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CubeSats: The Next Big "Little" Thing in Internet of Things

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The Internet of Things has experienced exponential growth and use across the globe with 25.1 billion devices currently in use. IoT device manufacturers are now looking to outer space nanosatellite constellations, or CubeSats, to connect to a different type of internet. Until recently, the functionality of the IoT was dependent on secure data flow between internet terrestrial stations and the IoT devices. Now, an alternative path of data flow is on the horizon that is being tailored to specific IoT devices and needs. This new internet is no longer terrestrial with fiber cables six feet underground but now looking up, literally, 200 to 300 miles above the earth, to communicate, connect and transmit data.

Remarkably innovative, CubeSats, the opposite of typical or historically sizable satellites. Also called nanosatellites, they can be as small as a shoebox and are ruggedized enough to be placed into orbit for 2 to 5 years, all while communicating ubiquitously to earth. CubeSats offer low-cost solutions for a viable alternative to traditional terrestrial-based internet for IoT's device needs.

The current annual U.S. investment in space of $350 billion annually is expected to grow to $1 Trillion or more by 2040.[2] Indeed, a new era of data flow to and from "things" may soon result in a "satellite network of things" in place of IoT.

The design for purpose feature of low-cost satellites has lowered the barrier to entry. Tailoring generally results in a higher-than-average return on investment, thus making CubeSats attractive to both investors and industry. Many countries recognize the value. For example, France has invested in this new arena, and the US is poised to learn from their approach. This is the space, literally outer space, to watch.

WITH DATA NEEDS EVERYWHERE, IoT IS THERE

The IoT industry is booming, with global internet connected devices numbering 21.1 billion. Which does not even include mobile telephones.[3] This number is expected to grow by 17% to 31 % annually for the next 10 years.[4]

The IoT is the network of physical objects that contain embedded technology to communicate and sense or interact with their internal states or external environment.[5] Thousands of types of IoT devices exist; a Palo Alto Network report identified 8,355 different "device types."[6] Examples include security cameras, printers, conference room tablets, remote property sensors, coffee makers, doorbells and door openers.

Coincidentally, IoT growth has driven the increased utilization of space assets to control and monitor IoT devices. Expansion and innovation in space, particularly in CubeSats, have filled the void in IoT coverage where terrestrial internet does not exist. With affordable and accessible launch vehicles for CubeSats, IoT can explore previously closed doors. Innovation of CubeSats, commercial launch access, and tailored functionality, offer much promise. IoT devices can now connect to the internet, companies' intranet, cloud services providers, and/or dedicated networks derived from dedicated satellites. Because of the relative affordability of having a dedicated network from somewhat dedicated satellites, the production and sales of nanosatellites to global customers, including IoT manufacturers, have grown exponentially.

Significant benefits arise from CubeSats' low cost, beginning with a lower barrier to entry into the IoT device marketplace, and the potential profit with expanded sales of IoT devices in rural areas without terrestrial internet. With functionality tailored to manufacturers' needs, the higher return on the investment accounts for many companies across multiple countries now recognizing the value of nanosatellites. The field is exploding.[7] How influential this may be if the United States uses this opportunity to seize the global lead.

WHAT EXACTLY ARE CUBESATS?

New generation CubeSats are launched at between 200 and 400 miles from the earth. While future launches may be deployed at 710 miles, they are considerably closer to earth than those launched in geostationary (GSO) orbit at 22,000 miles. According to the Union of Concerned Scientists, the number of operating satellites today is 2,787.[8] Of this number, the United States operates 1,425.[9] This number will rise exponentially with nanosatellites being launched into LEO, with greater ease and lower cost.[10] In 2017, the largest challenge to full adoption of CubeSats was the unavailability of launch vehicles.[11] In 2021, that challenge was partially

overcome by commercial launch vendors such as SpaceX that launch others' satellites for a service.[12]

The shorter distance from earth (200 miles verses 22,000 miles) helps dramatically with latency.[13] CubeSats are the future of IoT as early concepts are now in research, development and production stages. [14] Designs of CubeSats have come a long way from 2017 when it was first reported that the "conceptual design" for use "as an IoT communications platform . . . is feasible."[15] The dramatic sea change is a testament to the confidence of the return on the investment.

There is both optimism and confidence in space investments. Grand View Research Market predicts that the global market will grow to more than $645 billion by 2027.[16] For example, Lacuna Space, a small U.K.-based startup with three communications satellites (with two being the size of a briefcase and the third as big as a shoebox) in orbit, is seeking to deploy dozens more satellites to cover *the entire earth at all times*.[17]

Manufacturers and researchers worldwide are exploring the use of nanosatellites for IoT. In a short period of time, CubeSats "are changing the paradigm, from just 24 months ago.[18]" With latency time reduced to the milliseconds, and lower costs for CubeSats, many are researching innovative use cases. While the field is still in its infancy, early indicators suggest much promise. As the saying goes, "the sky is the limit." In this case, not really. Maybe "deep space" is the limit.[19]

WHY CUBESATS FOR IoT?

From 2017 to 2019, potential for nanosatellites for IoT use continued to grow. Confidence levels rose each year with research predictions incrementally validated. At the International Conference on Mechatronics in 2017, three researchers asserted that the then-existing wired and wireless networks were "almost being fully utilized by the current IoT for control and communication" of the devices, and that "one of the solutions to overcome the need" for greater data communication capacity is to explore investing in space infrastructure.[20] The engineers detailed possible approaches for nanosatellites "as a means to address" the issue in a "rapid and much more affordable manner" as the low earth orbit (LEO) would be best.[21]

While affordability by investing in space assets appears to be a contradiction in terms, this prediction appears valid, when comparing these costs to terrestrial-based fiber optic cables for traditional internet. Experts acknowledge that the internet is "expensive" to expand across the globe, especially less-populated areas, as it involves "lay[ing] fiber optic cables and build[ing] cell towers in remote

areas."[22] So widely available satellite-based internet, envisioned in the 1990s, may no longer be a fantasy in 2021 and beyond, and may be less risky for investors.[23]

In 2018, Sky and Space Global reported its successful "critical design review" of 200 nanosatellites (calling them "pearls"), and proceeded while the world watched as it sought to bring internet access to underserved regions of the earth through a nanosatellite constellation.[24]

In 2019 three PhD students studying in France, the United States, and Northern Ireland collectively assessed that "[e]xtending the internet of things (IoT) networks to remote areas under extreme conditions or for serving sometimes unpredictable mobile applications has increased the need for satellite technology to provide effective connectivity."[25] Today researchers are exploring this need across multiple industries, including weather and climate research; resource management; mapping; multimedia communications; data distribution; transportation and logistics; navigation; safety, security, and rescue; agriculture; defense, and land management. Use cases have demonstrated successful pairing of IoT devices and CubeSats to agriculture and land management.

YES, CUBESATS CAN DO PENGUIN TRACKING!

Creatives uses of CubeSats now exist. As **"**globe-spanning networks of nanosatellites enable[e] a new kind of everywhere, all-the-time connectivity for people, animals and assets on Earth.,[26] scientists who track the health of Adélie penguins on the ice-covered wastes of Antarctica can now manage their cameras from thousands of miles away "—via tiny satellites orbiting above our heads… this evolving satellite technology… [are the] novel networks of nanosats—aka cubesats."[27]

What a nanosatellite may not have in terms of 24/7 coverage, it compensates for with lower-cost and designed purpose. The director of the Adélie penguin project, the Arriba Initiative, built ruggedized low-cost cameras to withstand harsh Antarctica conditions and to store images on SD cards collected once a year. The cameras rely on satellite internet data transmission, not terrestrial internet, to frequently report the camera's status, such as "low battery, covered in give, tipped over, etc.- to their keepers in London".[28] This capability reflects why "16 companies" are now investing in similar types of satellites networks."[29]

Due to global innovation and advanced technology, nanosatellites are universally enjoying success. As in other lucrative fields, competition is increasing among those with an eye toward the future. For example, Remco Timmermans, of Open Cosmos Head of Communications, intends to "make space accessible by making space missions simple."[30] Others have this same ambition. There is tremendous interest

in this newest investment space, especially with investment expected to reach to $1 trillion or more by 2040.[31] Thus, the heavens are becoming an increasingly crowded space.[32]

Not only is space getting congested, but the number of satellite manufacturers and investors interested in getting in at ground zero is growing. Launching LEO satellites is less expensive to launch. For example, Sara Spangelo, CEO of California-based Swarm Technologies, stated it could soon complete the first commercially available nanosatellite constellation, which would enable customers to engage a satellite whenever they choose.[33] Swarm has already launched 45 satellites, 36 for commercial customers and the remainder experimental. The company expects have a total "of 164 aloft" by the end of 2021, with 150 of them active.[34] Swarm is keeping costs low by producing satellites that are extra small, about the size of a "grilled cheese sandwich." Swarm's satellites communicate in the VHF spectrum—adjacent to but not overlapping with the spectrum used by shipboard radio systems—which allows for good signal penetration, even in cities and indoors.[35]

Wider adoption of nanosatellite technology is coming to the United States.[36] Next is the discussion on development in France.

FRANCE SPONSORS THE ANGELS EFFORT

In May 2017, the French government space agency, "the National Centre for Space Studies," or CNES, announced a partnership with a new space joint venture, "Thales Alenia Space."[37] Thales Alenia Space was announced as the supplier of the Argos Neo instrument that would be part of the nano-satellite demonstrator "Argos Neo on a Generic Economical and Light Satellite" or ANGELS program.[38] Thales Alenia Space's additional development partner for Argos Neos is Syrlinks,[39] a well-respected manufacturer of radio-communications and geo-location equipment.[40] French satellite manufacturer NEXEYA was added to the list of talented mission partners.[41] That the proponent for ANGELS is France's space agency is notable, as it assists with risk and high investment costs.[42]

Many see ANGELS as "the symbol of French New Space: innovative working methods in action." Three years after a 2017 press conference, ANGELS was literally launched. ANGELS was designed, developed, manufactured and "qualified in record time," all with a record range in weighing less than 50 kg.[43] 2020 was a notable year as with the launching of France's first industrial nanosatellite, thus extending the scope of "space-borne IoT" and satellite telemetry.[44]

In 2018, CNES created "an investment fund of 80 to 100 million euros ($95 to $119 million) to spur innovation" in the space sector for CNES to work with startups in "NewSpace," viewed as aggressive and innovative "firms typically running on

venture capital with a mission to disrupt the space sector with new products and services."[45] ANGELS was designed for NewSpace being five times more powerful and ten times smaller than its predecessors. [46] The French Government had both the foresight and the desire to partner to achieve France's vision to be on the international stage as a world leader in space.

This venture has demonstrated that with the support of its home country and assistance with regulatory approval, private space investments can yield dividends for both industry and the country. Revealing of transformational change is that the term "non-terrestrial IoT networks" is now getting global attention.[47] The utility of non-terrestrial IoT networks is so expansive that novel opportunities literally beyond the horizon can be realistically explored.[48]

LET'S EMBRACE US INVESTMENT IN SPACE

The US needs to put in motion now a strong American commercial space policy that promotes ease of entry and relaxed regulations. Morgan Stanley estimates that satellite internet will represent 50% of the projected growth of the global space economy by 2040. [49]

Innovative approaches to satisfy the growing global demand for data, secure transmission, and internet access, through novel, tailored nanosatellite constellations are needed. France offered its blueprints to success, and US companies will be looking now for favorable countries in which *to launch*, literally to launch new enterprises and to launch new CubeSats.

Globally, all countries are recognizing that data transmission may be better from space, or at least optimized when combined with terrestrial internet communications. Nations are reckoning that space is truly the next frontier that can change one's trajectory toward economic prosperity.

The US has always been a leader in space, but this could change with new international awakening to what is on the horizon. The US should heed this awakening and take deliberate steps to actively demonstrate its support of U.S. commercial space activities.[50] A more welcoming approach to space will assist in sustaining and promoting economic prosperity.[51]

Elon Musk's SpaceX has generated much excitement in the U.S. However, his model will not work for smaller space technology companies without large research and development budgets or other significant income-producing assets (Like Bezos' Amazon). Accordingly, the U.S. Congress should seize the moment and zealously advocate for US commercial space investments before these businesses look to

other more favorable countries to launch a satellite venture. There is some positive movement as efforts are underway to relax strict U.S. licensing requirements, specifically to consolidate and streamline the regulatory framework and organizations for U.S. commercial space capabilities.[52]

While Congress has reviewed the issue, legislation should be enacted. On an optimistic note, legislation was previously introduced. In view of French activity, there should now be momentum to pass the legislation. Specifically, the 115th Congress, the American Space Commerce Free Enterprise Act (H.R. 2809) and the Space Frontier Act of 2018 (S. 3277) included provisions to streamline the current onerous licensing process.[53] Then in the 116th Congress, the American Space Commerce Free Enterprise Act of 2019 was introduced by Rep. Brian Babin, Ranking Member of the House Science, Space, and Technology Subcommittee on Space & Aeronautics.[54] Rep. Babin seeks to affirm American competitiveness and security, and believes the U.S, could lose its "commercial space entrepreneurs, industry jobs, and innovative technology because of our slow, uncertain, and difficult regulatory process."[55]

If Congress supports space investment through tax-credits and regulatory relaxation, as did France, the United States will be poised to both embrace these opportunities and remain as the world leader in space technology. Congress recently rallied behind the "Internet of Things Cybersecurity Improvement Act of 2020" and passed it unanimously. So there is both precedent and optimism that there could be "Satellite IoT" legislation and a firm commitment of support.[56] CubeSats are here- no longer just on the horizon. Together, let us get ready for the next big 'little' thing![57]

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[1] Author serves as the National Security Agency's Training Director and Commandant of the National Cryptologic School. The opinions expressed herein are those of the author alone and do not represent the opinions of the Department of Defense. She thanks her mentor, Dr. Ian McAndrew, Dean of Doctoral Programs, Capitol Technology University.

[2] "Investing in Space Exploration," July 24, 2020, *MorganStanley.Com,* accessible at

Investing in Space Exploration | Morgan Stanley

[3] IoT devices are estimated to account for 30 percent of networked-connected endpoints, not including mobile phones. Fleischer-Black, Matt, "How to Address

Intensifying Enterprise IoT Security Risks," Cybersecurity Law Journal, Oct. 7, 2020. Accessible by subscription at www.cslawreport.com.

[4] "Gartner Says 5.8 Billion Enterprise and Automotive IoT Endpoints Will Be in Use in 2020," Gartner Newsroom Egham, U.K, Aug. 29, 2019. Accessible at Gartner Says 5.8 Billion Enterprise and Automotive IoT Endpoints Will Be in Use in 2020 Specific estimates in the 2019 report are: "Utilities will be the highest user of IoT endpoints, totaling 1.17 billion endpoints in 2019, and increasing 17% in 2020 to reach 1.37 billion endpoints [with] 'Electricity smart metering [and] 'Physical security" for , building intruder detection and indoor surveillance. These areas will drive volume user of IoT endpoints in 2020. Also, the report noted that, "Building automation, driven by connected lighting devices, will be the segment with the largest growth rate in 2020 (42%), followed by automotive and healthcare [to include] fleet management."

[5] "Cyber Physical Systems Report." U.S. Department of Homeland Security and Department of Defense Report on 2020, at 39 Appendix 7 Glossary; referencing Definition of Internet Of Things (iot) – Gartner Information Technology Glossary located at https//:www.gartner.com/en/information-technology/glossary/internet-of-things (accessed on February 6, 2021).

[6] Fleischer-Black, Matt, "How to Address Intensifying Enterprise IoT Security Risks," *Cybersecurity Law Journal*, Oct. 7, 2020. Accessible by subscription at www.cslawreport.com.

[7] Mims, Christopher. "The Tiny Satellites That Will Connect Cows, Cars and Shipping Containers to the Internet." *Wall Street Journal (Online);* New York, N.Y., 09 Jan 2021.

[8] https://www.ucsusa.org/resources/satellite-database (accessed February 7, 2021). Total number of operating satellites is 2,787, and here is breakdown by country: United States 1,425; Russia 172; China 382, and all others at 808. These 2,787 satellites are flying in the following orbit:

- LEO/Low Earth Orbit: 2,032 (200 to 400 miles in altitude)
- MEO: 137
- Elliptical: 58
- GEO/Geostationary: 560 (22,500 miles in altitude)

[9] The breakdown by type of the total 1,425 US satellites is Civil 33; Commercial 1,011, Government 173, and Military 208. Id.

Id. See also Kelvey, Jon, "SpaceX Wants to Conquer the Internet," October 2020, *Air & Space Magazine*, accessible at SpaceX Wants to Conquer the Internet | Space | Air & Space Magazine (opining the limitations of LEO is that each LEO satellite can only see 2% of the world).

[10] Id.

[11] Narayanasamy, A., Ahmad, Y.A., Othman, M (2017). "Nanosatellites constellation as an IoT communication platform for near equatorial countries." *IOP Conf. Ser.: Mater. Sci. Eng.* 260, 012028, at 11 (which read, "The absence of sufficiently small or inexpensive launch vehicles for the delivery of nanosatellites to orbit.")

[12] Nelson, Patrick. "Satellite-based internet possible by year-end, says SpaceX." Network World (Online) Southborough, May 29, 2019. Accessible at: https://www.proquest.com/trade-journals/satellite-b

[13] Id. (quoting Elon Musk about SpaceX's Starlink that it has "existing connections" which lags hundreds of milliseconds, but with "latency below 20 milliseconds…somebody could play a fast-response video game at a competitive level").

[14] "In recent years, the space industry has seen significant growth in numbers of sub 10kg satellite platforms now known more broadly in the industry as nanosatellites. Nanosatellites potential applicability is driven by flourishing technologies miniaturisation in the consumer electronics market and commercialisation of space. Currently nanosatellite mission operations are limited in both lifetime and manoeuvrability due to limitations in on board propulsion technologies. Further enhancement of mission operations relies on more effective integration of current reaction-mass-based propulsion technologies and further development of miniaturised propulsion systems." Macario Rojas, A. (2018). *Design considerations for leo nanosatellite propulsion technologies* (Order No. 10836822). Available from ProQuest Dissertations & Theses Global. (2116891136). Retrieved from https://franklin.captechu.edu:2074/dissertations-theses/design-considerations-leo-nanosatellite/docview/2116891136/se-2?accountid=44888

[15] Narayanasamy, A., Ahmad, Y.A., Othman, M (2017). "Nanosatellites constellation as an IoT communication platform for near equatorial countries." *IOP Conf. Ser.: Mater. Sci. Eng.* 260, 012028, at 12.

[16] Kelvey, Jon, "SpaceX Wants to Conquer the Internet," October 2020, *Air & Space Magazine*, accessible at SpaceX Wants to Conquer the Internet | Space | Air

& Space Magazine (opining the limitations of LEO is that each LEO satellite can only see 2% of the world).

[17] Mims, Christopher. "The Tiny Satellites That Will Connect Cows, Cars and Shipping Containers to the Internet." *Wall Street Journal (Online);* New York, N.Y., 09 Jan 2021. According to Lacuna Space, its satellites connect to things on the ground using LoRaWAN networks, already widely used for earthbound devices sold by Amazon and others. Presently, many customers testing the company's technology can only connect to the satellite only two to four times a day. Customers accept this timing limitation as "for applications like monitoring remote infrastructure, such as the penguin cameras, that's often enough" according to Rob Spurrett, Lacuna Space's chief executive and founder. See Mims, Christopher. "The Tiny Satellites That Will Connect Cows, Cars and Shipping Containers to the Internet." *Wall Street Journal (Online)*; New York, N.Y., Jan. 9, 2021 (emphasis added).

[18] This is the perspective of Alasdair Davies, director of the Arribada Initiative, which designs and builds satellite tracking and connectivity systems for researchers. Id.

[19] Pushing all boundaries, there is even ongoing research exploring if nansatellites can be ruggedized and used for deep space. See Chahat, N., Decrossas, E., Gonzalez-Ovejero, D., Yurduseven, O., Radway, M. J., Hodges, R. E., Chattopadhyay, G. (2019). Advanced CubeSat antennas for deep space and earth science missions: A review. *IEEE Antennas & Propagation Magazine, 61*(5), 37-46. doi:http://franklin.captechu.edu:2123/10.1109/MAP.2019.2932608

[20] Narayanasamy, A., Ahmad, Y.A., Othman, M (2017). "Nanosatellites constellation as an IoT communication platform for near equatorial countries." *IOP Conf. Ser.: Mater. Sci. Eng.* 260, 012028, at 2 and 8 (opining the lower costs and their analysis is only focused on, or applicable to the "design of constellation with Equatorial orbit near Equatorial counties").

[21] Narayanasamy, A., Ahmad, Y.A., Othman, M (2017). "Nanosatellites constellation as an IoT communication platform for near equatorial countries." *IOP Conf. Ser.: Mater. Sci. Eng.* 260, 012028 (adding LEO is "the simplest constellation as it eliminates many constellation design issues, such as orbit perturbation [and] number of orbit planes").

[22] Kelvey, Jon, "SpaceX Wants to Conquer the Internet," October 2020, *Air & Space Magazine*, accessible at SpaceX Wants to Conquer the Internet | Space | Air & Space Magazine

[23] Investors have been wary of investing in satellite manufacturing, due to high risk of financial loss. In 2020, SpaceX Starlink's competitor, OneWeb, did declare bankruptcy. Id.

[24] According to M2 Presswire, Sky and space global started construction and integration of its network of 200 nano-satellites to serve the world's unconnected population upon successfully completed the critical design review of its "pearls" nano-satellites in 2018. See Sky Space Global Starts Construction," *M2 Presswire,* Oct 29, 2018. Accessible at https://franklin.captechu.edu:2074/wire-feeds/sky-space-global-starts-construction-integration/docview/2126478242/se-2?accountid=44888

[25] Chahat, N., Decrossas, E., Gonzalez-Ovejero, D., Yurduseven, O., Radway, M. J., Hodges, R. E., Chattopadhyay, G. (2019). Advanced CubeSat antennas for deep space and earth science missions: A review. *IEEE Antennas & Propagation Magazine, 61*(5), 37-46. doi:http://franklin.captechu.edu:2123/10.1109/MAP.2019.2932608

[26] Mims, Christopher. "The Tiny Satellites That Will Connect Cows, Cars and Shipping Containers to the Internet." *Wall Street Journal (Online);* New York, N.Y., Jan 9, 2021.

[27] Mims, Christopher. "The Tiny Satellites That Will Connect Cows, Cars and Shipping Containers to the Internet." *Wall Street Journal (Online);* New York, N.Y., Jan 9, 2021.

[28] Similar to tracking penguins in Antarctica, nanosatellites are being explored for the tracking of animals in Africa as part of the Smart Parks project. In testing today is an elephant collar which can track animals into "deserts, forests, and transborder parks between counties in Southern Africa" where "no other wireless" is available. The elephant collar in testing in Malawi has a single battery that is expected to last ten years due to relatively low power needs, combined with the satellite connection Id. (stating that the elephant collar being tested in Malawi "connects with LoRaWan ground stations there, but can also connect to Lacuna Space Satellites" according to Smart-Park co-founder Tim van Dam).

[29] Id.

[30] Writers, S., "Interactive space simulation for nanosatellites," Feb 22, 2019, *UPI Space Daily* (stating that in Paris, "Pioneer partner Open Cosmos are taking mission development to a new dimension, using a virtual reality-like simulation that replicates life in orbit for space technologies. Through an innovative combination of

a plug-and-play test platform and software, the UK Harwell-based SME is slashing the time it takes for space missions to be designed and qualified for launch.") Retrieved from https://franklin.captechu.edu:2074/wire-feeds/interactive-space-simulation-nanosatellites/docview/2184361136/se-2?accountid=44888

[31] "Investing in Space Exploration," July 24, 2020, *MorganStanley.Com,* accessible at

Investing in Space Exploration | Morgan Stanley

[32] The proliferation of these nanosat companies is ongoing. Aravind Ravichandran, an independent consultant in the space industry, says "At this point there's basically one IoT-from-space company per country. It's just crazy, and I don't know if you have that much demand. See Mims, Christopher. "The Tiny Satellites That Will Connect Cows, Cars and Shipping Containers to the Internet." *Wall Street Journal (Online)*; New York, N.Y., Jan, 9, 2021.

[33] Dr. Spangelo is a former NASA Jet Propulsion Laboratory engineer and as she says, a "failed Canadian astronaut"—she made it to her cohort's final 32 before being cut. Id.

[34] Mims, Christopher. "The Tiny Satellites That Will Connect Cows, Cars and Shipping Containers to the Internet." *Wall Street Journal (Online*); New York, N.Y., Jan 9, 2021.

[35] Two years ago, Ford Motor Co. announced a partnership with Swarm. "Whatever they're working on is still under wraps." Mims, Christopher. "The Tiny Satellites That Will Connect Cows, Cars and Shipping Containers to the Internet." *Wall Street Journal (Online*); New York, N.Y., Jan 9, 2021.

[36] Kelvey, Jon, "SpaceX Wants to Conquer the Internet," October 2020, *Air & Space Magazine*, accessible at SpaceX Wants to Conquer the Internet | Space | Air & Space Magazine.

[37] This joint venture was established at 67% Thales and 33% Leonardo. See Thales Alenia Space Press Release, May 18, 2017, available press release at https://www.thalesgroup.com/en/worldwide/space/press-release/thales-alenia-space-provide-argos-neo-instrument-french-space-agency

[38] https://directory.eoportal.org/web/eoportal/satellite-missions/content/-/article/angels#:~:text=The%20ANGELS%20nanosatellite%20is%20being,spaceborne%20IoT%2C%20starting%20in%202022.

[39] See "Angels, France's first industrial nanosatellite, extends the scope of space IoT." *UPI Space Daily*. Oct 20, 2020 (stating "ANGELS gives a first taste of the opportunities provided by Kineis, the first constellation of European nanosatellites dedicated to IoT. Carrying a state-of-the-art ARGOS instrument, ANGELS is the operational proof of the success of the French nanosatellite sector"). Retrieved from https://franklin.captechu.edu:2074/wire-feeds/angels-frances-first-industrial-nanosatellite/docview/2451995979/se-2?accountid=44888

https://www.syrlinks.com/documents/55A

[40] Caroline Laurent, CNES's Director of Orbital Systems stated that the opening of new services and the inclusion of ANGELS in the ARGOS satellite fleet represent a new milestone in the ARGOS system success story, and that it was due to the unique partnership between CNES, Thales Alenia Space, Syrlinks and HEMERIA. See "Angels, France's first industrial nanosatellite, extends the scope of space IoT."Oct 20, 2020. *UPI Space Daily* Retrieved from https://franklin.captechu.edu:2074/wire-feeds/angels-frances-first-industrial-nanosatellite/docview/2451995979/se-2?accountid=44888

https://www.syrlinks.com/documents/55

[41] Id. See Thales Alenia Space Press Release, May 18, 2017, available press release at https://www.thalesgroup.com/en/worldwide/space/press-release/thales-alenia-space-provide-argos-neo-instrument-french-space-agency (stating "the aim of Argos Neo is to demonstrate the operational capability of a complex miniaturized instrument offering high performance on a nanosat platform").

[42] CNES in French is "Centre national d'études spatiales." The French government space agency, CNES, manages space assets with either industrial or a commercial purpose. While its headquarters are in Paris, it operates the Toulouse Space Center and Guiani Space Center where it can service both French sand other nation's satellite launches. See https://france-science.com/en/cnes-2/

[43] Details were careful considered and Angels is carrying ARGOS Neo which was the precursor of a new generation of low-cost, highly miniaturized instruments. "Angels- France's First Industrial Nanosatellite," *UPI Space Daily*, Oct 20, 2020 (adding that "All the innovations developed on board of the satellite in orbit has immediate benefits for users….this new instrument allows the transmitters to become smaller and lighter [to] open[] up the range of objects inside…. While the ANGELS model already offers exceptional performance, the 25 similar nanosatellites of the future constellation will meet even more demanding specifications"). Retrieved from https://franklin.captechu.edu:2074/wire-

feeds/angels-frances-first-industrial-nanosatellite/docview/2451995979/se-2?accountid=44888

[44] "Angels- France's First Industrial Nanosatellite," *UPI Space Daily,* Oct 20, 2020. Retrieved from https://franklin.captechu.edu:2074/wire-feeds/angels-frances-first-industrial-nanosatellite/docview/2451995979/se-2?accountid=44888

[45] Henry, Caleb, "CNES Creating a Space Startup Fund," May 7, 2018, *SpaceNews*, accessible at https://spacenews.com/cnes-creating-a-space-startup-fund/

[46] "Angels- France's First Industrial Nanosatellite," *UPI Space Daily* (Oct 20, 2020) (stating "Technology offering a five-time performance increase and greater service capability ANGELS is so sensitive that transmitters on the ground can reach it with a transmission power of just 100 mW, about a fifth of the power needed by current ARGOS transmitters. It also provides access to a new frequency band, boosting the capabilities of the seven satellites in the current system. These major innovations will enable users to extend the battery life of their transmitters and reduce their size and weight. Data from the 20,000 transmitters are currently processed by the whole system, a figure that will increase to several million by 2030. For biologists, who have been using the ARGOS system with CLS for more than 40 years, this means that their studies can last longer and can include new, smaller species through suitably miniaturized transmitters Retrieved from https://franklin.captechu.edu:2074/wire-feeds/angels-frances-first-industrial-nanosatellite/docview/2451995979/se-2?accountid=44888

[47] For early discussions, see Clyde space secures new nanosatellite contract. (2016). *Satellite Today,* (0) Retrieved from https://franklin.captechu.edu:2074/trade-journals/clyde-space-secures-new-nanosatellite-contract/docview/1932059796/se-2?accountid=44888

[48] Id. See also for expanded technology background Ferrer, T., Céspedes, S., & Becerra, A. (2019). Review and evaluation of MAC protocols for satellite IoT systems using nanosatellites. *Sensors, 19*(8) doi: http://franklin.captechu.edu:2123/10.3390/s19081947

[49] "Investing in Space Exploration," July 24, 2020, *MorganStanley.Com*, (stating "The demand for data is growing at an exponential rate, while the cost of access to space (and, by extension, data) is falling by orders of magnitude…. We believe the largest opportunity comes from providing Internet access to under- and unserved parts of the world, but there also is going to be increased demand for bandwidth from autonomous cars, the Internet of things, artificial intelligence, virtual reality, and video."

accessible at Investing in Space Exploration | Morgan Stanley

[50] See Foust, Jeff, "Commerce Department seeks big funding boost for Office of Space Commerce," Feb. 16, 2020, *SpaceNews* (stating Department's desire to consolidate and hire more personnel to streamline, but noting budget increase has not yet been approved); accessible at https://spacenews.com/commerce-department-seeks-big-funding-boost-for-office-of-space-commerce/

[51] SpaceX launches record rideshare mission carrying 143 satellites. (Jan. 25, 2021). *Satellite Today*. (stating that, "Spaceflight's customers included Astrocast, which will deploy a nanosatellite Internet of Things (IoT) network; a cluster of Radio Frequency (RF) mapping satellites for HawkEye 360, a Synthetic Aperture Radar (SAR) satellite for iQPS (Institute for Q-shu Pioneers of Space); and the NASA cubesat Pathfinder Technology Demonstrator-1"). Retrieved from https://franklin.captechu.edu:2074/trade-journals/spacex-launches-record-rideshare-mission-carrying/docview/2480477220/se-2?accountid=44888

[52] https://spacenews.com/commerce-department-seeks-big-funding-boost-for-office-of-space-commerce/

[53] In the 115th Congress, the American Space Commerce Free Enterprise Act (H.R. 2809) and the Space Frontier Act of 2018 (S. 3277) include provisions to streamline the licensing process. See U.S. Committee on Science, Space and Technology Press Release, "Babin Introduces American Space Commerce Free Enterprise Act" dated Jul 2, 2019, accessible at Babin Introduces American Space Commerce Free Enterprise Act | Committee on Science, Space, and Technology (house.gov)

[54] The "American Space Commerce Free Enterprise Act of 2019" was introduced in the 116th Congress by Representative Brian Babin (R-TX). U.S. Committee on Science, Space and Technology Press Release, "Babin Introduces American Space Commerce Free Enterprise Act" dated Jul 2, 2019, accessible at Babin Introduces American Space Commerce Free Enterprise Act | Committee on Science, Space, and Technology (house.gov)

[55] The "American Space Commerce Free Enterprise Act of 2019" was introduced in the 116th Congress by Representative Brian Babin (R-TX). U.S. Committee on Science, Space and Technology Press Release, "Babin Introduces American Space Commerce Free Enterprise Act" dated Jul 2, 2019, accessible at Babin Introduces American Space Commerce Free Enterprise Act | Committee on Science, Space, and Technology (house.gov)

[56] See P.L.116-207, 15 U.S.C. Section 278g-3a "Internet of Things Cybersecurity Improvement Act of 2020."

[57] "Investing in Space Exploration," July 24, 2020, *MorganStanley.Com,* accessible at Investing in Space Exploration | Morgan Stanley