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At a time when government space programs like NASA's seem to be in permanent retrenchment — shifting to a strategy focused on uncrewed probes, fighting to maintain an "International Space Station" that looks like a joke compared to Golden Age science fiction visions of giant cartwheel stations in orbit — a lot of people see Elon Musk's private space venture SpaceX as a sign of hope that we have a future in space after all.

SpaceX has had considerable success developing reusable spacecraft and orbital boosters — the Dragon spacecraft has resupplied the International Space Station — and has achieved a controlled descent with tail landing by a Falcon booster.

Starting with the first Dragon spacecraft to Mars, Musk has committed himself to regular Mars runs every 26 months, using low costvehicles10. The goal is an affordable and predictable cargo route, in order to encourage Mars-related research and industry.

> Essentially what we're saying is we're establishing a cargo route to Mars. It's a regular cargo route. You can count on it. It's going happen every 26 months. Like a train leaving the station. And if scientists around the world know that they can count on that, and it's going to be inexpensive, relatively speaking compared to anything in the past, then they will plan accordingly and come up with a lot of great experiments.

According to Tim Fernholz,

> This is akin to the way that massive container ships ply the oceans to bring components between far-flung factories. Planners don't rely on a specific ship to make it across the Pacific at a discrete time, but instead imagine the ships as a kind of conveyor belt, constantly in motion, and plan their operations around the idea that goods are constantly in motion between two given sites.

The first mission will be followed by several Dragons in 2020, and in 2022 a larger number carrying the infrastructure for a permanent base on Mars — laying the groundwork for the planned transportation of human passengers in 2024.

Speaking of which, SpaceX's Mars project — which envisions humans living in a permanent base constructed there — is easily the most famous.

But if state-directed space exploration fizzled out, let's not accept, as the alternative, human expansion into the solar system under the direction of corporations and billionaire venture capitalists.

Even now, there are all sorts of interesting space projects operating on relatively little capital, and taking advantage of cheap, ephemeral micro-manufacturing technology.

Copenhagen Suborbitals, for example, is an amateur, crowdfunded spaceflight program based in Denmark11. They use a

sea-based launch platform. At the time of Aaronson's 2012 article, the venture was "comprised of a coterie of 20-plus specialists determined to create the first homemade, manned spacecraft to go into suborbital flight." The estimated cost of such a mission is expected to be in the hundreds of thousands of dollars, eventually falling to $63,000 a shot.

The project achieves enormous economies over government (and presumably corporate) bureaucracies by using off-the-shelf components whenever possible.

> One man's kitchen sink valve is another rocket man's missing component. A D.I.Y. spaceflight project can start with a good rummage at your local plumbing or hardware store. With everyday,off-the-shelf products, the guys behind Copenhagen Suborbitals found cheaper solutions to expensive, complex systems."Instead of trying to invent our own valve for instance, why not buy one that's been produced maybe a million times," explained Kristian.

The peer-to-peer nature of the project means much faster turnaround times or iteration cycles — "OODA loops," in the late Col. John Boyd's words — than is possible in government or corporate bureaucracies.

> Since Copenhagen Suborbitals is bereft of the red tape and regulations characteristic of federally or commercially funded spaceprojects, Kristian explained that his team can go from a revised sketch to an improved prototype, sometimes in less than five minutes. That's far quicker than NASA, of course, where he helped to design new moon rovers and co-authored the agency's Human Integration Design Handbook.

As for their achievements,

> so far, their accomplishments are impressive: their solid-and-liquid-fuel rocket, the HEAT-1X, is the first "amateur" rocket flown with a payload of a full-size crash test dummy, and the first to perform a successful Main Engine Cut-Off, or MECO command, and the first launched from a "low budget" sea-based platform. It's also the most powerful amateur rocket ever flown.

Since then, Copenhagen Suborbitals has tested the Sapphire (with improved guidance and maneuver systems), and has a Nexø I & II in the work. The Spica II, the rocket actually intended to send a live person into space, is expected to be tested.

Bitnation — a transnational network created to organize a variety of non-state governance services using the Blockchain infrastructure — has created a Bitnation Space Agency. The Agency intends to be a coordination platform for open-source space efforts around the world, and has its own Five-Year Plan for crowdfunded technology developmentand space missions. Iman Mirbioki ("Bitnation Space Agency," A Blog About Nothing Particular, June 2, 2015), who co-founded the venture with Susanne Tarkowski Tempelhof, estimates BSA will radically cheapenspaceflight by eliminating administrative overhead altogether (an 80% cost reduction by itself) as well as open-sourcing all technologies. Tempelhof argues that corporate efforts like SpaceX are "just the beginning of democratizing the technology"; BSA will "take it further, not just make it accessible to people outside of the government, but also make it open source, and DIY friendly"

The Agency's Five Year Plan states a list of objectives:

1. Create a decentralized and open-source space agency.
2. Research and develop new and better technology for space-travel/space-missions.
3. Develop new eco-friendly fuel for space vehicles. (Rocket fuel)

The effect of the space program's focus on blockbuster projects like Apollo was to push space travel technology towards extreme capital-intensiveness, and away from the kinds of modular, granular, multi-purpose and reusable building blocks that could evolve into a sustainable technological ecosystem.

Corporate space efforts like Musk's are a first, intermediate step towards developing an affordable, sustainable infrastructure for exploring and developing outer space. And projects like Copenhagen Suborbital and Bitnation Space Agency are completing the evolution by relying entirely on open-source hardware, and replacing high-overhead managerial bureaucracies with peer-network governance.

Things look genuinely optimistic for the future of space exploration and human expansion into the solar system. The reason for hopefulness doesn't lie with the state; and with luck, maybe it won't lie with Elon Musk for much longer either.

4. Develop a new generation of navigational systems, as the current GPS accuracy and maximum performance (speed and altitude) is limited due to enforced rules by the U.S military.

5. Create a cheaper technology and platform on an open source basis that enables those with limited budgets to reach space and/or do experiments in microgravity environments.

6. Develop new and cheaper space vehicles able of reaching LEO (Low Earth Orbit), GSO (Geostationary Orbit) and other celestial bodies like the Moon or asteroids.

7. Research alternative energy sources, mainly anti-matter trapped in the Earth's magnetic field.

8. Research and develop technology for mining minerals and resources on other celestial bodies, like the Moon or asteroids.

9. Creating communication networks and datacenters in Earth orbit, beyond the reach of any state or regime to work toward totalimmunity and neutrality of the future IT-infrastructure.

10. Building fuel-depots and an international network based on virtual currencies for refueling of satellites and other space vehicles.

11. Doing research in the field of space-medicine and the effects of microgravity and cosmic radiation on living organisms.

12. Doing research on the effect of cosmic radiation on electronic components in order to develop new technology that is able to withstand the harsh environment of outer space.

The agenda of milestone projects in the Plan — including orbital satellite launches, moon shots, probes to near-earth asteroids and

the deployment of a permanent space station by the end of 2020 — seems implausibly ambitious. But to be fair, even the fully and partly funded items at the top of the list (e.g. the BULLDOG rocket launch for deploying a payload in low-earth orbit is partly funded) are quite impressive. Extrapolate the Copenhagen Suborbitals and BSA model far enough and you get something like Openshot, a fictional open source moon shot in a short story by Craig DeLancey14. The open source hardware spacecraft, the Stallman, was the product of a network of ten thousand volunteers worldwide — and it beat the big corporate players in a competition to be "the first non-governmental organization to put a person back on the moon." Cutter, leader of one of the corporate-funded teams, warned that "the Opensource Rocket Program will have a tremendously pernicious effect on humanity and human destiny by destroying the benefit of privatizing space exploration with an unscalable stunt." And in the ultimate irony, the Stallman's crew rescued Cutter's crew and repaired his disabled ship based on crowdsourced advice from the Openshot global network.

Once you've bootstrapped affordable orbital ferries, the addition of 3-D printers and other cheap, open-source micromanufacturing technologies that can be used to construct interplanetary craft in orbit or construct buildings on the surface of other worlds means that the path to the entire solar system lies open. The focus by both corporate ventures like SpaceX and open-source ventures like Copenhagen Suborbital and Bitnation Space Agency, on developing bottom-up infrastructures, one step at a time, arguably amounts to backtracking to a crossroads and getting on the path that space exploration should have taken in the first place.

Jim Henley of Unqualified Offerings, in a comment at Pixel Scroll, noted that the Apollo project essentially destroyed the long-term future of the U.S. space program by diverting it away from the necessary work of building a sustainable technological ecosystem:

> When I was but a lad, reading Golden Age Science Fiction like Grandpa used to write, because it was what was in the middle-school libraries back in the early 70s, I was struck by how late the dates for a first moon-landing were in stories from the 40s and 50s.I think the earliest date I encountered was maybe 1978, and some of them placed it in the 1990s. And I thought, "Hah! We already got there!"
>
> But the mistake those Campbell-era authors made was assuming we'd do it right. That first we'd build a real space station, and develop a sustainable outer-space infrastructure, and then when we went to the Moon, go for keeps.
>
> Instead we raced to get there with a few cans full o' humans, hit some golf balls, planted a flag, and – bagged the whole business. By 1978, that earliest date for a moonshot I'd encountered in fiction, it was like we'd never been there at all.

Rather than organically building an entire technological ecosystem from the ground up, with infrastructures that were immediately useful in their own right at each stage, and then using the existing stage of infrastructure as the jumping off place to build the next stage when it became necessary for the needs of the existing system, Kennedy chose an arbitrary goal for its symbolic value — and the moon has since gone unvisited for forty years while the U.S. space program atrophied.

Henley also, anticipating those who point to Elon Musk's space ventures as a hopeful sign, points out that *"the private Mars foundation gang admits that their strategic plan way underestimates the likely cost."* But it's worth considering that the same blockbuster projects that diverted the space program from sustainability also tended to push it towards high-cost technologies beyond the reach of voluntary associations.