear weapons programs has significantly increased over time.24 Moreover, in the past 20 years, several states have either given up their nuclear weapons (South Africa and the Soviet successor states Belarus, Kazakhstan and Ukraine) or ended their highly developed nuclear weapons programs (e.g., Argentina, Brazil and Libya).25 Indeed, by one estimate, 37 countries have pursued nuclear programs with possible weaponsrelated dimensions since 1945, yet the overwhelming number chose to abandon these activities before they produced a bomb. Over time, the number of nuclear reversals has grown while the number of states initiating programs with possible military dimensions has markedly declined.26 Furthermore – especially since the Nuclear Non-Proliferation Treaty (NPT) went into force in 1970 – reactive proliferation has been exceedingly rare. The NPT has near-universal membership among the community of nations; only India, Israel, Pakistan and North Korea currently stand outside the treaty. Yet the actual and suspected acquisition of nuclear weapons by these outliers has not triggered widespread reactive proliferation in their respective neighborhoods. Pakistan followed India into the nuclear club, and the two have engaged in a vigorous arms race, but Pakistani nuclearization did not spark additional South Asian states to acquire nuclear weapons. Similarly, the North Korean bomb did not lead South Korea, Japan or other regional states to follow suit.27 In the Middle East, no country has successfully built a nuclear weapon in the four decades since Israel allegedly built its first nuclear weapons. Egypt took initial steps toward nuclearization in the 1950s and then expanded these efforts in the late 1960s and 1970s in response to Israel’s presumed capabilities. However, Cairo then ratified the NPT in 1981 and abandoned its program.28 Libya, Iraq and Iran all pursued nuclear weapons capabilities, but only Iran’s program persists and none of these states initiated their efforts primarily as a defensive response to Israel’s presumed arsenal.29 Sometime in the 2000s, Syria also appears to have initiated nuclear activities with possible military dimensions, including construction of a covert nuclear reactor near al-Kibar, likely enabled by North Korean assistance.30 (An Israeli airstrike destroyed the facility in 2007.31) The motivations for Syria’s activities remain murky, but the nearly 40-year lag between Israel’s alleged development of the bomb and Syria’s actions suggests that reactive proliferation was not the most likely cause. Finally, even countries that start on the nuclear path have found it very difficult, and exceedingly time consuming, to reach the end. Of the 10 countries that launched nuclear weapons projects after 1970, only three (Pakistan, North Korea and South Africa) succeeded; one (Iran) remains in progress, and the rest failed or were reversed.32 The successful projects have also generally needed much more time than expected to finish. According to Jacques Hymans, the average time required to complete a nuclear weapons program has increased from seven years prior to 1970 to about 17 years after 1970, even as the hardware, knowledge and industrial base required for proliferation has expanded to more and more countries.33 Yet throughout the nuclear age, many states with potential security incentives to develop nuclear weapons have nevertheless abstained from doing so.34 Moreover, contrary to common expectations, recent statistical research shows that states with an enduring rival that possesses or is pursuing nuclear weapons are not more likely than other states to launch nuclear weapons programs or go all the way to acquiring the bomb, although they do seem more likely to explore nuclear weapons options.35 This suggests that a rival’s acquisition of nuclear weapons does not inevitably drive proliferation decisions. One reason that reactive proliferation is not an automatic response to a rival’s acquisition of nuclear arms is the fact that security calculations can cut in both directions. Nuclear weapons might deter outside threats, but leaders have to weigh these potential gains against the possibility that seeking nuclear weapons would make the country or regime less secure by triggering a regional arms race or a preventive attack by outside powers. Countries also have to consider the possibility that pursuing nuclear weapons will produce strains in strategic relationships with key allies and security patrons. If a state’s leaders conclude that their overall security would decrease by building a bomb, they are not likely to do so.36 Moreover, although security considerations are often central, they are rarely sufficient to motivate states to develop nuclear weapons. Scholars have noted the importance of other factors, most notably the perceived effects of nuclear weapons on a country’s relative status and influence.37 Empirically, the most highly motivated states seem to be those with leaders that simultaneously believe a nuclear deterrent is essential to counter an existential threat and view nuclear weapons as crucial for maintaining or enhancing their international status and influence. Leaders that see their country as naturally at odds with, and naturally equal or superior to, a threatening external foe appear to be especially prone to pursuing nuclear weapons.38 Thus, as Jacques Hymans argues, extreme levels of fear and pride often “combine to produce a very strong tendency to reach for the bomb.”