Response to Questions 30-34: Alien Ownership

In response to Questions 30 and 31 of Form 312, Telesat Canada is organized under the laws of Canada. It is wholly-owned by Telesat Interco, Inc. which is, in turn, wholly owned by Telesat Holdings Inc., both companies organized under the laws of Canada. Additional details regarding Telesat Canada's ownership can be found in Exhibit 3.

Questions 32 and 33 of Form 312 ask whether the Applicant, Telesat Canada, is: (1) a corporation of which more than 20 percent of the capital stock is owned of record or voted by aliens or their representatives or by a foreign government or representative thereof or by any corporation organized under the laws of a foreign country; or (2) directly or indirectly controlled by a corporation of which more than 25 percent of the capital stock is owned of record or voted by aliens or their representatives or by a foreign government or representative thereof or by any corporation organized under the laws of a foreign country. These questions are intended to ascertain whether the applicant complies with Sections 310(b)(3) and 310(b)(4) of the Communications Act, which establish limits on foreign ownership of the licensees of broadcast, common carrier, aeronautical en route, and aeronautical fixed stations. Sections 310(b)(3) and 310(b)(4) are inapplicable to the proposed satellite constellation, because the satellite constellation is not an aeronautical en route or aeronautical fixed station and Telesat Canada does not propose to provide broadcast or common carrier service via the satellite constellation.

Response to Question 36: Licenses Revoked or Applications Denied

Neither Telesat Canada, which is the Applicant, nor Loral Space & Communications, Inc. ("Loral Space"), which is an indirect shareholder of Telesat Canada's parent company, has had any FCC station authorization or license revoked or had any application for an initial, modification or renewal of FCC station authorization, license, or construction permit denied by the Commission.

The following information involves entities owned by Loral Space:

In an order issued April 1, 2003, the International Bureau declared null and void authorizations held by Loral SpaceCom Corporation and Loral Space & Communications Corporation to construct, launch and operate geostationary Fixed Satellite Service Ka-band payloads at 89° WL, 81 ° W.L., 47° W.L., and 78° E.L.[1] The Bureau affirmed its earlier decision not to extend the construction milestones associated with these authorizations.[2]

In an order issued July 7, 2005, the International Bureau declared null and void, by its own terms, Loral SpaceCom Corporation's authorization to launch and operate a satellite at the 69° W.L. orbit location.[3]

In an order issued September 26, 2005, the International Bureau declared null and void, by its own terms, CyberStar Licensee, LLC's Ka-band system authorization to launch and operate satellites at the 93° WL and 115° W.L. orbital locations.[4]

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[1] *See Loral SpaceCom Corporation and Loral Space & Communications Corporation*, Memorandum Opinion, Order and Authorization, 18 FCC Rcd 6301 (2003).

[2] *See Loral Space & Communications Corporation*, Order, 16 FCC Rcd 11044 (2001).

[3] *See Loral SpaceCom Corporation (Debtor-in-Possession)*, Memorandum Opinion and Order, 20 FCC Rcd 12045 (2005).

[4] *See CyberStar Licensee, LLC*, Order, 20 FCC Rcd 15412 (2005).

Response to Question 40:
Officers, Directors, and Ten Percent or Greater Shareholders

The Applicant, Telesat Canada, is organized under the laws of Canada.

The officers and directors of Telesat Canada are:

Officers
Daniel S. Goldberg, President and CEO
Christopher S. DiFrancesco, Vice President, General Counsel & Secretary
Michel G. Cayouette, CFO and Treasurer

Directors

John P. Cashman	Daniel Garant
Clare R. Copeland	Michael Boychuk
Guthrie Stewart	Mark H. Rachesky
Richard Fadden	Colin D. Watson
Hank Intven	Michael Targoff

Address for all officers and directors:
Telesat
1601 Telesat Court
Ottawa ON K1B 5P4 Canada

Telesat Canada is wholly owned by Telesat Interco Inc., which is wholly owned by Telesat Holdings Inc. The officers and directors of Telesat Holdings Inc. and Telesat Interco Inc. are the same as the officers and directors of Telesat Canada. The ownership of Telesat Holdings Inc. is as follows:

Loral Space & Communications Inc. ("Loral"), through its wholly-owned subsidiary, Loral Holdings Corporation, a U.S. company, holds 62.70% of the equity of Telesat Holdings Inc. Loral, through its subsidiary previously mentioned, holds a 32.66% voting interest for all matters.

The Public Sector Pension Investment Board ("PSP"), through its wholly- owned subsidiary Red Isle Private Investments Inc., a Canadian company, holds 35.77% of the equity of Telesat Holdings Inc. PSP is a Canadian Crown corporation established by the Canadian Parliament pursuant to the Public Sector Pension Investment Board Act. PSP, through its subsidiary previously mentioned, holds a 67.34% voting interest for all matters except the election of the board of directors, and a 29.39% voting interest for the election of the board of directors.

Certain past and present employees of Telesat Canada hold combined 1.53% of the equity of Telesat Holdings Inc.

John P. Cashman, a citizen of Canada and Ireland, holds a 31.12% voting interest solely for the election of the board of directors of Telesat Holdings Inc.

Colin D. Watson, who is a Canadian citizen, holds a 6.83% voting interest solely for the election of the board of directors of Telesat Holdings Inc.

Shareholder	**Jurisdiction of Incorporation**	**Address**	**Participating Equity**	**Shares with voting rights for direct**	**Shares with voting rights on all other**
PSP	Created by Act of Canadian Parliament	1250 René Lévesque Blvd., West, Suite 900 Montréal QC H3B 4W8	35.77%	29.39%	67.34%
Loral	Delaware	Loral Space & Communications Inc. 888 Seventh Avenue, 40th Floor New York, NY 10106 USA	62.70%	32.66%	32.66%
Past and Present Employees of Telesat Canada		c/o 1601 Telesat Court Ottawa, ON Canada K1B 5P4	1.53%		
John P. Cashman		13 Admiral Road Toronto, ON M5R 2L4 Canada		31.12%	
Colin D. Watson		72 Chestnut Park Rd Toronto, ON M4W 1W8 Canada		6.83%	

Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, D.C. 20554

In the Matter of	)	
	)	
Telesat Canada	)	File No. _______________
	)	
Petition for Declaratory Ruling to Grant	)	
Access to the U.S. Market for Telesat's	)	
NGSO Constellation	)	

PETITION FOR DECLARATORY RULING

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November 15, 2016

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Washington, D.C. 20554

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PETITION FOR DECLARATORY RULING

I. INTRODUCTION AND SUMMARY

Pursuant to Section 25.137 of the Commission's rules and the Commission's *Public Notice* initiating a processing round for additional non-geostationary-satellite orbit ("NGSO")-like satellite applications in bands that include the Ka-band,[1] Telesat Canada ("Telesat") hereby petitions for a declaratory ruling ("Petition") authorizing the NGSO low earth orbit ("LEO") constellation system (the "Telesat LEO Constellation" or "LEO Constellation") to serve the U.S. market using Ka-band frequencies.

Access to broadband Internet and other high speed data services has been transformative. Advances in fiber optic and wireless technology have brought capabilities that were not even envisaged a decade ago. Yet for many around the world, including residents of vast areas of rural America, tribal lands, and other

[1] *See Public Notice*, *OneWeb Petition Accepted for Filing*, DA 16-804, File No. SAT-LOI-20160428-00041 (July 15, 2016) ("*Public Notice*").

communities unserved and underserved with broadband, high-speed low latency data services remain an unfulfilled dream. Geostationary satellite orbit (GSO) satellite networks have played, and continue to play, an important role, in providing broadband services, but GSO networks have limitations in providing worldwide coverage and meeting the requirements of increasingly-prevalent latency-sensitive applications. Fortunately, innovative and spectrally-efficient NGSO constellations can deliver on all fronts, both serving currently unserved and underserved areas as well as providing additional differentiated and competitive offerings in areas now served by terrestrial means and GSO-based networks.

But the task should not be underestimated. Success in operating an NGSO network will come to those who have depth of experience, technical expertise, innovative ideas, significant financial resources, and a willingness to invest those resources in the future. Telesat meets these criteria. Telesat has developed an innovative design, for which a patent is pending, that combines polar and inclined orbits and incorporates almost 4 GHz of Ka-band spectrum. The Telesat LEO Constellation will provide significant benefits including:

- High speed – Gigabits-per-second (Gbps) links;
- High capacity – Terabits-per-second (Tbps) of total capacity;
- Significantly lower latency than GSO – equivalent to, and in some cases even lower than, terrestrial networks;
- Global broadband coverage, including coverage of unserved and underserved areas, giving the ability to connect any two points on the globe;

- Highly secure – ability to avoid traversing any third-party networks, thereby minimizing risk to user information;
- High resiliency – no single point of failure;
- Seamless extension of today's advanced terrestrial telecom networks – provision of Carrier Ethernet service[2] which allows users to access the constellation data capacity as they would access any other network; and
- Efficiency - efficient use of spectrum and orbital resources.

Telesat has a long history of relying upon U.S. satellite manufactures and service providers. These relationships have brought innovative communications services to customers around the world, and have created U.S. jobs and contributed to the competitiveness of U.S. industry. Telesat currently has three satellites under construction being built by U.S.-based manufacturer SSL. Two of those satellites are under contract to be launched by SpaceX, a U.S. company. Telesat's global GSO constellation consists of 15 satellites, 11 of which were built by U.S. manufacturers. Telesat's LEO Constellation will require the manufacture of hundreds of advanced satellites. A project of this scope, coupled with the use of the latest technologies, has the potential to greatly benefit U.S. workers, U.S. industry and the U.S. technology base.

Telesat's LEO constellation was designed in part to meet the objectives of U.S. military officials for a more resilient space architecture in an increasingly congested,

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[2] The technical specifications for Carrier Ethernet are developed by MEF, a global industry alliance comprising more than 220 organizations including telecommunications service providers, cable MSOs, network equipment/software manufacturers, semiconductors vendors and testing organizations. *See* *https://www.mef.net/about-us/mef-overview*.

contested and competitive space environment. Specifically, the Department of Defense is interested in more distributed space architectures to enhance network resiliency as well as networks with greater security features to mitigate cyber attacks.[3]

Telesat's highly distributed and resilient network architecture will advance these objectives. Specifically, each of the well over 100 advanced satellites in Telesat's LEO Constellation will operate as a network node so that traffic will be automatically routed around a failure point, similar to a ground-based IP network. This is made possible due to the system's regenerative payload and inter-satellite links (ISLs). In addition, the constellation will include multiple spare satellites contributing to its robustness. Telesat's LEO Constellation also provides the ability to connect any two points on the globe without the need to transit terrestrial communications networks, significantly mitigating the risk of cyber attacks. Telesat's LEO Constellation will provide a level of resiliency and security not possible with GSO, terrestrial networks or NGSO constellations not having these features.

The Telesat LEO Constellation will be a highly secure, reliable and resilient system with truly global coverage, ensuring customers can be served anywhere on the earth including remote locations. It will allow the provision of broadband services to unserved and underserved communities and individuals, as well as provide unique connectivity capabilities to governments and enterprises.

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[3] *See, e.g.*, Command, Air Force Space, *Resiliency and Disaggregated Space Architectures* (2013), at http://www. afspc. af. mil/shared/media/document/AFD-130821-034.Pdf, *copied at* https://www.telesat.com/sites/default/files/telesat/files/governance/resiliency.pdf.

The Telesat LEO Constellation will have a minimum of 117 satellites, plus in-orbit spares. The constellation is a hybrid of two NGSO orbits: a Polar Orbit at an inclination of 99.5°, and an Inclined Orbit at an inclination of 37.4°. Each satellite in the Telesat LEO Constellation will incorporate on-board processing and inter-satellite communication capability via optical inter-satellite links.

Telesat plans to operate in the 17.8 – 18.6 GHz, 18.8 – 19.3 GHz, and 19.7 – 20.2 GHz bands in the space-to-Earth direction, and the 27.5 – 29.1 GHz and 29.5 – 30.0 GHz bands in the Earth-to-space direction. Although the 19.7 - 20.2 GHz band is not part of the current processing round, Telesat plans to make use of this frequency band in its LEO Constellation and is, therefore, seeking authority to operate in this band.

Telesat plans to start commercial service for its LEO Constellation in 2021. The company is now in discussions with prospective customers and industry partners and is undertaking a host of other actions to assure timely implementation. Telesat has already contracted for two prototype satellites,[4] planned for launch in 2017, which will be used for testing and design verification purposes, and will assist in optimization of the Telesat LEO Constellation.

Grant of Telesat's Petition is in the public interest. A grant will afford the public the benefits of access to an innovative and technologically advanced Ka-band NGSO broadband service. Further, a grant will enhance competition with existing and future

[4]See https://www.telesat.com/news-events/telesat-procures-two-prototype-satellites-global-ka-band-low-earth-orbit-constellation

GSO and NGSO systems, thereby expanding the options available to customers in the United States.

Telesat demonstrates below that it has the experience, technical qualifications and expertise necessary to design, develop, and successfully implement and commercialize its highly innovative, technologically advanced LEO Constellation for providing new and vastly needed broadband services to the public. Telesat also provides below a summary description of the Telesat LEO Constellation, which is presented in detail in the associated Technical Exhibit and Schedule S submitted herewith.

Telesat further demonstrates that it is technically and legally qualified to serve the U.S. market via its LEO Constellation. This Petition, the Technical Exhibit, and Schedule S show compliance with the Commission's technical requirements, including appropriate protections for fixed-satellite services using GSO and NGSO satellites and for other services. Telesat's Form 312 submission in combination with this Petition shows its legal qualifications. Telesat also shows that serving the United States via its LEO Constellation is presumed to enhance competition because the authorizing country, Canada, is a member of the World Trade Organization. Telesat further shows that no national security, law enforcement, foreign policy, or trade concerns are implicated by the proposed use of the Telesat LEO Constellation to serve the United States. Accordingly, the Commission's requirements for U.S. market access are satisfied.

II. TELESAT'S EXPERIENCE AND TECHNICAL QUALIFICATIONS AND EXPERTISE ARE UNPARALLELED

No one should underestimate the challenges inherent in the design, development, implementation and operation of an NGSO Ka-band constellation of the kind proposed by Telesat or other applicants for such systems. The development and use of an innovative design and advanced technology is critical, but that is only the first step. The experience required to harness those tools, build and manage a network, and create a commercially viable and sustainable network is essential. Given the experience, technical qualifications and expertise, and financial strength of Telesat, the company's capabilities make it uniquely qualified to construct and operate an advanced NGSO Ka-band constellation.

Telesat is headquartered in Ottawa, Canada, and was established in 1969 with an initial mandate to provide satellite services to all parts of Canada, especially to remote areas where terrestrial alternatives were unavailable or prohibitively expensive. Thus, providing service to unserved or underserved communities is part of Telesat's heritage, which it has fostered and enhanced since its inception. Telesat launched the world's first domestic commercial geostationary satellite in 1972 and, since that time, has evolved into an international, diversified, and end-to-end satellite services company, with an unparalleled reputation for innovation, technical and operational expertise and customer service.[5]

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[5] Almost 70% of Telesat's staff is employed in its engineering and other technical departments. Telesat's engineering and technical staff average over 17 years of service with the company and many hold advanced degrees in mathematics, physics and engineering.

In 2007, Telesat's operations were combined with the satellite operations of Loral Skynet, a U.S. company with a strong technical background tied to the achievements of AT&T Skynet, Bell Labs and the Telstar program. As a result, Telesat greatly expanded its coverage and transitioned to a truly global operator with ties to four licensing administrations: Canada, U.S., Brazil and the United Kingdom. Telesat's subsidiary, Skynet Satellite Corporation, operates the Telstar 11N (37.55W), Telstar 12 VANTAGE (15W) and Telstar 12 (109.2W) satellites under license from the FCC. Telesat also has U.S. market access for its Canadian-licensed Nimiq-5 (72.7W), Anik-F1 (107.3W), Anik-F1R (107.3W), Anik-F2 (111.1W), and Anik-F3 (118.7W) satellites, and its Brazilian-licensed Estrela do Sul 2 also known as Telstar-14R (63W) and planned Telstar 19 VANTAGE (63W) satellites.

Presently, Telesat is one of the largest and most successful satellite operators in the world and a leading provider of voice, data, video and IP networking services to the private sector and governments. The company's advanced communications are delivered through its global fleet of 15 satellites, with an additional two GSO and two NGSO satellites under construction. Telesat also operates a robust global teleport and terrestrial infrastructure that is seamlessly integrated with its fleet. Through this combination of space and ground assets, Telesat's communications solutions support the demanding requirements of customers throughout the world.

Telesat engineers are highly skilled at managing the flight operations of its own GSO satellite fleet and providing tracking, telemetry and control (TT&C) services for a number of third-party GSO operators.

Telesat also has experience in operating non-geostationary LEO satellites. Specifically, since 2007 Telesat has been operating Radarsat-2, a LEO non-geostationary satellite at an altitude of 798 km.

The company's engineers and support personnel monitor, control, operate and maintain satellite networks 24 hours a day, seven days a week. In addition, Telesat's network operations team has extensive experience in detecting, investigating and locating sources of both unintentional and intentional electromagnetic interference (EMI).

Telesat is widely respected for its ability to design, provision, implement and manage comprehensive, end-to-end, state-of-the-art, satellite-based communication networks, including in harsh and remote environments, for governments and commercial satellite users around the world. Telesat's deep technical expertise and customer-oriented culture, as reflected in the company's Consulting Engineering Group and Research and Development Lab, provide Telesat with depth and breadth of engineering and development expertise:

- **Telesat's Consulting Engineering Group** – has helped commercial and government customers in over 40 countries design, procure, build and/or operate more than 100 satellite systems. These projects have included many GSO systems, and several LEO and MEO NGSO satellite systems including Radarsat-1, Radarsat-2, the original ICO system, Iridium (Ground Segment), Nigeriasat-2 and the UAE FalconEye system. Over the past 10 years alone, no other satellite operator in the world has monitored the construction of as many different satellites (53), with as many different spacecraft manufacturers (10). Telesat's unparalleled industrial involvement with the world's major satellite industry suppliers means that the company remains at the leading edge of space technology. The fact that so many satellite operators and governments entrust Telesat to advise on and/or oversee critical programs is a testament to the depth and breadth of Telesat's expertise and customer-centric culture.

- **Telesat's Research & Development ("R&D") Lab** – is responsible for the evaluation and demonstration of next-generation satellite services, including the NGSO constellation that is the subject of this Petition. The R&D Lab has been a valued technology partner for some of the biggest space agencies in the world, helping them conduct research, validate system architecture concepts, and support the development of their satellite programs. Telesat has also partnered with a variety of private and public sector organizations, including equipment manufacturers, software developers, service providers, satellite service users, business and community groups, as well as government agencies and departments, to research, develop and test new service applications. The R&D Lab plays a crucial role in developing satellite applications for Telesat's customers and enables Telesat to deliver state-of-the-art performance across the company's satellite fleet.

Telesat, its antecedents, and affiliates have a long history serving the United States. From operating the Telstar program in the early 1960s to enabling WildBlue (now ViaSat) in 2005 to introduce Ka-band consumer broadband to U.S. homes and businesses for the first time, Telesat's communications advances have been improving the lives of Americans for decades. Today the United States is Telesat's second largest market worldwide. Telesat's main international teleport is in Virginia (described below) and the company has offices supporting sales and operations in: Bedminster, NJ, Bethesda, MD (Washington, DC), Houston, TX and North Hollywood, CA.

Telesat's commercial U.S. customers include:

- Video Providers – including DISH-EchoStar and AMC Networks;
- Satellite broadband service providers ViaSat and Hughes Network Systems;
- Mobile Broadband Providers – including Panasonic, a global leader in mobile broadband services via satellite to ships and planes operating within and beyond U.S. territory; and
- Companies Serving the U.S. Government - including Harris CapRock, Lockheed Martin, Intelsat General, SES Government Solutions, Artel, DRS Technologies, Comtech TCS, and Boeing.

In addition to serving commercial customers, Telesat has long provided advanced satellite solutions to support mission critical requirements of allied governments and their departments, including the U.S. Department of Defense (DoD) and other U.S. government agencies, including the following:

- U.S. Central Command – CENTCOM has relied on Telesat satellites to provide secure broadband communications for its in-theater operations centers;

- Operation Iraqi Freedom – Telesat satellites supported various initiatives including UAV missions and providing morale, welfare and recreation communications for the troops;
- U.S. DoD – Continues to rely on Telesat satellites for secure communications in remote and harsh environments;
- U.S. State Department – Has used Telesat satellites with coverage of Iraq for activities that have ranged from supporting national elections to utilizing secure broadband for diplomatic missions;
- Army Blue Force Tracking – Telesat satellites are supporting this GPS-enabled system that provides location information to U.S. friendly forces;
- Air Force One – Telesat satellites have enabled the President and his staff to have seamless communications connectivity on Air Force One over the Middle East and Atlantic Ocean;
- US Department of Homeland Security/FEMA – Telesat satellites are supporting government requirements for hurricane disaster response and recovery;
- U.S. Department of Justice (DoJ) Drug Enforcement Administration (DEA) – Telesat is supporting DoJ in its communications between the US and Guantanamo;
- Armed Forces Radio & Television Service (AFRTS) – Telesat satellites are enabling the distribution of AFRTS content to personnel stationed overseas, promoting troop morale and welfare;

- U.S. Air Force – Telesat satellite capacity supports the BBSN (Boeing Broadband Satcom Network) enabling reliable and secure communications for government officials traveling on USG aircraft over the North Atlantic; and
- Federal Aviation Administration (FAA) – Telesat hosts a navigational payload on the Anik F1R satellite that enhances the global positioning system (GPS) for aviation use in Canada and the United States. The payload is part of the FAA's Wide Area Augmentation System (WAAS) geostationary communication and control segment operated by Lockheed Martin to provide precision guidance to aircraft.

Telesat's main teleport supporting its international satellite fleet is located in Mount Jackson, Virginia. Using Mount Jackson, Telesat customers can implement satellite service from the U.S. to coverage areas including the Middle East and North Africa, the Americas and Europe, which are served by Telesat's Telstar 11N, Telstar 12 VANTAGE, Telstar 14R and other Telesat and third-party satellites. Both commercial and government customers use Mount Jackson to implement advanced satellite broadband services and host their own communications equipment at the facility, making Mount Jackson a node on their proprietary networks.

A. Telesat Has Achieved Continued Financial Success

The satellite service industry in which Telesat operates is among the most competitive communications markets in the world. There are over 40 companies today with their own satellites and more seeking market entry. Despite the industry's rising competitive intensity, Telesat has consistently achieved strong financial results. Telesat's operating revenue was US $752 million in 2015. Since 2007 Telesat's satellite investments, expended and contracted, are in excess of US $2 billion.

Telesat is highly regarded in the capital markets for achieving consistently strong financial and operating performance. Telesat's strong and consistent growth in revenue and profitability and outstanding customer service have been recognized by an independent panel of industry experts that twice this decade awarded Telesat the title "Global Satellite Operator of the Year" based on business performance.[6]

B. Telesat's Innovations Have Transformed the Global Communications Satellite Industry

Since the earliest days of satellite communications, hundreds of companies have come before the Commission seeking regulatory approval for new satellite systems. Only a small number of these proposed systems actually have been deployed[7] and far fewer aspiring applicants have been able to match Telesat's decades-long record of satellite service innovation – innovations that have transformed the satellite industry and the lives of millions of users worldwide. The following describes a few of Telesat's significant innovations:

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[6] https://www.telesat.com/news-events/telesat-again-selected-global-satellite-operator-year-panel-industry-experts

[7] See for example http://spacejournal.ohio.edu/issue13/pdf/David_Brown_WildBlue.pdf that shows out of 15 first round Ka-band applications filed with the Commission in 1995, most of the proposed systems never entered service.

- **Telstar 1 (1962), Started the Commercial Satellite Communications Industry** – Built by Telesat's predecessors at AT&T and Bell Labs, Telstar 1 captivated the world during its seven months in orbit with live images of sports, entertainment and news while establishing many industry firsts. Launched by NASA from Cape Canaveral in July 1962, it was the first privately-sponsored space launch. Telstar 1 also introduced the era of live transatlantic broadcasts connecting the U.S. and Europe for the first time.
- **Anik A1 (1972), Demonstrated the critical role satellites can play in connecting the unconnected** – Anik A1 was the world's first domestic communications satellite and was equipped with 12 C-band transponders to improve telephone and TV services across Canada, especially in remote areas previously served only by HF radio. It proved effective at bringing Canadians closer together over the country's vast territory and provided nearly 10 years of service.
- **Anik B (1978), Laid the groundwork for the global DTH industry** – Anik B became the world's first domestic communications dual-band (C and Ku) satellite. With Anik B, Telesat started providing the world's first direct-to-home (DTH) TV service, which laid the groundwork for the global DTH

industry which now has over 200 million subscribers[8] of which 34 million are in the United States.

- **Orion 1/Telstar 11 (1996), First to provide Internet access to ISPs over satellite** – In the mid-1990s, demand for Internet services was surging around the world but there was limited means for countries in developing regions to obtain Internet access. Telesat engineers (at the time part of Orion Network Systems in Rockville, MD, which later merged with Loral Skynet) developed a complete, end-to-end solution to provide ISPs in developing regions with direct access to the US Internet backbone via the Mount Jackson Teleport in Virginia. The service was highly successful and, for a number of years, was the prime means for telecom operators in such countries as Turkey and others in Eastern Europe to meet surging demand for Internet services from both commercial and government customers.
- **Anik F2 (2004), Named by Via Satellite magazine in 2016 as one of 30 key satellite industry developments over the last 30 years** – At the time of its launch, Anik F2 was the largest communications satellite ever carried into space. With its 45 Ka-band spot beams, and 32 Ku-band and 24 C-band transponders, it also was the world's most complex communications satellite. Anik F2 started the global boom in Ka-band and opened an important new

[8] See for example https://www.digitaltvresearch.com/ugc/Global%20satellite%20TV%20Forecasts%202015%20TOC_toc_121.pdf

market – consumer Ka-band broadband services. Within two years of Anik F2's launch, WildBlue (now ViaSat) was using Ka-band capacity it had acquired on the satellite to serve subscribers in the U.S., thereby bringing broadband to many U.S. homes and businesses for the first time (WildBlue's own satellite, WildBlue 1, also operated by Telesat, was launched in late 2006). Today there are nearly two million satellite broadband subscribers in the United States. Globally, satellite broadband is forecasted to grow to almost seven million subscribers by 2025.[9] Anik F2 is also recognized as a precursor of today's high throughput satellites (HTS) that are transforming the industry and which are expected to generate billions of dollars in new revenues through the next decade.

- **Telstar 11N (2009), Confirmed the commercial viability of mobile broadband –** Telstar 11N was the first satellite to provide Ku-band coverage of the Atlantic Ocean from the Arctic Circle to the equator, making it ideal for both maritime and aeronautical broadband. Telstar 11N, along with Telesat's Telstar 14R launched in 2011, spurred demand for satellite broadband across the oceans. Mobility applications for maritime and aeronautical broadband services are forecasted to be the fastest growing markets for the global satellite industry.[10]

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[9] Euroconsult's 2016 Satellite Communications & Broadcasting Markets Survey: Forecasts to 2025
[10] Id.

- **Telstar 12 VANTAGE (2015), Significant HTS Ku-band capacity serving aeronautical and maritime routes over Europe, the Mediterranean, the Middle East and the North Sea** – Telstar 12 VANTAGE became fully operational in December 2015. The flexibility Telesat built into the satellite enabled Telesat engineers to reposition its HTS beams and bring new mobile broadband capabilities to customers in aeronautical and maritime markets.[11]

C. Telesat is an NGSO Innovator

GSO satellites like Telstar 12 VANTAGE that offer high throughput capabilities are expected to remain core to Telesat's mission. However, in keeping with Telesat's goal to implement new leaps in technology and capability, the company is looking to augment GSO as the satellite industry pursues more data-centric applications with price and performance standards comparable to or exceeding terrestrial technologies. Telesat is working on NGSO innovations that will revolutionize the satellite industry. Telesat's LEO Constellation will provide unserved and underserved communities with high speed, low latency broadband services and deliver differentiated services to those that already have access to broadband.

As part of this focus, and in addition to the NGSO constellation that is the subject of this Petition, Telesat has developed an innovative, patented orbital design for a highly elliptical orbit (HEO) NGSO that will serve the polar regions. Telesat is in discussions with the Canadian government and industry partners to advance this

[11] See https://www.telesat.com/news-events/panasonic-signs-contract-telstar-12-vantage-hts-capacity

program that will serve a vast and underserved, but critically important, region of the world that has very few communications options.

III. DESCRIPTION OF TELESAT'S LEO CONSTELLATION

Telesat's LEO Constellation will offer high-speed, high-capacity broadband connectivity, with performance equivalent or superior to terrestrial networks with respect to security, resiliency and latency. It will bring broadband connectivity that is currently unavailable on either satellite systems or terrestrial telecommunications systems and will provide a valuable new broadband option for unserved and underserved communities, for both private sector and government users.

A. System Overview

The Telesat LEO Constellation will have a minimum of 117 satellites, plus spares. The LEO Constellation uses two sets of orbits. The first, a Polar Orbit at an inclination of 99.5°, consists of a minimum of 6 planes at 1000 km, with a minimum of 12 satellites in each plane. The second, an Inclined Orbit at an inclination of 37.4°, consists of a minimum of 5 planes at 1248 km, with a minimum of 9 satellites in each plane. Polar Orbits provide global coverage, with a concentration of satellites in the polar regions. Inclined Orbits concentrate satellites over equatorial and mid-latitude areas where demand for communications services is greater than in the polar regions. By using two complementary orbits the system achieves true global coverage while concentrating satellite resources on areas of demand, thereby making the system much more efficient.

Users will link directly to a Telesat NGSO satellite through a high-gain steerable spot beam. The user signal will then connect: directly to a terrestrial hub (gateway);

directly to another user; or indirectly to a gateway or other user through an inter-satellite link ("ISL"). Telesat will be able to assign capacity dynamically to locations and routes with high demand by varying the number and size of the satellite spot beams, as well as the amount of spectrum and power allocated to each beam, thereby achieving highly efficient use both of satellite resources and of scarce orbital spectrum. In addition to its spot beams, each satellite in the constellation will have a fixed wide-area beam covering the satellite's entire field of view. The wide-area beam will allow the satellite to detect a user request to initiate communication. This will enable the network to provide complete global coverage 100% of the time. Through the use of inter-satellite links, the system will deliver connectivity to remote locations, even when the same satellite does not have visibility to both user and gateway locations. This will provide customers with the ability to connect from any point to any point on the globe.

In addition, subject to regulatory approval, capacity can be quickly and efficiently added to the system by simply adding satellites in each of the planes of the Inclined and/or Polar Orbit, and/or by adding additional planes to either or both orbits.

As the number of satellites increases, the elevation angle to the gateways and users increases, allowing for increased capacity and more efficient use of satellite and spectrum resources. Each satellite will employ on-board processing and will effectively be a node in an IP network. Each satellite will also incorporate inter-satellite communication capability. Thus, the system's design will maximize the functionality of services offered while providing these services cost effectively.

As described more fully in the Technical Exhibit, minimum discrimination angles between GSO satellites and Telesat's NGSO satellites have been calculated based on limits defined by the ITU, where applicable. These will be adjusted based on coordination agreements, as required. Steerable beams on each Telesat NGSO satellite allow handover to an adjacent satellite before the minimum discrimination angle is reached. Interference management will be carried out through the operation of Telesat's Radio Resource Management system, which will manage the overall radio resource allocation of the entire constellation and ensure proper handling of in-line events.

The frequency bands of the Telesat LEO Constellation include the 17.8 – 18.6 GHz, 18.8 – 19.3 GHz, and 19.7 – 20.2 GHz bands in the space-to-Earth direction, and the 27.5 – 29.1 GHz and 29.5 – 30.0 GHz bands in the Earth-to-space direction.

B. Space and Ground Segment

Each satellite in the constellation will be designed for maximum flexibility in terms of coverage, by means of steerable beams and inter-satellite links, and in bandwidth and power assignment, by means of onboard processing. Specifically:

- **Direct Radiating Array (DRA)** – Will provide independent agile beams each with steering and forming capabilities allowing beams to be generated where and when required based on traffic demand;
- **On-board Processing** – Will perform signal regeneration (*i.e.*, demodulation and re-modulation) and routing of traffic, thereby improving link

performance and increasing capacity compared with a simple channelizer or bent-pipe payload;

- **Optical Inter-Satellite Links (ISL)** – Multiple ISL beams on each satellite will connect to other satellites in the Telesat LEO Constellation. The ISLs will be able to communicate with satellites within the same plane, within adjacent planes of the same orbit, and between the Polar Orbit and Inclined Orbit.

Satellite user beams will be formed using active array antennas with state-of-the-art beam-forming capability. Two steerable gateway beams are also provided. The onboard processing and ISL capabilities will enable the constellation to route traffic flexibly and to make the most efficient use of gateways. The use of two NGSO orbits and satellites employing beam-forming technology connected through ISL links enables Telesat to avoid interference to GSO satellites and to NGSO satellites in the equatorial plane. It also allows for continuous and seamless TT&C and collision-avoidance maneuvers.

A wide variety of user terminals will access the Telesat LEO Constellation, both electronically steered terminals and mechanically tracking terminals. The system is capable of operating with both fixed terminals and mobile terminals. Since the FCC Rules do not authorize use of mobile terminals in the frequency bands used in the Telesat LEO Constellation, such terminals would be used in the U.S. only upon filing of the requisite waiver requests and their grant by the Commission. Telesat's system will utilize a Carrier Ethernet interface, the *de facto* standard for networking, with the associated benefits and performance.

C. Summary

Telesat's unique NGSO design and combination of space and ground assets will support a network with a number of important advantages for the user community:

- **Truly Global Coverage** – Ability to provide service anywhere on the globe, even to locations where the serving satellites cannot see a gateway;
- **Low Latency** – Equal or superior to the latency of terrestrial networks;
- **High Speed and Capacity** – The design provides Gbps links, and a total system capacity in the Tbps range;
- **High Level of Security** – Ability to directly connect locations, bypassing third-party networks, and providing a heightened level of service integrity;
- **Seamless Extension of Today's Advanced Terrestrial Telecom Networks** - The Telesat LEO Constellation satellite network will provide a Carrier Ethernet service. With a standard network interface, users will access the constellation data capacity as they would access any other network;
- **Highly Resilient**
  - No single point of failure - The use of in-orbit spares, the combination of Polar Orbits and Inclined Orbits, and inter-satellite links, provide multiple routes for user traffic to ensure no single point failure, even in the case of a satellite anomaly;
  - Network Auto Recovery/Routing – Since each satellite, gateway and terminal acts as a node in an IP network, traffic is automatically routed around a failure point similar to what occurs in a terrestrial network;

- **Efficient and Scalable** – Scarce spectrum and spacecraft resources are focused where there is customer demand. Capacity can readily be increased by adding relatively few satellites targeted at areas of greatest need;
- **Can Operate with a Variety of User Terminals** –Both electronically steered and mechanically tracking terminals may be used.

IV. TELESAT'S LEO CONSTELLATION SATISFIES THE FCC'S REQUIREMENTS FOR SERVING THE UNITED STATES

The Commission has an established framework for considering requests for non-U.S. licensed space stations to access the U.S. market. In evaluating requests for such authority, the Commission considers the effect on competition in the United States, spectrum availability, eligibility and operational requirements, and concerns related to national security, law enforcement, foreign policy, and trade.[12]

Operators seeking U.S. market access for non-U.S. licensed space stations need to provide the same information concerning legal and technical qualifications as must be provided by applicants for space station licenses issued by the FCC.[13]

The proposed operation of the Telesat LEO Constellation to serve the United States satisfies all of these tests.

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[12] *See Amendment of the Commission's Regulatory Policies to Allow Non-U.S. Licensed Space Stations to Provide Domestic and International Satellite Service in the United States*, 12 FCC Rcd 24094, ¶ 29 (1997))("*DISCO II Order*"), *on reconsideration,* 15 FCC Rcd 7207, ¶ 5 (1999). *See also* Section 25.137 of the Commission rules, 47 C.F.R. § 25.137.

[13] *See In the Matter of Amendment of the Commission's Space Station Licensing Rules and Policies; Mitigation of Orbital Debris,* First Report and Further Notice of Proposed Rulemaking in IB Docket No. 02-34, and First Report and Order in IB Docket No. 02-54, 18 FCC Rcd 10760, ¶ 288 (2003) *("Space Station Licensing Reform Order").* Some of the Commission's application policies for authorizing non-U.S. licensed space stations are codified in Section 25.137 of the Commission's rules, 47 C.F.R. § 25.137.

A. Legal and Technical Qualifications

The information set forth in this legal narrative, the attached Technical Exhibit and the Schedule S that is filed herewith establish that the proposed operation of the Telesat LEO Constellation is consistent with the Commission's legal and technical requirements, including those specified in Section 25.114 of the Commission's rules. In addition, Telesat makes specific note below of its compliance with other applicable parts of the Commission's rules.

1. Prohibition on Exclusive Arrangements

Section 25.145(e) of the Commission's rules provides:

> "No license shall be granted to any applicant for a space station in the FSS operating in portions of the 18.3-20.2 GHz and 28.35-30.0 GHz bands if that applicant, or any persons or companies controlling or controlled by the applicant, shall acquire or enjoy any right, for the purpose of handling traffic to or from the United States, its territories or possessions, to construct or operate space segment or earth stations, or to interchange traffic, which is denied to any other United States company by reason of any concession, contract, understanding, or working arrangement to which the Licensee or any persons or companies controlling or controlled by the Licensee are parties."

Telesat hereby affirms that neither it nor any person or company controlling or controlled by Telesat has or shall acquire or enjoy any such right.

2. Milestones

Pursuant to Sections 25.137(d)(1) and 25.164(b) of the Commission's rules, recipients of U.S. market access grants are subject to Commission rules that require

NGSO system licensees to launch and operate their NGSO constellations within six years of grant. Telesat will demonstrate compliance with the FCC requirement by submitting Section 25.164(f) information as and when required.

3. Posting of Bond

Pursuant to Sections 25.137(d)(4) and 25.165(a) of the Commission's rules, recipients of U.S. market access grants for non-U.S. licensed satellites that are not in orbit and operating are subject to the modified, escalating post-grant bond requirement. Telesat will post the required initial bond amount of $1 million within 30 days of grant of this Petition, as required by the Commission's rules. Telesat will also increase the bond amount as necessary in order to comply with the Commission's escalating bond requirements.[14]

4. Mitigation of Orbital Debris

Section 25.114(d) (14) of the Commission's rules requires applicants for space station licenses to provide a description of the design and operational strategies that will be used to mitigate orbital debris. In lieu of the particular showings required of applicants for U.S.-licensed space stations, Section 25.114(d) (14) (v) provides "[f]or non-U.S.-licensed space stations, the requirement to describe the design and operational strategies to minimize orbital debris risk can be satisfied by demonstrating that debris mitigation plans for the space station(s) for which U.S. market access is requested are subject to direct and effective regulatory oversight by the national licensing authority."

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[14] *See* Public Notice, International Bureau Updates Procedures for Filing and Maintaining Surety Bonds Pursuant to Revised Milestone and Escalating Bond Requirements, DA 16-1157 Report No. SPB-266 (Oct. 7, 2016).

Telesat is subject to the direct regulatory oversight of its Canadian licensing authority, Innovation, Science and Economic Development Canada ("ISED"), formerly Industry Canada, with regard to issues of orbital debris mitigation plans for the satellites that will comprise the LEO Constellation. Those regulations require that space debris mitigation measures be implemented in accordance with best industry practices so as to minimize adverse effects on the orbital environment."[15] The license issued by ISED to Telesat for the LEO Constellation[16] specifies the same condition. Accordingly, no separate showing relative to the mitigation of orbital debris is required under the Commission's rules. Nevertheless, given the importance of the issue, Telesat makes a full orbital debris mitigation showing in Section A11 of the Technical Exhibit.

The sheer number of spacecraft proposed for operation, not just by Telesat, but by other would-be NGSO LEO constellation operators requires coordination among operators to avoid physical collision, which Telesat is committed to do.

It is imperative that satellites be designed and operated with the technology, experience, and resources necessary to monitor, control, and take ongoing efforts to avoid collisions in space. As demonstrated in Telesat's orbital debris mitigation showing, the operational and design features of the Telesat LEO Constellation are geared toward mitigating the risk of orbital debris, including with maneuverability, shielding and resiliency to protect against external influences that may be encountered

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[15] Industry Canada RP-008 Issue 3, November 2013, "Policy Framework for Fixed-Satellite Service (FSS) and Broadcasting-Satellite Service (BSS), Section 3.2.6.

[16] Industry Canada Approval in Principle, See http://www.ic.gc.ca/eic/site/smt-gst.nsf/eng/sf11065.html

and the ability to avoid collision with other spacecraft. Further, in addition to spacecraft design, as detailed in Section II, Telesat is uniquely qualified to operate and manage complex satellite systems as a satellite operator for the past 45 years and as the world's leading satellite technical consultant and manager of satellite systems for other operators. Telesat has the ground resources around the world and extensive operational experience, both with GSO and NGSO satellites, which allow for greater confidence in its ability to prevent collisions or other events that might pose a risk.

B. Other Public Interest Factors

1. Effect on competition in the United States

The *DISCO II Order,* as implemented in Section 25.137(a) of the Commission's rules, establishes a presumption that granting applications to provide service in the United States via satellites licensed by countries that are members of the World Trade Organization ("WTO") will enhance competition and therefore is in the public interest.[17] All of the satellites that will comprise the Telesat LEO Constellation will be operated under authority of Canada, which is a member of the WTO.

Telesat's Petition is limited to services covered by the WTO Basic Telecommunications Agreement. It does not seek authority to provide direct-to-home, Direct Broadcast Satellite, or Digital Audio Radio Service services in the United States. Accordingly, this Petition satisfies the requirements of Section 25.137, giving rise to a

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[17] *See In re Amendment of the Commission's Regulatory Policies to Allow Non-U.S. Licensed Space Stations to Provide Domestic and International Satellite Service in the United States*, Report and Order, 12 FCC Rcd. 24094, 24112 (1997) ("*DISCO II Order*"). *See also* Estrela do Sul 1 Order, ¶ 5.

presumption that granting U.S. market entry to the Telesat LEO Constellation is in the public interest.

2. Spectrum availability

The Commission considers under the "other public interest factors" element of *DISCO II* whether grant of an application would have an impact on spectrum availability.[18] In so doing, the Commission evaluates whether grant of access would create the potential for harmful interference with U.S.-licensed satellite and terrestrial systems. As demonstrated in the Technical Exhibit, the Telesat LEO Constellation satisfies this aspect of *DISCO II*.

As shown therein, the Telesat LEO Constellation architecture is based on highly flexible payload and antenna technologies. Each satellite will have the capability to steer and form independently a number of beams to focus on customer service areas where need exists. The ability to focus the beams in specific areas allows for a reduction in power for the same throughput or an increase in data rate. Beams are generated only when traffic is present, optimizing on-board power management and reducing aggregate equivalent power-flux density ("epfd"). The combination of a Polar Orbit providing global coverage, with an Inclined Orbit providing increased capacity over mid-latitude regions allows users to have access to multiple LEO satellites within their field of

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[18] *See DISCO II Order*, ¶¶ 146-182.

view. The use of inter-satellite links provides further flexibility. These features promote an efficient use of the finite spectrum resource.

Interference management will be carried out through the operation of Telesat's Radio Resource Management ("RRM") system, which will manage the overall radio resource allocation of the entire constellation. The RRM will plan traffic connectivity and beam power. It will pre-plan handovers taking into account such elements as the orbital locations of GSO satellites, the ephemeris data of NGSO systems in the equatorial plane, earth station information, and epfd criteria (either ITU Radio Regulations Article **22** epfd limits, or epfd limits established through coordination, as applicable).

3. National security, law enforcement, foreign policy, and trade issues

The Commission also considers under the "other public interest factors" element of *DISCO II* whether grant of an application would implicate national security, law enforcement, foreign policy, or trade concerns.[19] The Commission has found in similar circumstances involving affiliates of Telesat that using non-U.S. licensed satellites to serve the United States raises no national security, law enforcement, foreign policy, or trade concerns. The Commission made this finding, for example, in its grant of market access to Telesat International Limited for the Telstar 19 VANTAGE spacecraft.[20] These findings apply with equal force to the Telesat LEO Constellation.

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[19] *See DISCO II Order,* ¶¶ 146-182.

[20] *See Telesat International Limited Application Petition for Declaratory Ruling* FCC File No. SAT-PPL-20110112-00012 (granted Aug 31, 2016). *See also Telesat Brasil Capacidade de Satelites Ltda. Application for*

C. Waiver Requests

1. Table of Frequency Allocations and Ka-band Frequency Plan

Telesat respectfully requests waivers of the U.S. Table of Allocations and the FCC's Ka-Band Plan, as applicable, to allow Telesat to use NGSO FSS Ka-band frequencies on a non-conforming basis relative to the allocated services in the following bands:

- *The 17.8–18.3 GHz band.* In the FCC Table of Frequency Allocations, the frequency band 17.8-18.3 GHz is allocated to the Fixed Service as well as to federal GSO and NGSO FSS, but is not allocated to the FSS for non-federal systems either in the Table or in the Commission's Ka-Band Plan. Telesat seeks a waiver of the FCC Table of Frequency Allocations and the Commission's Ka-Band Plan to allow its LEO Constellation to operate in this band.
- *The 18.3-18.6 GHz band.* Although the 18.3-18.6 GHz band is allocated to the FSS in the United States, Footnote NG164 of the FCC's Table of Frequency Allocation33-36s and the Commission's Ka-Band Plan designate this band for the use of the GSO FSS. Telesat seeks a waiver of the Commission's Table of Frequency Allocations and its Ka-Band Plan to permit its LEO Constellation to operate in this band.

Space Station Authorization, FCC File No. SAT-PPL-20110112-00012 (granted Apr. 4, 2011).Telesat Canada Petition for Declaratory Ruling for Inclusion of ANIK F3 on the Permitted Space Station List, FCC File No. SAT-PPL-20160225-00020 (granted 18, 2007); *Loral Orion Services, Inc., Order,* 15 FCC Rcd. 12419 (IB 2000).

- *The 19.7-20.2 GHz band.* While the 19.7-20.2 GHz band is allocated to the FSS in the United States, the Commission's Ka-Band Plan designates this band for the use of the GSO FSS. Telesat seeks a waiver of the Commission's Ka-Band Plan to permit the Telesat LEO Constellation satellite network to operate in this band.

The Commission has allowed similar non-conforming uses in the Ka-band downlink when applicants are prepared to accept interference from primary operations and can demonstrate that their proposed operations are not likely to cause harmful interference to primary operations.[21]

As shown in the Technical Exhibit, Telesat's operations on a non-conforming basis would not cause harmful interference to primary operations in the bands in question. Telesat will comply with the power flux density (pfd) limits and equivalent power flux density (epfd) limits as applicable, and will coordinate with commercial and government operators as required and in accordance with governing provisions and rules. Telesat is also prepared to accept interference from primary operations in these bands. There is good cause, therefore, for a waiver.

2. Band Segmentation Requirements.

There appears to be an inconsistency between Section 25.157 of the Commission's rules and the Commission's subsequent pronouncements regarding the applicability of

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[21] *See, e.g.,* Letter from Jose P. Albuquerque, Chief Satellite Division, International Bureau, to Suzanne Malloy, Vice President, Regulatory Affairs, O3b Limited, DA 15-601, File No. SES-MSC-20150206-00066 (May 20, 2015); Contactmeo Communications, LLC, Order and Authorization, 21 FCC Rcd 4035, 4044 (IB 2006); *see also* 47 C.F.R. § 1.3.

band segmentation requirements to NGSO systems. Section 25.157 establishes certain band segmentation procedures if there is not enough spectrum available to accommodate all qualified applicants in a processing round. But the band segmentation approach set forth in Section 25.157 appears to be inconsistent with the "avoidance of in-line interference events" approach adopted by the Commission in 2002 regarding Ku-band sharing[22] that was recently reaffirmed by the International Bureau as applicable to Ku-band NGSO systems.[23] Under the circumstances, and especially in light of the Commission's contemplated proceeding to update its rules regarding NGSO-like satellite operations in the Ka-band, it is unclear whether or how the Commission's band segmentation rule would be deemed to apply.

Telesat submits that application of the rule would frustrate the underlying purpose of the rule and not serve the public interest because band-splitting among multiple NSGO-like constellation applicants will provide too little spectrum to enable commercial viability for any of the applicants, resulting in no systems being launched. Accordingly, if deemed applicable, Telesat requests waiver of the band segmentation requirements of Section 25.157 of the Commission's rules.[24]

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[22] *Establishment of Policies and Service Rules for the Non-Geostationary Satellite Orbit, Fixed Satellite Service in the Ku-Band*, Report and Order and Further Notice of Proposed Rulemaking, FCC 02-123, 17 FCC Rcd 7841, 7843 (2002) ("

[23] *See International Bureau Provides Guidance Concerning Avoidance of In-Line Interference Events Among Ku-Band NGSO FSS Systems*, DA 15-1197 (Oct. 20, 2015).

[24] Telesat notes that a similar waiver request was requested by WorldVu Satellites Limited, doing business as OneWeb ("OneWeb"), in its Petition for Declaratory Ruling. *See Public Notice*, Petition for Declaratory Ruling of OneWeb ("OneWeb's Petition"), and referenced discussion at 17-21 of OneWeb's Petition. Several parties filing petitions or comments with respect to OneWeb's Petition, including Telesat, were supportive of the view that the public interest would not be served by application of the band segmentation requirements set forth in Section 25.157 to NGSO LEO constellations. *See, e.g.*, Petition

CONCLUSION

In view of the foregoing, grant of Telesat's application is in the public interest, and it is respectfully requested that the Commission grant the application expeditiously.

Respectfully submitted,

/s/________________________________

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November 15, 2016

to Deny of Telesat, File No. SAT-LOI-20160428-00041 (filed Aug. 15, 2016), at 3; Comments of The Boeing Company, File No. SAT-LOI-20160428-00041 (filed Aug. 15, 2016), at 2; Comments of Space Exploration Technologies Corp, File No. SAT-LOI-20160428-00041 (filed Aug. 15, 2016), at 15.

Appendix A

Technical Exhibit for the Telesat LEO Constellation Satellite Network

A1. Introduction

This document is the technical appendix to Telesat's Petition for a Declaratory Ruling for the Ka-band non-geostationary low-earth orbit (LEO) satellite network referred to as Telesat LEO Constellation. The technical information for the proposed system, as required by paragraph (d) of Section §25.114[1] of the FCC rules, is provided in this document. The information specified in paragraph (c) of that section has been provided in the Schedule S and is not repeated in this document. (Some clarifying remarks regarding the content of the Schedule S are contained in this document.)

A2. §25.114(d)(1): General Description of the Overall System

The space segment of the Telesat LEO Constellation satellite network will consist of a minimum of 117 operating satellites and spare satellites to fulfill the reliability requirements. There will be a minimum of 6 circular orbits with an altitude of 1000 km and an inclination angle of 99.5° (these orbits are referred to as "Polar Orbits"). Each of the Polar Orbits will include a minimum of 12 operating satellites. There will also be a minimum of 5 circular orbits with an altitude of 1248 km and an inclination angle of 37.4° (these orbits are referred to as "Inclined Orbits"). Each of the Inclined Orbits will include a minimum of 9 operating satellites. Figure 1 shows the Polar Orbits and Figure 2 shows the Inclined Orbits. Polar Orbits provide coverage over all latitudes. Inclined Orbits concentrate satellites over equatorial and mid-latitude areas that are generally highly populated. The Inclined Orbits and Polar Orbits have been designed to work together and the Telesat LEO Constellation satellite network takes advantage of the complementary nature of the two types of orbit.

The Telesat LEO Constellation satellite network will have a global coverage and will provide a range of satellite services to the United States and elsewhere in the world It will be an integrated system capable of providing layer-2 Carrier Ethernet connectivity from any point to any point with highly secure and resilient low-latency links. Flexible satellite and network technologies provide power and spectrum where and when needed. Each Telesat LEO Constellation satellite will incorporate onboard processing and inter-satellite communication capabilities enabling the satellite network to connect any point on the Earth to any other point on the Earth without the need for the use of terrestrial infrastructure. Gateway earth stations will form part of the system to serve as interface

[1] 47 C.F.R. §25.114

points between the Telesat LEO Constellation network and the terrestrial infrastructure. With these features, the constellation will offer mesh connectivity between users, VSAT network connectivity for enterprises, and consumer broadband services worldwide. It will provide broadband services to unserved and underserved communities.

Figure 1: The Polar Orbits

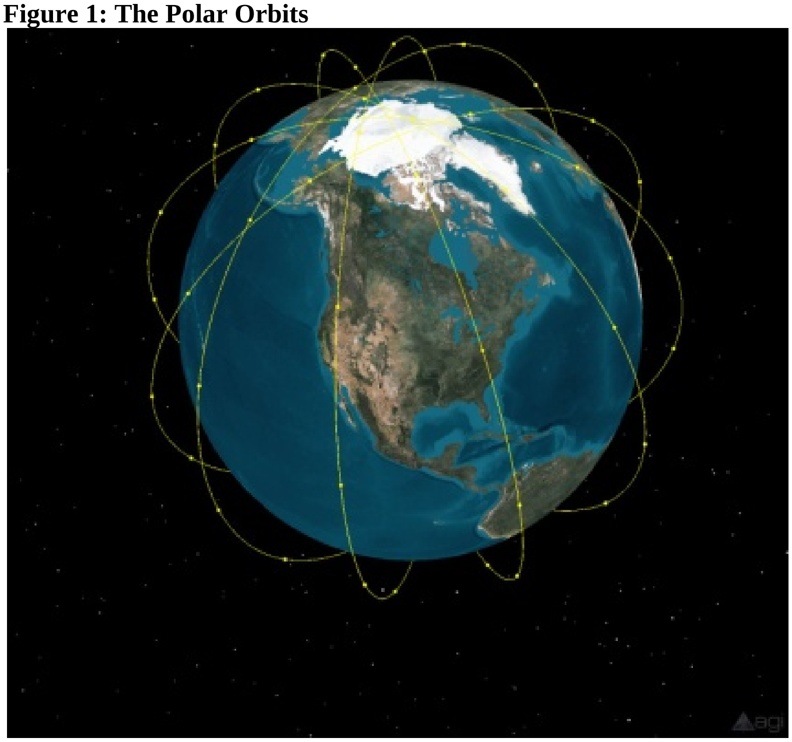
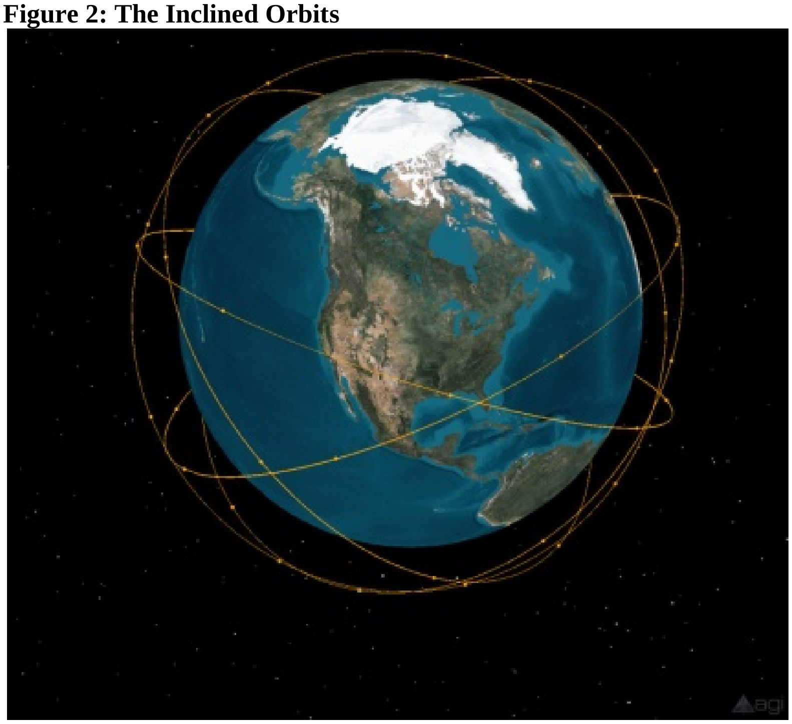


Figure 2: The Inclined Orbits



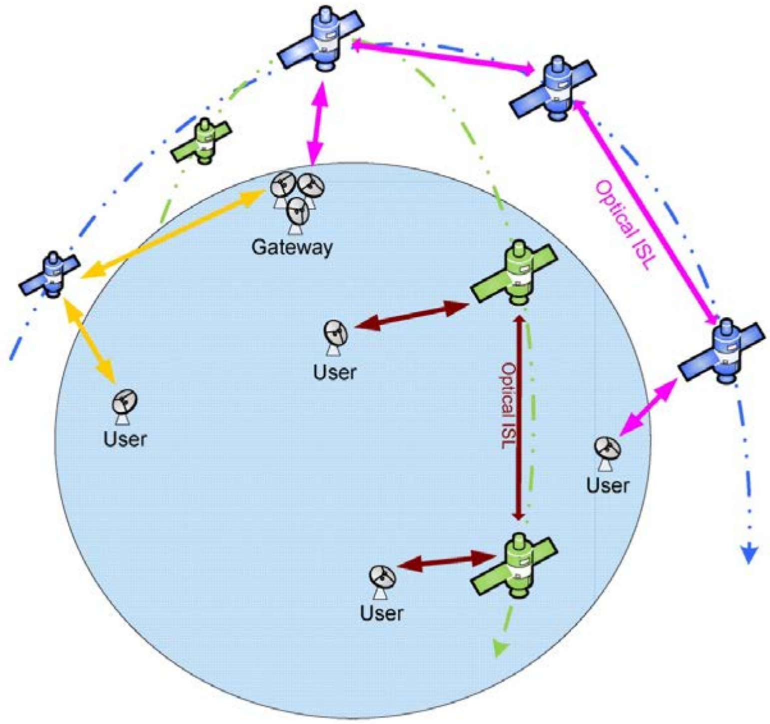
All the satellites of the Telesat LEO Constellation satellite network will be identical. Each satellite will use Direct Radiating Array (DRA) antennas and beam forming to generate a minimum of 16 downlink user beams and a minimum of 16 uplink user beams. Each of the user beams will be shapeable and steerable. Each satellite will also have two steerable spot beams for communication with the gateways. In addition, each satellite will have a wide-area receive beam, which will allow the satellite to detect user requests to initiate communication. Each satellite will have optical terminals for inter-satellite links (ISL). These optical terminals will provide the capability of transmission within the same plane, within adjacent planes of the same orbit and between the Polar Orbits and Inclined Orbits.

Each satellite will employ a regenerative payload, including on-board processing and IP packet self-routing switching, to improve link performance. On the receive side, the on-board processor will perform analog-to-digital conversion (ADC), followed by digital beam forming, de-multiplexing, and demodulation. The processor will decode each packet header allowing the IP switch to provide routing of the information contained within the packet. On the transmit side, the on-board processor will perform modulation, multiplexing, digital beam forming, and digital-to-analog conversion (DAC). On-board regeneration of the signal will also permit separate optimization of the uplink and downlink, decoupling the uplink impairments from the downlink impairments in the link.

The system will use a network of gateway facilities enabling access to the constellation from a number of locations. From these gateway facilities, access to every satellite of the constellation will be possible at all times either directly or through other satellites via inter-satellite links. Selected gateways will also provide the necessary TT&C links to ensure redundant and reliable control of the constellation.

The network architecture is illustrated in Figure 3. The Telesat LEO Constellation satellite network will provide Carrier Ethernet Service in a seamless extension of advanced terrestrial telecom networks. With a standard network interface, users will access the constellation data capacity as they would access any other network.

Figure 3: Telesat LEO Constellation satellite network architecture



The Telesat LEO Constellation satellite network will have an integrated control system comprised of a mission planning system and a network control system. The mission planning system will manage the satellite fleet health and orbits. The network control system will manage the payload resources and the operation of the network. The integrated control system will be primarily distributed among the satellites, gateways, and user terminals. However, Telesat's Satellite Control Centre in Ottawa, Ontario, Canada, at the address below, will monitor and have ultimate control of the Telesat LEO Constellation satellite network. The backup control facility will be located in Mt. Jackson, VA, USA.

Telesat
1601 Telesat Court,
Ottawa, ON, Canada K1B 5P4
Phone: 613-748-8700
SCC direct phone number: 613-747-3000
North American Toll Free: 1-888-662-8728 (option 3 – carrier access)
International: +1 519-371-5746 (option 3 – carrier access)
Email: tccsupport@telesat.com

One of the modules of the network control system will be the Radio Resource Management system (RRM) which will oversee the scheduling and maintenance of radio channels and will allocate satellite resources (power, bandwidth and beam size) to provide service. RRM will be responsible for radio resource allocation and control, such that the network quality of service (QoS) is optimized against bandwidth utilization. It will do so taking into account physical, operational, regulatory and coordination constraints.

A wide variety of user terminals will access the Telesat LEO Constellation, both electronically steered terminals and mechanically tracking terminals. The system will be capable of operating with both fixed terminals and mobile terminals. Since the FCC Rules do not authorize use of mobile terminals in the frequency bands used in the Telesat LEO Constellation, such terminals would be used in the U.S. only upon filing of the requisite waiver requests and their grant by the Commission. Telesat is working with the industry to develop innovative, next generation, lower cost tracking antenna making the access to the constellation simple and cost effective.

The frequency bands of the Telesat LEO Constellation satellite network are summarized in Table 1. In the FCC Table of Frequency Allocations and other FCC documents there are restrictions for the use of some of the frequency band segments of Table 1 for fixed satellite service by a non-geostationary satellite network. These are described below.

Table 1: Frequency bands of the Telesat LEO Constellation satellite network

Lower Frequency Limit (GHz)	Upper Frequency Limit (GHz)	Downlink/ Uplink
17.8	18.3	Downlink
18.3	18.6	Downlink
18.8	19.3	Downlink
19.7	20.2	Downlink
27.5	28.35	Uplink
28.35	28.6	Uplink
28.6	29.1	Uplink
29.5	30.0	Uplink

17.8-18.3 GHz frequency band

In the FCC Table of Frequency Allocations, the frequency band 17.8-18.3 GHz is allocated to the Fixed Service as well as federal GSO and NGSO FSS, but is not allocated to the FSS for non-federal systems either in the Table or in the Commission's Ka-Band Plan. Telesat seeks a waiver of the FCC Table of Frequency Allocations and the Commission's Ka-Band Plan to allow its LEO Constellation to operate in this band. The Telesat LEO Constellation will comply with the power flux density (PFD) limits of Article **21** of the ITU Radio Regulations to assure the Fixed Service is protected. Telesat LEO Constellation will also meet the equivalent power flux density (epfd) limits of Article **22** of the ITU Radio Regulations applicable to this band to assure no unacceptable interference will be received by geostationary satellites. Telesat will coordinate with federal satellite services to assure they do not receive harmful interference. Telesat will operate on a non-harmful interference basis with respect to the Fixed Service, Meteorological-satellite Service, and federal GSO and NGSO FSS, and will not cause harmful interference to them nor seek protection from them.

18.3-18.6 GHz frequency band

Although the 18.3-18.6 GHz band is allocated to the FSS in the United States, Footnote NG164 of the FCC's Table of Frequency Allocations and the Commission's Ka-Band Plan designates this band for the use of the GSO FSS. Telesat seeks a waiver of the Commission's Table of Frequency Allocations and its Ka-Band Plan to permit its LEO Constellation to operate in this band. The Telesat LEO Constellation will comply with the epfd limits of Article **22** of the ITU Radio Regulations applicable to this band to assure no unacceptable interference will be received by geostationary satellite services. Telesat will operate on a non-harmful interference basis with respect to the GSO FSS and will not cause harmful interference to that service nor seek protection from it.

18.8-19.3 GHz frequency band

In the FCC Table of Frequency Allocations and the Commission's Ka-Band Plan, the use of the frequency band 18.8-19.3 GHz for FSS by non-federal satellites is limited to non-geostationary satellites. Telesat will coordinate with the existing NGSO and GSO satellite networks in this band.

19.7-20.2 GHz

Although the 19.7-20.2 GHz band is allocated to the FSS in the United States, the Commission's Ka-Band Plan designates this band for the use of the GSO FSS. Telesat seeks a waiver of the Commission's Ka-Band Plan to permit the Telesat LEO Constellation satellite network to operate in this band. Telesat will comply with the equivalent power flux density (epfd) requirements of Article **22** of the ITU Radio Regulations to assure no unacceptable interference will be received by geostationary satellites in this frequency band. Telesat will operate on a non-harmful interference basis to GSO FSS and will not cause harmful interference to, nor seek protection from, GSO FSS operations in this band.

27.5-28.35 GHz frequency band

In the United States the frequency band 27.5-28.35 GHz is allocated to the local multipoint distribution service ("LMDS") on a primary basis and the use of this band for non-geostationary fixed-satellite services would be on a non-interference basis to LMDS systems and only for providing limited uplink gateway-type services. NGSO FSS operations are allocated on a secondary basis in the same band. A secondary NGSO user in the Ka-band must not cause harmful interference to primary operations, nor can it claim protection from interference caused by primary operations. Telesat's proposed use of the 27.5-28.35 GHz band satisfies this standard. As a secondary NGSO user in the 27.5-28.35 GHz frequency band, Telesat makes no claim for protection from interference caused by LMDS operations. Earth station applications that propose to transmit from the United States to the Telesat LEO Constellation satellites in the 27.5-28.35 GHz band will include a demonstration that will address protection of LMDS stations.

Recently FCC allocated the frequency band 27.5-28.35 GHz to Upper Microwave Flexible Use Services (UMFUS) while still allowing fixed-satellite services to share this band with the UMFUS through several mechanisms. Telesat's use of the frequency band 27.5-28.35 GHz in the U.S. will be for gateway uplink communication and it will comply with the FCC mechanisms for sharing with the UMFUS.[2]

28.35-28.6 GHz

In the FCC rules the frequency band 28.35-28.6 GHz is allocated to the GSO FSS on a primary basis and to the NGSO FSS on a secondary basis. Telesat will comply with the epfd requirements of Article **22** of the ITU Radio Regulations to assure no unacceptable interference will be received by geostationary satellites in this frequency band. Telesat will operate on a non-harmful interference basis to GSO FSS and will not cause harmful interference to, nor seek protection from, GSO FSS operations in this band.

28.6-29.1 GHz frequency band

In the FCC's band plan, the use of the frequency band 28.6-29.1 GHz by the FSS is primary for non-geostationary satellites and secondary for geostationary satellites. However, Telesat has begun coordination discussions with GSO operators in accordance with of No. **9.12A** of the Radio Regulations. Telesat also notes there are GSO systems operating on a secondary basis in this band. Telesat has begun coordination discussions with other operators of NGSO systems in this band in accordance with No. **9.12**.

29.5-30.0 GHz frequency bands

In the FCC rules the frequency band 29.5-30.0 GHz is allocated to the GSO FSS on a primary basis and to the NGSO FSS on a secondary basis. Telesat will comply with the epfd requirements of Article **22** of the ITU Radio Regulations to assure no unacceptable interference will be received by geostationary satellite services in this frequency band. Telesat will operate on a non-harmful interference basis to GSO FSS and will not cause harmful interference to, nor seek protection from, GSO FSS operations in this band.

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[2] *See In the Matter of Use of Spectrum Bands Above 24 GHz For Mobile Radio Services*, Report and Order and Further Notice of Proposed Rulemaking, 206 FCC Lexis 2470 (2016).

As requested in §25.114(d)(1) an explanation of how the uplink frequency bands are connected to the downlink frequency bands is provided. The frequency bands of the Telesat LEO Constellation satellites are listed in Table 1. The Telesat LEO Constellation satellite network will make efficient use of spectrum. As mentioned earlier, the Telesat LEO Constellation satellites will use on-board processing and, as part of the on-board processing, any uplink frequency band segment will be able to be connected to any downlink frequency band segment. Each Telesat LEO Constellation satellite will have an IP network router and optical inter-satellite link terminals so that any user or any gateway can be connected to any other user or gateway. Thus, any uplink frequency band from any user or any gateway can be connected to any downlink frequency band to any user or any gateway.

The polarization used for all signals will be circular. Frequency reuse will be exploited through the use of orthogonal polarization and geographical isolation of the beams.

A3. §25.114(c)(4)(vi): Space station antenna gain contours

The antenna gain contours of Telesat LEO Constellation satellites have been provided in a GIMS database attached to the Schedule S, as per FCC §25.114(c)(4)(vi). This section of the Technical Exhibit only provides a clarification.

The service area of Telesat LEO Constellation is the entire Earth. The satellites of Telesat LEO Constellation will be identical and each satellite will use Direct Radiating Array (DRA) antennas and beam forming to generate a minimum of 16 downlink user beams and 16 uplink user beams. Therefore, a minimum of 32 (uplink and downlink) user beams will be available for each satellite. The user beams are capable of operating in both right hand circular polarization (RHCP) and left hand circular polarization (LHCP). Each user beam will be capable of being independently formed and steered. Each user beam will be capable of being formed to provide circular ground cell coverage as small as 35km in diameter and as large as 560km in diameter. Since all the uplink user beams will have the same capability (i.e., technically identical) and all the downlink user beams will have the same capability (i.e., technically identical), in the Schedule S only one uplink user beam and one downlink user beam have been provided. It is noted that the Schedule S allows one beam ID for each continuous frequency band segment in each polarization. Table 2 provides a description of the user beams specified in the Schedule S. The corresponding gain contours have been provided in the GIMS database attached to the Schedule S.

Table 2: Description of user beam IDs in the Schedule S

Beam	Corresponding Beam IDs in the Schedule S	Notes
Uplink user beam with RHCP polarization	F1P1 and F2P1	Since the beam operates in two separate band segments (27.5-29.1 and 29.5-30 GHz), Schedule S mandates using two beam IDs (F1P1 for 27.5-29.1 and F2P1 for 29.5-30.0 GHz).
Uplink user beam with LHCP polarization	F1P2 and F2P2	Since the beam operates in two separate band segments, the Schedule S mandates using two beam IDs (F1P2 for 27.5-29.1 and F2P2 for 29.5-30.0 GHz).
Downlink user beam with RHCP polarization	M1P1, M2P1, and M3P1	Since the beam operates in three separate band segments, the Schedule S mandates using three beam IDs (M1P1 for 17.8-18.6, M2P1 for 18.8-19.3, and M3P1 for 19.7-20.2 GHz)
Downlink user beam with LHCP polarization	M1P2, M2P2, and M3P2	Since the beam operates in three separate band segments, the Schedule S mandates using three beam IDs (M1P2 for 17.8-18.6, M2P2 for 18.8-19.3, and M3P2 for 19.7-20.2 GHz)

Each satellite will also have two steerable spot beams for communication with the gateways. In addition, each satellite will have a wide-area receive beam, which will allow the satellite to detect a user request to initiate communication. The corresponding gain contours have been provided in the GIMS database attached to the Schedule S.

Table 3 shows how the gain contours of the GIMS database are related to the satellite beams (GIMS database has been attached to the Schedule S). The GIMS database includes the antenna gain contours when the peak antenna gain is pointed at nadir for one Polar Orbit satellite location and one Inclined Orbit satellite location. As required by Section §25.114(c)(4)(vi), for the steerable beams (i.e., the user beams and gateway beams) the contours that would result from moving the beam peak around the limit of the effective beam peak area and the 0 dB relative antenna gain isoline have also been included in the GIMS database. For the shapeable beams (i.e., the user beams), in the downlink direction the gain contours for the beam configuration that results in the highest EIRP have been provided and in the uplink direction the gain contours of the configuration that results in the smallest gain-to-temperature ratio have been provided, as required by §25.114(c)(4)(vi).[3]

[3] Peak antenna gain values have been provided in the Schedule S. For clarification, it is noted that when the uplink user beam has the configuration with the smallest gain-to-temperature ratio, its peak antenna gain is equal to 15.8 dBi and when it has the configuration with the largest gain-to-temperature ratio, its peak antenna gain is equal to 42.5 dBi.

Table 3: Description of the beam names in the GIMS database

Orbit type	Beam type	Uplink/Downlink	Beam name in the GIMS database	Associated beams in the Schedule S
Polar	User	Uplink	USRPOLRX	F1P1, F1P2, F2P1, F2P2
Inclined	User	Uplink	USRINCRX	F1P1, F1P2, F2P1, F2P2
Polar	Gateway	Uplink	GWPOLRX	G1P1, G1P2, G2P1, G2P2, H1P1, H1P2, H2P1, H2P2
Inclined	Gateway	Uplink	GWINCRX	G1P1, G1P2, G2P1, G2P2, H1P1, H1P2, H2P1, H2P2
Polar	Wide-area	Uplink	WAPOLRX	J1P1, J1P2, J2P1, J2P2
Inclined	Wide-area	Uplink	WAINCRX	J1P1, J1P2, J2P1, J2P2
Polar	User	Downlink	USRPOLTX	M1P1, M1P2, M2P1, M2P2, M3P1, M3P2
Inclined	User	Downlink	USRINCTX	M1P1, M1P2, M2P1, M2P2, M3P1, M3P2
Polar	Gateway	Downlink	GWPOLTX	N1P1, N1P2, N2P1, N2P2, N3P1, N3P2, R1P1, R1P2, R2P1, R2P2, R3P1, R3P2
Inclined	Gateway	Downlink	GWINCTX	N1P1, N1P2, N2P1, N2P2, N3P1, N3P2, R1P1, R1P2, R2P1, R2P2, R3P1, R3P2

A4. §25.114(d)(6): Public interest considerations in support of grant

Please refer to the legal narrative portion of this Petition for a Declaratory Ruling for the Telesat LEO Constellation for a comprehensive explanation of why the grant of this application will be in the public interest.

A5. §25.208: Compliance with power flux density limits at the Earth's surface to protect terrestrial services

Downlink frequency bands of Telesat LEO Constellation satellites consist of 17.8-18.6 GHz, 18.8-19.3 GHz, and 19.7-20.2 GHz. In Section §25.208[4] of the FCC rules as well as Article **21** of the ITU Radio Regulations there are limits for the power flux density (PFD) generated by a satellite at the Earth's surface. These limits are for the protection of the Fixed Service. Below it is demonstrated that the Telesat LEO Constellation will meet those limits at all times. In the operating downlink bands of the Telesat LEO

[4] 47 C.F.R. §25.208

Constellation, as per Section §25.208 of the FCC rules and Article **21** of the ITU Radio Regulations, the smallest limit for the power flux density produced by a satellite at the Earth's surface is equal to -115-X dB(W/m^2/MHz) where X is a function of the number of satellites in the non-geostationary constellation, n. X is calculated by the formula below (as per Section §25.208 of the FCC rules).

$X = 0$ (dB) for $n \leq 50$
$X = (5/119)\,(n - 50)$ (dB) for $50 < n \leq 288$
$X = (1/69)\,(n + 402)$ (dB) for $n > 288$

It should be noted that although this limit applies to the angles of arrival of 0° to 5°, Telesat LEO Constellation satellites will meet this limit for all angles of arrival. The analysis provided below is for the minimum constellation size of 117 satellites. With the addition of more satellites the calculations will be adjusted accordingly to ensure compliance with the PFD limits. Given that there are n = 117 satellites in the Telesat LEO Constellation, the parameter X can be calculated as X = (5/119)(117-50) = 2.8 dB and therefore the downlink PFD limit that has to be met is equal to -117.8 dB(W/m^2/MHz). As presented in the Schedule S, in the frequency bands 17.8-18.6 GHz and 18.8-19.3 GHz, the peak downlink EIRP density is equal to -50 dB(W/Hz) and in the frequency band 19.7-20.2 GHz the peak downlink EIRP density is -56.4 dB(W/Hz). The smallest distance between a Telesat LEO Constellation satellite and any point at the Earth's surface will be 1000 km. Thus, the maximum power flux density at the Earth's surface produced by any satellite would be -121.0 dB(W/m^2/MHz) in the bands 17.8-18.6 GHz and 18.8-19.3 GHz, and -127.4 dB(W/m^2/MHz) in the band 19.7-20.2 GHz. Telesat will ensure compliance with the PFD limits of Section §25.208 of the FCC rules and Article **21** of the ITU Radio Regulations.[5]

A6. Equivalent power flux density compliance for protecting GSO systems

The Telesat LEO Constellation will comply with the equivalent power flux density (epfd) limits of Article **22** of the ITU Radio Regulations in order to protect geostationary satellite networks.[6] For the operating frequency bands of the Telesat LEO Constellation, there are three types of epfd limits that have to be met. These are epfd limits at the Earth's surface for downlink transmissions, epfd limit at the geostationary orbit for uplink transmissions, and epfd limit at the geostationary orbit for downlink transmissions.

[5] Section §25.208 of the FCC rules and Article **21** of the ITU Radio Regulations do not include a PFD limit for the band 19.7-20.2 GHz. The PFD at the Earth surface for this frequency band was provided here for completeness.

[6] There are no FCC rules that include epfd limits in the frequency bands of Telesat LEO Constellation. The design and operation of Telesat LEO Constellation incorporates the epfd limits of the ITU Radio Regulations.

The equivalent power flux-density is defined as the sum of the power flux-densities produced at a geostationary-satellite system receive station on the Earth's surface or in the geostationary orbit, as appropriate, by all the transmit stations within a non-geostationary-satellite system, taking into account the off-axis discrimination of a reference receiving antenna assumed to be pointing in its nominal direction. The equivalent power flux-density is calculated using the following formula:

$$epfd = 10\log_{10}\left[\sum_{i=1}^{N_a} 10^{\frac{P_i}{10}} \cdot \frac{G_t(\theta_i)}{4\pi d_i^2} \cdot \frac{G_r(\varphi_i)}{G_{r,max}}\right] \qquad \text{Equation (1)}$$

where:

N_a: number of transmit stations in the non-geostationary-satellite system that are visible from the geostationary-satellite system receive station considered on the Earth's surface or in the geostationary orbit, as appropriate

i: index of the transmit station considered in the non-geostationary-satellite system

P_i: RF power at the input of the antenna of the transmit station, considered in the non-geostationary-satellite system (dBW) in the reference bandwidth

θ_i: off-axis angle between the boresight of the transmit station considered in the non-geostationary-satellite system and the direction of the geostationary-satellite system receive station

$G_t(\theta_i)$: transmit antenna gain (as a ratio) of the station considered in the non-geostationary-satellite system in the direction of the geostationary-satellite system receive station

d_i: distance (m) between the transmit station considered in the non-geostationary-satellite system and the geostationary-satellite system receive station

φ_i: off-axis angle between the boresight of the antenna of the geostationary-satellite system receive station and the direction of the *i*-th transmit station considered in the non-geostationary-satellite system

$G_r(\varphi_i)$: receive antenna gain (as a ratio) of the geostationary-satellite system receive station in the direction of the *i*-th transmit station considered in the non-geostationary-satellite system

$G_{r,max}$: maximum gain (as a ratio) of the antenna of the geostationary-satellite system receive station

epfd: computed equivalent power flux-density (dB(W/m2)) in the reference bandwidth.

Below it is demonstrated that the Telesat LEO Constellation will satisfy all the epfd requirements. The analyses provided below are for the minimum constellation size of 117 satellites. With the addition of more satellites the calculations will be adjusted accordingly to ensure compliance with the epfd limits.

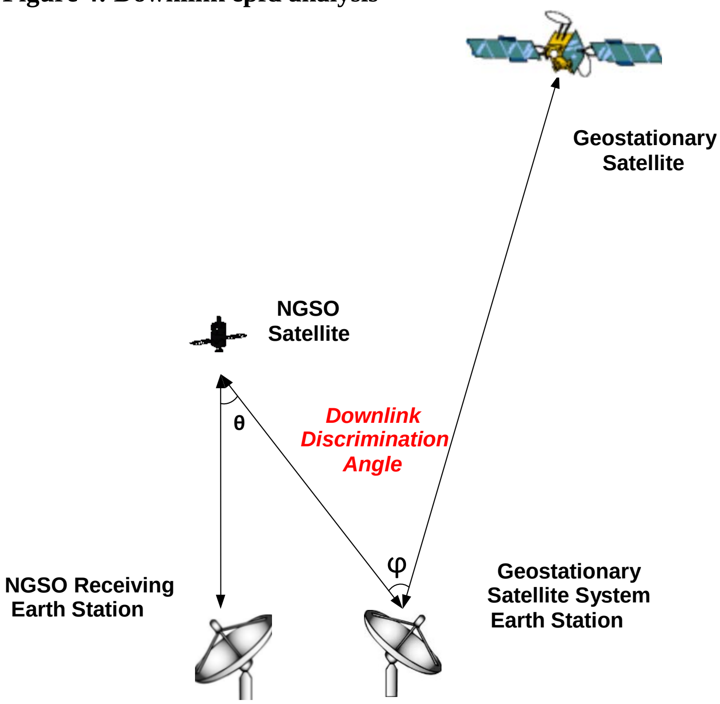
epfd limits at the Earth's surface for downlink transmissions

Article **22** of the ITU Radio Regulations has four tables for the epfd limits in the downlink frequency bands of the Telesat LEO Constellation. One table applies only to the band 17.8-18.6 GHz, one table is for the band 19.7-20.2 GHz, and the other two tables apply to both 17.8-18.6 GHz and 19.7-20.2 GHz frequency bands. The epfd limits in those tables are for several reference earth station antenna sizes for the geostationary earth station having the antenna pattern of the ITU-R Recommendation S.1428. The relevant tables of Article **22** of the ITU Radio Regulations have been provided in Annex 1 and the antenna pattern of the ITU-R Recommendation S.1428 has been provided in Annex 2.

Although ITU Article **22** downlink epfd limits allow larger interference levels for small percentages of time, the Telesat LEO Constellation will meet the worst-case epfd limit 100 percent of the time. Every satellite in the Telesat LEO Constellation will communicate only with geographical areas on the Earth that will provide a minimum discrimination angle which would result in meeting the epfd limits of Article **22**. In order to calculate the minimum discrimination angles that will satisfy the epfd limits, the epfd formula in Equation (1) is used. Figure 4 shows a GSO satellite and a GSO earth station associated with it, as well as a LEO NGSO satellite and a LEO NGSO earth station communicating with that LEO satellite. Figure 4 also shows the discrimination angle φ. From Equation (1) it can be seen that the downlink epfd is a function of the number of satellites with co-frequency co-coverage operation, downlink EIRP of the satellites, the distance of the satellites to the GSO earth station, the peak gain of the GSO earth station, and the off-axis gain of the GSO earth station toward the LEO satellite. The design of the Telesat LEO Constellation is such that any location on the Earth receives co-frequency signals from a maximum of two satellites. In fact, in normal operation, at any frequency only one satellite will serve any location on the Earth and only during the handover between satellites will two satellites serve that location at that frequency. Therefore, in Equation (1), N_a is equal to 2. As presented in the Schedule S, in the frequency bands 17.8-18.6 GHz the peak downlink EIRP density of the Telesat LEO Constellation satellites is equal to -50 dB(W/Hz) and in the frequency band 19.7-20.2 GHz the peak downlink EIRP density is equal to -56.4 dB(W/Hz). It is necessary to calculate the angular separation at which the transmission will be shut off to ensure no harmful interference from the Telesat LEO Constellation will be received by the GSO earth stations. For a worst case, we consider that the Telesat LEO Constellation ground station and the GSO ground station are co-located, the boresight of the Telesat LEO Constellation satellite transmit beam is towards the GSO ground station (i.e., $\theta = 0°$) and the Telesat LEO Constellation satellite downlink EIRP is at its maximum.

The analysis for the calculation of the downlink discrimination angle needed to meet the downlink epfd limits of Article **22** is presented below. It should be noted that these calculations are for the worst case, when the handover is taking place, the satellites operate at the peak downlink EIRP density level, and the distance from the satellites to the GSO earth station is the lowest distance possible (i.e., the satellite altitude). In practice, the Radio Resource Management system will calculate the downlink discrimination angle based on the operating downlink EIRP density levels and the distance from both LEO satellites involved in the handover to the area on the Earth that is served by the corresponding spot beams of the satellites. The Radio Resource Management system will continuously manage the communications link parameters and appropriately configure the communication links by adjusting power, bandwidth, frequency selection, or handover to another satellite to ensure the epfd limits are met.

Figure 4: Downlink epfd analysis



Polar Orbits in the band 17.8-18.6 GHz

Table 4 shows the analysis for the calculation of the minimum downlink discrimination angle (φ) that should be met in order to comply with the downlink epfd limits of Article **22** of the ITU Radio Regulations in the frequency band 17.8-18.6 GHz for the satellites of the Polar Orbits. From Table 4 it can be seen that in order to meet the worst-case downlink epfd requirements for the frequency band 17.8-18.6 GHz, the satellites in the Polar Orbits should have a downlink discrimination angle that is greater than or equal to φ = 14.8°.

Table 4: Minimum discrimination angle calculation for the Polar Orbits in the band 17.8-18.6 GHz

Applicable Table from Article **22** of the ITU Radio Regulations	TABLE **22-1B**			TABLE **22-4A1**		TABLE **22-4B**
Reference GSO earth station antenna diameter [m]	1	2	5	3	10	1.8
epfd limit for the constellation [dB(w/m²/40 kHz)]	-175.4	-178.4	-185.4	-182	-185	-164
epfd limit for the constellation [dB(w/m²/MHz)]	-161.4	-164.4	-171.4	-168.0	-171.0	-150.0
epfd limit for each satellite (since N_a = 2) [dB(w/m²/40 kHz)]	-178.4	-181.4	-188.4	-185	-188	-167
epfd limit for each satellite (since N_a = 2) [dB(w/m²/MHz)]	-164.4	-167.4	-174.4	-171.0	-174.0	-153.0
Peak EIRP density [dB(W/Hz)]	-50	-50	-50	-50	-50	-50
Peak EIRP density [dB(W/MHz)]	10	10	10	10	10	10
Minimum satellite to Earth distance [km]	**1000**	**1000**	**1000**	**1000**	**1000**	**1000**
D/λ for f=17.8 GHz	59.3	118.7	296.7	178.0	593.3	107.2
D/λ for f=18.6 GHz	62	124	310	186	620	112.0
$G_{r,max}$ [dBi] using ITU-R Rec. S.1428 for f=17.8 GHz	43.2	49.9	57.8	53.4	63.9	49.0
$G_{r,max}$ [dBi] using ITU-R Rec. S.1428 for f=18.6 GHz	43.5	50.3	58.2	53.8	64.2	49.4
$G_r(φ)$ for f=17.8 GHz[dBi]	-0.3	3.5	4.4	3.4	10.8	17.0
$G_r(φ)$ for f=18.6 GHz[dBi]	0.1	3.8	4.8	3.8	11.2	17.4
φ [deg] for f=17.8 GHz	14.8	10.4	9.6	10.5	5.3	3.0
φ [deg] for f=18.6 GHz	14.3	10.1	9.3	10.2	5.1	2.9
Minimum downlink discrimination angle (φ) that should be met [deg]	14.8					

Inclined Orbits in the band 17.8-18.6 GHz

Table 5 shows the analysis for the calculation of the minimum downlink discrimination angle (φ) that should be met in order to comply with the downlink epfd limits of Article **22** of the ITU Radio Regulations in the frequency band 17.8-18.6 GHz for the satellites of the Inclined Orbits. From Table 5 it can be seen that in order to meet the worst-case downlink epfd requirements for the frequency band 17.8-18.6 GHz, the satellites in the Inclined Orbits should have a downlink discrimination angle that is greater than or equal to φ = 12.4°.

Table 5: Minimum discrimination angle calculation for the Inclined Orbits in the band 17.8-18.6GHz

Applicable Table from Article **22** of the ITU Radio Regulations	TABLE **22-1B**			TABLE **22-4A1**		TABLE **22-4B**
Reference GSO earth station antenna diameter [m]	1	2	5	3	10	1.8
epfd limit for the constellation [dB(w/m²/40 kHz)]	-175.4	-178.4	-185.4	-182	-185	-164
epfd limit for the constellation [dB(w/m²/MHz)]	-161.4	-164.4	-171.4	-168.0	-171.0	-150.0
epfd limit for each satellite (since N_a = 2) [dB(w/m²/40 kHz)]	-178.4	-181.4	-188.4	-185	-188	-167
epfd limit for each satellite (since N_a = 2) [dB(w/m²/MHz)]	-164.4	-167.4	-174.4	-171.0	-174.0	-153.0
Peak EIRP density [dB(W/Hz)]	-50	-50	-50	-50	-50	-50
Peak EIRP density [dB(W/MHz)]	10	10	10	10	10	10
Minimum satellite to Earth distance [km]	**1248**	**1248**	**1248**	**1248**	**1248**	**1248**
D/λ for f=17.8 GHz	59.3	118.7	296.7	178.0	593.3	107.2
D/λ for f=18.6 GHz	62	124	310	186	620	112.0
$G_{r,max}$ [dBi] using ITU-R Rec. S.1428 for f=17.8 GHz	43.2	49.9	57.8	53.4	63.9	49.0
$G_{r,max}$ [dBi] using ITU-R Rec. S.1428 for f=18.6 GHz	43.5	50.3	58.2	53.8	64.2	49.4
$G_r(φ)$ for f=17.8 GHz[dBi]	1.7	5.4	6.3	5.3	12.8	18.9
$G_r(φ)$ for f=18.6 GHz[dBi]	2.0	5.8	6.7	5.7	13.1	19.3
φ [deg] for f=17.8 GHz	12.4	8.8	8.1	8.9	4.5	2.5
φ [deg] for f=18.6 GHz	12.0	8.5	7.8	8.6	4.3	2.4
Minimum downlink discrimination angle (φ) that should be met [deg]	12.4					

Polar Orbits in the band 19.7-20.2 GHz

Table 6 shows the analysis for the calculation of the minimum downlink discrimination angle (φ) that should be met in order to comply with the downlink epfd limits in the frequency band 19.7-20.2 GHz for the satellites of the Polar Orbits. From Table 6 it can be seen that the worst-case corresponds to the GSO earth station antenna diameter of 0.9 meter and that in order to meet the epfd limit the off-axis gain of this GSO earth station antenna toward the LEO satellite should be -8.9 dBi or less. Referring to the antenna pattern of the ITU-R Recommendation S.1428 (provided in Annex 2) the calculations show that if φ is in the range 32.8° ≤ φ ≤ 80° or 120° ≤ φ ≤ 180°, the off-axis gain will be less than or equal to -8.9 dBi. Therefore, in order to meet the epfd requirements for the Polar Orbits satellites in the frequency band 19.7-20.2 GHz, the downlink discrimination angle should be in the range 32.8° ≤ φ ≤ 80° or 120° ≤ φ ≤ 180°.

Table 6: Minimum discrimination angle calculation for the Polar Orbits in the band 19.7-20.2 GHz

Applicable Table from Article **22** of the ITU Radio Regulations	TABLE **22-1C**				TABLE **22-4A1**		TABLE **22-4B**
Reference GSO earth station antenna diameter [m]	0.7	0.9	2.5	5	3	10	1.6
epfd limit for the constellation [dB(w/m²/40 kHz)]	-187.4	-190.4	-196.4	-200.4	-182	-185	-157
epfd limit for the constellation [dB(w/m²/MHz)]	-173.4	-176.4	-182.4	-186.4	-168.0	-171.0	-143.0
epfd limit for each satellite (N_a = 2) [dB(w/m²/40 kHz)]	-190.4	-193.4	-199.4	-203.4	-185	-188	-160
epfd limit for each (N_a = 2) [dB(w/m²/MHz)]	-176.4	-179.4	-185.4	-189.4	-171.0	-174.0	-146.0
Peak EIRP density [dB(W/Hz)]	-56.4	-56.4	-56.4	-56.4	-56.4	-56.4	-56.4
Peak EIRP density [dB(W/MHz)]	3.6	3.6	3.6	3.6	3.6	3.6	3.6
Minimum satellite to Earth distance [km]	**1000**	**1000**	**1000**	**1000**	**1000**	**1000**	**1000**
D/λ for f=19.7 GHz	46.0	59.1	164.2	328.3	197.0	656.7	107.2
D/λ for f=20.2 GHz	47.1	60.6	168.3	336.7	202.0	673.3	109.9
$G_{r,max}$ [dBi] using ITU-R Rec. S.1428 for f=19.7 GHz	40.9	43.1	52.7	58.7	54.3	64.7	49.0
$G_{r,max}$ [dBi] using ITU-R Rec. S.1428 for f=20.2 GHz	41.2	43.3	52.9	58.9	54.5	65.0	49.2
G_r(φ) for f=19.7 GHz[dBi]	-8.1	-8.9	-5.3	-3.3	10.7	18.1	30.4
G_r(φ) for f=20.2 GHz[dBi]	-7.9	-8.7	-5.1	-3.1	10.9	18.3	30.6
φ [deg] for f=19.7 GHz	30.4	32.8	20.5	17.5	5.4	2.7	0.9
φ [deg] for f=20.2 GHz	29.8	32.1	20.1	17.2	5.3	2.7	0.9
Minimum downlink discrimination angle (φ) that should be met [deg]	32.8						

Inclined Orbits in the band 19.7-20.2GHz

Table 7 shows the analysis for the calculation of the minimum downlink discrimination angle (φ) that should be met in order to comply with the downlink epfd limits in the frequency band 19.7-20.2 GHz for the satellites of the Inclined Orbits. From Table 7 it can be seen that the worst-case corresponds to the GSO earth station antenna diameter of 0.9 meter and that in order to meet the epfd limit the off-axis gain of this GSO earth station antenna toward the LEO satellite should be -7.0 dBi or less. Referring to the antenna pattern of the ITU-R Recommendation S.1428 (provided in Annex 2) the calculations show that if φ is in the range 27.5° ≤ φ ≤ 80° or 120° ≤ φ ≤ 180°, the off-axis gain will be less than or equal to -7.0 dBi. Therefore, in order to meet the epfd requirements for the Inclined Orbits satellites in the frequency band 19.7-20.2 GHz, the downlink discrimination angle should be in the range 27.5° ≤ φ ≤ 80° or 120° ≤ φ ≤ 180°.

Table 7: Minimum discrimination angle calculation for the Inclined Orbits in the band 19.7-20.2GHz

Applicable Table from Article **22** of the ITU Radio Regulations	TABLE **22-1C**				TABLE **22-4A1**		TABLE **22-4B**
Reference GSO earth station antenna diameter [m]	0.7	0.9	2.5	5	3	10	1.6
epfd limit for the constellation [dB(w/m²/40 kHz)]	-187.4	-190.4	-196.4	-200.4	-182	-185	-157
epfd limit for the constellation [dB(w/m²/MHz)]	-173.4	-176.4	-182.4	-186.4	-168.0	-171.0	-143.0
epfd limit for each satellite (N_a = 2) [dB(w/m²/40 kHz)]	-190.4	-193.4	-199.4	-203.4	-185	-188	-160
epfd limit for each satellite (N_a = 2) [dB(w/m²/MHz)]	-176.4	-179.4	-185.4	-189.4	-171.0	-174.0	-146.0
Peak EIRP density [dB(W/Hz)]	-56.4	-56.4	-56.4	-56.4	-56.4	-56.4	-56.4
Peak EIRP density [dB(W/MHz)]	3.6	3.6	3.6	3.6	3.6	3.6	3.6
Minimum satellite to Earth distance [km]	**1248**	**1248**	**1248**	**1248**	**1248**	**1248**	**1248**
D/λ for f=19.7 GHz	46.0	59.1	164.2	328.3	197.0	656.7	107.2
D/λ for f=20.2 GHz	47.1	60.6	168.3	336.7	202.0	673.3	109.9
$G_{r,max}$ [dBi] using ITU-R Rec. S.1428 for f=19.7 GHz	40.9	43.1	52.7	58.7	54.3	64.7	49.0
$G_{r,max}$ [dBi] using ITU-R Rec. S.1428 for f=20.2 GHz	41.2	43.3	52.9	58.9	54.5	65.0	49.2
$G_r(φ)$ for f=19.7 GHz[dBi]	-6.2	-7.0	-3.4	-1.4	12.6	20.0	32.3
$G_r(φ)$ for f=20.2 GHz[dBi]	-5.9	-6.8	-3.2	-1.2	12.8	20.3	32.5
φ [deg] for f=19.7 GHz	25.5	27.5	17.6	15.1	4.5	2.3	0.7
φ [deg] for f=20.2 GHz	25.0	26.9	17.4	14.9	4.4	2.2	0.7
Minimum downlink discrimination angle (φ) that should be met [deg]	27.5						

epfd limit at the geostationary orbit for uplink transmissions

Article **22** of the ITU Radio Regulations has one table for the epfd limits in the uplink frequency bands of the Telesat LEO Constellation. This table, which applies to the frequency bands 27.5-28.6 GHz and 29.5-30 GHz, has been provided in Annex 1. The uplink epfd requirement will be satisfied by limiting the uplink power transmitted by the Telesat LEO Constellation earth stations toward geostationary orbit. In order to demonstrate how the uplink epfd limit is met, the epfd formula of Equation (1) is used. Figure 5 shows an NGSO earth station transmitting to one of the satellites of the Telesat LEO Constellation as well as a GSO satellite communicating with a GSO earth station. The uplink discrimination angle (θ) is shown in Figure 5. In order to consider the worst case, it is assumed that the gain of the GSO satellite receive antenna toward its earth station is at its peak value and that the GSO earth station and the NGSO earth station are co-located, i.e., φ = 0 in Figure 5.

Every earth station of the Telesat LEO Constellation network may communicate with a LEO satellite only if that earth station and that satellite are at locations that result in a minimum uplink discrimination angle which would satisfy the uplink epfd limit of Article **22** of the ITU Radio Regulations. Table 8 shows the calculations of the minimum uplink discrimination angle (θ) required for complying with the uplink epfd limit. In Table 8 two earth station antennas have been considered: a 1 meter antenna and a 3.5 meter antenna, both meeting the antenna pattern of the ITU-R Recommendation S.1428-1. As mentioned earlier, the Telesat LEO Constellation will include a minimum of 117 operating satellites. For every satellite, at any given time, there will be a maximum of two co-frequency uplink signals transmitted toward that satellite (two-fold frequency reuse for each satellite). Therefore, at any given time, for a constellation of 117 satellites, the maximum number of co-frequency uplink signals transmitted by the Telesat LEO Constellation earth stations will not be more than 2 ×117 = 234, globally. Our simulation results show that no more than one third of the above earth stations will be visible by a geostationary satellite, and thus, for uplink epfd calculations in Equation (1), N_a is equal to 234/3 = 78. Another parameter that is essential in determining the required uplink discrimination angle is the maximum power spectral density fed into the transmitting earth stations. As shown in Table 8, the power spectral density of the signal fed into a transmitting earth station of the Telesat LEO Constellation will not exceed a value of -67 dB(W/Hz). From Table 8 it can be seen that in order to meet the uplink epfd limit of Article **22**, a minimum uplink discrimination angle of 11.9° is required.[7] The uplink discrimination angle is a function of the location of the LEO earth station and the direction of the LEO earth station antenna boresight. Every LEO earth station will be aware of its location (longitude and latitude) and the number of satellites in the constellation and will use software to calculate the range of directions which will satisfy the minimum uplink discrimination angle. Its boresight will operate only in that range.

[7] If a LEO earth station antenna is used that is not compliant with the ITU-R Recommendation S.1428-1, the maximum power spectral density of the signal fed into the antenna will be reduced from the -67 dB(W/Hz) value used in Table 8 so that the off-axis EIRP of the antenna at off-axis angles of 11.9° or larger does not exceed the level of -67 + (2.12) = -64.88 dB(W/Hz) to be consistent with Table 8 and meet the uplink epfd limit.

The software mentioned above will be part of the Radio Resource Management system. It should be noted that the calculations of Table 8 are for the worst case when the earth station operates at the peak flange power spectral density level of -67 dB(W/Hz) and the distance from the earth station to the GSO satellites is the lowest distance possible (i.e., 35786 km). In practice, the Radio Resource Management system will calculate the uplink discrimination angle based on the operating flange power spectral density levels, the number of earth stations visible from a geostationary satellite, and the distance from the LEO earth station to the visible geostationary arc.

Figure 5: Uplink epfd analysis

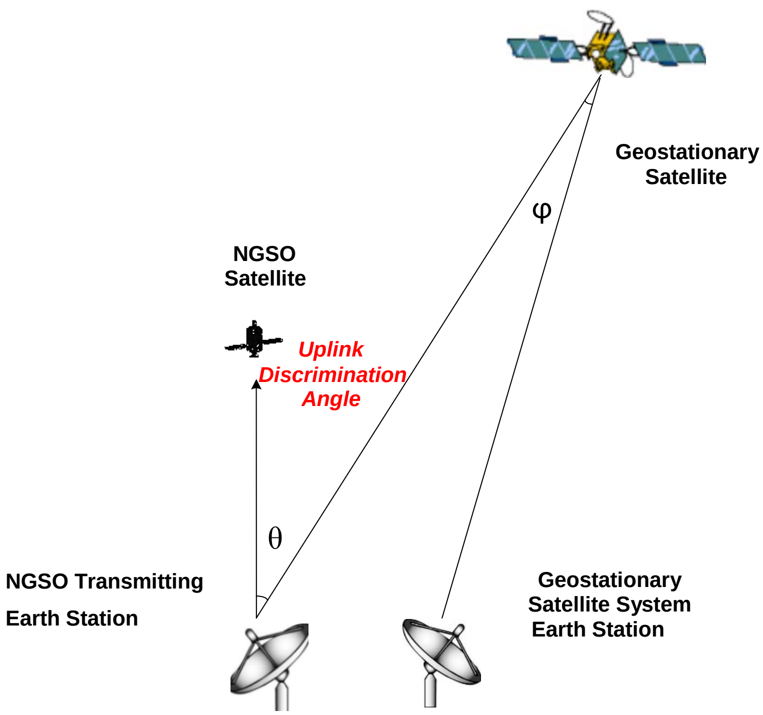


Table 8: Calculation of the uplink discrimination angle needed to meet the uplink epfd limit

NGSO earth station antenna diameter [m]	1	3.5
NGSO earth station antenna pattern	ITU-R Rec. S.1428	ITU-R Rec. S.1428
epfd limit for the constellation [dB(w/m^2/40 kHz)]	-162	-162
Maximum number of co-frequency operating NGSO earth stations visible by a GSO satellite	78	78
epfd limit for each satellite [dB(w/m^2/40 kHz)]	-180.9	-180.9
Minimum distance between the NGSO transmitting earth station and the GSO satellite [km]	35786	35786
Peak uplink power spectral density fed into the NGSO transmitting earth station [dB(W/Hz)]	-67	-67
Peak uplink power spectral density fed into the NGSO transmitting earth station [dB(W/40 kHz)]	-21.0	-21.0
D/λ for f=27.5 GHz	91.7	320.8
D/λ for f=30 GHz	100	350
$G_t(\theta)$ for f=27.5 GHz[dBi]	2.12	2.12
$G_t(\theta)$ for f=30 GHz[dBi]	2.12	2.12
θ [deg] for f=27.5 GHz	11.9	11.5
θ [deg] for f=30 GHz	11.9	11.5
Minimum uplink discrimination angle (θ) that should be met [deg]	11.9	

epfd limit at the geostationary orbit for downlink transmissions

For NGSO satellites that transmit toward the Earth in the frequency band 17.8 – 18.4 GHz, Article **22** of the ITU Radio Regulations requires that the epfd generated by the downlink transmissions of the NGSO satellites at any point in the GSO orbit meets a limit of -160 dB(W/m^2/40 kHz).[8] Table 9 shows the calculations of the power flux density generated by Telesat LEO Constellation satellites at the geostationary orbit. In order to consider the worst-case scenario, no gain discrimination has been considered for the geostationary satellite receiver antennas toward the LEO satellites, and the smallest distances possible between the LEO satellites and the geostationary orbit have been considered. The satellite transmit antenna toward the GSO arc from the Polar Orbit satellites will have a minimum discrimination of 15 dB from the peak gain when transmitting at the edge of the field-of-view with a high beam scanning angle. In the case of the LEO satellites from the inclined Orbit, moving along the equatorial orbit, beam transmissions will be in a North/South direction, away from the equator, generating PFD from the back-lobe towards the GSO arc. As a result, a higher antenna gain discrimination of 25 dB will be applicable to the Inclined Orbit satellites. Our simulation results show that from any location on the GSO arc, a maximum of 50 Polar Orbit satellites and a maximum of 30 Inclined Orbit satellites will be visible. These numbers have been used in the calculations of Table 9. From Table 9 it can be seen that under the worst case assumptions, the peak power flux density generated by all the satellites of the

[8] This is based on the TABLE 22-3 of the ITU Radio Regulations which has been provided in Annex 1.

Telesat LEO Constellation at any point in the geostationary orbit will not exceed -163.55 dB(W/m^2/40 kHz) and therefore the ITU limit of -160 dB(W/m^2/40 kHz) will be satisfied. It should be noted that the analysis presented above and in Table 9 corresponds to the worst-case assumption that all the LEO satellites visible by a GSO satellite will operate at peak downlink EIRP density and in the same frequency band. In addition, no discrimination by the GSO receive antenna toward the LEO satellites was considered. Thus, in practice, the epfd at any GSO satellite generated by the Telesat LEO Constellation will be smaller than the -163.55 dB(W/m^2/40 kHz) calculated in Table 9.

Table 9: Demonstration of compliance with the ITU epfd limit at the geostationary orbit for downlink transmissions

	Polar Orbits	Inclined Orbits
Satellite peak downlink EIRP density [dB(W/Hz)]	-50	-50
Satellite transmit antenna gain discrimination toward the GSO arc compared to the beam peak [dB]	15	25
Maximum satellite downlink EIRP density toward the GSO arc [dB(W/Hz)]	-65	-75
Geostationary orbit to Earth distance [km]	35786	35786
NGSO to Earth distance [km]	1000	1248
Minimum distance between NGSO satellite and the geostationary orbit [km]	34786	34538
Peak power flux density generated by each satellite at the geostationary orbit under worst-case assumption [dB(W/m^2/40 kHz)]	-180.8	-190.7
Maximum number of satellites in Polar Orbits or Inclined Orbits visible by a GSO satellite at any given time	50	30
Peak power flux density generated by all satellites of the Polar Orbits or Inclined Orbits at the geostationary orbit under the worst-case assumption [dB(W/m^2/40 kHz)]	-163.81	-175.97
Peak power flux density generated by all 117 satellites at the geostationary orbit under worst-case assumption [dB(W/m^2/40 kHz)]	-163.55	

A7. §25.145: Compliance with the coverage requirements

§25.145(c)(1)
The proposed system must be capable of providing Fixed-Satellite Service to all locations as far north as 70° North Latitude and as far south as 55° South Latitude for at least 75% of every 24-hour period.

The Telesat LEO Constellation will provide a global coverage using a minimum of 117 operating satellites in a minimum of 11 orbits, with each satellite having the capabilities that were described earlier. Telesat has simulated the operation of its LEO Constellation using a combination of Systems Tool Kit (STK) of Analytical Graphics Inc. (AGI)[9] and MATLAB.[10]

Figure 6 shows a two-dimensional view of the global coverage of the Telesat LEO Constellation. In Figure 6, each of the circles shown on the Earth represents the field of view from one LEO satellite. The field of view is defined as the area where an earth station can communicate with the satellite at a ground elevation angle of 10 degrees or more. The red circles correspond to the field of view of the satellites of the Inclined Orbits and the purple circles correspond to the field of view of the satellites of the Polar Orbits. The simulation results show that all locations between 55° South Latitude and 70° North Latitude will have access to the Telesat LEO Constellation at all times. Therefore, any location between 70° North Latitude and 55° South Latitude can be served 100% of the time and thus, the Telesat LEO Constellation will satisfy the requirement of §25.145(1).

§25.145(c)(2)
The proposed system must be capable of providing Fixed-Satellite Service on a continuous basis throughout the fifty states, Puerto Rico and the U.S. Virgin Islands.

The Telesat LEO Constellation will satisfy the requirements of §25.145(2).

Figure 7 shows the coverage of the U.S. fifty states plus Puerto Rico and U.S. Virgin Islands by the Telesat LEO Constellation. The circular cells in Figure 7 are of 560km diameter. A video of the simulated operation of Telesat LEO Constellation demonstrating the continuous coverage of the U.S. fifty states, the Virgin Islands and Puerto Rico is provided as an attachment which is submitted as part of this FCC application (the file name is "Telesat-Simulation.wmv") and it can be viewed using Windows Media Player. A snapshot of this video is shown in Figure 8. Ten snapshots of that video, showing the status of satellites every 1 minute, are also shown in Annex 3 of this document.

[9] https://www.agi.com
[10] https://www.mathworks.com

Figure 6: A view of global coverage of the Telesat LEO Constellation

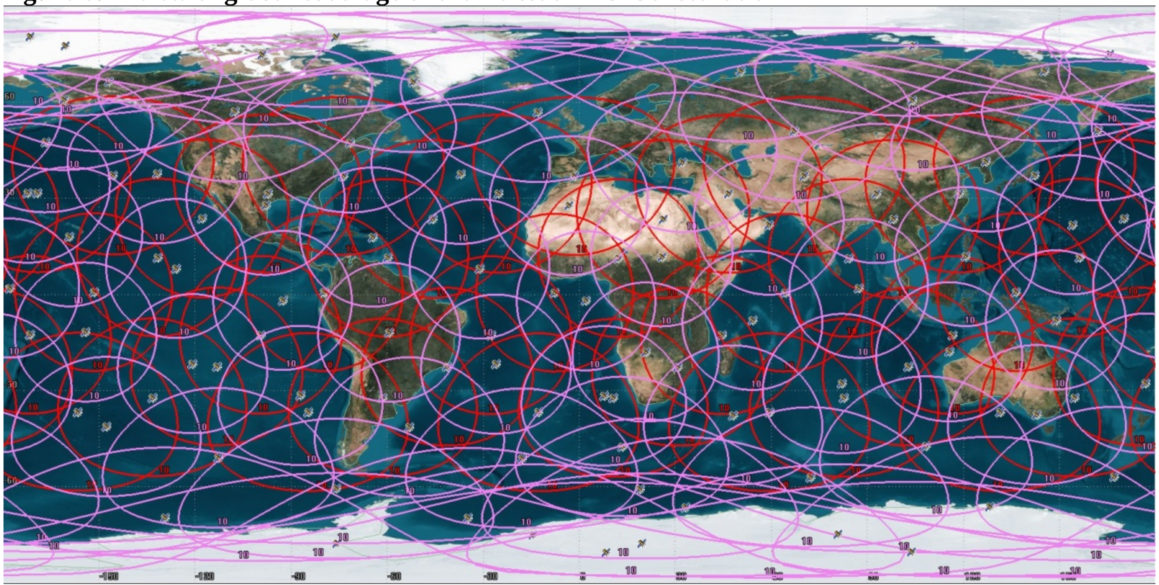


Figure 7: Coverage of the U.S. fifty states, Virgin Islands, and Puerto Rico

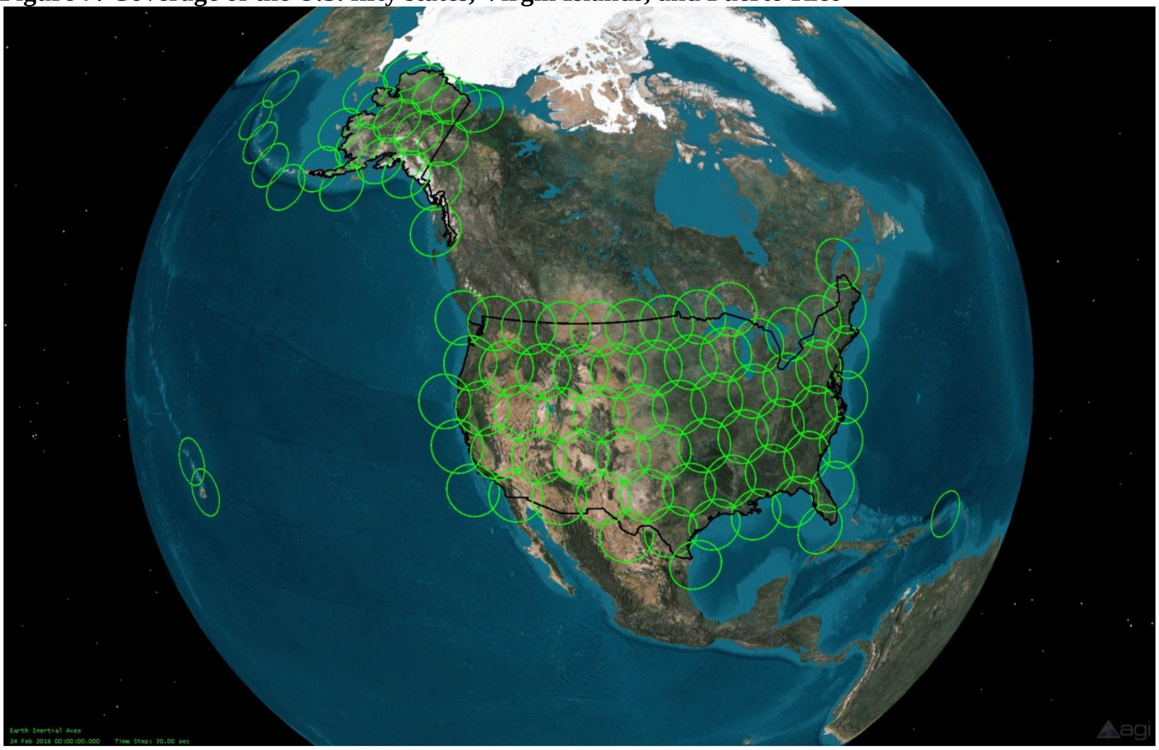
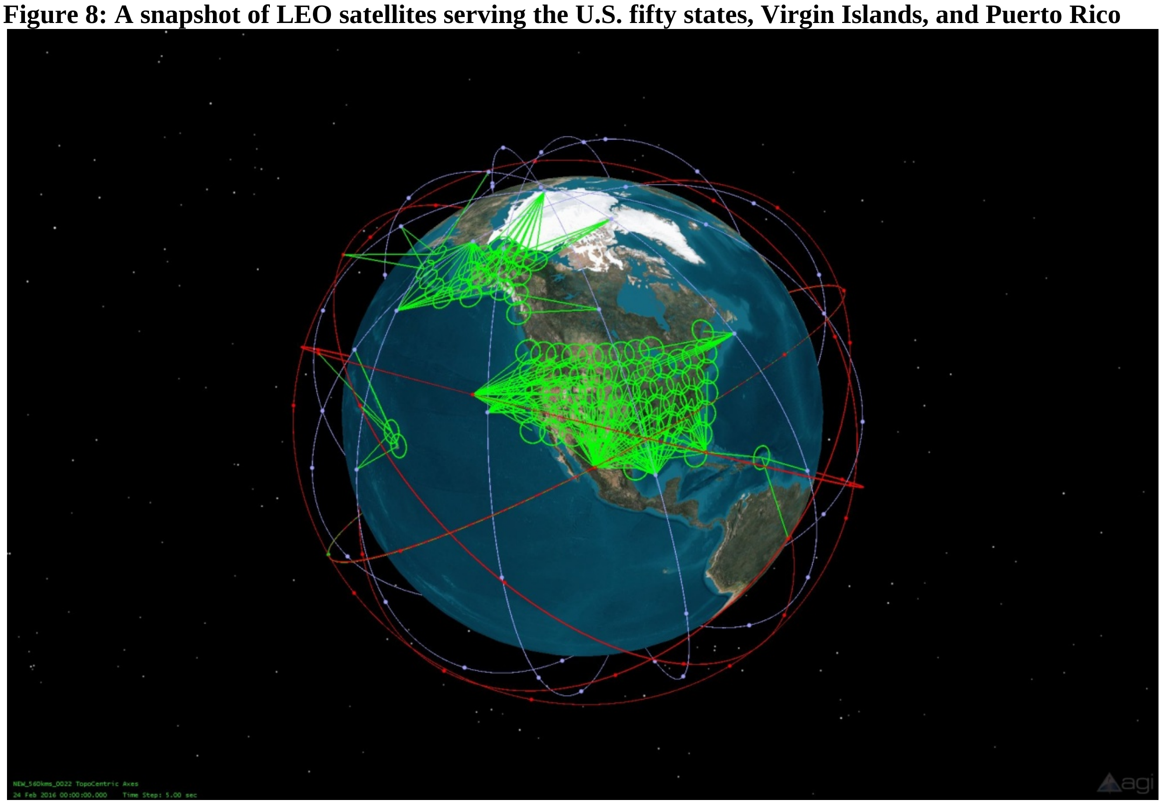


Figure 8: A snapshot of LEO satellites serving the U.S. fifty states, Virgin Islands, and Puerto Rico



A8. Link budgets

As mentioned earlier, the Telesat LEO Constellation will use on-board processing and therefore, uplink and downlink link budgets are analyzed independently. In order to make efficient use of the spectrum, the Telesat LEO Constellation will use adaptive modulation and coding based on the signal to noise plus interference ratio. Sample clear-sky uplink and downlink budgets for the Telesat LEO Constellation have been provided in Table 10 and Table 11, respectively. The adjacent satellite interference (ASI) from geostationary satellite networks has been estimated using our simulations with the following assumptions: every 2 degrees in the GSO arc a GSO satellite has been considered, the maximum uplink power spectral density input to the GSO earth station antennas has been assumed to be -56.5 dB(W/Hz), it has been assumed that the transmit GSO earth station antennas comply with the ITU-R Rec. S.1428 and have a D/λ between 25 and 100. Given the size of the beams used for the Telesat LEO Constellation, it has been assumed that associated with every GSO satellite there is one earth station transmitting in the same frequency band of the subject LEO earth station. No ASI has been considered from other non-geostationary satellite networks in the sample link budgets. It should be noted that the link budgets of Table 10 and Table 11 represent sample link budgets and in practice the Radio Resource Management system will select the proper modulation and coding scheme for each of the downlink and uplink communications based on the actual levels of noise and interference for that link.

Table 10: Sample clear-sky uplink link budgets

	Forward Link		Return Link	
Orbit type	Polar Orbit	Inclined Orbit	Polar Orbit	Inclined Orbit
TX Earth Station Location	Inuvik, NT, Canada (68.4N,133.7W)	Allan Park, ON, Canada (44.2N,80.9W)	Shishmaref, AK, USA (66.2N, 166.1W)	Bismarck, ND, USA (46.8N, 100.8W)
Emission Bandwidth [kHz]	10000	10000	10000	10000
Modulation type	256APSK 3/4	256APSK 31/45	256APSK 31/45	64APSK 4/5
Information (bit) rate [kbps]	60000	55111.1	55111.1	48000.0
FEC Rate	0.75	0.689	0.689	0.8
Frequency [GHz]	28.5	28.5	28.5	28.5
Earth Station antenna diameter [m]	3.5	3.5	1	1
Earth Station antenna gain [dBi]	58.8	58.8	47.3	47.3
Antenna feed flange power density [dB(W/Hz)]	-75.5	-75.5	-70	-70
Antenna feed flange power [dBW]	-5.5	-5.5	0	0
Earth Station antenna elevation angle [deg]	36.8	25.5	40	23.7
Earth Station to Satellite Distance [km]	1505	2254	1429.0	2341.0
Free-Space Loss [dB]	185.1	188.6	184.6	188.9
Satellite RX antenna gain towards the TX Earth Station [dBi]	31.5	31.5	36.5	36.5
Satellite Rx system noise temperature [K]	850	850	850	850
Atten. due to Atmospheric Gases [dB]	0.3	0.3	0.3	0.3
Thermal C/N [dB]	28.7	25.1	28.0	23.7
C/I (ASI from GSO networks) [dB]	29.6	22.9	23.1	20.2
C/I (Xpol) [dB]	25	25	25	25
C/I (IM) [dB]	25	25	25	25
C/(N+I) [dB]	20.6	18.4	18.9	17.0
Required C/(N+I) [dB]	19.6	18.1	18.1	15.9
Margin [dB]	1.0	0.3	0.8	1.1

Table 11: Sample clear-sky downlink link budgets

	Forward Link		Return Link	
Orbit type	Polar Orbit	Inclined Orbit	Polar Orbit	Inclined Orbit
RX Earth Station Location	Shishmaref, AK, USA (66.2N, 166.1W)	Bismarck, ND, USA (46.8N, 100.8W)	Inuvik, NT, Canada (68.4N,133.7W)	Allan Park, ON, Canada (44.2N,80.9W)
Emission Bandwidth [kHz]	10000	10000	10000	10000
Modulation type	32APSK 3/4	16APSK 25/36	128 APSK 3/4	64APSK 5/6
Information (bit) rate [kbps]	37500.0	27777.8	52500.0	50000
FEC Rate	0.750	0.694	0.750	0.833
Frequency [GHz]	18.5	18.5	18.5	18.5
Downlink EIRP density [dB(W/Hz)]	-52.5	-52.5	-50	-52.5
Downlink EIRP [dBW]	17.5	17.5	20	17.5
Earth Station antenna elevation angle [deg]	40	23.7	36.8	25.5
Earth Station to Satellite Distance [km]	1429.0	2341.0	1505.0	2254.0
Free-Space Loss [dB]	180.9	185.2	181.3	184.8
RX Earth Station antenna diameter [m]	1	1	3.5	3.5
RX Earth Station antenna gain [dBi]	43.5	43.5	55.1	55.1
RX Earth Station system noise temperature [K]	200	200	200	200
Atten. due to Atmospheric Gases [dB]	0.2	0.2	0.2	0.2
Thermal C/N [dB]	15.2	10.9	28.9	22.9
C/I (ASI from GSO networks) [dB]	32.9	29.9	48.3	39.3
C/I (Xpol) [dB]	25	25	25	25
C/I (IM) [dB]	20	20	20	20
C/(N+I) [dB]	13.6	10.2	18.4	17.3
Required C/(N+I) [dB]	12.7	9.3	17.7	16.6
Margin [dB]	0.9	1.0	0.7	0.8

A9. ITU filings and frequency coordination

The ITU filing administration for the Telesat LEO Constellation is Canada. The ITU networks listed in Table 12 have been licensed to Telesat by the Innovation, Science and Economic Development (ISED) Department of the Canadian government.

Table 12: Relevant ITU filings licensed to Telesat

Satellite Network	Special Section	IFIC/Published Date
COMMSTELLATION	CR/C/3313	2743 / 30.04.2013
	CR/C/3313 MOD-2	2806 / 27.10.2015
CANPOL-2	CR/C/3474 MOD-1	2800 / 04.08.2015
CANSAT-LEO	API/A/11755	2822 / 21.06.2016

Telesat will conduct frequency coordination for the Telesat LEO Constellation with the relevant radio services, including geostationary and non-geostationary satellite services in accordance with the relevant provisions of the ITU Radio Regulations. Telesat has already begun the frequency coordination of the Telesat LEO Constellation with various operators, including with O3b and with the U.S. government for GSO and NGSO satellite networks.

A10. Compliance with §25.202(g)

The frequency and bandwidth of the telemetry, tracking, and command (TT&C) signals of the Telesat LEO Constellation have been listed in the Schedule S. The on-axis and off-axis EIRP density levels of TT&C signals will not be more than the on-axis and off-axis EIRP density levels of the signals of the service links, in both the uplink and downlink directions. The methodology that is used for protecting other services applies identically to both the user communication signals and the TT&C signals. Therefore, the interference from the TT&C signals into other services will be at the same level as, or less than, the interference from the user communication traffic, and both the TT&C and the user communication will not cause any harmful interference into other services. The TT&C signals of the Telesat LEO Constellation also require no greater protection from harmful interference than the communications traffic. In addition, the operation of all frequency bands of the Telesat LEO Constellation satellite network, including the user traffic and the TT&C, will be coordinated in accordance with applicable FCC and international requirements.

A11. §25.114(d)(14): Description of the design and operational strategies that will be used to mitigate orbital debris

Telesat has been operating GSO satellites for more than 40 years during which multiple generations of its satellites have been retired and duly disposed of in the appropriate (graveyard) orbit to avoid adding debris to the GSO orbit. Telesat takes LEO orbital debris mitigation very seriously, as it plans to be a major operator of satellites in LEO orbits. Debris control and mitigation are stated requirements for our spacecraft design specifications. Telesat has always met the requirements of the regulatory bodies and intends to fully meet the debris mitigation requirements as provided below.[11]

§25.114(d)(14)(i), Debris Release Assessment. The Telesat LEO Constellation satellites will be designed so that during their normal operation they will release no debris. The appendage deployment release mechanisms will be designed so as to contain all debris within the mechanism. The materials on the outside will be chosen to be tolerant of radiation and thermal cycling/mechanical fatigue to ensure no release of extraneous material. Items that will not be built within the spacecraft nor shielded (e.g., antennas) will be able to withstand impacts by small debris and meteoroids. All critical components (e.g., computers and control devices) will be built within the structure and shielded from external influences to ensure the spacecraft remains in full control from the ground

§25.114(d)(14)(ii), Accidental Explosion Assessment. Telesat will review failure modes for all equipment to assess the possibility of an accidental explosion onboard the spacecraft. The spacecraft will be designed with redundancy considerations so that individual unit faults will not cause the loss of control of the spacecraft.

In order to pre-empt accidental explosion in orbit, Telesat will take specific precautions. All pressure vessels (pressurized propellant tanks, heat pipes, Lithium ion batteries etc.) on board will have the appropriate structural margins to failure as per the MIL-Spec requirements used in the industry. All batteries and fuel tanks will be monitored for pressure or temperature variations. The batteries will be operated utilizing a redundant automatic recharging scheme. Doing so will ensure that charging terminates normally without building up additional heat and pressure. Alarms in the Satellite Control Centre will inform controllers of any anomalous variations. Additionally, long-term trending analysis will be performed to monitor for any unexpected trends. On board fault protection will ensure the isolation of the affected units and their replacement with the

[11] According to Section 25.114(d)(14)(v) of the FCC rules, " For non-U.S.-licensed space stations, the requirement to describe the design and operational strategies to minimize orbital debris risk can be satisfied by demonstrating that debris mitigation plans for the space station(s) for which U.S. market access is requested are subject to direct and effective regulatory oversight by the national licensing authority." Telesat LEO Constellation is subject to the regulatory oversight of the Canadian licensing authority, Innovation, Science and Economic Development (ISED), with regard to the orbital debris mitigation plan. Nevertheless, given the importance of the issue, the orbital debris mitigation plan for Telesat LEO Constellation has been provided in this document.

back-up hardware/systems. As this process will occur within the spacecraft, it will also afford protection from command link failures (on the ground).

§25.114(d)(14)(iii), Assessment Regarding Collision with Larger Debris and Other Space Stations. Telesat has been operating geostationary satellites for many years and has been performing the station-keeping for its satellite fleet from its Satellite Control Centre in Ottawa, Ontario, Canada.

Telesat also has experience of operating non-geostationary LEO satellites. Specifically, since 2007 Telesat has been operating Radarsat-2 for MacDonald, Dettwiler and Associates Ltd. (MDA). Radarsat-2 is a LEO non-geostationary satellite at an altitude of 798 km.

Telesat will use its highly developed and tested station-keeping schemes to maintain the orbital parameters of the Telesat LEO Constellation satellites with a level of accuracy sufficient to avoid collision with other non-geostationary satellites.

In order to protect against collision with other orbiting objects, Telesat has been sharing ephemeris data with the Canadian Space Agency (CSA), the Joint Space Operations Center (JSpOC), MIT Lincoln Laboratory and the Space Data Center (SDC). The JSpOC and the CSA provide notifications to Telesat for any object they see approaching a Telesat satellite, together with assessments of whether avoidance maneuvers are required, and Telesat will maneuver its satellites accordingly.

For the LEO satellite Radarsat-2, Telesat has been working with the Canadian Space Agency to use Probability of Collision (PoC) analysis to determine the need for collision avoidance maneuvers.

Telesat will coordinate with other non-geostationary satellite networks to minimize the risk of collision between Telesat LEO Constellation satellites and any other NGSO satellite.

To further limit the potential for future collision, Telesat will continue to monitor new satellite launches to ensure that future satellites do not present a danger to the Telesat LEO Constellation satellites.

All the satellites of the Telesat LEO Constellation will have a propulsion system to maintain their orbit. The propulsion system on each satellite will also enable the satellite to make necessary maneuvers to avoid collision with any approaching object. Avoidance of other space objects will be achieved by the satellite firing its thrusters to adjust its position within its control box in order to avoid the other object. The clearance required between space objects is typically about 2 km, and this is significantly smaller than the allowable control box, so that the impact to the full mission is minimal or non-existent.

For orbit insertion, the spacecraft will be phased into the final orbits after release from the launcher, with due regard to the debris environment in the transition orbits. The maneuvers will be planned after appropriate conjunction analyses to ensure safe delivery into the operational orbit. By design, Telesat LEO satellites in both the Polar Constellation and Inclined Constellation will have a minimum close approach of 10 km with other satellites in the constellations. The orbits will be propagated a few days ahead and compared with the data from debris monitoring agencies so that appropriate collision avoidance maneuvers will be undertaken as necessary.

To ensure the above, the spacecraft can be controlled through the normal payload antennas and wide angle antennas as well as through Intersatellite Links. The likelihood of all of these receive paths being damaged by a collision is minimal. The wide-angle antennas on these spacecraft will be passive omni-directional antennas. (There will be one set on each side of the spacecraft and either set could be used to de-orbit the spacecraft.) These wide-angle antennas would continue to operate even if struck, ensuring control of the satellite.

§25.114(d)(14)(iv), Post-Mission Disposal Plans. At the end of life, each satellite will be de-orbited by re-entering the satellite into the Earth's atmosphere and burning.

The de-orbiting has two phases. In the first phase, the satellite will be moved from its operational orbit to a planned lower orbit, the "Decaying Lower Orbit". The Decaying Lower Orbit will be an orbit with an apogee of less than 1000 km and a perigee of not more than 550 km. Once the satellite is moved to this lower orbit, all stored energy sources onboard the satellite will be removed by venting the remaining propellant and the remaining helium pressurant. All propulsion lines and latch valves will be vented and left open. All battery chargers will be turned off and batteries will be left in a permanent discharge state. All momentum storage devices will be switched off. These steps will ensure that no buildup of energy can occur and eliminate the risk of explosion after the satellite has stopped operating. In the second phase, the satellite will be left in the Decaying Lower Orbit which, within 25 years, will result in the re-entry of the satellite into the Earth's atmosphere and burning of the satellite. (The design will be consistent with the requirement 4.7.-1 of NASA-STD 8719.14- Process for Limiting Orbit Debris.) Sufficient (worst case 3sigma) propellant will be budgeted for the de-orbit maneuvers to insert the spacecraft into the Decaying Lower Orbit which will ensure re-entry into the Earth's atmosphere and burning up of the satellite.

One of the critical requirements for the satellite design will be to ensure the materials, processes and assemblies are selected, designed, and integrated such that the probability of survival of spacecraft components through the re-entry into the Earth's atmosphere is extremely limited. The design will be assessed using NASA DAS (Debris Assessment Software) and modified as required to ensure that the human casualty risk resulting from the de-orbiting of the satellites is less than 1 in 10,000, in accordance with the applicable guidelines.

Annex 1

epfd limits of Article 22 of the ITU Radio Regulations

Table 13 to Table 18 show the epfd limits of Article **22** of the ITU Radio Regulations applicable to the frequency bands of Telesat LEO Constellation.

Table 13: Downlink epfd limits of TABLE 22-1B of Article 22 of the ITU Radio Regulations

Frequency band (GHz)	epfd↓ (dB(W/m²))	Percentage of time during which epfd↓ may not be exceeded	Reference bandwidth (kHz)	Reference antenna diameter and reference radiation pattern
17.8-18.6	−175.4 −175.4 −172.5 −167 −164 −164	0 90 99 99.714 99.971 100	40	1 m Recommendation ITU-R S.1428-1
	−161.4 −161.4 −158.5 −153 −150 −150	0 90 99 99.714 99.971 100	1 000	
	−178.4 −178.4 −171.4 −170.5 −166 −164 −164	0 99.4 99.9 99.913 99.971 99.977 100	40	2 m Recommendation ITU-R S.1428-1
	−164.4 −164.4 −157.4 −156.5 −152 −150 −150	0 99.4 99.9 99.913 99.971 99.977 100	1 000	
	−185.4 −185.4 −180 −180 −172 −164 −164	0 99.8 99.8 99.943 99.943 99.998 100	40	5 m Recommendation ITU-R S.1428-1

	−171.4 −171.4 −166 −166 −158 −150 −150	0 99.8 99.8 99.943 99.943 99.998 100	1 000	

Table 14: Downlink epfd limits of TABLE 22-1C of Article 22 of the ITU Radio Regulations

Frequency band (GHz)	epfd↓ (dB(W/m^2))	Percentage of time during which epfd↓ may not be exceeded	Reference bandwidth (kHz)	Reference antenna diameter and reference radiation pattern[7]
19.7-20.2	−187.4 −182 −172 −154 −154	0 71.429 97.143 99.983 100	40	70 cm Recommendation ITU-R S.1428-1
	−173.4 −168 −158 −140 −140	0 71.429 97.143 99.983 100	1 000	
	−190.4 −181.4 −170.4 −168.6 −165 −160 −154 −154	0 91 99.8 99.8 99.943 99.943 99.997 100	40	90 cm Recommendation ITU-R S.1428-1
	−176.4 −167.4 −156.4 −154.6 −151 −146 −140 −140	0 91 99.8 99.8 99.943 99.943 99.997 100	1 000	
	−196.4 −162 −154 −154	0 99.98 99.99943 100	40	2.5 m Recommendation ITU-R S.1428-1
	−182.4 −148 −140 −140	0 99.98 99.99943 100	1 000	

	−200.4 −189.4 −187.8 −184 −175 −164.2 −154.6 −154 −154	0 90 94 97.143 99.886 99.99 99.999 99.9992 100	40	5 m Recommendation ITU-R S.1428-1
	−186.4 −175.4 −173.8 −170 −161 −150.2 −140.6 −140 −140	0 90 94 97.143 99.886 99.99 99.999 99.9992 100	1 000	

Table 15: Downlink epfd limits of TABLE 22-4A1 of Article 22 of the ITU Radio Regulations

epfd↓ (dB(W/(m² · 40 kHz)))	Percentage of time during which epfd↓ may not be exceeded	Geostationary-satellite system receive earth station antenna diameter (m)
−182 −179 −176 −171 −168 −165 −163 −161.25 −161.25	99.9 99.94 99.97 99.98 99.984 99.993 99.999 99.99975 100	3
−185 −183 −179 −175 −171 −168 −166 −166	99.97 99.98 99.99 99.996 99.998 99.999 99.9998 100	10

Table 16: Downlink epfd limits of TABLE 22-4B of Article 22 of the ITU Radio Regulations applicable to Telesat LEO Constellation

Frequency band (GHz)	epfd↓ (dB(W/m^2))	Percentage of time during which epfd↓ may not be exceeded	Reference bandwidth (kHz)	Geostationary-satellite system receive earth station antenna gain (dBi)	Orbital inclination of geostationary satellite (degrees)
19.7-20.2	−157 −155	100 100	40 40	≥ 49 ≥ 49	≤ 2.5 > 2.5 and ≤ 4.5
19.7-20.2	−143 −141	100 100	1 000 1 000	≥ 49 ≥ 49	≤ 2.5 > 2.5 and ≤ 4.5
17.8-18.6	−164 −162	100 100	40 40	≥ 49 ≥ 49	≤ 2.5 > 2.5 and ≤ 4.5
17.8-18.6	−150 −148	100 100	1 000 1 000	≥ 49 ≥ 49	≤ 2.5 > 2.5 and ≤ 4.5

Table 17: Uplink epfd limits of TABLE 22-2 of Article 22 of the ITU Radio Regulations in the applicable frequency bands of Telesat LEO Constellation

Frequency band	epfd↑ (dB(W/m^2))	Percentage of time epfd↑ level may not be exceeded	Reference bandwidth (kHz)	Reference antenna beamwidth and reference radiation pattern
27.5-28.6 GHz	−162	100	40	1.55° Recommendation ITU-R S.672-4, *Ls* = −10
29.5-30 GHz	−162	100	40	1.55° Recommendation ITU-R S.672-4, *Ls* = −10

Table 18: Inter-satellite epfd limits of TABLE 22-3 of Article 22 of the ITU Radio Regulations in the applicable frequency bands of Telesat LEO Constellation

Frequency band (GHz)	$epfd_{is}$ (dB(W/m^2))	Percentage of time during which $epfd_{is}$ level may not be exceeded	Reference bandwidth (kHz)	Reference antenna beamwidth and reference radiation pattern
17.8-18.4	−160	100	40	4° Recommendation ITU-R S.672-4, *Ls* = −20

Annex 2

The antenna pattern of the ITU-R Recommendation S.1428

The antenna pattern of the ITU-R Recommendation S.1428-1 is shown below.

for $20 \le \frac{D}{\lambda} \le 25$:

$G(\varphi) = G_{max} - 2.5 \times 10^{-3} \left(\frac{D}{\lambda}\varphi\right)^2$ dBi for $0 < \varphi < \varphi_m$

$G(\varphi) = G_1$ for $\varphi_m \le \varphi < \left(95\frac{\lambda}{D}\right)$

$G(\varphi) = 29 - 25 \log \varphi$ dBi for $95\frac{\lambda}{D} \le \varphi < 33.1°$

$G(\varphi) = -9$ dBi for $33.1° < \varphi \le 80°$

$G(\varphi) = -5$ dBi for $80° < \varphi \le 180°$

for $25 < \frac{D}{\lambda} \le 100$:

$G(\varphi) = G_{max} - 2.5 \times 10^{-3} \left(\frac{D}{\lambda}\varphi\right)^2$ dBi for $0 < \varphi < \varphi_m$

$G(\varphi) = G_1$ for $\varphi_m \le \varphi < \left(95\frac{\lambda}{D}\right)$

$G(\varphi) = 29 - 25 \log \varphi$ dBi for $95\frac{\lambda}{D} \le \varphi \le 33.1°$

$G(\varphi) = -9$ dBi for $33.1° < \varphi \le 80°$

$G(\varphi) = -4$ dBi for $80° < \varphi \le 120°$

$G(\varphi) = -9$ dBi for $120° < \varphi \le 180°$

where:

D: antenna

λ: wavelength expressed in the same unit*

φ: off-axis angle of the antenna (degrees)

$G_{max} = 20 \log \left(\frac{D}{\lambda}\right) + 7.7$ dBi

$G_1 = 29 - 25 \log \left(95\frac{\lambda}{D}\right)$

$\varphi_m = \frac{20\lambda}{D}\sqrt{G_{max} - G_1}$ degrees for $\frac{D}{\lambda} > 100$:

$$G(\varphi) = G_{max} - 2.5 \times 10^{-3}\left(\frac{D}{\lambda}\varphi\right)^2 \quad \text{dBi} \qquad \text{for } 0 < \varphi < \varphi_m$$

$$G(\varphi) = G_1 \qquad \text{for } \varphi_m \le \varphi < \varphi_r$$

$$G(\varphi) = 29 - 25 \log \varphi \quad \text{dBi} \qquad \text{for } \varphi_r \le \varphi < 10°$$

$$G(\varphi) = 34 - 30 \log \varphi \quad \text{dBi} \qquad \text{for } 10° \le \varphi < 34.1°$$

$$G(\varphi) = -12 \quad \text{dBi} \qquad \text{for } 34.1° \le \varphi < 80°$$

$$G(\varphi) = -7 \quad \text{dBi} \qquad \text{for } 80° \le \varphi < 120°$$

$$G(\varphi) = -12 \quad \text{dBi} \qquad \text{for } 120° \le \varphi \le 180°$$

where:

$$G_{max} = 20 \log\left(\frac{D}{\lambda}\right) + 8.4 \quad \text{dBi}$$

$$G_1 = -1 + 15 \log \frac{D}{\lambda} \quad \text{dBi}$$

$$\varphi_m = \frac{20\,\lambda}{D}\sqrt{G_{max} - G_1} \quad \text{degrees}$$

$$\varphi_r = 15.85\left(\frac{D}{\lambda}\right)^{-0.6} \quad \text{degrees}$$

Annex 3

Snapshots of the video demonstrating the continuous serving of the U.S. fifty states, Virgin Islands, and Puerto Rico

A sample video of the simulated operation of the Telesat LEO Constellation demonstrating the continuous service to the U.S. fifty states, Virgin Islands, and Puerto Rico has been provided as an attachment to this FCC application (the file name is "Telesat-Simulation.wmv"). The video can be viewed using Windows Media Player. Ten snapshots of that video, showing the status of satellites every 1 minute, are shown in the figures below.

Figure 9: The first snapshot (Telesat LEO Constellation satellites serving the U.S. fifty states, Virgin Islands, and Puerto Rico)

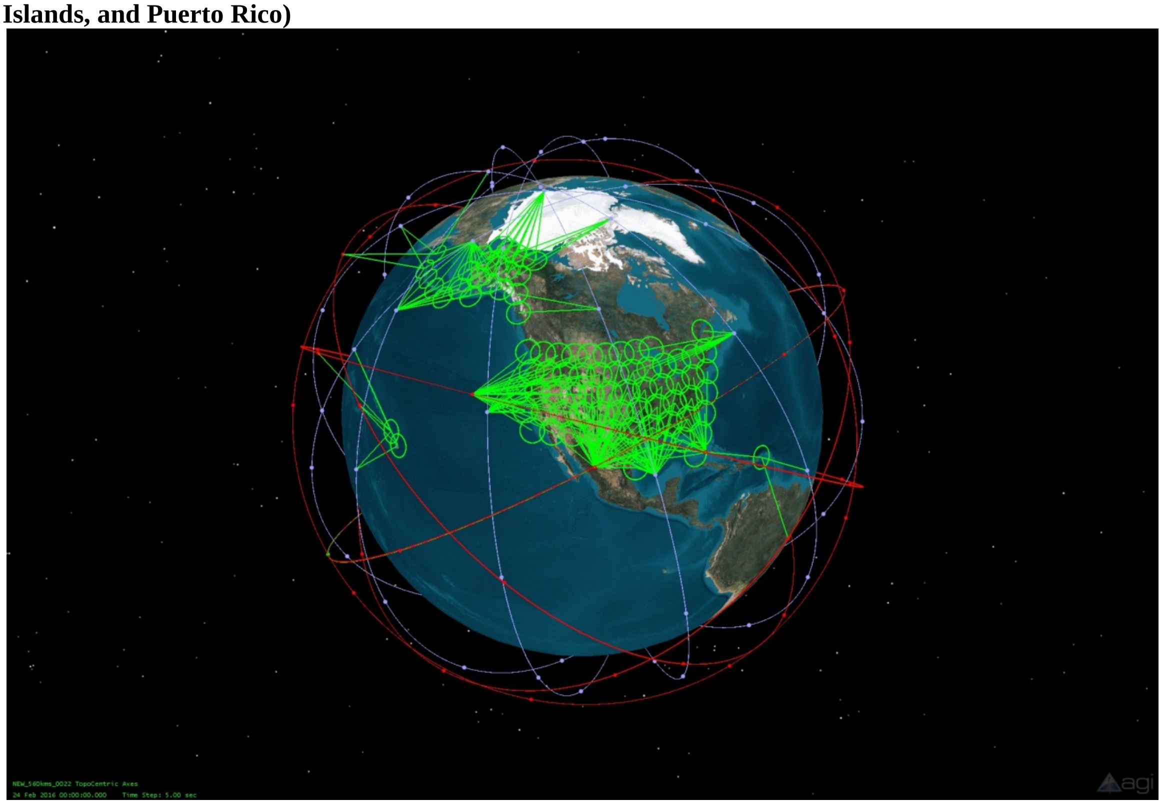


Figure 10: The second snapshot (1 minute after the first snapshot)

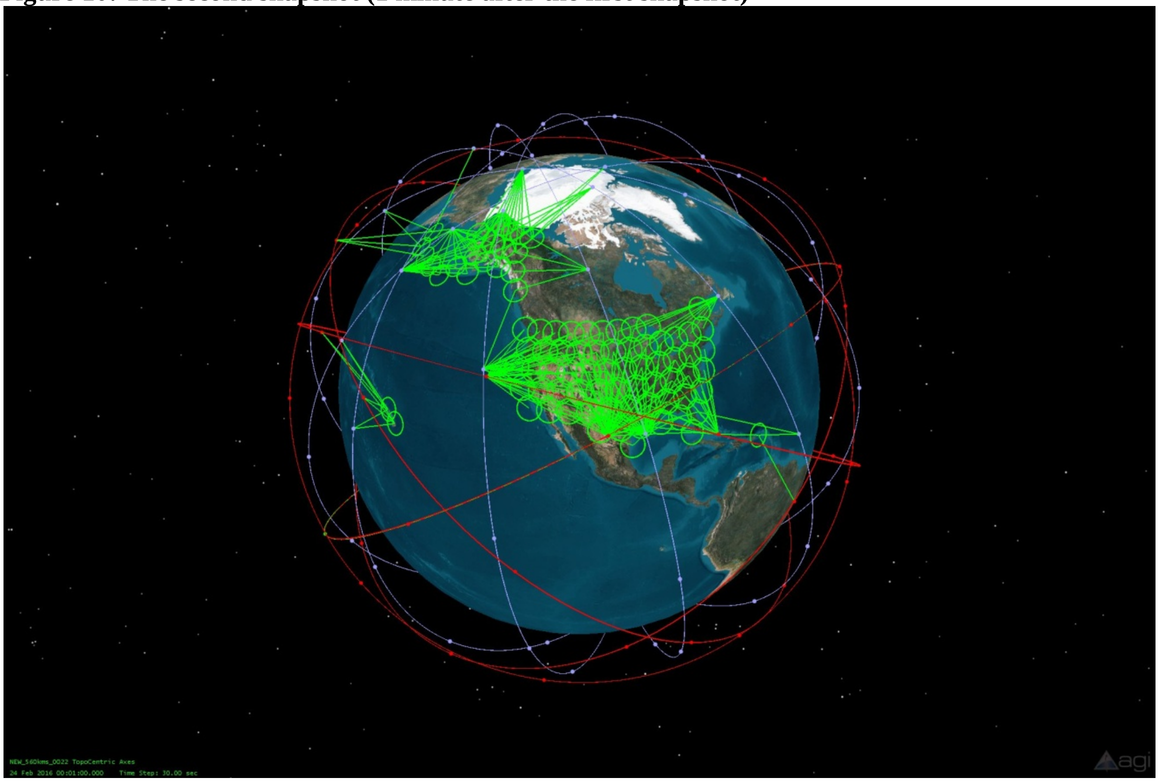


Figure 11: The third snapshot (2 minutes after the first snapshot)

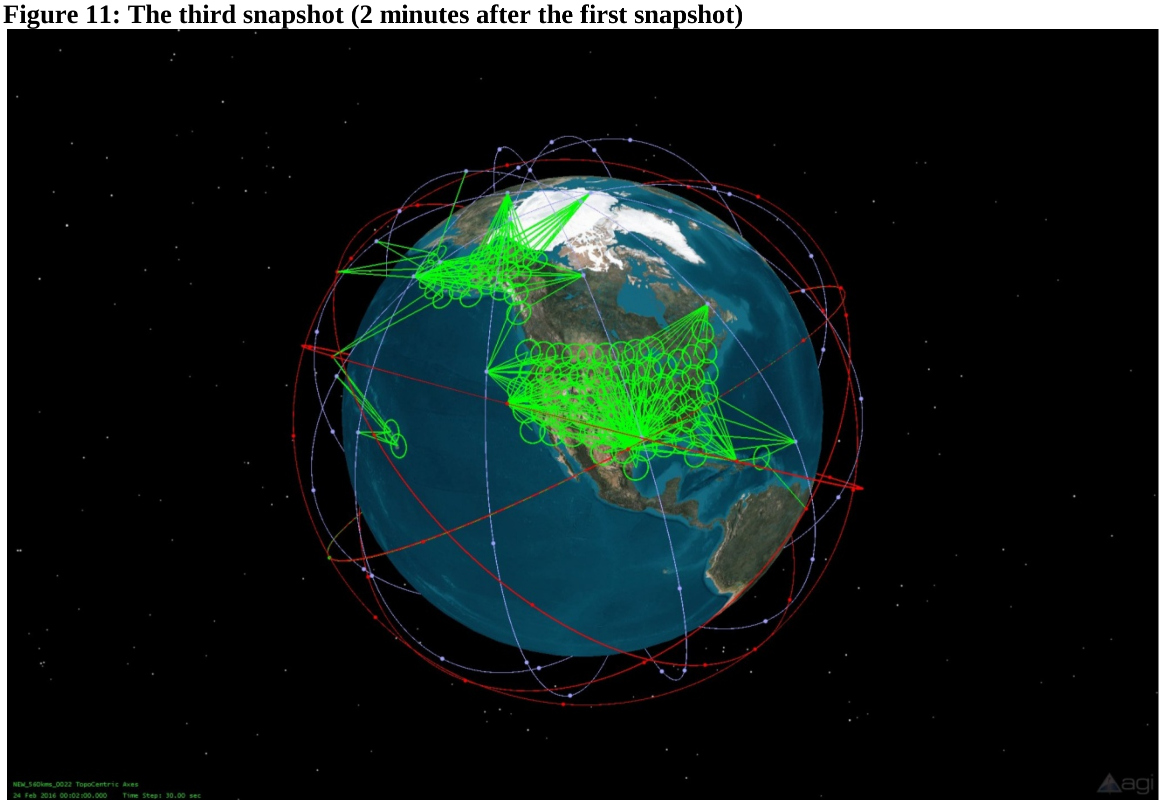


Figure 12: The forth snapshot (3 minutes after the first snapshot)

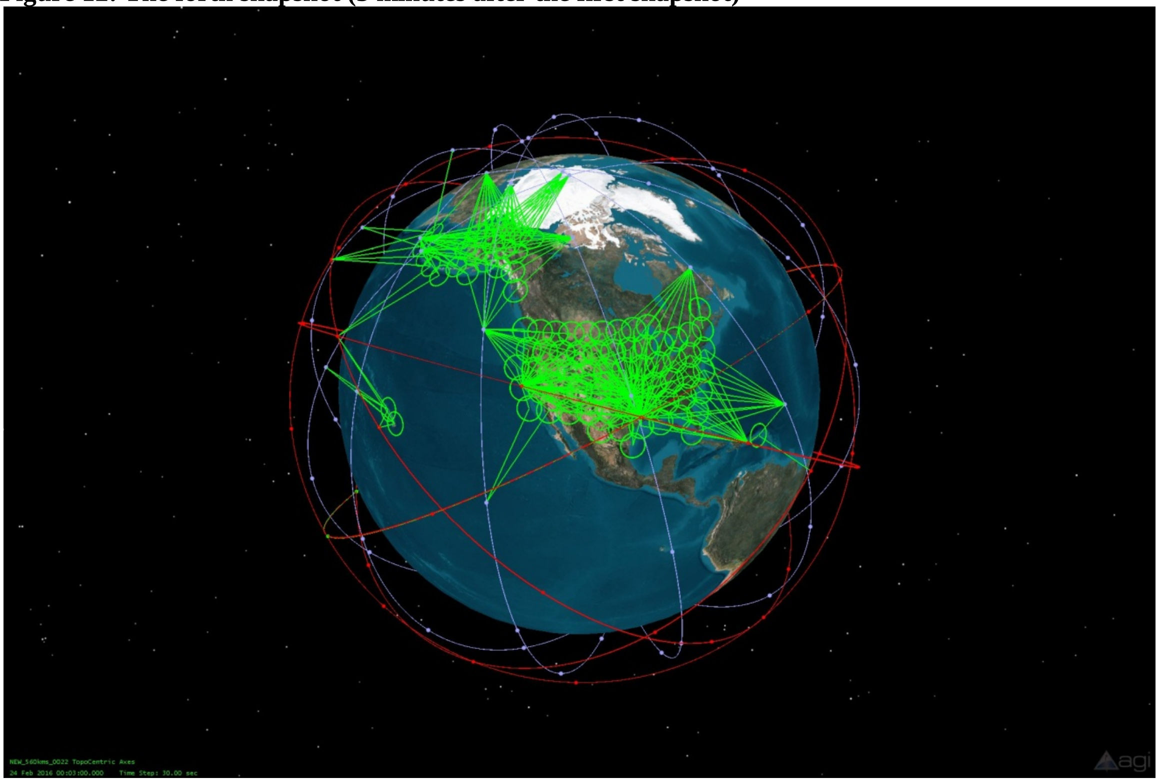


Figure 13: The fifth snapshot (4 minutes after the first snapshot)

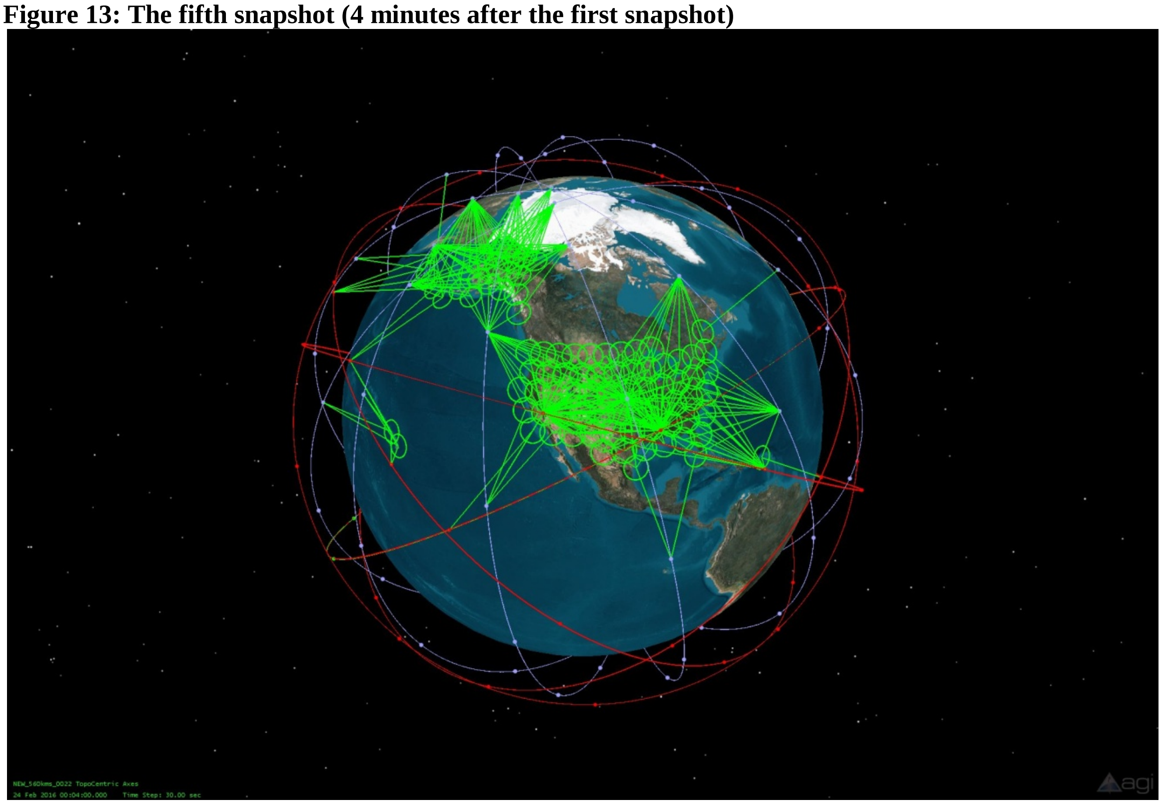


Figure 14: The sixth snapshot (5 minutes after the first snapshot)

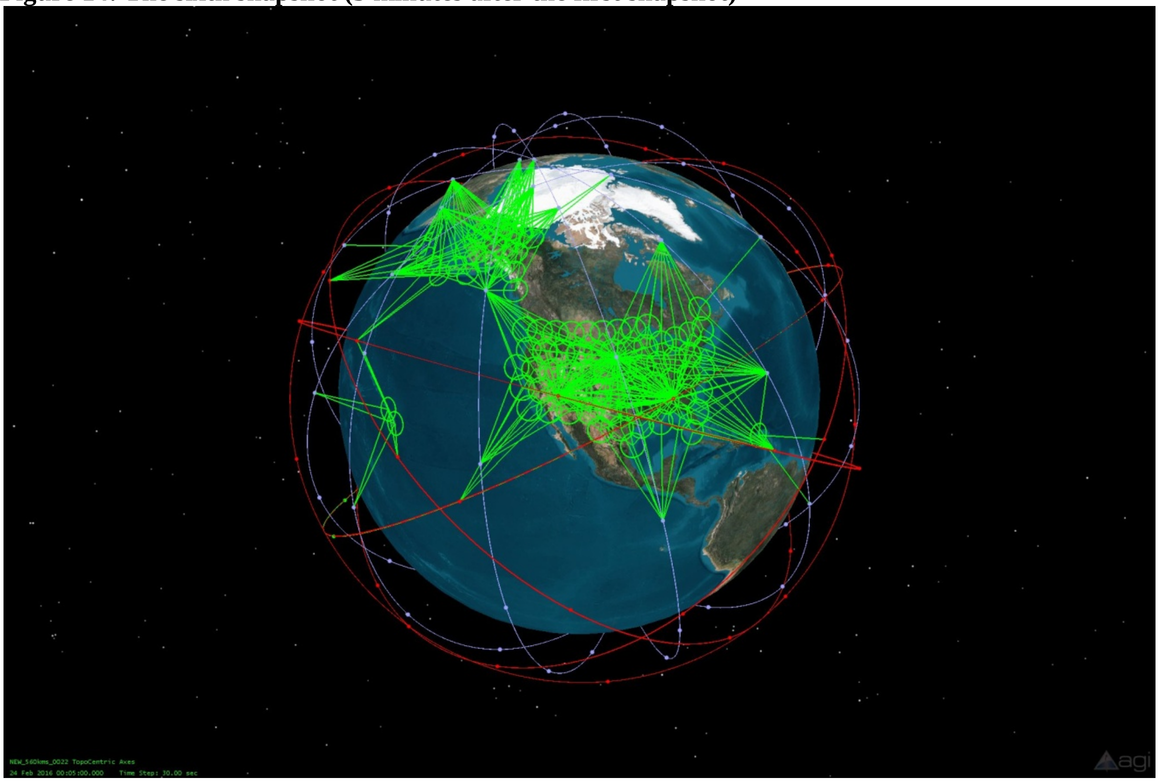


Figure 15: The seventh snapshot (6 minutes after the first snapshot)

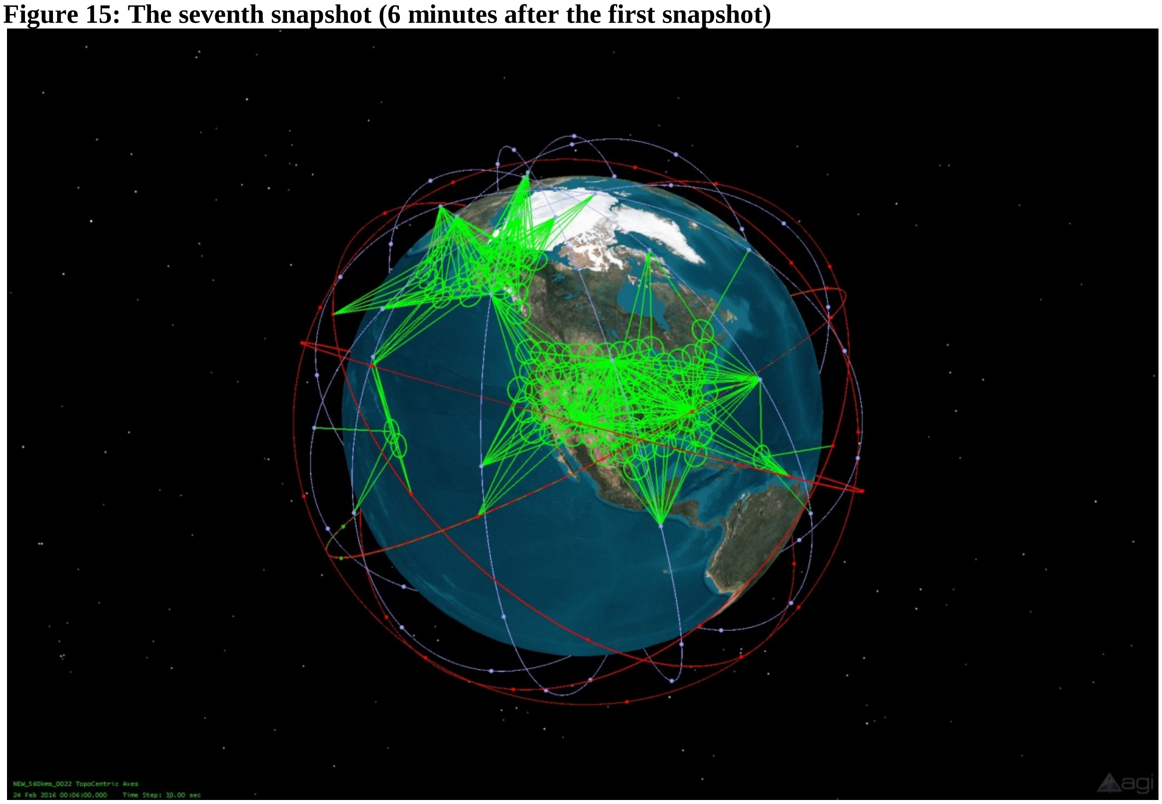


Figure 16: The eighth snapshot (7 minutes after the first snapshot)

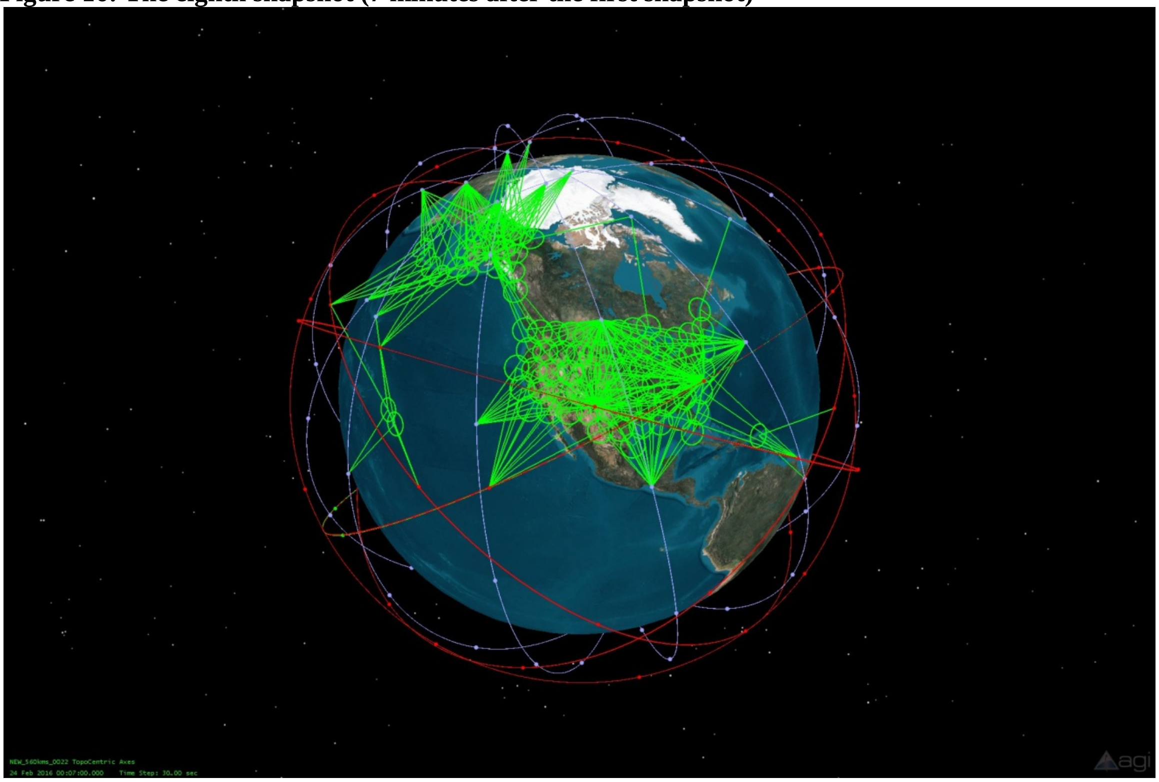


Figure 17: The ninth snapshot (8 minutes after the first snapshot)

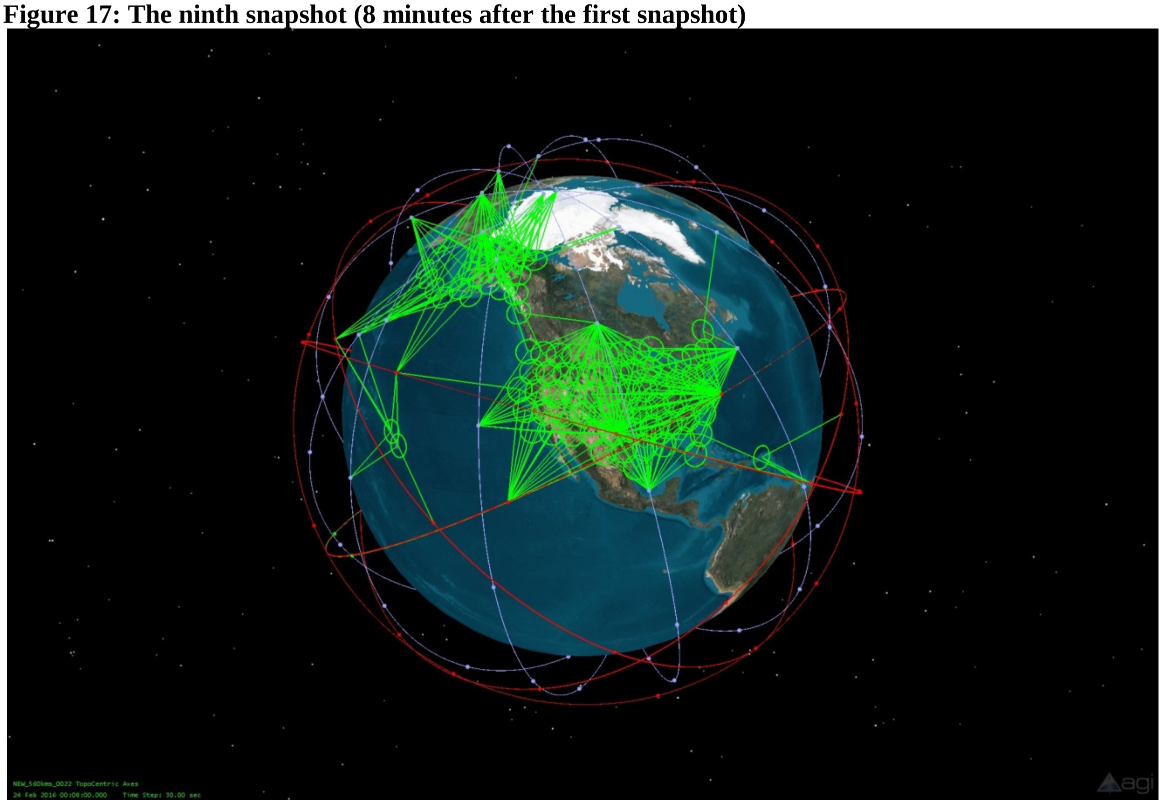
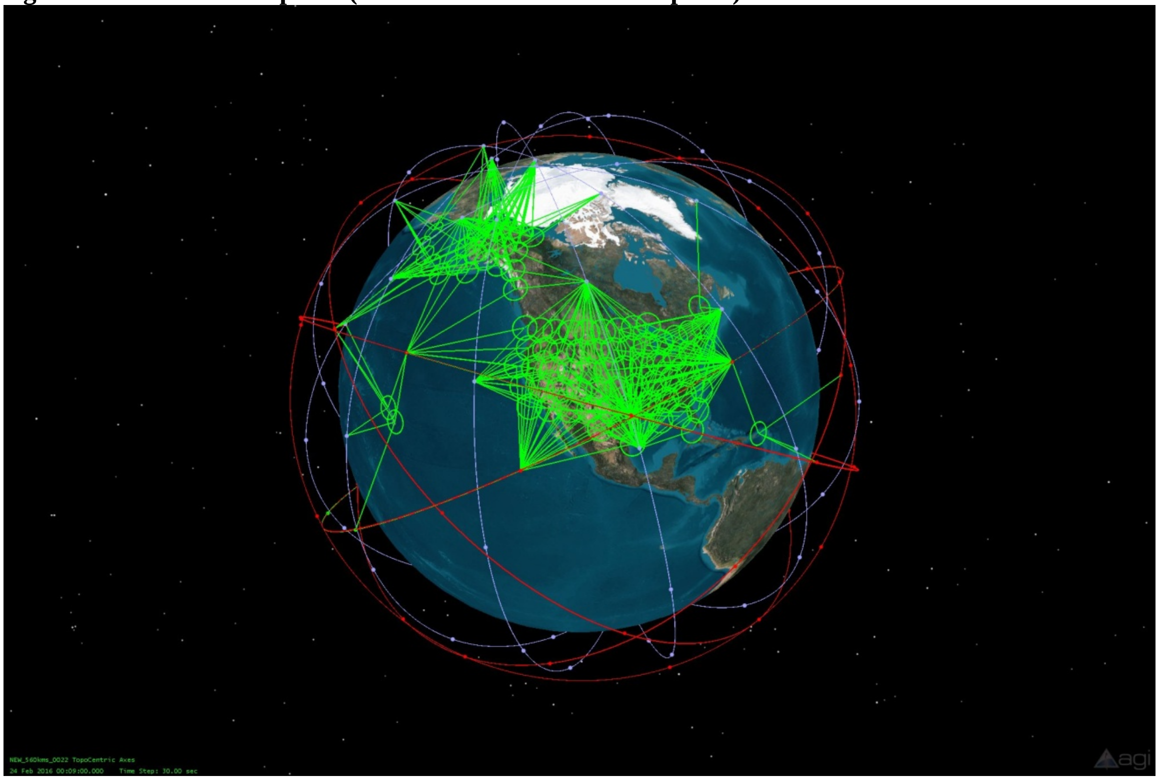


Figure 18: The tenth snapshot (9 minutes after the first snapshot)



CERTIFICATION OF PERSON RESPONSIBLE FOR PREPARING ENGINEERING INFORMATION

I hereby certify that I am the technically qualified person responsible for preparation of the engineering information contained in this application, that I am familiar with Part 25 of the Commission's rules, that I have either prepared or reviewed the engineering information submitted in this application and that it is complete and accurate to the best of my knowledge and belief.

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