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Flatirons Report

3D Wireless

The Promise and Challenges of Next-Generation Space and Airborne Wireless Systems Conference Report

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Silicon Flatirons is a center for innovation at the University of Colorado Boulder. It serves students, entrepreneurs, policymakers, and professionals at the intersection of law, policy, and technology.

Flatirons Reports capture analysis of various issues in law, technology, and entrepreneurship. These reports are derived from research conducted by Silicon Flatirons faculty, fellows, and research assistants, as well as from thoughtful conference and roundtable conversations hosted by Silicon Flatirons that include academics, policymakers, legal professionals, entrepreneurs, and students sharing their knowledge and best practices.

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Executive Summary

As the number of airborne and space systems increases, their coordination becomes more challenging. This proliferation of wireless devices operating above the Earth may lead to several types of collisions. One potential risk is physical collisions. A second risk is the collision of signals within the receivers of the devices, known as interference. Finally, there may be collisions of regulations as operators work to comply with a range of national and international rulemaking bodies.

To examine these issues, the Silicon Flatirons Center for Law, Technology, and Entrepreneurship held a conference titled *3D Wireless: The Promise and Challenges of Next-Generation Space and Airborne Wireless Systems* with industry experts on October 4, 2017. Participants explored ways that airborne and space systems' use of physical space and the radio spectrum could be improved to support innovation, while also protecting public safety and incumbent operators. They offered a series of recommendations to accomplish these goals, including:

- Better coordinating satellites to prevent pollution of space by collision debris;
- Reusing spectrum by having radio links look outside of the equatorial band to satellites with orbits that do not stay directly over the equator;
- Using multi-stakeholder groups and risk-based interference assessments to address interference issues;
- Allowing overlays, which permit new rights in the marketplace that are subordinate to existing transmission rights;
- Encouraging projects like NASA's Unmanned Aerial Systems Traffic Management, which would provide identification and tracking services for drones that are currently in the air;
- Recognizing that drones are not fully autonomous today, and better educating operators of their responsibility to fly drones safely; and
- Scaling production and pursuing vertical integration within companies to reduce per-unit costs.

These steps, along with other suggestions detailed in this report, should aid in the process of bolstering innovation, while protecting public safety and incumbent operators in the airborne and space systems industry.

Glossary

ADS-B: "Automatic dependent surveillance – broadcast is a surveillance technology in which an aircraft determines its position via satellite navigation and periodically broadcasts it, enabling it to be tracked. The information can be received by air traffic control ground stations as a replacement for secondary radar as no interrogation signal is needed from the ground. It can also be received by other aircraft to provide situational awareness and allow self-separation."[1]

ARC: Advisory Rulemaking Committee

Cell-on-wheels: "Cell on wheels (COW) is a portable mobile cellular site that provides temporary network and wireless coverage to locations where cellular coverage is minimal or compromised."[2]

Command and control: Communication technology that allows a wireless system's movement to be controlled remotely. Command and control includes tracking, telemetry, and control.

DARPA: "The Defense Advanced Research Projects Agency is an agency of the United States Department of Defense responsible for the development of emerging technologies for use by the military."[3]

DoD: "The Department of Defense is an executive branch department of the federal government of the United States charged with coordinating and supervising all agencies and functions of the government concerned directly with national security and the United States Armed Forces."[4]

FAA: "The Federal Aviation Administration of the United States is a national authority with powers to regulate all aspects of civil aviation. These include the construction and operation of airports, air traffic management, the certification of personnel and aircraft, and the protection of US assets during the launch or re-entry of commercial space vehicles."[5]

FCC: "The Federal Communications Commission is an independent agency of the United States government created by statute to regulate interstate communications by radio, television, wire, satellite, and cable."[6]

GSO: A geostationary satellite orbit is where a satellite placed at approximately 36,000 kilometers above the Earth's surface will move perfectly in tandem with the Earth's rotation. Thus, viewed from the Earth's surface, GSO satellites appear to be stationary.

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[1] Wikipedia.com, Automatic dependent surveillance – broadcast, https://en.wikipedia.org/wiki/Automatic_dependent_surveillance_%E2%80%93_broadcast (last visited Dec. 2, 2017).

[2] Techopedia.com, Cell On Wheels (COW), https://www.techopedia.com/definition/26001/cell-on-wheels-cow (last visited Dec. 2, 2017).

[3] Wikipedia.com, DARPA, https://en.wikipedia.org/wiki/DARPA (last visited Dec. 2, 2017).

[4] Wikipedia, United States Department of Defense, https://en.wikipedia.org/wiki/United_States_Department_of_Defense (last visited Dec. 2, 2017).

[5] Wikipedia.com, Federal Aviation Administration, https://en.wikipedia.org/wiki/Federal_Aviation_Administration (last visited Dec. 2, 2017).

[6] Wikipedia.com, Federal Communications Commission, https://en.wikipedia.org/wiki/Federal_Communications_Commission (last visited Dec. 2, 2017).

HALE: "High-Altitude Long Endurance is the description of an [airborne] vehicle which functions optimally at high-altitude and is capable of flights which last for considerable periods of time without recourse to landing."[7]

HAPS: "[A] station located on an object at an altitude of 20 to 50 kilometers and at a specified, nominal, fixed point relative to the Earth."[8]

ICAO: "The International Civil Aviation Organization, is a specialized agency of the United Nations. It codifies the principles and techniques of international air navigation and fosters the planning and development of international air transport to ensure safe and orderly growth."[9]

ITU: "The International Telecommunication Union, originally the International Telegraph Union, is a specialized agency of the United Nations that is responsible for issues that concern information and communication technologies."[10]

Jamming and Spoofing: "[B]rute-force jamming [is] sending a powerful, interfering signal that obscures the desired signal. Spoofing, on the other hand, involves sending a fake signal, and is therefore much more difficult to perceive. For example, spoofing a GPS signal could lead navigation devices to believe a person or vehicle is in one location when they are really in another."[11]

LEO: A low earth orbit, where a satellite orbits the Earth at approximately 700 to 1,500 kilometers above the Earth's surface.

LTE: "In telecommunication, Long-Term Evolution is a standard for high-speed wireless communication for mobile devices and data terminals, based on the GSM/EDGE and UMTS/HSPA technologies."[12]

MEO: A medium earth orbit, where a satellite orbits the Earth at approximately 10,000 kilometers above the Earth's surface.

NASA: "The National Aeronautics and Space Administration is an independent agency of the executive branch of the United States federal government responsible for the civilian space program, as well as aeronautics and aerospace research."[13]

NGSO: A non-geostationary satellite orbit is where a satellite does not move perfectly in tandem with the Earth's rotation.

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7 Wikipedia.com, High Altitude Long Endurance, https://en.wikipedia.org/wiki/High-Altitude_Long_Endurance (last visited Dec. 2, 2017).
8 Int'l Telecomm. Union, Radio Reg. 1.66A (2016), http://search.itu.int/history/HistoryDigitalCollectionDocLibrary/1.43.48.en.101.pdf.
9 Wikipedia.com, International Civil Aviation Organization, https://en.wikipedia.org/wiki/International_Civil_Aviation_Organization (last visited Dec. 2, 2017).
10 Wikipedia.com, International Telecommunications Union, https://en.wikipedia.org/wiki/International_Telecommunication_Union (last visited Dec. 2, 2017).
11 3D Wireless Conference: The Promise and Challenges of Next-Generation Space and Airborne Wireless Systems, Transcript: Panel 2, Challenges at 17-18, available at https://siliconflatirons.org/wp-content/uploads/2017/10/Spectrum-Panel-2.pdf.
12 Wikipedia.com, LTE, https://en.wikipedia.org/wiki/LTE_(telecommunication) (last visited Dec. 2, 2017).
13 Wikipedia.com, NASA, https://en.wikipedia.org/wiki/NASA (last visited Dec. 2, 2017).

OET: Federal Communication Commission's Office of Engineering and Technology

Payload: In the communications context, payload refers to application or service data, as distinct from command and control.

RTCA: "Radio Technical Commission for Aeronautics is a United States volunteer organization that develops technical guidance for use by government regulatory authorities and by industry. It was founded in 1935, and was re-incorporated in 1991 as a private not-for-profit corporation. It has over 200 committees and overall acts as an advisory body to the FAA."[14]

TAC: "The Technical Advisory Council is a federal advisory committee of the Federal Communications Commission and the FCC's Office of Engineering and Technology. Its mandate is to provide the FCC with technical advice in such rapidly growing fields as cable television, telephony, and the Internet."[15]

UAV: "An unmanned aerial vehicle, commonly known as a drone, is an aircraft without a human pilot aboard."[16]

UTM: Unmanned Aerial Systems Traffic Management is a potential low-altitude traffic management system, which would provide identification and tracking services for drones that are currently in the air. This service would help law enforcement detect nefarious intent by identifying drones that are not registered.

WRC: "World Radiocommunication Conference is organized by ITU to review, and, as necessary, revise the Radio Regulations, the international treaty governing the use of the radio-frequency spectrum and the geostationary-satellite and non-geostationary-satellite orbits. It is held every three to four years."[17]

3GPP: "The 3rd Generation Partnership Project is a collaboration between groups of telecommunications associations, known as the Organizational Partners. The [scope of the 3GPP includes, among other things,] the development and maintenance of…LTE and related "4G" standards [and] Next generation and related "5G" standards."[18]

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[14] Wikipedia.com, Radio Technical Commission for Aeronautics, https://en.wikipedia.org/wiki/Radio_Technical_Commission_for_Aeronautics (last visited Dec. 2, 2017).
[15] Wikipedia.com, Technical Advisory Council, https://en.wikipedia.org/wiki/Technical_Advisory_Council (last visited Dec. 2, 2017).
[16] Wikipedia.com, Unmanned Aerial Vehicle, https://en.wikipedia.org/wiki/Unmanned_aerial_vehicle (last visited Dec. 2, 2017).
[17] Wikipedia.com, World Radiocommunication Conference, https://en.wikipedia.org/wiki/World_Radiocommunication_Conference (last visited Dec. 2, 2017).
[18] Wikipedia.com, 3GPP, https://en.wikipedia.org/wiki/3GPP (last visited Dec. 2, 2017).

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Introduction

On October 4, 2017, Pierre de Vries (University of Colorado) opened the Silicon Flatirons Center's annual spectrum conference, *3D Wireless: The Promise and Challenges of Next-Generation Space and Airborne Wireless Systems*.[19] De Vries explained that, "spectrum policy used to be simple, at least as far as geometry went." In the past, spectrum was licensed by "points;" that is, a physical location where a transmitter could be permanently placed, such as a radio tower. Even satellites were points, in the sense that they maintained geostationary orbits (GSOs), moving perfectly in tandem with the Earth in a designated orbital slot. Regulation then progressed to licenses along lines (fixed point-to-point microwave). And then in the 1980s, licensing moved to cellular areas.

De Vries observed that today, however, we are seeing a move to volumes as innovation has led to a proliferation of devices moving at different altitudes above the Earth's surface, hence wireless in 3D. For example, satellites, high-altitude platform stations (HAPS), drones, and manned aerial vehicles, such as commercial planes, all must coordinate with each other as they move through space. Each of these technologies uses radios for command and control, and many also use radios for payload (e.g., providing broadband internet service on a commercial flight or video streaming from a surveilling drone). Thus, De Vries pointed out, policymakers must work to prevent at least two forms of collisions: first, the physical collision of space and airborne wireless systems, and second, the collision of radio signals inside receivers, known as interference. There may also be regulatory collisions when different national and international agencies' regulations intersect and overlap.

Policymakers, therefore, must find a way to support and balance innovation and public safety. For instance, a physical collision in outer space may result in an explosion of debris and potentially even a chain of subsequent collisions rendering large swaths of space unusable. If debris pollutes too much of space, it may even prevent the launch of any future technologies into orbit. And within the Earth's atmosphere, of course, physical collisions present tremendous risk to human lives in the air and on the ground below.

Dean Robert Braun (University of Colorado) noted that private companies like SpaceX, Blue Origin, OneWeb, Lockheed Martin, and Planet are at the center of this wave of innovation. These companies, and their ability to execute their future plans—be it the delivery of broadband by satellites or landing humans on Mars—will in large part be shaped by policy decisions. Braun stressed the importance of interdisciplinary understanding and skills to continue powering this innovation, as he sees synergies in the advances being made across industries. For example, Braun explained that both space and aeronautics are working toward miniaturization and autonomy. One manifestation of this work is the creation of unmanned aerial systems, such as drones and small satellites. In describing flight systems, Braun emphasized, "these systems are critically dependent on telecom," as shown by the imagery, data, and health status systems required for their successful operation. Lastly, Braun expressed the common concern that there may not be enough spectrum for deserving

19 The full titles of all of conferences speakers and panelists can be found in Appendix A.

activities, and that because of this, he expects to see “some sort of allocation, sharing scheme, in time…”

De Vries’ and Braun’s remarks highlight several underlying questions of the conference.[20] What are the challenges of coordinating space and airborne wireless systems and their operators to avoid collisions? Are there problematic overlaps between governing institutions at the national level and the international level, and between national and international agencies?[21] What are the driving factors and critical uncertainties that will determine the maturation of the many new technologies and business models that are emerging?

This report collates participant and audience comments under the themes the authors believe to be most relevant. (A full transcript of the conference is available.[22]) Section I discusses traffic management concerns around physical and radio-signal collisions, Section II takes stock of the current national and international regulations governing space and airborne systems, and Section III explores the key drivers powering innovation.

I. Managing Traffic of Space and Airborne Wireless Systems

Julius Knapp (FCC), the keynote speaker, noted that “[i]f you are going to put up a satellite system, or a terrestrial system, you want to be sure that the investment that you are making…is going to work.” The challenge is to coordinate an increasing number of these moving pieces, which are owned and operated by many different providers, so that physical collisions and interference do not occur.

A. An Increase in Traffic

Conference participants first explained what is causing an increase in traffic; that is, why companies are choosing to launch more wireless systems above the Earth. Knapp offered a metaphor of a lightbulb to help illustrate this technological trend: the higher up you place a lightbulb, the more surface area the bulb can illuminate below. Similarly, the higher up these wireless systems are placed above the Earth, the greater the surface area to which these systems can provide service. For instance, a single geostationary satellite, which sits approximately 36,000 kilometers above the Earth, can provide coverage to approximately 42% of the Earth’s surface.[23] To be able to provide service to such a large area without

20 Conference Brief, 3D Wireless: The promise and challenges of next-generation space and airborne wireless systems, Silicon Flatirons, Sept. 10, 2017, available at https://siliconflatirons.org/wp-content/uploads/2017/09/Conf-brief-v.11-3D-wireless.pdf.

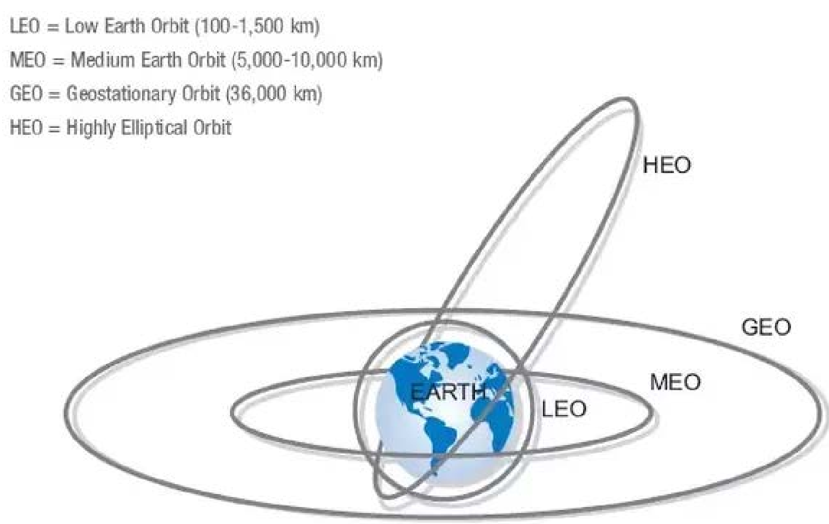
21 E.g., governing institutions at the national level include the Federal Aviation Administration (FAA), the Federal Communications Commission (FCC), the National Aeronautics and Space Administration (NASA), and the Department of Defense (DoD); and international agencies include the International Telecommunication Union (ITU) and International Civil Aviation Organization (ICAO).

22 3D Wireless Conference: The Promise and Challenges of Next-Generation Space and Airborne Wireless Systems, Transcript, https://siliconflatirons.org/wp-content/uploads/2017/10/Spectrum-Conference.pdf.

23 Geostationary Satellite Orbit: GEO, Radio-Electronics.com, http://www.radio-electronics.com/info/satellite/satellite-orbits/geostationary-earth-orbit.php (last visited Nov. 8, 2017).

having to lay copper or fiber cables from end to end is very appealing. That being said, tradeoffs exist. Communication through a geostationary satellite comes with high latency—about half a second per roundtrip.[24] This latency is not ideal for some services, such as real-time voice, so providers have launched wireless systems to lower altitudes to address this issue.

Today, a range of wireless systems can be found moving above the Earth's surface, including non-geostationary satellite orbits (NGSOs), such as medium Earth orbit satellites (MEOs), located at altitudes near 10,000 kilometers and low Earth orbit satellites (LEOs), located at altitudes between 100 to 1,500 kilometers.



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Dr. David Reed (University of Colorado) asked for a description of the advantages of MEOs and LEOs. Larry Alder (OneWeb) provided two explanations. First, Alder re-emphasized the issue of latency. Placing satellites closer to Earth reduces latency by simply shortening the distance data must travel. Second, LEOs and MEOs can help reuse spectrum. Alder discussed the scenario for a company with only geostationary satellites: "Unfortunately, if all of your satellites are sitting in an equatorial band, and that's all you have, everything has to look to the equatorial band." Thus, there is a high demand for radio links to and from high equatorial orbit, but some links could be re-used by pointing them in a different direction. MEOs and LEOs can take advantage of these formerly unused links by establishing orbits around the Earth that do not stay directly over the equator. In Alder's words, "the reason for the innovation is to unlock more spectrum…instead of all [communication] being constrained to just one plane, you can now look in other directions." While adding MEOs

24 Greg Berlocher, Minimizing Latency in Satellite Networks, Via Satellite, Sept. 1, 2009, http://www.satellitetoday.com/telecom/2009/09/01/minimizing-latency-in-satellite-networks/; see also WTPF 1996 Fact Sheet, Int'l Telecomm. Union, https://www.itu.int/newsarchive/wtpf96/fact.html.

25 Namura Gonzalez, GEO, MEO, LEO Satellite (Posted Oct 25, 2015), available at https://namuragonzalez.quora.com/GEO-MEO-LEO-Satellite (last visited Dec. 3, 2017).

and LEOs reduces latency and frees up spectrum, they also present challenges, such as ensuring that the satellites do not physically collide.

B. Coordination of Physical Traffic

Alder went on to state that we must think carefully about coordinating satellites moving through space; that "we can't pollute space for the future." He warned that one potential catastrophic consequence of large numbers of satellites could be that space debris may prevent the launch of future satellites. Alder offered several suggestions for innovation: one, the ability of satellite owners to take evasive maneuvers to avoid collisions, and two, requiring satellite providers to safely de-orbit their property at the end of its use. This second step may include fuel requirements to ensure that the satellite can re-enter the Earth's atmosphere, as well as requirements that all satellite materials must safely burn up on re-entry. Lastly, Alder offered the idea of a space debris collection process.

Phil Larson (University of Colorado) noted that Senator Cory Booker recently announced a plan to mitigate space debris, and that the Department of Defense (DoD) and the Defense Advanced Research Projects Agency (DARPA) are currently considering some of the options Alder mentioned. Larson stated that while the DoD is currently in charge of space traffic control in the United States, the commercial sector may be able to provide ideas for more accurate and comprehensive space traffic control data to aid in the safe launching and de-orbiting of satellites. He further added that he believes it will take "technology to push the policy." For example, endeavors like SpaceX's goal to send a human to Mars, or plans of other private companies to mine asteroids, will push national and international regulators to tackle new issues in regard to sharing space.

In addition to satellites, companies have launched high-altitude platform stations (HAPS), which fly even closer to the Earth's surface than MEOs and LEOs. The International Telecommunications Union (ITU) defines HAPS as, "a station located on an object at an altitude of 20 to 50 kilometers and at a specified, nominal, fixed point relative to the Earth."[26] Dr. Reed offered the example of Alphabet's HAPS, developed under Project Loon, which was re-directed to areas of Peru that experienced severe flooding in order to deliver broadband service. According to Alphabet, "the balloons provided 160 GB of data to tens of thousands of users."[27] Cory Dixon (University of Colorado) explained that HAPS, as shown in the Project Loon example, can act as pseudo-satellites, but with more flexibility in cost, timing, and deployment than space satellites. He added that drones can also help serve the last-mile needs of consumers with the commercial deliveries of goods. Dixon went on to point out that in the United States the Federal Aviation Administration (FAA) has provided waivers allowing providers to use their HAPS and drones in times of disaster, and from this we are seeing that HAPS and lower-altitude drones can quickly address demands in space and time.

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26 Int'l Telecomm. Union, Radio Reg. 1.66A (2016), http://search.itu.int/history/HistoryDigitalCollectionDocLibrary/1.43.48.en.101.pdf.

27 Selena Larson, Google's Project Loon helps bring the internet to flooded Peru, CNNTech, May 17, 2017, available at http://money.cnn.com/2017/05/17/technology/project-loon-peru-flooding/index.html.

Conference panelists also discussed several other contributors to airborne traffic—commercial airlines and recreational drone users—and the challenges to coordinate their use in space. Joe Cramer (Boeing) stated that the number one priority in traffic management is human safety. Cramer asked, "how do we [prevent], at a technological level…a small UAV [unmanned aerial vehicle]…from flying in airspace used by the planes you fly on?" To highlight his concern, Cramer explained that currently, cellular providers want to provide control of UAVs. That means that the signals used by the cell phones of commercial airplane passengers while at the airport could potentially be the same signal used to control UAVs. Cramer continued, "the regulation can say, 'thou shall not fly at the airport,' but…how do we physically prevent that from happening?" Cramer's question of technological control leads to the next theme of the conference: the autonomy of airborne wireless systems and its role in preventing collisions.

i. Autonomy of Space and Airborne Wireless Systems

For commercial airplanes, Cramer stated that technology for autonomy already exists; planes can navigate to the runway, take off, and land on their own, but regulations do not allow this, and neither does public perception. Anne Swanson (Wilkinson Barker Knauer) agreed with Cramer stating, "I don't think autonomy is a regulatory problem. I think it's a political problem…[i]n terms of perception." Both Cramer and Michael Tseytlin (Facebook) predicted that regulations allowing for autonomous commercial aircraft will not be updated until people are first comfortable with driverless cars. Cramer posited that he expects this to take another 10 or 20 years.

Dixon noted that drones are rapidly becoming autonomous. For example, flying a military drone 10 years ago required a 60-person ground crew. Today only one operator is needed. With more autonomy, Dixon expects applications of drones to continue to grow. That is, drones are more likely to be used when an operator can fly a drone up to a certain point and essentially set it and forget it. The operator can then return to their job, say as a firefighter, while the drone can autonomously evaluate its surroundings, as well as its own health.

Skip Miller (UASUSA) emphasized that we must recognize that drones are not yet fully autonomous today, and so we must continue to focus on how to educate users of their responsibility to operate drones safely. Dixon, as well as Jennifer Warren, (Lockheed Martin) agreed that training flyers of drones remains a challenge. Miller noted that, unlike obtaining a license to drive a car, the Part 107 rules do not require any previous experience flying a drone. The FAA states on its website: "There is no required practical training to fly under the Part 107 rule or to get a remote pilot certificate…Under the Small UAS Rule (Part 107), operators must pass an aeronautical knowledge test to obtain a Remote Pilot Certificate."[28] Miller concluded that although 107 rules are a step in the right direction, he believes challenges remain. For instance, he asked, how do we best teach people what

28 Unmanned Aircraft Systems (UAS) Frequently Asked Questions, FAA, https://www.faa.gov/uas/faqs/ (last visited Nov. 8, 2017).

autonomous means, and how do we ensure operators understand their responsibilities in controlling a drone well enough to prevent accidents?

ii. Property Rights and a Traffic Cop

Thomas Hazlett (Clemson University) discussed two approaches to mitigating physical collisions: property rights and a traffic cop. In Hazlett's view, the challenge in coordinating physical space and airborne devices, "is just a very standard property rights conflict." The new business models discussed throughout the conference, which require flying wireless systems above the Earth, are like any other business models in history that forced conflict by using property in a way that the law did not clearly resolve. As an example, Hazlett described the evolution of the famous English jurist Sir William Blackstone's traditional rule of property—that the rights of the property owner were supposed to extend from the surface of the Earth up to the Heavens above and down to the center of the Earth.[29] This rule prompted conflict when planes flew through other people's property, because the plane owners did not receive the permission of, or contract with, each property owner. However, Hazlett explained, the issue was resolved by the Air Commerce Act of 1926, which allowed planes to fly overhead without the consent of property owners on the Earth's surface.[30] Other laws and courts resolved similar property rights disputes for claims to oil beneath the Earth's surface.

Hazlett indicated that the additional uses of space above the Earth's surface can be worked out by similar evolutions in the law, and that new property rights would bring "tremendous opportunities for…efficiencies." Additionally, Hazlet said that "there does need to be a traffic cop… but there is no reason it should be a government organization…." He suggested a non-profit organization. Whomever the traffic cop role falls to will need to make decisions that will affect the ability of the industry to grow and innovate. For instance, Hazlett explains that cheap registration requirements for space and airborne systems make sense, but mandating expensive sensing technology may stifle or even kill some technologies. Overall, even though Hazlett recognized that we need rules going forward, he emphasized that flexibility is vital, and that the formulation of any new rules should include commercial stakeholders.

C. Coordination of Spectrum Use

Knapp, in his keynote speech, plainly laid out the challenge of coordinating the use of radio spectrum in space:

> 3D isn't really something new…[we've] been aiming signals at satellites for years and years, but it's getting more complicated. [There are] a lot more things going up in the sky, and if we had the luxury of giving them all of their own separate bands, maybe it wouldn't be so hard. But we don't have enough to do that so, so much of this is about doing the engineering, so that systems in some cases can share spectrum;

29 2 William Blackstone, Commentaries *18.

30 Air Commerce Act of 1926, Pub. L. 69-254, 44 Stat. 568 (codified as amended in scattered sections of 49 U.S.C.).

> that they can aim their signals in such a way that they don't interfere with each other…

Thus, while the challenge of allocating and enforcing the use of spectrum is not new, it has become increasingly complex to license spectrum for devices that are perpetually crisscrossing through space. Panelists discussed the challenges in avoiding interference, while at the same time not stifling innovation. Several recommendations were also proffered, including working with multi-stakeholder groups, following risk-based interference assessment guidelines, improving cell-splitting technologies, using ground terminals to spread out signals via fiber, and distributing overlay licenses.

Cramer noted two challenges to mitigating radio frequency (RF) interference: getting regulatory approvals and designing the antennas to be used by wireless systems. In regard to the first challenge, Cramer described a common scenario: different technologies all vying for the same band of spectrum. The World Radiocommunication Conference (WRC) in 2015 adopted Agenda Item 1.14,[31] which discusses regulations for HAPS, and which spectrum HAPS could potentially use. Cramer pointed out that the band HAPS owners would like access to is the same band terrestrial cellular providers desire for 5G, and the same band that Boeing is interested in using for its NGSO system. This means competition between the technologies to demonstrate they deserve access to the band, and at least for the HAPS owners and Boeing, it means obtaining approvals from several national and international regulating bodies.

For antenna design, a major tradeoff exists between the receiver cost and its ability to reject undesired signals; further, an antenna's size must correspond to the frequency the device is licensed to use. As bands become more and more crowded, receiver quality must be improved to sift through the noise for the correct signal.

On a related note, Brennan Price (EchoStar) added that the WRC in 2019 will consider what the appropriate protection criteria and power limits should be between GSOs and NGSOs. Price expressed optimism that coordination agreements could be reached, but noted that "[d]etermining when these reductions are necessary is easier in the GSO versus NGSO case, as opposed to the NGSO versus NGSO case, because you have one target that's not moving [in the first scenario], as opposed to two satellites that are moving at the same time [in the second scenario]."[32]

Steve Lanning (ViaSat) explained that in interference situations, an even more fundamental challenge exists "just in identifying and being able to know who your interferer is." Although the conference panelists mostly discussed interference in terms of unintentional collisions of signals within receivers, an audience member, Professor Dale Hatfield, cautioned that we must also prepare for intentional and malicious forms of interference, such as jamming and spoofing.[33] Hatfield pointed out that he has seen progress

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31 Int'l Telecomm. Union, World Radio Conference 2015 (WRC-15), Agenda Item 1.14.

32 From the perspective of an observer on the ground, a GSO satellite is stationary in the sky, whereas NGSO satellites move.

33 3D Wireless Conference: The Promise and Challenges of Next-Generation Space and Airborne Wireless Systems, Transcript: Panel 2, Challenges at 17-18, available .

in improving external electronics, but explained he is worried about signals coming into the aircraft and affecting critical command and control channels, because "[y]ou can't shut off the communications." While several panelists stated their respective companies are also concerned with intentional jamming and spoofing, Michael Tseytlin noted that, presently, certification does not look at jamming. Anne Swanson shared Hatfield's concern saying, "we do need human intervention when we have bad actors." She added there could be a whole other conference just on aircraft security.

i. Recommendations

Throughout the conference, multi-stakeholder groups were mentioned as resources for solving interference issues. Julius Knapp briefly talked about the FCC's Technological Advisory Council (TAC), which has been charged with, among many other things, preparing a Satellite Communications Plan to be presented in December 2017.[34] Price further suggested the Space Data Association and their Space Data Center as a "great resource for evaluating collision potential and RF interference potential." The efforts of the ITU, 3rd Generation Partnership Project (3GPP), and WRC were touched on by many panelists as well.

Knapp also spoke about risk-based, or risk-informed, interference assessment, citing work by Pierre de Vries.[35] With the goal of co-existence between different technologies sharing the same frequency band, De Vries has recommended rethinking the traditional "worst-case" scenarios of interference. Although historically incumbent spectrum licensees have pushed regulators to prevent all interference, no matter how small or how brief, risk-informed interference assessment recommends setting acceptable interference levels based on the risk that the interference poses. Knapp framed this idea in terms of cultivating innovation. If an incumbent service suffers interference for only several minutes a year, and that interference only lowers the incumbent service's bit rate by 25% for those few minutes, then should the interference "be the roadblock to an entire new service?" Knapp believed risk-informed interference assessment is the best way to answer this question.

Larry Alder acknowledged that any incumbent will "say any interference is unacceptably bad," but he also expressed optimism that rules can improve for 3D. He encouraged audience members to look into a regulatory process prompted by the company Teledesic, which resulted in ITU's Article 22.[36] Article 22 dictates "how much power you can transmit in different directions, and it's a function of time. It's a cumulative distribution function," Alder stated. Therefore, he noted, innovation takes place not only in the form of new technologies, but in "how you transmit and get access to the spectrum." On the same panel, Lanning suggested that positive interactions between organizations also helps create a culture of innovation around spectrum sharing. That is, he thinks it is in the best interest of organizations to respectfully communicate with clear data when they have identified an

34 See Federal Communications Commission: Technological Advisory Council, https://www.fcc.gov/general/technological-advisory-council (last visited Nov. 9, 2017).

35 J. Pierre de Vries, Risk-informed interference assessment: A quantitative basis for spectrum allocation decisions, 41 Telecomm. Policy 434 (2017), available at http://dx.doi.org/10.1016/j.telpol.2016.12.007.

36 Int'l Telecomm. Union, Radio Reg. Article 22, Space Services at 279 (2016), http://search.itu.int/history/HistoryDigitalCollectionDocLibrary/1.43.48.en.101.pdf.

interferer. If companies can work together to solve interference issues, it can lead to broader collaboration on sharing regimes that benefit the industry overall.

Alder also described improving throughput as another option to minimize spectrum interference. Essentially, high-throughput is about cell-splitting, focusing transmissions into narrower and narrower beams toward the Earth. Alder explained that a two-way exchange of data benefits from high throughput, because total data capacity of a band is increased. Further, it is easier to divide cells into smaller and smaller areas, because as the frequency of the spectrum increases, to say 40 gigahertz, the required size of the antennas transmitting and receiving the signal shrinks.

Lastly, Thomas Hazlett recommended using overlays to solve the friction between minimizing interference and maximizing innovation. Overlays permit "new rights in the marketplace that are subordinate to the existing transmission rights that can allow the owners, presumably the new winners…to make bargains with incumbents and transition or reconfigure markets such that you can have new technologies, new services, and new business models deployed." The goal is to make opportunity costs evident. With overlays, decisions about tradeoffs and the best use of spectrum move away from regulators and move toward the market. As an example, Hazlett referred to a joint comment submitted to the FCC by Intel and Intelsat,[37] that discusses incumbent licensees, in this case satellite licensees "being able to make commercial deals with terrestrial providers." Hazlett contended that the ability of private companies to strike bargains in the marketplace, i.e., to pay one another, will ultimately lead to effective sharing of spectrum.

II. Taking Stock of the Current Regulatory Environment

Section II transitions from a discussion of physical collisions and collisions of signals inside receivers to the potential collision of the regulations promulgated by different national and international institutions. Specifically, this section will touch on the current regulations for obtaining the necessary licenses to launch space and airborne systems, as discussed by the conference panelists. These bodies and agreements are listed below under their respective device category.

Non-geostationary orbit systems. NGSOs are regulated by two treaties: the International Telecommunications Union (ITU) Treaty and the 1967 Outer Space Treaty. Already over a century old, the ITU was designated by the 1961 United Nations resolution to "report on those aspects of space communications in which international cooperation would be required".[38] As Larry Alder noted, one of the ITU's first objectives was to find a way to coordinate NGSOs with GSOs. The ITU has created rules that determine how

37 Comments of Intelsat License LLC, Intel Corporation, Expanding Flexible Use in Mid-Band Spectrum Between 3.7 and 24 GHz, GN Dkt. No. 17-183 (filed Oct. 2, 2017), https://www.fcc.gov/ecfs/filing/1002726526846.

38 Reports on Telecommunication and the Peaceful Uses of Outer Space, Int'l Telecomm. Union, http://handle.itu.int/11.1004/020.1000/8 (last visited Nov. 8, 2017).

satellites are to be registered, how to coordinate them, and how much power they can transmit in different directions.

Jennifer Warren also noted that the ITU rules provide for only a seven-year launch window for each satellite. Should the satellite not be launched during the ITU window, the satellite filing is cancelled and the applicant must either start over or get an extension via unanimous agreement from all 194 member countries. An additional ITU constraint on NGSO operations is found in Article 44 of the Constitution of ITU, which establishes the concept of equitable access to orbital resources.[39] The article indicates that every country is expected to try to minimize its needs for orbital access in order to ensure that all countries have the ability to access space.

The second regulation relevant to NGSO operations discussed during the conference was Article VI of the 1967 Outer Space Treaty, which states that each country must have a designated entity in charge of authorizing and supervising any non-governmental or private activity in space. For instance, in the United States, the FCC's International Bureau handles the licensing of all satellites, including NGSOs. Knapp explained that if one company applies for operating permission in a frequency band, the FCC issues a public notice inviting others that are interested in operating in that band to apply. The FCC then works to grant as many licenses as possible. Knapp pointed out that the FCC has recently issued an order and a further notice of proposed rulemaking to update the rules for NGSO satellite systems.[40] The goal is to add efficiency and assurance that these large investments are not going to result in satellites generating interference. Knapp emphasized the goal is to get companies working together to figure how best they can share both spectrum and space.

The 1967 Outer Space Treaty also obligates signatories to manage space debris. As Phil Larson explained, the treaty established that the launching state is responsible if and when a satellite deorbits. Steve Lanning noted, however, that despite the 1967 Treaty, there is no current method for bringing down abandoned satellites that were put in place by operators who since have gone out of business.

High-altitude platform stations. Knapp stated that, currently, the FCC has fairly flexible rules for HAPS with regard to spectrum allocation. That is, the FCC will grant a spectrum license without putting constraints on how the service should be provided. Some panelists highlighted that the organizations that may license spectrum do not have much regulation when it comes to HAPS. For instance, neither the ITU nor the FCC's International Bureau are involved in the regulation of HAPS launches. Another concern is the fact that the ITU has only one global spectrum allocation for HAPS. However, as mentioned earlier in this report, additional spectrum allocations for HAPS was accepted as an agenda item to be discussed at the 2019 WRC.

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39 Int'l Telecom Union Constitution, Art. 44, Use of the Radio-Frequency Spectrum and of the Geostationary-Satellite and Other Satellite Orbits, available at http://search.itu.int/history/HistoryDigitalCollectionDocLibrary/5.21.61.en.100.pdf, p. 78.

40 Update to Parts 2 and 25 Concerning Non-Geostationary, Fixed-Satellite Service Systems and Related Matters, IB Dkt. No 16-408 Report and Order and Further Notice of Proposed Rulemaking, FCC 17-122, released September 27, 2002, https://apps.fcc.gov/edocs_public/attachmatch/FCC-17-122A1.pdf.

Michael Tseytlin highlighted a current issue between the ITU and the International Civil Aviation Organization (ICAO) in how the names and standards for HAPS vary between organizations. For example, HAPS is a term that is used by the ITU for devices operating at 20 kilometers of altitude (roughly 66,000 feet) or higher. ICAO, on the other hand, refers to these devices as high-altitude, long-endurance platforms (HALEs), which operate at 60,000 feet or above. This represents a mismatch between aviation and spectrum. This is an issue that will be discussed at the WRC in 2019.

Low-altitude UAVs. According to Julius Knapp, the FCC has been somewhat involved in the creation of regulations for the use of low-altitude UAVs. However, currently the top priority is developing a system that can prevent collisions between UAVs and manned aircrafts. One of the Technology Advisory Council's (TAC) recommendations for the FCC was that it should promote the use of existing communications infrastructure whenever possible. Specifically, the TAC noted that commercial wireless networks are one solution for control tracking and payload communications for small low-altitude UAVs.[41]

Similar to HAPS, UAVs have few international regulations governing their use today. Jennifer Richter (Akin Gump Strauss Hauer & Feld LLP) expressed concern about the lack of an ITU spectrum allocation for low-altitude UAVs, stating that the ITU's focus has been on devices at higher altitudes. According to Richter, there has not been an international body that has worked on a spectrum solution for low-altitude drones regarding control links, payload communications, collision avoidance, or remote identification and tracking.

While there is an upcoming agenda item at WRC 2019 to discuss new allocation of spectrum for HAPS, there has not been a similar discussion for low-altitude UAVs. One encouraging step, Richter noted, was a discussion that took place at ICAO's last conference regarding international systems for low-altitude traffic management for drones, and the fact that there are no international standards for UAVs. In response to this issue, ICAO put out a Request for Information asking for interested parties to submit proposals for potential regulatory systems. Roughly 50 proposals were made and 17 were chosen to be presented at ICAO's Drone Enable Conference. Richter mentioned that one of the proposals suggested using Long Term Evolution (LTE) networks to manage UAV traffic, an idea she had suggested in the past. Richter also emphasized the importance of a project being run by NASA called Unmanned Aerial Systems Traffic Management (UTM). UTM is a potential low-altitude traffic management system, which would provide identification and tracking services for drones that are currently in the air. This service would help law enforcement detect nefarious intent by identifying drones that are not registered.

In terms of granting spectrum for the command and control of low-altitude airborne systems, Joe Cramer highlighted how difficult it is in aviation for companies like Boeing to obtain spectrum. Cramer explained that in order to launch a device, the company is required to get approval from multiple international regulatory bodies. One of them is the ITU, from

41 FCC Technological Advisory Council, Implications for Mass Deployments of Aeronautical/Space Transmitters (Dec. 7, 2016), available at https://transition.fcc.gov/bureaus/oet/tac/tacdocs/meeting12716/TAC-presentations-12-7-16.pdf, p. 75.

which it is necessary to obtain a safety allocation. Cramer explained that "a communications or navigation or surveillance system on a commercial airplane requires…failure rates of one to a billion." According to Cramer the standards for HAPS and UAVs should be the same as those for commercial airlines since these devices need to provide the same level of reliability in terms of command and control and also the sensing and avoidance of other aircrafts. For example, Cramer explained, the FAA is now requiring medium-sized UAVs to have Automatic Dependence Surveillance Broadcast (ADS-B), a system that aids in identifying the UAV and its location. However, regulatory requirements like these force UAV operators to sacrifice other potential services due to the ADS-B system's extra weight.

The discussion regarding UAV regulation and advisory groups prompted the question of what is the appropriate mix of government and private action in generating solutions for the current regulatory problems. Warren explained that due to the fact that there are many sectors in the industry playing a role, there is a need for dialogue between them before anything gets accomplished or any new treaties are signed. Richter added that even now this is visible in several working groups that include both industry and government working together. One example Warren gave is the Drone Advisory Committee (DAC), which is composed of government officials, as well as members of the industry such as manufacturers and even pilots.

A. Keeping up with the Technology

The conference's final panel offered the opportunity to reflect on the ways in which regulators are seeking to keep up with technology. Anne Swanson mentioned how the Radio Technical Commission for Aeronautics (RTCA), a volunteer organization in charge of recommending new solutions to the FAA, helps the FAA stay up to speed with advances in technology. Swanson explained that the RTCA is multi-stakeholder body that involves technical experts. Anna Gomez (Wiley Rein LLP) noted how the FAA also runs very quick processes through Advisory Rulemaking Committees (ARCs) and highlighted the committees' efficiency in providing recommendations. Swanson added that the FCC uses its Office of Engineering and Technology (OET) similarly to how the FAA uses the RTCA, but calls on it on an ancillary basis and the process tends to be much slower.

III. Key Drivers for Continued Innovation

Throughout the conference, moderators and panelists described what they consider to be the key drivers to the innovation taking place in space and airborne wireless systems industries: automation, miniaturization, and cost reduction through scale. Sources of investment were also discussed.

Steve Lanning outlined the approach ViaSat has taken to reduce costs. Sometimes when a company is attempting to make large leaps in innovation, Lanning explained, it can be difficult to convince and coordinate all the outside firms and regulators needed to bring your product to market. Therefore, ViaSat pursues vertical integration, bringing a microelectronics group, an antennas group, and a systems group all under the ViaSat umbrella to build new satellites together. Space X, Phil Larson added, has brought major innovations to the launch market, and will likely do the same for satellite production, potentially creating a streamlined process resembling the Ford's famous Model T assembly line. Although ambitious, the goal is to take the million-dollar price tag per satellite today and reduce it to somewhere around a thousand dollars. Larry Alder expressed similar cost-reduction-through-scale plans for OneWeb, stating, "[t]raditionally, the satellites produced are [a] one-off, hand-done, highly customizable process. We're going to be producing 600 satellites in much more of a manufacturing process. [T]hat's a big area of innovation, getting the production going, miniaturization, launch, costs, terminal."

While Alder discussed OneWeb's effort to shrink the size of satellites, Cory Dixon brought up another version of the miniaturization of technologies, where people are talking about taking the cell-on-wheels idea and putting it in the air.[42] In this scenario, mobile LTE networks will provide capacity not from the ground, but while hovering above an area. Larson indicated that the miniaturization of aircraft could bring potential payoffs similar to that of the miniaturization of transistors on chips, which resulted in "a trillion dollars of economic growth in over a decade combined with the internet." He added: "And that was all terrestrial, so how do we take that type of thinking and investment into [these new] frontiers, is a key question."

Larson also touched on the role of investment policies and sources. Historically, he said, the Reagan administration helped enable the commercial launch market by signing the first Commercial Space Launch Act and the Obama administration helped build on that by having the government act as a venture capitalist for launch providers. While many space-news headlines are grabbed by billionaires investing in space companies, Larson noted that venture capitalism, both from small to billionaire investors, has taken off over the last 15 years helping to bring "innovative space companies across all 50 states." Larson emphasized the importance of policymaking decisions in reaching what he called the "holy grail," which is "enabling a new economy in space."

IV. Conclusion

The conference had three recurring themes. First, the importance of air and space traffic control to mitigate the risk of collisions. Second, the concern that the perennial tussles over spectrum allocation, spectrum sharing, and radio interference will continue, perhaps with more complexity, as more devices operate at different altitudes above the Earth's surface. Third, the key drivers for developments in the space and airborne wireless systems industries, which are automation, miniaturization, and cost reduction through scale.

V. Acknowledgements

[42] Wikipedia.com, Mobile Cell Sites – Cell on wheels, https://en.wikipedia.org/wiki/Mobile_cell_sites#Cell_on_wheels (last visited Dec. 2, 2017).

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Appendix A: Conference Moderators and Panelists

Larry Alder — Panelist
Vice President, Product Definition, OneWeb, Ltd

Bobby Braun — Speaker
Dean, College of Engineering and Applied Science, University of Colorado Boulder

Joe Cramer — Panelist
Regional Director, Spectrum Regulatory Affairs, The Boeing Company

Pierre de Vries — Moderator
Spectrum Policy Initiative Co-director and Executive Fellow, Silicon Flatirons

Cory Dixon — Panelist
IRISS Chief Technologist, Grand Challenge Integrated Remote and In Situ Sensing, University of Colorado Boulder

Anna M. Gomez — Moderator
Partner, Wiley Rein LLP

Thomas W. Hazlett — Panelist
Hugh H. Macaulay Endowed Professor of Economics, Clemson University

Julius Knapp — Keynote Speaker, Panelist
Chief, Office of Engineering and Technology, Federal Communications Commission

Steve Lanning — Panelist
Director, Advanced Analytics, ViaSat

Phil Larson — Panelist
Assistant Dean, Chief of Staff, College of Engineering and Applied Science, University of Colorado Boulder

Skip Miller — Panelist
Founder and Chief Executive Officer, UASUSA

Brennan Price — Panelist
Senior Principal Engineer, Regulatory Affairs, EchoStar Corporation

David Reed — Moderator
Faculty Director, Interdisciplinary Telecom Program, University of Colorado Boulder

Jennifer L. Richter — Panelist
Partner, Akin Gump Strauss Hauer & Feld LLP

M. Anne Swanson — Moderator
Partner, Wilkinson Barker Knauer, LLP

Michael Tseytlin — Panelist
Director of Engineering, Facebook

Jennifer Warren — Panelist
Vice President, Technology Policy & Regulation, Lockheed Martin