BEFORE THE

FEDERAL COMMUNICATIONS COMMISSION

Washington D.C. 20554

LETTER OF INTENT

OF

New Spectrum Satellite, Ltd

TECHNICAL NARRATIVE

A GLOBAL FIXED-SATELLITE SERVICE SYSTEM EMPLOYING NONGEOSTATIONARY SATELLITES IN SUB-GEOSYNCHRONOUS ELLIPTICAL ORBITS

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July 26, 2017

EXECUTIVE SUMMARY

New Spectrum Satellite, Ltd ("NSS") hereby files this Letter of Intent for in order to participate in the Commission's most recent processing round for NGSO-like satellite systems, *Public Notice*, DA 17-524 (May 26, 2017). CNSP has initiated the process for licensing of its satellite system by Canada prior to this filing.

The state-of-the-art satellite system of fifteen (15) non-geostationary satellites in sub-geosynchronous inclined elliptical orbits utilizes a satellite system design that the Commission previously reviewed and authorized for NSS's affiliate, Virtual Geosatellite, LLC.[1] NSS's proposed satellite system, called Virtual Geo™, will provide fixed-satellite services to all of the world's populated land masses through a combination of user and gateway links in the C, Ku and Ka-bands, as well as through inter-satellite links in the optical frequencies.[2] Virtual Geo is the core of a novel, advanced, hybrid solution for a world-wide content delivery network (CDN) aimed at providing state-of-the-art services now and in the future to users in the United States and world-wide.

The initial fifteen-satellite constellation is part of a global infrastructure utilizing elliptical orbits that could ultimately include 300 or more satellites – deployed and owned by various operators. Use of similarly designed elliptical orbits can replicate the entire

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1 Virtual Geosatellite, LLC, 21 FCC Rcd 14687 (2006). Virtual Geosatellite subsequently surrendered that authorization due to adverse economic conditions at that time. *See*, Letter from Stephen D. Baruch to Marlene H. Dortch, dated February 5, 2007.

2 The *Public Notice* invited additional applications in the 12.75-13.25 GHz, 13.85-14.0 GHz, 18.6-18.8 GHz, 19.3-20.2 GHz, and 29.1-29.5 GHz bands. NSS is seeking authority in this application for some of these bands, but will operate in additional bands, including the C-band, outside of the United States. NSS also intends to operate in the C-band for the launch and early operations phase, and may operate gateways and subscriber links using C-band spectrum in the United States. NSS will operate in these additional bands within the United States only if such usage is specifically authorized by the Commission. In light of the *Public Notice*, it is not clear whether the Commission will grant NSS C-band authority in this application, or whether such authorization will a separate earth station or Petition for Declaratory ruling application. In any event, NSS is including information on the C-band operations to provide a more complete picture of the proposed satellite system.

geostationary belt, reutilizing ALL frequencies already attributed to all the GEOs, worldwide. This ground breaking achievement is the result of Virtual Geo's unique architecture, as perfected in the intervening years since FCC licensing of the original Virtual Geosatellite, LLC system.

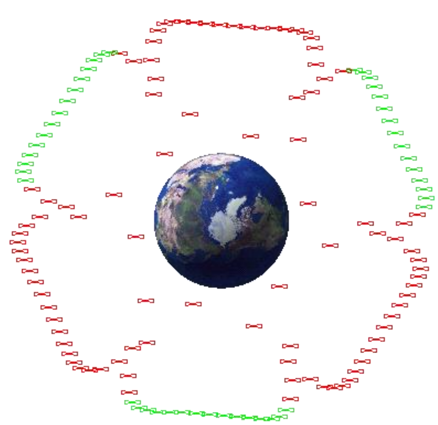
The Virtual Geo concept resides on the key characteristics that all operating portions of the elliptical orbit occur when the satellite is at an angular separation from the geostationary circle of at least 40 degrees. As a result, spectrum reutilization of all frequencies previously allocated to fixed geostationary-based satellite service would be possible.

Since the original licensing by the Commission, the satellite system design has been refined to incorporate advances in satellite technologies. In particular, a better and more efficient use of the modulation scheme than originally authorized, combined with a more judicious placement of gateway stations – in itself much more flexible than for other systems because of the unique architecture – should provide additional capacity with equal or lower interference. Moreover, novel constellation characteristics should allow a robust approach to interference protection from other NGSOs, in a manner similar to that achieved to and from the GEOs, inherent to the Virtual Geo constellation architecture.

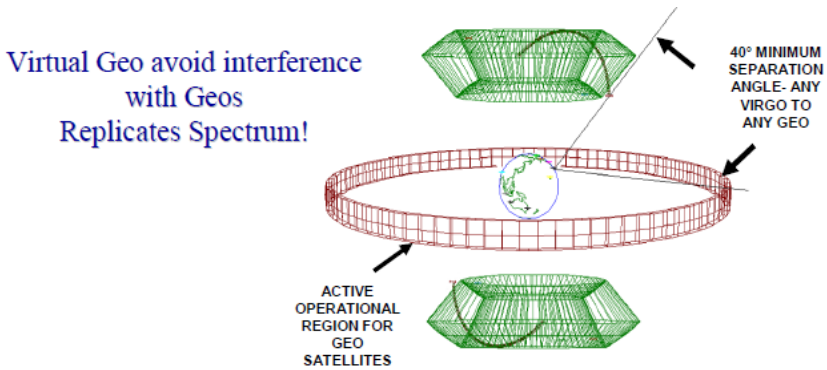
Upon deployment, Virtual Geo will therefore be the first of a new class of constellation systems that are virtually geo-synchronous. Unlike geostationary systems or so-called "quasi-geostationary" systems in which the individual satellites attempt to follow the Earth, all of the satellites in a virtual geostationary system, as a whole, follow the Earth in unique geosynchronous ground tracks. It is this feature which gives this constellation type the name "virtual geo." Of importance and as previously demonstrated to the Commission is the fact that several virtual geo systems can operate interference-free from the each other and the GEOs, a welcome feature that could simplify spectrum management in the current crowded field of NGSO proponents.

Unique features

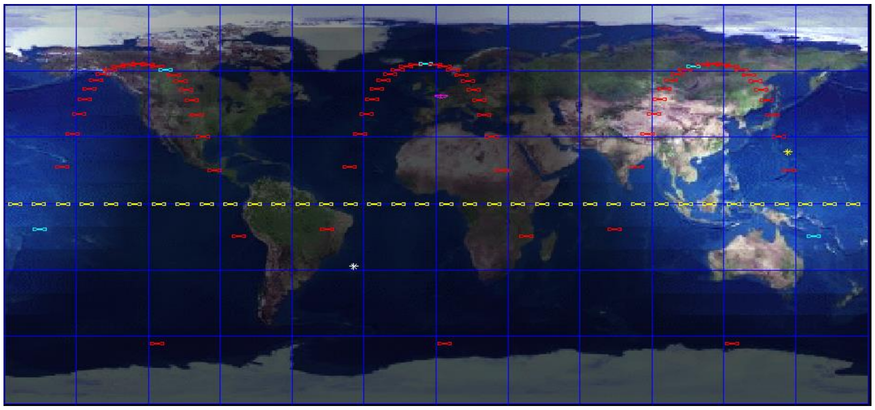
Using a continent-following orbital configuration that is covered by issued and pending patents, the Virtual Geo constellation, though operating at non-geostationary altitudes, will appear virtually geostationary to users within the system's coverage area. Virtual Geo is comprised of three five-satellite sub-constellations – two for Northern Hemisphere operation (and identified herein as "Aurora I™" and Aurora II™") and one for Southern Hemisphere operation (identified herein as "Australis™"). In the diagram below which shows a polar view of such a configuration with as an example 45 such slots (only five are required for full-time hemispheric coverage per system), several satellite positions – the "virtual slots" – form the "petals" around the earth. A satellite enters and exits these "petals" by following its own individual orbit, the "petals" being the locci of the potential apogees of the orbits, and thus representing the region of activity with the orbits, or the "active arcs." The "petals" rotate at the same rate as the earth. Hence a virtual geostationary effect is obtained for the constellation as a whole.



In order to maintain a stable position of the apogees, the orbits are inclined at the critical inclination of 63.4°, and when this is combined with the active arc operating parameters, it provides a key feature for this class of satellite – a more than 40° of angular separation with the equatorial GEO orbital arc. This wide separation allows the complete reuse of all frequencies previously allocated to GEO's on a non-interfering basis, as illustrated below:



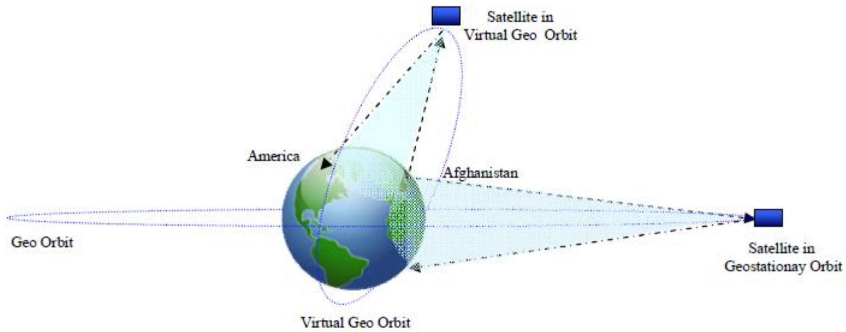
Built around a set of uniform orbits achieved through the deployment of satellites in specific individual orbits, Virtual Geo achieves a continent-following orbital configuration that is unique in the industry. As a result, though operating at non-geostationary altitudes – the mean altitude is 60% that of Geo's – the Virtual Geo tracks appear geostationary to users within the system's coverage area – hence virtual geo. The diagram below illustrates five northern apogee satellites following the locci within the fixed ground tracks around apogee (active arcs):



The active arcs of the Virtual Geo satellites occur only when the satellites are at latitudes above 42 degrees, when they are at high elevations over much of their primary service areas in the Northern (and respectively Southern) Hemisphere. The design of the constellation provides an optimized combination of very high elevation angles, low signal propagation delays compared to geostationary satellites, and limited satellite handoffs. Each satellite remains in an active arc for 4 hours and 48 minutes. A 5 satellite constellation will provide continuous 24 hour coverage to the US and to two other Northern active arcs in other parts of the world. Moreover, propagation delay, end-to-end, will be comparable or superior to systems operating at much lower altitudes, as the large footprint of Virtual Geo permits single hop operation over wide areas, including as noted below, over an entire hemisphere.

As mentioned, two beneficial effects of this architecture are 1) the system can be deployed in phases a ground track at a time (the Northern hemisphere first, the globe thereafter), thus reducing business risk and capital requirements; and 2) when fully deployed, Virtual Geo provides non-uniform distribution of capacity to the Northern and Southern Hemispheres in proportion with expected demand.

As mentioned above, a unique feature of Virtual Geo is that it permits single hop communications within a hemisphere, due to the position of the virtual geo arc in the high latitude areas, as illustrated below:



Coordination with GEO's and other NGSO's

Virtual Geo operates in a manner that is effectively transparent to the geostationary fixed-satellite service ("FSS") with which it will operate on a co-primary and fully compatible basis. And like FSS satellites, the Virtual Geo satellites can also readily be coordinated with terrestrial fixed services. Although sharing between Virtual Geo and other types of NGSO systems is more complex than sharing with either GEO networks or fixed service systems, with proper coordination and a multilateral commitment to interference mitigation – as established by the Commission in its NGSO Rule Making Order[3] – co-frequency operation among several inhomogeneous non-geostationary FSS systems is attainable. The Commission previously established the criteria for coexistence between circular NGSOs and Virtual Geo.[4]

Since the Virtual Geo satellites are separated from the geostationary arc by at least 40° at all times within the system's active service areas, Virtual Geo not only fully protects current geostationary FSS networks, but it also leaves those geostationary satellite system operators an

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3 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*, 17 FCC Rcd 7841 (2002) (*Ku-band NGSO FSS Service Rules Order);* Amendment of Parts 2 and 25 of the Commission's Rules to Permit Operation of NGSO FSS Systems Co-Frequency with GSO and Terrestrial Systems in the Ku-band Frequency Range, *Third Memorandum Opinion and Order*, 18 FCC Rcd 2307 (2003) (*Third Order).*

4 *Ku-band NGSO FSS Service Rules Order* at ¶¶ 39-55.

effectively unfettered opportunity to evolve their technologies to meet their own future service requirements.

In its full implementation, Virtual Geo is capable of providing continuous coverage of all points on the globe from Pole to Pole. This includes capacity focused on all of the world's populated land masses via the purposely designed location of the Virtual Geo orbits' apogees (the "fixed" apogees are centered around a preferred continental mass, thus providing the geo effect). This design maximizes capacity available to <u>all</u> of the US and Canada and key Northern Hemisphere locations such as the continental North America, Hawaii, Europe, Northern Africa and Asia.

Virtual Geo will operate in the United States with user links in the 14.0-14.5 GHz band (Earth-to-space) and in the 11.2-12.7 GHz band (space-to-Earth), and with gateway links in the 12.75-13.25 GHz, 13.8-14.0 GHz, 17.8-18.6 GHz and 5.925-6.725 GHz bands (Earth-to-space) and the 10.7-12.7 GHz and 3.7-4.2 GHz bands (space-to-Earth).

Each Virtual Geo satellite provides "bent pipe" communications channels in these bands, and achieves a frequency reuse factor of up to fourteen times in some frequency bands through the use of dual orthogonal circular polarizations and spatial separation of the individual uplink and downlink actively-steered beams (four times per satellite on feeder links). Virtual Geo will also provide multi-beam coverage using its phased array antennas on the satellites – a capability that will allow each Virtual Geo satellite to reconfigure its coverage for the service area corresponding to each apogee, and for the particular traffic requirements the satellite encounters as it traverses the globe. Virtual Geo Satellites control their beams to maintain the beam array stationary over a service area as each satellite transits its active arc. This minimizes and in many cases eliminates beam handovers within a satellite.

Issuance to Virtual Geo of an authorization to operate in the United States will serve the public interest in several key respects. First, it will promote the efficient use of the orbital spectrum resource by permitting the overlay in the same band of a novel nongeostationary satellite system design that operates completely transparently with respect to existing and future geostationary FSS satellites. Virtual Geo's relatively high elevation angles from its earth terminals to the satellites serving the primary coverage areas also greatly facilitates sharing between Virtual Geo and fixed service systems. Second, Virtual Geo will provide affordable digital services, including high-speed Internet access and direct-to-home data and video streams, to small user terminals in most of the populated areas of the world. Third, the design characteristics of the Virtual Geo system and its orbital configuration will permit several similar elliptical orbit systems to be implemented on a co-frequency basis – without disturbing the sharing situation with geostationary satellites or terrestrial systems.

The deployment of such sub-constellations is expected to be achieved progressively as market develops, thus reducing capital risk and enabling revenue based financing of the constellation at least in part, a feature seldom found in complex satellite systems such as the NGSOs. The active arcs of the Virtual Geo satellites in each sub-constellation occur only when the satellites are at latitudes above 42 degrees, when they are at high elevations over much of their primary service areas in the Northern and Southern Hemispheres, respectively. Virtual Geo thus achieves an optimized combination of very high elevation angles, low signal propagation delays compared to geostationary satellites, and limited satellite handoffs. Virtual Geo provides non-uniform distribution of capacity to the Northern and Southern Hemispheres in proportion with demand, thus reducing capital cost for effective usable capacity in actual markets, cost of capital and ultimately cost to the end-user.

Public Interest Considerations

The Virtual Geo the system has the potential to offer high bandwidth GEO-type services at low cost to the currently underserved or unserved communities – especially in the extreme Northern latitudes.

Grant of an authorization for the Virtual Geo system will the public interest in several key respects. First, through use of spectrum resources otherwise laying fallow, it will promote the efficient use of the orbital spectrum resource by permitting the overlay in the same band of a novel non-geostationary satellite system design that operates completely transparently with respect to existing and future geostationary FSS satellites. Without Virtual Geo, this spectrum resource would go unused when only GEO's operate using that spectrum. The inherent reuse of that spectrum band defines the "virtual space", with its own "virtual slots". Virtual Geo's relatively high elevation angles from its earth terminals to the satellites serving the primary coverage areas also greatly facilitates sharing between Virtual Geo and fixed service systems.

Second, Virtual Geo will provide affordable digital services, especially serving as the backbone for state-of-the-art and future Content Delivery Networks, and of course high-speed Internet access and direct-to-home data and video streams, to small user terminals throughout the United States and, with full implementation, to most of the populated areas of the world.

Third, the design characteristics of the Virtual Geo system and its orbital configuration will permit similar elliptical orbit NGSO systems to be implemented on a co-frequency basis with inter-system coordination as simple as that at GEO – without disturbing the sharing situation with geostationary satellites or terrestrial systems. There will thus be opportunities for additional virtual geo systems in the future. In sum, the Virtual Geo system offers the world a novel, efficient, and affordable satellite system that is technically compatible with respect to other types of users of the spectrum bands within which the system will operate.

NSS and its American affiliates are legally and technically qualified for authorization to operate the Virtual Geo satellite system in the United States. NSS thus urges the Commission to conclude that the grant of such authority will advance the public interest, convenience, and necessity

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New Spectrum Satellite, Ltd. ("NSS"), pursuant to Sections 308 and 309 of the Communications Act of 1934, as amended, 47 U.S.C. §§ 308 and 309 (1996), Parts 1 and 25 of the Commission's Rules, and the Commission's *Public Notice* (DA 17-524, released May 26, 2017), hereby seeks authority to operate within the United States a state-of-the-art system of fifteen (15) non-geostationary satellites in sub-geosynchronous inclined elliptical orbits that will be licensed by Canada. NSS's proposed system, called "Virtual Geo™," will also include three additional in-orbit spare satellites that will be placed into a parking orbit. Virtual Geo will provide fixed-satellite services to all of the world's populated land masses through a combination of user and gateway links in the C-, Ku- and Ka-bands,[5] as well as through inter-satellite links in the optical frequencies.

Virtual Geo is the first of a new class of constellation systems that are virtually geo-synchronous. Unlike geostationary systems or so-called "quasi-geostationary" systems in which the individual satellites attempt to follow the Earth, all of the satellites in a virtual geostationary system, as a whole, follow the Earth in fixed geosynchronous ground tracks. It is this feature which gives this constellation type the name "virtual geo."

Using a continent-following orbital configuration that is covered by issued and pending patents, the Virtual Geo constellation, though operating at non-geostationary

5 The *Public Notice* invited additional applications in the 12.75-13.25 GHz, 13.85-14.0 GHz, 18.6-18.8 GHz, 19.3-20.2 GHz, and 29.1-29.5 GHz bands. NSS is seeking authority in this application for these bands, but will operate in additional bands, including the C-band, outside of the United States. NSS will operate in these additional bands within the United States only if such usage is authorized by the Commission. *See* n. 2, *supra*.

altitudes, will appear virtually geostationary to users within the system's coverage area. Virtual Geo is comprised of three five-satellite sub-constellations – two for Northern Hemisphere operation (and identified herein as "Aurora I™" and "Aurora II™") and one for Southern Hemisphere operation (identified herein as "Australis™"). The active arcs of the Virtual Geo satellites in each sub-constellation occur only when the satellites are at high latitudes over their primary service areas in the Northern and Southern Hemispheres, and at relatively high elevation angles to many users in those primary service areas, respectively. Virtual Geo thus achieves an optimized combination of good satellite visibility, low signal propagation delays compared to geostationary satellites and lower orbit systems requiring multiple hops over large areas, limited satellite handoffs, and the distribution of capacity between the Northern and Southern Hemispheres relative to demand. Moreover, it does so in a manner that is effectively transparent to the geostationary fixed-satellite service ("FSS") networks with which it will operate on a co-primary basis, and on a fully compatible basis with the terrestrial point-to-point fixed service systems with which it will share radiofrequency spectrum.

Virtual Geo satellites are separated from the geostationary arc by at least 40 degrees at all times within the system's service areas. This key feature of the virtual geostationary concept means that Virtual Geo not only fully protects current geostationary FSS networks, it leaves them an effectively unfettered opportunity to evolve their technologies to meet future service requirements.

1 Introduction

This application and its appendices contain all of the information required for a space station authorization as specified in Part 25 of the Commission's Rules. In accordance with the Commission's rules, the information provided throughout this application includes references to the specific subsections of Section 25.114 of the Commission's Rules to which the submitted information pertains.

Consistent with Commission policy and precedent, and with the above-referenced *Public Notice*, Virtual Geo understands that it will be afforded an opportunity "to amend or supplement this application, if necessary, to conform to any requirements or policies that may be subsequently adopted concerning NGSO-like satellite operation in these bands. *Public Notice*, DA 17-524 at p. 4.

1.1 Name and Address of Applicant (47 C.F.R. § 25.114(c)(1))

The applicant for the authority to launch and operate the proposed satellite system is:

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(514) 393-1100

In the US:
c/o Virtual Geosatellite, LLC
5335 Wisconsin Avenue, N.W.
Suite 640
Washington, DC 20015
(202) 466-4488

1.2 Correspondence (47 C.F.R. § 25.114(c)(2))

Correspondence and communications concerning this application should be addressed to the following:

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Managing Director
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(202) 466-4488

With copies to:

Stephen L. Goodman
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Washington, D.C. 20006
(202) 454-2851

1.3 Type of Authorization Requested (47 C.F.R. § 25.114(c)(3))

In this Application, NSS requests authorization to provide service in the United States using a constellation of nongeostationary satellites that will be licensed by Canada.

1.4 Overview of Virtual Geo and the "Virtual Geostationary Orbit" Concept

NSS is a Canadian company that has initiated the application filing procedures with Canada for authorization of the Virtual Geo system. NSS is a subsidiary of Virtual Geo, a Delaware limited liability company, which was formed by Ellipso, Inc., formerly a Commission licensee. Virtual Geosatellite, LLC holds intellectual property rights (consisting of U.S. and foreign patents and patent filings) relating to the use of constellations of elliptical orbit satellites in the field of communications and data transfer. These patents cover the arrangement and phasing of the satellites in the constellation, and cover as well the strategy for power management and other operating features in the unique elliptic orbits selected.

Virtual Geo's innovation in orbital configuration confers two major benefits. First, the earth terminals associated with Virtual Geo's system point at an entirely different portion of the sky from that occupied by geostationary satellites with which it will operate on a co-frequency basis. This means that conventional antenna masks will be more than adequate for avoiding radio frequency interference with the heavily-used geostationary arc. Second, due to the reduced velocity of the elliptical satellites at and near apogee, the active satellites appear to "hang" in the sky, as their rotational velocity more nearly matches that of the earth than is the case with nongeostationary satellites in circular orbits. In addition, the use of elliptical orbits with periods of less than 24 hours permits the use of smaller satellites and smaller launch vehicles, and thus contributes to the provision of a more cost-effective service.

The concept behind the "virtual geostationary" orbit can be illustrated with a simple analogy – the walking juggler. A juggler's clubs cluster together and move very slowly at the highest point in their trajectories; conversely, at the low point in the trajectories, the juggler is catching and transferring the clubs from hand-to-hand in rapid sequence, propelling each one in turn into its new upward trajectory. In a similar fashion, the satellites in a virtual geostationary constellation, which are intentionally placed in stable elliptical orbits with the apogees over intended users, will rise over the service area and appear to hang there. Using a Northern Hemisphere apogee orbit as an example, as the satellite is replaced after its hang time by the next satellite in the array, it falls rapidly past the Southern Hemisphere, quickly rising in the next adjacent Northern Hemisphere peak where it will repeat the process.

Virtual Geo uses the critical inclination of 63.4 degrees for all orbits. This prevents movement of the apogee around the orbit. Therefore, the apogees will always appear to be roughly at 63.4º North Latitude.[6] Through the use of overlying, repeating ground tracks, the satellites, which have roughly 8 hour orbits passing through 3 apogees each day, each apogee being separated by exactly 120º in longitude. By strategically placing the apogee, Virtual Geo is able to place each satellite's apogee over one of the three Northern Hemisphere continental masses – North/Central America, Asia, and Europe/Northern Africa – visited by each satellite once each day.

The active arc of the Virtual Geo satellites is limited to orbit locations displaced in latitude greater than 40 degrees from the equator and operating at altitudes exceeding 17,200 kilometers. Earth terminals associated with Virtual Geo will be pointed well

6 Two five-satellite sub-constellations, Aurora I™ and Aurora II™, are used to achieve continuous Northern Hemisphere coverage (between 85º North Latitude and 10º South Latitude). The phasing of the sub-constellations enables Virtual Geo to concentrate coverage on the populated land masses in the northern latitudes.

away from the equator to the North or South, depending on the hemisphere in which the user terminal is located. In other words, Virtual Geo users and geostationary FSS users are looking at different regions of the sky at all times. Thus, there is no opportunity for in-line interference events between the virtual geostationary Virtual Geo system and the geostationary FSS networks. It is as if the geostationary arc, for all of its congestion, did not exist, and the virtual geostationary orbit fixed-satellite service was to be established in fallow spectrum.

The key to the Virtual Geo's innovative virtual geostationary orbit concept is its transparency to co-frequency users of the geostationary orbit. Virtual Geo has combined this revolutionary approach with an orbital configuration that is optimized to maximize coverage of the continental land masses at altitudes substantially lower than geosynchronous -- and created a unique means of greatly expanding satellite capacity on an economical basis.

2. Types of Services to be Provided (47 C.F.R. § 25.114(c)(7))

Virtual Geo will provide state-of-the-art, affordable, digital fixed-satellite services directly to users throughout its global service area. *See* Section 3.3, below. Virtual Geo will be capable of accommodating very small earth terminals (on the order of 45 centimeters or 18 inches in diameter). Virtual Geo's gateway terminals will be larger, but may also be located on the premises of service providers or at the headquarters of corporate customers.

Among the many service offerings attainable through Virtual Geo are high-speed Internet access at megabit rates, video and broadband data distribution, and two-way video conferencing and content delivery via streaming.

3. System Description (47 C.F.R. §§ 25.114 (c)(4) – (c) (13) and 25.114 (d))

3.1 System Overview

3.1.1 Overall System Concept

The Virtual Geo global satellite communications system has been designed to meet the needs of its users. These are:

- Provision of state-of-the-art digital two-way telecommunications services;
- Very high service availability, even at high northerly and southerly latitudes, due to the near ideal elevation angles from the user terminals to the Virtual Geo satellites;
- Lower signal delay compared to geostationary satellite systems;
- Low-cost user terminals;
- Low-cost service.

The Virtual Geo system achieves these goals primarily as a result of its novel orbit constellation. The Virtual Geo satellites will operate in inclined elliptical orbits such that their active arcs occur when the satellites are at high latitudes and elevations over the primary service areas in the Northern and Southern hemispheres. These patented and patent pending orbits have been carefully selected to optimize the range of elevation angles to the users, the required service areas, the angular separation from the GSO orbit, the round-trip signal delay, and the total cost of the satellite constellation.

The Virtual Geo system will provide state-of-the-art digital services directly to small user terminals located on the premises of residential and small business users. The high satellite downlink EIRP and uplink sensitivity allows for small (45 cm/18 inch) user terminals. These user terminals will be connected through the Virtual Geo satellites to gateway earth stations which may be located on the premises of service providers or at the headquarters of corporate customers. The Virtual Geo system is very spectrally efficient, with a frequency re-use factor of fourteen times in the majority of its user terminal frequency bands.

One key to the Virtual Geo system's success is the fact that, in addition to the Ka-band frequencies which Virtual Geo use where useful and efficient, the system uses of conventional Ku and C frequency bands, where the ground and space segment components have been readily available for a long time at low cost as a result of the massive existing usage of these frequency bands by geostationary ("GSO") satellite systems throughout the world.[7] The Virtual Geo system, however, stands apart from all other non-geostationary ("NGSO") systems proposed to date for operation in these GSO frequency bands: it represents no threat of unacceptable interference – in the present or foreseeable future – to co-frequency GSO systems, because it only operates when its satellites are at least 40 degrees away from the line-of-sight to and from GSO satellites. As a result it represents a perfect "band-sharing" partner for GSO systems.

3.1.2 Space Segment

The Virtual Geo orbits are designed to position individual satellites for the maximum period of time at the highest elevation over the primary service areas in active arcs, while at the same time maximizing the angular separation from the GSO orbit. These parts of the orbit where the Virtual Geo satellites are active are close to the orbit apogee. As each Virtual Geo satellite leaves an active arc another Virtual Geo satellite enters. The Virtual Geo user and gateway terminals switch as necessary between the

7 Outside of the United States, the Virtual Geo system will use the C-band, where that spectrum is available. NSS also seeks to use the C-band frequencies in the United States if such usage is authorized. *See* n. 2, *supra*.

Virtual Geo satellites that are close to apogee in order to provide continuous 24 hour per day uninterrupted service to the users.

The details of the Virtual Geo orbit constellation are provided later in Section 3.2. For the purpose of this section, it is sufficient to summarize the features of the Virtual Geo constellation as follows:

- Fifteen active satellites in fifteen orbit planes, one per plane, plus three spare satellites in “parking” orbits;
- Active part of the Virtual Geo orbit occurs between altitudes of 17,164 km and 26,172km above the surface of the Earth, at sub-satellite latitudes that are always above 42 degrees.

Each Virtual Geo satellite provides “bent-pipe” communications channels in the Ku-, Ka and C- bands frequency ranges detailed in Section 3.4 below. Virtual Geo achieves a frequency re-use factor of fourteen times for the user terminal frequency bands and eight times for the gateway terminal frequency bands per satellite, and respectively 126- and 72-times frequency reuse system-wide. This is obtained by the use of dual orthogonal circular polarizations, and through the use of spatial separation of the individual uplink and downlink beams. The multi-beam coverage is implemented using active phased array antennas on the satellites, thereby allowing the Virtual Geo satellites to optimally reconfigure their coverage for the service area corresponding to each apogee and for the particular traffic requirements as the satellite moves and as demand varies. In addition, the use of an active phased array satellite antenna allows the beam configuration on the Earth’s surface to be made nearly constant as the satellite passes through its apogee, despite the 34% variation in altitude between the peak of the apogee and the points in the orbit where each satellite starts and ends its active service arc.

Finally, Virtual Geo will also include on-board storage capability for time and geographically shifted digital service retransmissions.

3.1.3 Ground Segment

The Virtual Geo ground segment is made up of the following types of terminals and facilities:

User Terminals: Virtual Geo will support large numbers of small and low-cost terminals deployed on the premises of residential and business users. They will provide a wide range of two-way (as well as one-way) digital communications services. The user terminals have the capability to track the active Virtual Geo satellite and seamlessly switch between active satellites when necessary. In addition, the terminals will be designed to acquire and maintain tracking reliably, and will employ uplink power control to maximize system performance and minimize interference to other users of the spectrum.

The user terminals are described in more detail in Section 3.16.1 below.

Gateway Terminals: There will be four gateway terminals in each regional service area of the Virtual Geo system, each equipped with two large tracking antennas. These gateway terminals will act as the "hub" facilities for the user terminal links, and will connect the user terminals to the terrestrial communications infrastructure within the respective service areas. In addition, any required links between two or more user terminals will connect through a gateway terminal. The gateway terminals also generate and transmit control information destined for the user terminals to assist in user terminal tracking and in the application of uplink power control by the user terminals. The gateway terminals are connected by terrestrial links to the Regional Network Control Center ("RNCC") and the primary Spacecraft Operations Control Center ("SOCC").

The gateway terminals are described in more detail in Section 3.16.2 below.

Regional Network Control Centers ("RNCC"): There will be three Regional Network Control Centers ("RNCCs"). Each RNCC manages the entire satellite resources available to the region by assigning capacity to user terminals upon request, and collecting system usage data for billing purposes.

The RNCCs are described in more detail in Section 3.16.3 below.

Spacecraft Operations Control Center ("SOCC") and TT&C Earth Stations: There will be a single primary Spacecraft Operations Control Center ("SOCC") in the Virtual Geo system plus a back-up facility. The SOCC will be connected by land-lines to regional TT&C earth stations located in the regional service areas. The SOCC will perform all spacecraft control and monitoring functions for the entire Virtual Geo constellation.

The SOCC and associated TT&C earth stations are described in more detail in Section 3.16.4 below.

3.2 The Virtual Geo Constellation

The Virtual Geo constellation uses a carefully synchronized array of fifteen satellites in individual elliptical orbits to form three ground tracks of five satellites each.[8] The orbits are constructed to place satellite operating arcs ("active arcs") over important

8 Note that Virtual Geo orbits are arranged to form common ground tracks with unique orbits, whereas conventional constellations of satellites (such as Walker Constellations) are arranged to form common orbits using unique ground tracks.

market areas in the Northern and Southern hemispheres. These active arcs are well displaced to the north and south of the GSO arc. Orbital parameters have been further selected for good constellation efficiency and desirable path characteristics.

Each satellite flies in a highly elliptical orbit whose apogee is placed either at the northernmost or southernmost extent of satellite travel. Satellites require an eight hour orbital period to complete one revolution, of which 4 hours and 48 minutes are spent on an active arc whose sub-satellite point is 42 degrees or more in latitude from the equator. After departing one active arc, each satellite passes quickly toward and through perigee in the opposite hemisphere to return to its next active arc on its ground track (being the next one to the west). Table 3.2-1 presents the orbital parameters of the 15 active satellites and three spares in the Virtual Geo System. Figure 3.2-1 illustrates the ground tracks, highlighting the active arcs. The orbital parameters are valid for an epoch date of 1 January 2020 at 0000 hours UTC.

Table 3.2-1: Virtual Geo Orbital Characteristics

	Aurora I™ Sats n=1-5	Aurora II™ Sats n=1-5	Australis™ Sats n=1-5	Spare Satellites
Semimajor Axis	20281	20281	20281	7285
Eccentricity	0.605	0.605	0.605	0.05346
Inclination	63.435	63.435	63.435	63.435
Right Ascension of the Ascending Node	306.5 18.5 90.5 162.5 234.5	6.5 78.5 150.5 222,5 294,5	286,5 358.5 70.5 142.5 214,5	0 180 30
Argument of Perigee	270 270 270 270 270	270 270 270 270 270	90 90 90 90 90	270 270 90
Mean Anomaly	0 144 288 72 216	0 144 288 72 216	0 144 288 72 216	0 0 0

The apogee of Virtual Geo satellites, at slightly above 26,000 kilometers, is around three-quarters of the altitude of geostationary satellites. This lower apogee results in less propagation delay than encountered with GSO satellite service or when using satellites in Molnya or higher orbits, and yields excellent coverage of northern and southern service areas. The Virtual Geo System offers pole-to-pole Earth coverage of all populated landmass areas. It is optimized to offer its highest elevation angles over primary markets around the world, while devoting less coverage resource to ocean areas.

The angular separation between Virtual Geo satellites in the active Virtual Geo arc and the GSO orbit always exceeds 42degrees regardless of location on the Earth.

This ensures at least 40 degrees of separation from GSO satellites operating in up to 5 degree inclined orbits. The lowest angular separation occurs for stations to the far north or far south, such as for those in Alaska. Stations within the continental United States operate with angular separations to the GSO arc exceeding 45 degrees. The Virtual Geo system will apply design and operating limits to ensure that no Virtual Geo link operates with less than 40 degrees of separation from the GSO arc, even in anomalous circumstances. As a consequence, as described in further detail in Section 3.13.1, Virtual Geo satellites and ground stations generate significantly less interference toward geostationary systems than the provisional limits already under consideration by the international satellite community.

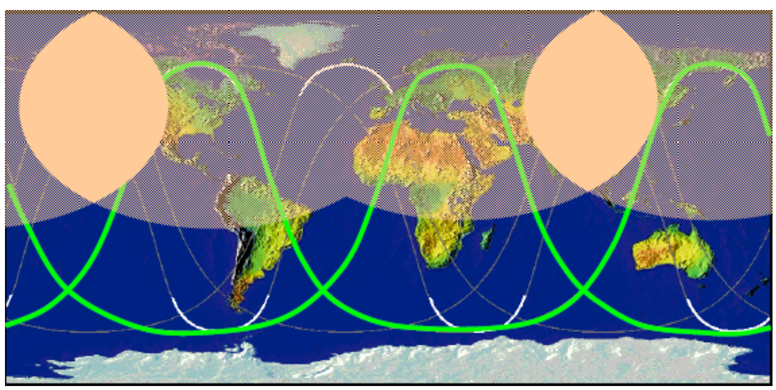


Figure 3.2-1: Virtual Geo's Aurora I ground track with the Aurora II and Australis ground tracks un-highlighted

Virtual Geo creates six active arcs over the northern hemisphere and three over the southern. Each active arc covers 54 degrees of longitude in the positions noted in Table 3.2-2. More active arcs are deployed in the northern hemisphere than in the southern hemisphere due to the greater land area in the northern hemisphere than in the southern. The Northern (Aurora™) and Southern (Australis™) service areas join without gap in the equatorial region, completing global coverage.

Table 3.2-2: Locations of the Virtual Geo Active Arcs (Sub-satellite Longitudes in º East)

Aurora I™ Northern Hemisphere	Aurora II™ Northern Hemisphere	Australis™ Southern Hemisphere
328 - 23 Europe	29 - 83 West Asia	9 - 63 Africa
88 – 143 Japan	269 - 323 E.North America	129 - 183 Australia-NZ
209 – 263 W. North America	149 - 203 Pacific	259 – 304249 - 303 South America

The Virtual Geo System will also fly one spare satellite per ground track in a sparing orbit designed to make the satellite available to any of the five orbital planes involved with each ground track. The orbital parameters for the spare satellites are given in Table 3.2-1 above

3.3 SYSTEM COVERAGE

The Virtual Geo Constellation ensures visibility from the Earth's surface to an active Virtual Geo satellite 100 percent of the time over the entire Earth pole-to-pole. However, Virtual Geo inherently provides service to land-based fixed terminals. Therefore the Virtual Geo constellation design has been further optimized to provide improved visibility performance, or visibility preference, to all the major continental land masses and important island areas of the Earth, as described and illustrated in Section 3.2 above.

Elevation angles to Virtual Geo satellites always exceed 42 degrees within the Continental United States and Alaska, while always exceeding 30 degrees from the Virgin Islands and Puerto Rico, and 35 degrees from Hawaii.

Virtual Geo exceeds the Commission's requirement for satellite visibilities in all relevant areas of the Earth. However, while Virtual Geo can provide service over the entire Earth's surface, its unique design permits the judicious concentration of space assets over important populated land masses, where Virtual Geo has optimized its performance. The global worst case minimum elevation angle on any significant populated land mass anywhere on the Earth falls to approximately 10 degrees once per 5 hours, and this occurs for less than 0.1% of the Earth's land areas. Minimum elevation angles are below 20 degrees for only 10% of significant populated landmasses and less than 30 degrees for 50% of the areas. However, it should be noted that these areas of low elevation angles are restricted to peripheries of the service areas where the requirement for service is likely to be small, and where the use of lower elevation angles is unlikely to present a problem.

Angular separations between Virtual Geo's active service arc and the geostationary arc from Virtual Geo ground stations average 45 degrees or more and, as stated, always exceed 40 degrees.

Virtual Geo satellites implement two kinds of service over their service areas: single beam and multi-beam. Single beam service supports high data rate user-specific traffic, while multi-beam handles traffic destined simultaneously to many geographically dispersed users within a service area.

The Virtual Geo satellites create user and gateway antenna beams using actively steered phased array antennas so designed and operated as to maintain a given beam on a service area at all times during the satellite's transit of its active arc. This minimizes any requirement for service handoffs from beam to beam, offers a more stable link to the user, and results in greater satellite and link operating efficiencies. Individual beams have a nominal 1.5 degree beamwidth and 40 dBi of peak gain on boresight. A cluster of beams corresponding to a service area will be steered together in a coordinated fashion. In addition, individual beams can be time-shared over several beam positions to serve larger, lower traffic density areas.

Since all user and feeder link antenna beams are selected in real time for active markets and users, and may be time-shared among several markets, and will vary in steering as activity varies in real time, it is infeasible to define fixed beam contours.

Figures 3.3-1 through 3.3-5 present some examples of single beam contour plots for beams directed to the south central United States, New England, Hawaii, and Alaska from the middle of the relevant service arc. Digital maps are submitted within Schedule S. Specific beam footprint contour positions for a given target will vary over time as the satellite moves through its arc and as the beam is steered to serve its user community best. In all cases, however, the satellites when active, will occupy a position in space separated from the geostationary arc by at least 40 degrees, thereby protecting GSO satellite services as described later below. TT&C contours are not provided, as the beams are omnidirectional.

Figure 3.3-1: Single Beam Service to South Central United States

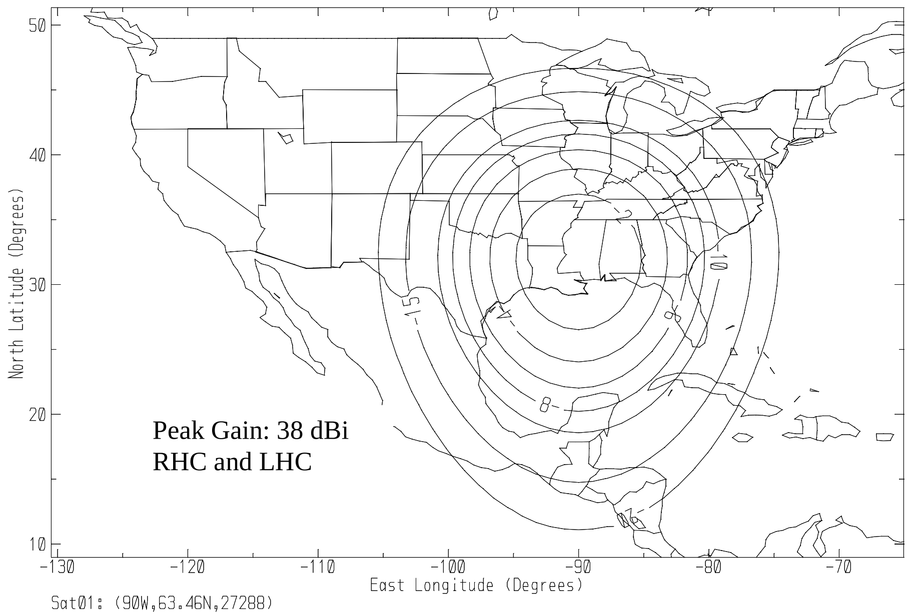


Figure 3.3-2: Single Beam Service to Northeastern United States

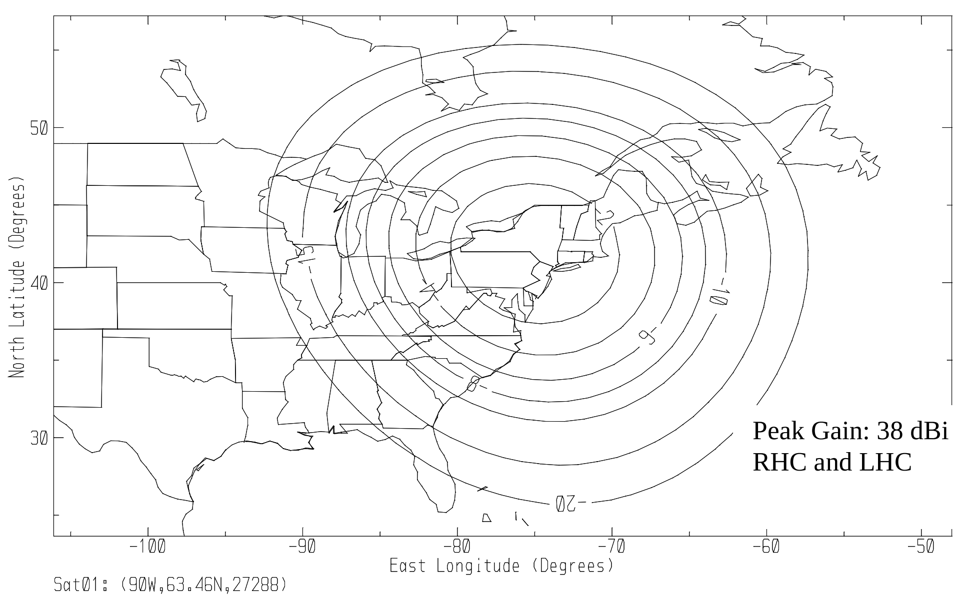


Figure 3.3-3: Single Beam Service to the Northwest United States

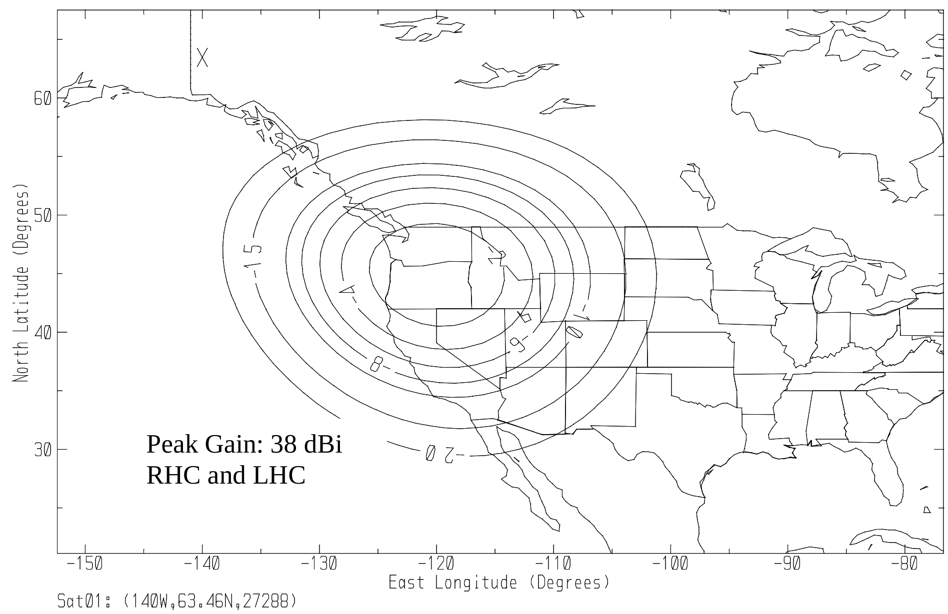


Figure 3.3-4: Single Beam Service to Alaska

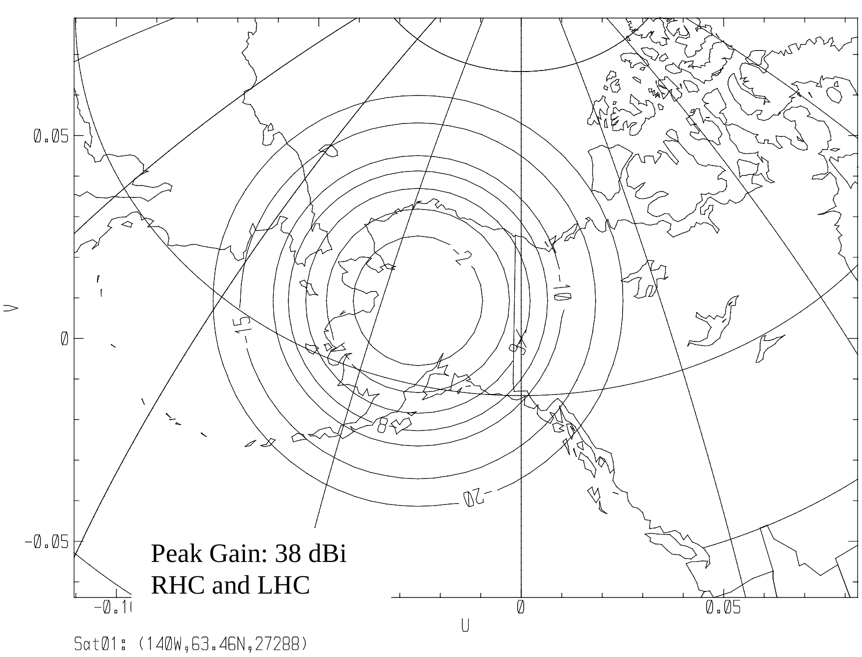
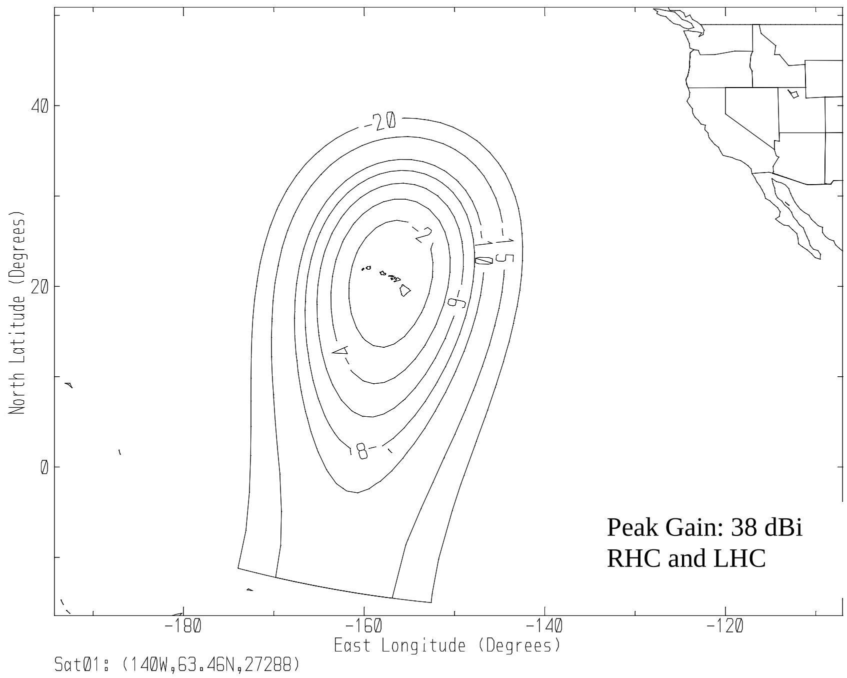


Figure 3.3-5: Single Beam Service to Hawaii



3.4 FREQUENCY AND POLARIZATION PLANS

This application responds to the Commission's *Public Notice* regarding NGSO FSS systems in the 12.75-13.25 GHz, 13.75-14.5 GHz, 17.3-17.8 GHz and 10.7-12.7 GHz frequency bands[9]. The proposed Virtual Geo system will utilize all these available frequency ranges with the exception of the 13.75 – 13.8 GHz band. In addition, outside the United States the Virtual Geo system proposes to make use of C-band frequency bands, as detailed below, which are already allocated under the International Telecommunication Union Table of Frequency Allocations to Fixed Satellite-Service ("FSS"). In addition, the Virtual Geo system will use C-band frequencies in the United States if authorized to do so.[9]

[9] *See* n. 2, *supra*.

3.4.1 FCC and ITU Allocations

3.4.1.1 Ku-Band Frequencies

The Virtual Geo system proposes to utilize the 12.75–13.25 GHz (Earth-to-space), 13.8-14.5 GHz (Earth-to-space), and the 10.7–12.7 GHz (space-to-Earth) bands.

In the U.S., incumbent users of the 12.75–13.25 GHz band are the Fixed Service ("FS"), the FSS (Earth–to-space), the Mobile Service ("MS"), and Space Research (deep space), on a co-primary basis. Internationally, the band is allocated to FS, FSS (Earth–to-space) and MS, except for aeronautical mobile, on a primary basis. It is also allocated to Space Research (deep space) (space-to-Earth) on a secondary basis.

In the U.S., incumbent users of the 13.8–14.0 GHz band are the FSS (Earth-to-space), Government Radiolocation and Space Research on a co-primary basis. In addition the Standard Frequency and Time Signal Satellite operates on a secondary basis. Internationally this band is allocated to FSS (Earth-to-space) and Radiolocation on a primary basis and to Standard Frequency and Time Signal-Satellite and Space Research on a secondary basis.

In the U.S., the incumbent primary user of the 14.0–14.5 GHz band is the FSS (Earth-to-space). In addition there are secondary allocations in various parts of the band that include Radionavigation, Land Mobile Satellite (Earth-to-space), Space Research, MS and Radio Astronomy. Internationally, the 14.0–14.3 GHz band is allocated to FSS (Earth-to-space) and Radionavigation on a primary basis and on a secondary basis to Mobile-Satellite and Space Research. The 14.3–14.4 GHz band is allocated on a primary basis to the FSS (Earth-to-space) in all three ITU Regions. In addition, in Regions 1 and

3, the MS and FS also have allocations on a primary basis. In all three Regions, there are secondary allocations to the Mobile-Satellite Service ("MSS") (Earth-to-space) and the Radionavigation-Satellite Service in this band. In the 14.4–14.5 GHz band, the primary allocations in all three ITU regions include FS, FSS (Earth-to-space) and MS, except aeronautical mobile. There are secondary allocations to the MSS (Earth-to-space), Space Research (space-to-Earth), and Radio Astronomy in portions of this band.

In the U.S., the incumbent users of the 17.3–17.7 GHz band are the FSS (Earth-to-space) on a primary basis, and Government Radiolocation on a secondary basis. In the 17.7–17.8 GHz band, the U.S. incumbent users are the FS, FSS (Earth-to-space), MS and FSS (space-to-Earth). Internationally, the 17.3–17.7 GHz band is allocated to the FSS (Earth-to-space) on a primary basis in all three Regions. In addition, in Region 2, the band is allocated to the BSS. The 17.7–17.8 GHz band is allocated to the FS and FSS (space-to-Earth) (Earth-to-space) in all three regions on a primary basis. In addition, in Region 2, the band is allocated to the BSS on a primary basis, and in Regions 1 and 3 to the MS on a primary basis. In Region 2, the band is allocated to the MS on a secondary basis.

In the U.S., the incumbent users of the 10.7–11.7 GHz band are the FS and FSS (space-to-Earth). Internationally, the band is allocated to the FS, MS (except aeronautical mobile), and FSS (space-to-Earth). In addition in Region 1, the FSS allocation is also in the Earth-to-space direction.   In the U.S., the incumbent users of the 11.7–12.2 GHz band are the FSS on a primary basis and the MS (except for aeronautical mobile) on a secondary basis. Internationally, the Region 2 allocation in the 11.7–12.1 GHz band is allocated to the FS and FSS (space-to-Earth) on a primary basis and MS, except for aeronautical mobile, on a secondary basis, while the 12.1–12.2 GHz band is allocated to the FSS (space-to-Earth). In Regions 1 and 3, the 11.7–12.2 GHz band is allocated to the FS, Broadcasting and BSS. In Region 3 the band is also allocated to the MS (except for aeronautical mobile) on a primary basis, while in Region 2 the MS is on a secondary basis. In the U.S., the incumbent users of the 12.2-12.7 GHz band are the BSS and FS. Internationally in Region 2 the band is allocated to FS, MS (except for aeronautical mobile), Broadcasting and BSS. In Region 1, the 12.2–12.5 GHz band is allocated to the FS, Broadcasting and BSS on primary basis and to MS, except for aeronautical mobile, on a secondary basis, while the 12.5–12.7 GHz portion of the band is allocated to the FSS (space-to-Earth) (Earth-to-space). In Region 3, the 12.2–12.5 GHz band is allocated to the FS, MS (except for aeronautical mobile), and Broadcasting, while the 12.5 – 12.7 GHz portion is allocated to FS, FSS (space-to-Earth), MS (except for aeronautical mobile), and BSS. At WRC-97, an additional primary allocation was made for NGSO FSS (space-to-Earth) systems in the 11.7–12.5 GHz band in Region 1, the 12.2–12.7 GHz band in Region 2, and the 11.7-12.2 GHz band in Region Three.

3.4.1.2 C-Band Frequencies

The Virtual Geo system is also designed to utilize the 5925–6725 MHz (Earth-to-space) and 3700–4200 MHz (space-to-Earth) bands.

In the U.S., the 5925–6425 MHz and the 6525-6725 MHz bands are allocated to the FS and FSS (Earth-to-space) on a co-primary basis, while the 6425-6525 MHz band is allocated to the FSS (Earth-to-space) and the MS. Internationally, in all three ITU Regions, the proposed band is allocated to FS, FSS (Earth-to-space) and MS, in addition, the 6700-6725 MHz band is also allocated to the FSS (space-to-Earth).

In the U.S., the 3700–4200 MHz band is allocated to FS and FSS (space-to-Earth) on a co-primary basis. Internationally, in Regions 2 and 3 this band is allocated to FS, FSS (space-to-Earth) and Mobile Service (MS), except for aeronautical mobile, on a primary basis. In Region 1, this band is allocated to the FS and FSS on a co-primary basis and to MS on a secondary basis.

NGSO FSS systems can utilize this band under the FSS allocation, and in accordance with Radio Regulation S22.2 of the ITU Radio Regulations.

3.4.2 Virtual Geo System Band Plan

The Virtual Geo satellites effectively provide flexible communications paths between user terminals and gateway terminals. The user terminals are located in at least 28 full time or a larger number of time-shared (time division multiplexed) spot beams throughout each service area. The four gateway terminals are each located within individual gateway spot beams in each service areas described in Section 3.2 above. This arrangement allows differentiation between the spectrum used for user terminals ("User Terminal Frequency Bands") and that used for gateway terminals ("Gateway Terminal Frequency Bands"), as described in Sections 3.4.2.1 and 3.4.2.2 below, respectively.

The overall frequency bands used by the Virtual Geo system are summarized in Table 3.4.2-1 below.

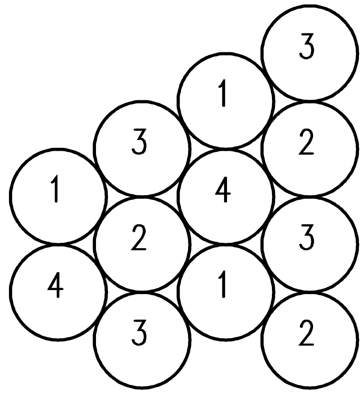
Table 3.4.2-1: Virtual Geo Frequency Band Plan

	User Terminal Frequency Bands		Gateway Terminal Frequency Bands	
	Uplink	Downlink	Uplink	Downlink
Frequency Bands	14.0-14.5 GHz	11.2-12.7 GHz	5.925-6.725 GHz 12.75-13.25 GHz 13.8-14.0 GHz 17.8-18.6 GHz	10.7-11.2 GHz 3.7-4.2 GHz
Total Bandwidth	500 MHz	1,500 MHz	2,300 MHz	1,000 MHz

3.4.2.1 User Terminal Frequency Bands

The Virtual Geo user terminal uplinks will utilize the 14.0-14.5 GHz Ku-band spectrum in both senses of circular polarization, creating an overall usable uplink spectrum of 1,000 MHz. Each user terminal uplink beam will be allocated one quarter of this (*i.e*., 250 MHz in a single polarization) and the overall service area will be covered with an array of potential beams operating in a 1-in-4 frequency re-use pattern, as shown in part in Figure 3.4.2.1-1. With this arrangement no two adjacent beams operate on the same frequency and polarization, and the instances where the same frequency and same polarization are used occurs only when the beams are spaced sufficiently far apart to allow full frequency/polarization re-use.

Figure 3.4.2.1-1: Example of 1-in-4 Frequency Re-Use Pattern for User Beams



The user terminal downlinks will operate in the 11.2-12.7 GHz Ku-band spectrum, also in both senses of circular polarization, creating an overall usable downlink spectrum of 3,000 MHz. As for the user terminal uplink, one quarter of this spectrum (*i.e.*, 750 MHz in a single polarization) will be allocated to each user terminal downlink beam, with a similar 1-in-4 frequency re-use pattern.

The asymmetry between uplink and downlink user spectrum is deliberate. The foreseen Virtual Geo services will consist of a broad array of multi-media two-way digital applications, and the expected aggregate traffic within a user beam from users to gateways (*i.e.*, "inbound" traffic) is expected to be approximately one third of the aggregate traffic from the gateways to users (*i.e.*, "outbound" traffic).

3.4.2.2 Gateway Terminal Frequency Bands

Within each service area the four Virtual Geo gateway terminals will interconnect the traffic from all the user terminals operating in the 28 equivalent user beams. The aggregate bandwidth capability of the gateway beams within a service area is equal to the aggregate bandwidth capability of all the user beams within each service area, because of the bent-pipe transponder arrangement of the Virtual Geo system. To achieve this without resorting to an unacceptably large number of gateways per service area, the Virtual Geo system needs to use all available gateway spectrum.

For the Virtual Geo gateway terminal uplinks the following frequency bands will be used: 12.75-13.25 GHz (500 MHz), 13.8-14.0 GHz (200 MHz), 17.8-18.6 GHz (800MHz), and 5.925-6.725 GHz (800 MHz). The aggregate amount of spectrum in these four distinct gateway frequency bands, after allowing for the use of both senses of circular polarization, is 4,600 MHz. Of this total gateway uplink spectrum, 250 MHz is connected to downlink throughout the entire Virtual Geo service area, which is effectively in all of the user downlink beams. Of the remaining spectrum 3,500 MHz is used to connect from each uplink gateway beam to seven separate user downlink beams. The total of 28 equivalent fully occupied user downlink beams is served by the use of the four gateway uplink beams, each serving seven user beams.

The gateway terminal downlinks will operate in the following frequency bands: 10.7-11.2 GHz (500 MHz) and 3.7-4.2 GHz (500 MHz). Accounting for the use of dual circular polarization this amounts to a total of 2,000 MHz of gateway downlink spectrum. Each gateway downlink beam is therefore capable of providing inbound links for up to eight user beams, each of which supports 250 MHz on its uplink. As for the gateway uplinks, the total of 28 equivalent user uplink beams is served by the use of the four gateway downlink beams, each serving up to eight equivalent user beams.

3.4.2.3 Channelization Plan

The Virtual Geo satellites use active phased array satellite transmit antennas (see Section 3.14) in which the power amplifiers are effectively distributed over the radiating elements of the array. There are no single high power amplifiers which are used for dedicated portions of the frequency spectrum, such as a TWTA (traveling wave tube amplifier) in a transponder of a conventional satellite. Instead, all of the distributed solid state power amplifiers operate wide-band, with each providing a small fraction of the overall RF power transmitted. As such, there is no need to channelize the frequency bands into conventional "transponder bandwidths" from the point of view of the satellite HPA constraints.

Furthermore, because of the "bent-pipe" arrangement of the payload, with connectivity provided only between gateways and user terminals (and vice versa), there is no requirement to channelize the spectrum more than is necessary to route traffic to and from the appropriate user and gateway beams. This requirement is discussed in Sections 3.4.2.1 and 3.4.2.2 above, and this is in fact the driver for the channelization plan within the Virtual Geo satellites.

Based on this, the spectrum used by the Virtual Geo system will be channelized in the satellite payload as given in Table 3.4.2-2 below.

Table 3.4.2-2: Virtual Geo System Channelization Plan

Frequency Band	Usage in Virtual Geo System	Channelization Scheme
14.0-14.5 GHz	User Terminal Uplinks	Two channels of 250 MHz bandwidth in each of two orthogonal polarizations.
11.2-12.7 GHz	User Terminal Downlinks	Two channels of 750 MHz bandwidth in each of two orthogonal polarizations. Each 750 MHz channel is subdivided into a 250 MHz sub-channel that is used for "multi-beam" downlinks and a 500 MHz sub-channel that is used for "single-beam" downlinks.
12.75-13.25 GHz	Gateway Terminal Uplinks	Two channels of 250 MHz bandwidth in each of two orthogonal polarizations.
13.8-14.0 GHz	Gateway Terminal Uplinks	One channel of 200 MHz bandwidth in each of two orthogonal polarizations. (See Note 1)
17.8-18.6 GHz	Gateway Terminal Uplinks	Two channels of 250 MHz bandwidth in each of two orthogonal polarizations, two 150 MHz channels
5.925-6.725 GHz	Gateway Terminal Uplinks	Three channels of 250 MHz bandwidth plus one channel of 50 MHz bandwidth in each of two orthogonal polarizations. (see Note 1)
10.7-11.2 GHz	Gateway Terminal Downlinks	Two channels of 250 MHz bandwidth in each of two orthogonal polarizations.
3.7-4.2 GHz	Gateway Terminal Downlinks	Two channels of 250 MHz bandwidth in each of two orthogonal polarizations.

Note 1: The gateway uplink channels of 200 MHz and 50 MHz are combined in the satellite payload to form one user downlink channel of 250 MHz

3.4.2.4 Order Wire Control Channels

Some of the communications capacity between the gateways and the user terminals will be set aside for order wire control channels. Current estimates suggest that an allocation of five megabits per second per user beam in both the outbound and inbound directions is appropriate, but further system development may result in changes to these allocations.

The outbound order wire control channel will consist of a TDM (Time Division Multiplex) signal containing control data destined for all the user terminals within a user beam, with individual headers preceding each control message to identify the individual user terminal to which the control message applies.

The inbound order wire control channel will use an FDMA (Frequency Division Multiple Access) scheme with each user terminal transmitting short data messages, when necessary, each modulated on its own RF carrier. The access protocol in this control channel will be a derivative of the ALOHA technique currently used by the inbound links of many VSAT networks.

The order wire channel will be used to carry network management information only, including the following:

- Requests by user terminals for satellite capacity. These requests will indicate the quantity and type of capacity required;
- Response by the RNCC/gateway to user terminal requests for capacity, indicating the availability of such capacity, and the frequency assigned for the transmission;
- Control information from the gateway to the user terminal for the implementation of uplink power control;
- Transmissions from the user terminals to the RNCC/gateway reporting on the health status of the user terminal equipment;
- Commands from the RNCC/gateway to the individual user terminals in the event that it is necessary to cease a particular uplink transmission;
- Transmission from the SOCC/RNCC/gateway of the latest Virtual Geo constellation ephemeris data.

The order wire control channels will operate with transmit power spectral densities that do not exceed those of the communications traffic channels, and as such do not cause any additional interference. These order wire control links are made more robust by the use of a higher level of FEC coding (1/3 rate FEC) than is used on the communications traffic channels, as the reduction in spectral efficiency for these relatively narrowband channels is not a problem. The exact frequencies to be used for these order wire control channels have not yet been determined, and will be decided only as a result of the more detailed studies that are underway. From an interference point of view, these order wire control channels are the same as the communications traffic channels so there is no need to distinguish them for the purpose of this application.

3.4.2.5 Beacons

On-board generated downlink beacons are used to ensure optimum tracking of the active Virtual Geo satellites by the user and gateway earth stations, and for uplink power control. The beacons consist of narrow-band (1 kHz occupied bandwidth) carriers modulated with pseudo-random noise bit sequences for signal spreading purposes.

The beacons must be located within the user terminal downlink spectrum in order to minimize the cost of the beacon receiver functions in the user terminals. Gateways will also use these same downlink beacons through the use of special beacon receivers even though the beacons operate within the user terminal downlink frequency band. Four such beacons are provided with opposite circular polarizations and in different halves of the user downlink frequency band in order to minimize cost impact to user terminals. These beacons are currently planned to be implemented at the extreme ends of the user terminal downlink frequency band as follows:

Beacons 1 & 2: Center frequency 11.2001 GHz in LHC and RHC polarizations

Beacons 3 & 4: Center frequency 12.6999 GHz in LHC and RHC polarizations

All Virtual Geo satellites will operate with beacons transmitting at the same frequencies as those given above. The angular spacing between the sequential Virtual Geo satellites in the same orbit plane will be used to distinguish between the "rising" and "setting" satellites.

The exact frequencies of these beacons may be changed as a result of coordination with other users of the spectrum. Further details of these beacons are given in Section 3.8.4 below.

3.4.2.6 TT&C Links

Telemetry, Tracking and Command ("TT&C") functions will be performed at C-band for the launch and early operations phase ("LEOP"), normal on-station mode, and emergency mode, using frequency assignments (± 1 MHz) at the edges of the conventional C-band frequency ranges. The preferred assignments are as follows:

Telecommand and Ranging Uplinks:	5.926 GHz and 6.424 GHz
Telemetry and Ranging Downlinks:	3.701 GHz and 4.199 GHz

The final frequency assignments for these TT&C transmissions will be determined only after coordination with all affected users of this band. As an aid to coordination with existing C-band satellites, the possibility is being investigated of prohibiting the normal-mode Virtual Geo TT&C transmissions when potential interference could occur with respect to GSO satellites, including GSO satellites with inclinations up to 5°.

3.4.2.7 Inter-Satellite Links

Line of sight connectivity can be achieved between the Virtual Geo satellites during the active arc of their orbits. This feature of the constellation can be exploited to allow inter-regional communications to be established without the need to "double-hop" through gateway earth stations. The IF switch in the Virtual Geo satellite payload will permit certain sub-channels to and from each user and gateway beam to be routed via the ISL to the active satellites in the other service areas.

Virtual Geo will employ optical ISLs to support this requirement, eliminating coordination concerns with other systems using RF-based ISLs.

3.5 SYSTEM CAPACITY

The Virtual Geo system provides simultaneous service in nine regional service areas around the world. Within each of the regional service areas the system provides a total outbound (gateway-to-user) transmission capacity of 24 Gbps and a total inbound (user-to-gateway) transmission capacity of 7 GHz using a nominal mix of terminal types. Virtual Geo will use the existing DVB-S2 standard for all modulation and coding, and anticipates using adaptive modulation to provide optimum channel performance.

All the inbound traffic is from individual user beams to gateways. Of the outbound traffic, 200 Mbps is used in "multi-beam" mode from a single gateway to all downlink beams of the service area (effectively configured as one large downlink beam).

The remaining capacity is connected between gateways and individual downlink spot beams.

The high system capacity is achieved by correspondingly high levels of frequency reuse, which can be summarized as follows:

- Fourteen times re-use in the user terminal uplink frequency band
- Fourteen times reuse in two-thirds of the user terminal downlink frequency band.

  Two times reuse in the remaining one-third which is used in multi-beam mode.
- Eight times reuse in both uplink and downlink gateway frequency bands.

3.6 SATELLITE TRANSMIT CAPABILITY

3.6.1 User Terminal Beams

The satellite transmit performance has been designed to provide high quality service into user terminals with antennas of equivalent apertures as small as 45 cm in diameter.

Due to the use of elliptical orbits, the altitude of the Virtual Geo satellite, during its active part of the orbit, varies from around 17,164 km to around 26,172 km, corresponding to a change in path loss of 3.9 dB. The transmit earth stations compensate for this change of path loss by adjusting the level of the uplink carriers so that they drive the satellites optimally during all parts of the active orbit arc. This feature is part of the uplink power control scheme which is discussed in detail in Section 3.8.4.2 below.

The Virtual Geo satellites use active phased array antennas. As a result, the conventional concept of separate satellite high power amplifiers ("HPAs") connected to a downlink antenna with a fixed gain is not appropriate. Instead, the satellite transmit capability can be thought of as a pooled power resource whose magnitude can be related to the aggregate power of the transmit amplifiers that make up the active antenna

See FCC Form 312 Schedule S for PFDs.

3.6.2 Gateway Terminal Beams

The Virtual Geo satellite gateway terminal beams are similarly generated by active phased array antennas at both Ku, Ka and C-bands. These beams are constructed to have the same gain and pattern as the user link antenna beams described earlier, and like them, are steering actively. See FCC Form 312 Schedule S for PFDs.

3.6.3 Beacon Signals

The beacon signals, which operate in the user terminal downlink bands of 11.2-12.7 GHz, will operate at 6 dB higher PFD spectral density (per-Hz) than the communications signals in order to provide greater link robustness. However, as the bandwidth of these beacon signals is only 1 kHz, the worst case PFD, when averaged over 4 kHz, is the same as that of the user downlink communications signals in this band, and are therefore as follows:

- Maximum PFD at the Earth's surface will not exceed -151.0 dBW/m^2/4kHz.

Further details of the beacon signals are given in Sections 3.8.4.

3.7 SATELLITE RECEIVE CAPABILITY

3.7.1 User Terminal Beams

Details on the user terminal beams are provided in Schedule S.

3.7.2 Satellite Channel Gain for User-to-Gateway Links

In a conventional system, the satellite channel gain is defined in terms of the Saturation Flux Density ("SFD"). The SFD is the power flux density at the input to the satellite receive antenna that just produces saturation of the satellite HPA. However, the concept of SFD is not relevant to the linear broad-band communications channels of the Virtual Geo satellites. Instead the linear gain from output of the satellite receive antenna to the input of the satellite transmit antenna is more appropriate and is used in link budget design for this type of system. This performance parameter can be varied in the range 108 dB to 125 dB for the overall user to gateway communications channels.

3.7.3 Gateway Terminal Beams

Details on the gateway terminal beams are provided in Schedule S.

3.8 TRANSMISSION CHARACTERISTICS

All communications traffic transmissions in the Virtual Geo System will use FDMA/FDM, supplemented in some cases by TDMA. The bandwidth of the individual carriers will vary depending on the transmission data rate of each link. No signal spreading will be used, other than that resulting from the FEC coding employed.

3.8.1 Order Wire Links

The order wire links will use 1/3 rate FEC convolutional coding.

3.8.2 TT&C Links

Virtual Geo TT&C links will employ ½ rate convolutional forward error correction encoding with cyclic redundancy checks, together with acknowledgment of all commands and all data receipt. All TT&C links will be encrypted.

The following emission designators are applicable to the beacon and TT&C transmissions in the Virtual Geo system:

Beacon: 1K00GXN

Telecommand: 45K0G1D

Telemetry: 45K0G1D

3.8.3 Transmission Channel Frequency Response and Unwanted Emissions

The channelization scheme described in Section 3.4.2 describes satellite transmitted bandwidths of 250 MHz, 500 MHz and 750 MHz. The corresponding unwanted emission masks (out-of-band responses) for each of these channel bandwidths are given in Figures 3.8.3-1, 3.8.3-2 and 3.8.3-3 respectively.

The in-band frequency responses of these channels will be consistent with normal satellite and earth station equipment performance standards and sufficient to ensure that negligible distortion occurs to the range of digital transmissions to be used. The exact specifications for these in-band frequency responses have not yet been fully defined and will be provided to the Commission in due course if required.

Figure 3.8.3-1: Unwanted Emission Mask for 250 MHz Channels

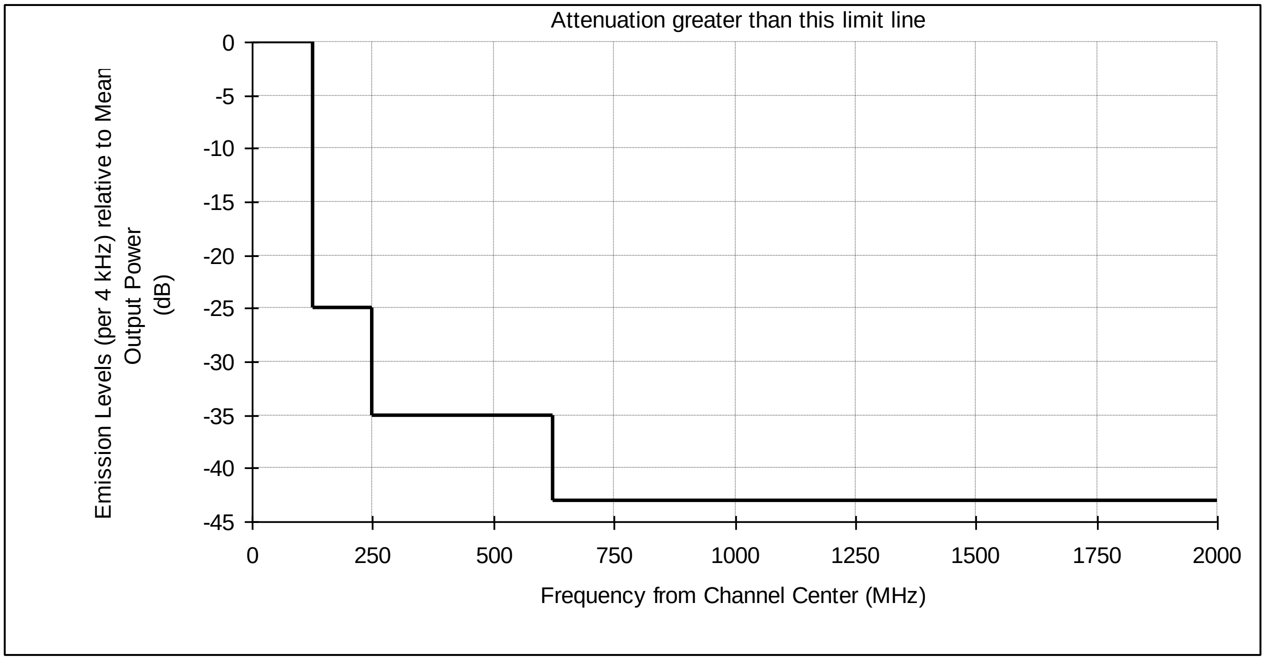


Figure 3.8.3-2: Unwanted Emission Mask for 500 MHz Channels

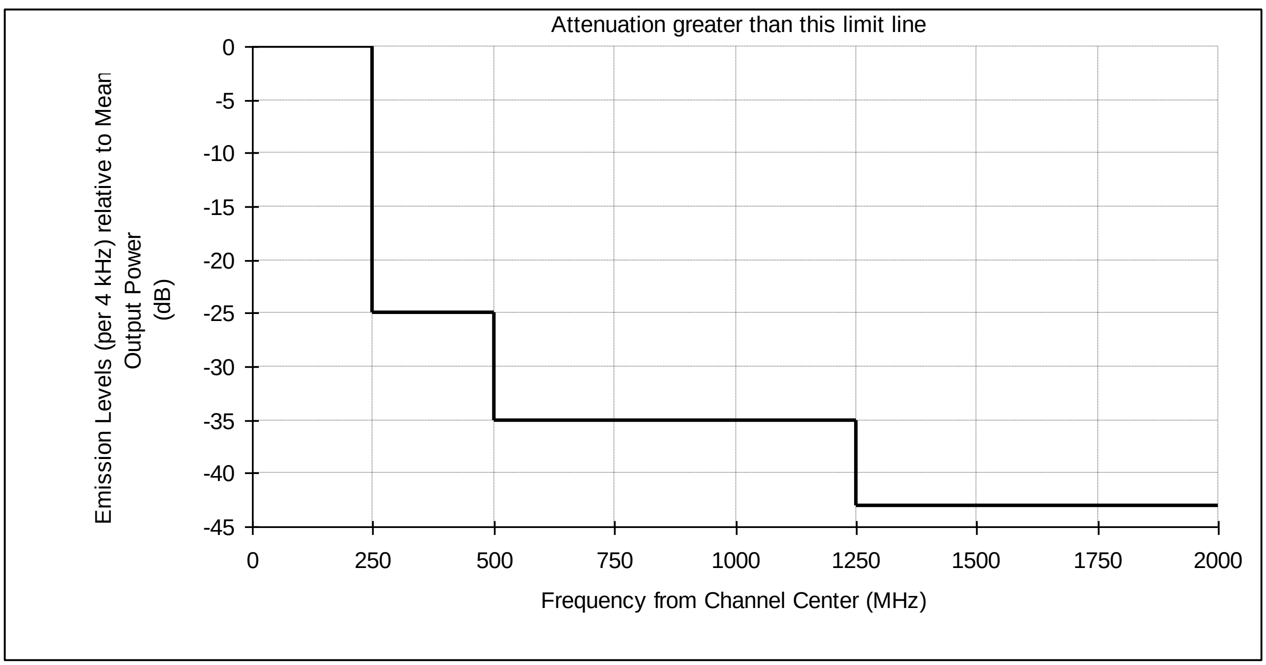
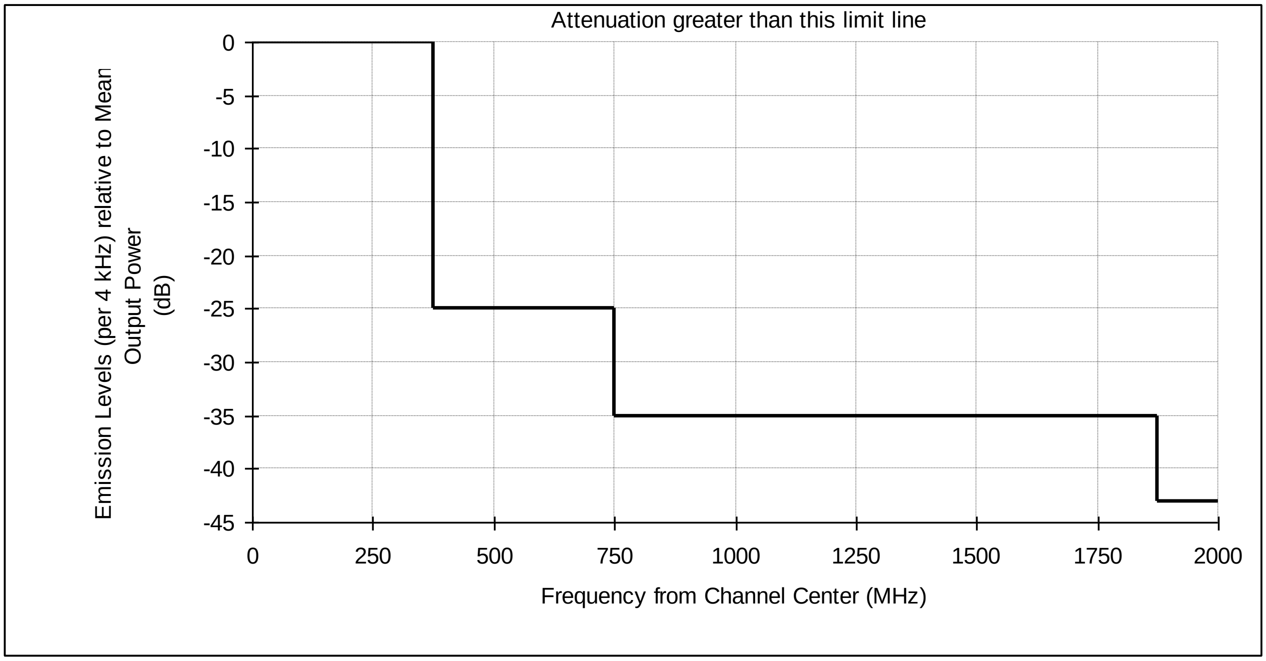


Figure 3.8.3-3: Unwanted Emission Mask for 750 MHz Channels



3.8.4 Frequency Tolerance

The local oscillator frequency stability in the Virtual Geo satellite communications payload will determine the accuracy of the frequency conversion between uplink and downlink transmissions. This frequency conversion error shall not exceed ±5 in 10^6 under all circumstances.

3.8.5 Cessation of Emissions

All carriers in the Virtual Geo satellite system, both those transmitted from gateway terminals as well as those from user terminals, will be able to be individually turned on and off through the network management functions controlled by the RNCC.

3.8.6 Downlink Beacon Applications

3.8.6.1 Earth Station Tracking

All user and gateway terminals must track the transmitting and receiving Virtual Geo satellite as it moves through the active part of its orbit. This is achieved by a combination of computer prediction (based on ephemeris data supplied on a regular basis by the RNCC/Gateway to all terminals via the order wire links) and tracking by the terminals of the downlink beacon transmitted by the Virtual Geo satellites. The EIRP spectral density (per-Hz) of the downlink beacons is approximately 6 dB higher than communications downlinks in order to provide more robust links for this important function. Further details of the frequencies, power levels and emission characteristics of these beacons are given in Section 3.4.2.5.

3.8.6.2 Uplink Power Control

Correct setting of the uplink carrier power levels of both the user and gateway terminals is essential to the correct operation of the Virtual Geo system. This issue is discussed in more detail in Sections 3.16.1 and 3.16.2 below. Measurement by the gateway terminals of the fading on the beacon downlink signal is essential to allow the gateway to distinguish between uplink and downlink fades on the inbound links, and hence to the proper implementation of uplink power control for the user terminals. It is also used to determine fading on the satellite-gateway path and hence derive uplink power control information for the gateway terminal transmissions.

3.9 LINK BUDGETS

All communications links in the Virtual Geo system will be digital, with the same modulation type and FEC coding. As such, the link budgets for various data rates are very similar in that they assume that the digital spectra are essentially flat. Other minor differences between the actual link budgets for different data rates are a result of slightly different channel filtering and the performance of the demodulators. There are, however, significant differences in the link budgets between the outbound (*i.e.*, gateway-to-user) and inbound (*i.e.*, user-to-gateway) links. Therefore, in this section there are just two types of link budget provided for each major frequency band, and these are intended to demonstrate the performance of the system for a wide range of actual data rates. The spectral densities of the signals provided in these links represents the maximum transmit powers regardless of actual link data rate.

Table 3.9-1 gives the outbound link between a 6 meter transmitting gateway terminal operating in the 12.75-13.25 GHz and 13.8-14.0 GHz bands and a minimum sized 45 cm receiving user terminal operating in the 11.2-12.7 GHz band. In practice the link power levels will be constantly changing by means of uplink power control as the satellite moves through its active orbit arc, but this link budget shows the near worst case situation when the satellite is at the maximum distance from anywhere in the service area. Four cases are shown in the columns of the link budget: the first is the clear sky edge of beam case; the second is clear sky nominal case, the third includes a rain fade on the uplink which is compensated by uplink power control; the fourth includes a rain fade on the downlink . Table 3.9-2 gives a similar outbound link budget but for the upper Ka-band gateway uplink frequency range (17.8-16.6 GHz). Table 3.9-3 gives the third type of outbound link budget for the gateway uplink operating in C-band (5.925-6.725 GHz).

Tables 3.9-4, 3.9-5 and 3.9-6 give the two cases of inbound link budgets between the transmitting 45 cm user terminal, the 6 meter receiving gateway terminal and the 1m user terminal, for gateway downlinks in the Ku-band (10.7-11.2 GHz) and C-band (3.7-4.2 GHz) respectively. Similar cases of clear sky, uplink rain fade and downlink rain fade are shown, as for the outbound links.

The link budgets shown in this section in Table 3.9.-7 are compatible with 99.9% availability on the user links (both uplink and downlink) in all the rain regions of CONUS with the exception of the small area in the south-east which is rain region N. In this region the availability is 99.7% with the same size user terminal, or higher with a corresponding increase in user terminal size. The gateway links are all 99.99% availability for the C-band and lower Ku-band (< 14 GHz) links, provided that the gateways are not located in rain region N. In the Ka-band (> 17.8 GHz) gateway links the availability in rain region M drops to 99.97%, unless the gateway antenna size is increased.

Table 3.9-1: Outbound Link Budget (14 GHz uplink)

Virtual Geo Link Budget

26-Jul-17

Gateway-to-User (14/12 GHz)

Earth stations: Tx (6m) to Rx (0.45m)

39558 Kbps user bit rate; 0.667 FEC / 16APSK Modulation / Alpha = 20

Link Parameters		Clear Sky Edge of Beam apogee	Clear Sky nominal apogee	Uplink Fade	Downlink Fade
Link Geometry:					
GW range to satellite	(km)	27,677	27,677	27,677	27,677
UT range to satellite	(km)	27,744	27,744	27,744	27,744
Uplink (per carrier):					
Carrier Frequency	(MHz)	13900	13900	13900	13900
Tx E/S Antenna Diameter	(m)	**6.0**	**6.0**	6.0	6.0
Tx E/S Power to Antenna terminals	(W)	**0.755**	**0.605**	2.7	1.001
Tx E/S PSD to Antenna - per 4 kHz	(dBW/4kH	-37.8	-38.7	-32.2	-36.5
Tx E/S PSD to Antenna - per Hz	(dBW/Hz)	-73.8	-74.7	-68.2	-72.5
antenna efficiency		0.6	0.6	0.6	0.6
Tx E/S Antenna Gain (60% eff.)	(dB)	56.6	56.6	56.6	56.6
Tx E/S EIRP per Carrier	(dBW)	55.4	54.4	61.0	56.6
Atmospheric and Other Losses	(dB)	0.5	0.5	7.0	0.5
Free Space Loss	(dB)	204.1	204.1	204.1	204.1
Spreading Loss	(dB)	159.8	159.8	159.8	159.8
Satellite:					
Total Power Flux at Satellite	(dBW/m2)	-104.9	-105.9	-105.9	-103.7
Satellite Rx Gain towards Tx E/S (bea	(dBi)	**42.3**	**42.3**	42.3	42.3
Diameter of Rcv antenna	m	1.0	1.0	1.0	1.0
antenna efficiency		0.8	0.8	0.8	0.8
Received Signal Power	(dBW)	-107.0	-107.9	-107.9	-105.7
Satellite Receive System Noise Temp	(K)	**600**	**600**	600	600
Satellite G/T towards Tx E/S (beam e	(dB/K)	14.5	14.5	14.5	14.5
(C/T) Thermal Uplink	(dBW/K)	-134.7	-135.7	-135.6	-133.5
Net Satellite Channel Gain	(dB)	**115.0**	**115.0**	115.0	115.0
Satellite Tx Power	(Watts)	**6.37**	**5.10**	5.17	8.44
Satellite Tx Gain towards Rx E/S	(dBi)	**35.0**	**40.0**	35.0	35.0
Satellite Tx EIRP towards Rx E/S	(dBW)	43.0	47.1	42.1	44.3
Downlink (per carrier):					
Carrier Frequency	(MHz)	11950	11950	11950	11950
Atmospheric and Other Losses	(dB)	0.5	0.5	0.5	6.0
Free Space Loss	(dB)	202.9	202.9	202.9	202.9
Spreading Loss	(dB)	159.9	159.9	159.9	159.9
PFlux at Earth's Surface	(dBW/m2/	-117.3	-113.3	-118.2	-121.6
Rx E/S Antenna Diameter	(m)	**0.45**	**0.45**	0.45	0.45
Rx E/S Antenna efficiency		**0.80**	**0.80**	0.80	0.80
Rx E/S Antenna Gain	(dB)	34.0	34.0	34.0	34.0
Squint loss	(dB)	1.0	1.0	1.0	1.0
Rx E/S G/T	(dB/K)	12.6	12.6	13.6	13.1
Received Signal Power	(dBW)	-127.3	-123.2	-127.2	-130.5
System (LNA+Sky) Noise Temp.	(K)	110	110	110	125
(C/T) Thermal Downlink	(dBW/K)	-147.7	-143.6	-147.6	-151.5
Total Link:					
Information Bit Rate	(kbps)	26,700	39,558	29,710	45,000
Symbol rate	ksps	15,000	15,000	15,000	15,000
FEC Rate	(fraction)	**.600**	**.667**	**0.667**	**0.667**
Modulation Type (BPSK, QPSK, 8PS	(? PSK)	**8PSK**	**16APSK**	**8PSK**	**QPSK**
Rx filter "alpha" factor	(%)	**20.0**	**20.0**	20.0	20.0
Carrier Noise Bandwidth	(kHz)	**18,000**	**18,000**	**18,000**	**18,000**
(C/N) - Thermal Uplink	(dB)	21.3	20.3	20.4	22.5
(C/N) - Thermal Uplink	(dB)	21.3	20.3		
(C/N) - Thermal Downlink	(dB)	8.4	12.4	8.5	4.5
(C/N) - Thermal Downlink	(dB)	8.4	12.4		
(C/I) - Intermodulation Noise	(dB)	99.0	99.0	99.0	99.0
(C/I) - Cross-Polar Interference	(dB)	25.0	25.0	25.0	25.0
(C/I) - Multi-Beam Effects	(dB)	20.0	25.0	20.0	20.0
(C/I) - interchannel interference	(dB)	25.0	25.0	25	
(C/N+I) - Total Actual	(dB)	7.7	11.2	7.8	4.3
(Es/No) - Total Actual	(dB)	8.5	12.0	8.6	5.1
Desired BER		QEF	QEF	QEF	QEF
Es/No required, coded	(dB)	5.50	8.97	6.62	3.10
implementation margin	(dB)	1.0	1.0	1.0	1.0
Excess Margin	(dB)	2.0	2.0	1.0	1.0

Table 3.9-2: Outbound Link Budget (17.8-18.6 GHz uplink)

Virtual Geo Link Budget

26-Jul-17

Gateway-to-User (17/12 GHz)

Earth stations: Tx (6m) to Rx (0.45m)

39558 Kbps user bit rate; 0.667 FEC / 16APSK Modulation / Alpha = 20

Link Parameters		Clear Sky Edge of Beam apogee	Clear Sky nominal apogee	Uplink Fade	Downlink Fade
GW range to satellite	(km)	27677	27677	27677	27677
UT range to satellite	(km)	27744	27744	27744	27744
Uplink					
Carrier Frequency	(MHz)	17550	17550	17550	17550
Tx E/S Antenna Diameter	(m)	**6.0**	**6.0**	6.0	6.0
Tx E/S Power to Antenna terminals	(W)	**0.741**	**0.612**	2.7	0.972
Tx E/S PSD to Antenna - per 4 kHz	(dBW/4kH	-37.8	-38.7	-32.2	-36.7
Tx E/S PSD to Antenna - per Hz	(dBW/Hz)	-73.9	-74.7	-68.2	-72.7
GW antenna effic		0.6	0.6	0.6	0.6
Tx E/S Antenna Gain (60% eff.)	(dB)	59.9	59.9	59.9	59.9
Tx E/S EIRP per Carrier	(dBW)	58.6	57.7	64.2	59.8
Atmospheric and Other Losses	(dB)	0.5	0.5	7.0	0.5
Free Space Loss	(dB)	206.2	206.2	206.2	206.2
Spreading Loss	(dB)	159.8	159.8	159.8	159.8
Satellite					
Total Power flux at Satellite	(dBW/m2)	-101.8	-102.6	-102.6	-100.6
Satellite Rx Gain towards Tx E/S (beam edge)	(dBi)	**41.2**	**41.2**	41.2	41.2
Antenna diameter		0.7	0.7	0.7	0.7
Received Signal Power	(dBW)	-106.9	-107.7	-107.8	-105.7
Satellite Receive System Noise Temperature	(K)	**800**	**800**	800	800
Satellite G/T towards Tx E/S (beam edge)	(dB/K)	12.2	12.2	12.2	12.2
(C/T) Thermal Uplink	(dBW/K)	-135.9	-136.8	-136.8	-134.7
Net Satellite Channel Gain	(dB)	**115.0**	**115.0**	115.0	115.0
Satellite Tx Power	(Watts)	**6.47**	**5.34**	5.27	8.49
Satellite Tx Gain towards Rx E/S	(dBi)	**35.0**	**40.0**	35.0	35.0
Satellite Tx EIRP towards Rx E/S	(dBW)	43.1	47.3	42.2	44.3
Downlink					
Carrier Frequency	(MHz)	11950	11950	11950	11950
Atmospheric and Other Losses	(dB)	0.5	0.5	0.5	6.0
Free Space Loss	(dB)	202.9	202.9	202.9	202.9
Spreading Loss	(dB)	159.9	159.9	159.9	159.9
PFD at Earth's Surface (in 4 kHz)	(dBW/m2/	-150.8	-146.6	-151.7	-155.1
Rx E/S Antenna Diameter	(m)	**0.45**	**0.45**	0.45	0.45
Rx E/S Antenna efficiency		**0.80**	**0.80**	0.80	0.80
Rx E/S Antenna Gain	(dB)	34.0	34.0	34.0	34.0
Squint loss	(dB)	1.0	1.0	1.0	1.0
Rx E/S G/T	(dB/K)	12.6	12.6	13.6	13.1
Received Signal Power	(dBW)	-127.2	-123.0	-127.1	-130.5
System (LNA+Sky) Noise Temp.	(K)	110	110	110	125
(C/T) Thermal Downlink	(dBW/K)	-147.6	-143.4	-147.5	-151.5
Overall					
Information Bit Rate	(kbps)	26,700	39,558	29,710	45,000
Symbol rate	ksps	15,000	15,000	15,000	15,000
FEC Rate	(fraction)	**.600**	**.667**	**0.667**	**0.667**
Modulation Type (BPSK, QPSK, 8PSK, 16QAM)	(? PSK)	**8PSK**	**16APSK**	**8PSK**	**QPSK**
Rx filter "alpha" factor	(%)	**20.0**	**20.0**	20.0	20.0
Carrier Noise Bandwidth	(kHz)	**18,000**	**18,000**	**18,000**	**18,000**
(C/N) - Thermal Uplink	(dB)	20.1	19.3	19.2	21.3
(C/N) - Thermal Uplink	(dB)	20.1	19.3		
(C/N) - Thermal Downlink	(dB)	8.4	12.6	8.5	4.6
(C/N) - Thermal Downlink	(dB)	8.4	12.6		
(C/I) - Intermodulation Noise	(dB)	99.0	99.0	99.0	99.0
(C/I) - Cross-Polar Interference	(dB)	25.0	25.0	25.0	25.0
(C/I) - Multi-Beam Effects	(dB)	20.0	25.0	20.0	20.0
(C/I) - interchannel interference	(dB)	25.0	25.0	25	
(C/N+I) - Total Actual	(dB)	7.7	11.2	7.8	4.3
(Es/No) - Total Actual	(dB)	8.5	12.0	8.6	5.1
Desired BER		QEF	QEF	QEF	QEF
Es/No required, coded	(dB)	5.50	8.97	6.62	3.10
implementation margin	(dB)	1.0	1.0	1.0	1.0
Excess Margin	(dB)	2.0	2.0	1.0	1.0

Table 3.9-3: Outbound Link Budget (5.925-6.725 GHz uplink)

	Virtual Geo Link Budget					26-Jul-17
	Gateway-to-User (6/12 GHz)					
	Earth stations: Tx (6m) to Rx (0.45m)					
	39558 Kbps user bit rate; 0.667 FEC / 16APSK Modulation / Alpha = 20					
	Link Parameters		**Clear Sky Edge of Beam apogee**	**Clear Sky nominal apogee**	**Uplink Fade**	**Downlink Fade**
	GW range to satellite	(km)	27677	27677	27677	27677
	UT range to satellite	(km)	27744	27744	27744	27744
Uplink						
	Carrier Frequency	(MHz)	6325	6325	6325	6325
	Tx E/S Antenna Diameter	(m)	**6.0**	**6.0**	6.0	6.0
	Tx E/S Power to Antenna terminals	(W)	**2.415**	**1.936**	3.7	1.947
	Tx E/S PSD to Antenna - per 4 kHz	(dBW/4kH	-32.7	-33.7	-30.8	-33.6
	Tx E/S PSD to Antenna - per Hz	(dBW/Hz)	-68.7	-69.7	-66.9	-69.7
	GW antenna effic		0.6	0.6	0.6	0.6
	Tx E/S Antenna Gain (60% eff.)	(dB)	51.0	51.0	51.0	51.0
	Tx E/S EIRP per Carrier	(dBW)	54.8	53.9	56.7	53.9
	Atmospheric and Other Losses	(dB)	0.5	0.5	7.0	0.5
	Free Space Loss	(dB)	197.3	197.3	197.3	197.3
	Spreading Loss	(dB)	159.8	159.8	159.8	159.8
Satellite						
	Total Power flux at Satellite	(dBW/m2)	-105.5	-106.5	-110.1	-106.4
	Satellite Rx Gain towards Tx E/S (beam edge)	(dBi)	**36.0**	**36.0**	36.0	36.0
	Diameter of Receive Antenna	(dB-m2)	1.0	-1.5	1.0	1.0
	Received Signal Power	(dBW)	-107.0	-107.9	-111.6	-107.9
	Satellite Receive System Noise Temperature	(K)	**600**	**600**	600	600
	Satellite G/T towards Tx E/S	(dB/K)	8.2	8.2	8.2	8.2
	(C/T) Thermal Uplink	(dBW/K)	-134.7	-135.7	-139.4	-135.7
	Net Satellite Channel Gain	(dB)	**115.0**	**115.0**	115.0	115.0
	Satellite Tx Power	(Watts)	**6.37**	**5.10**	2.19	5.13
	Satellite Tx Gain towards Rx E/S	(dBi)	**35.0**	**40.0**	35.0	35.0
	Satellite Tx EIRP towards Rx E/S	(dBW)	43.0	47.1	38.4	42.1
Downlink						
	Carrier Frequency	(MHz)	11950	11950	11950	11950
	Atmospheric and Other Losses	(dB)	0.5	0.5	0.5	6.0
	Free Space Loss	(dB)	202.9	202.9	202.9	202.9
	Spreading Loss	(dB)	159.9	159.9	159.9	159.9
	Pwr Flux at Earth's Surface	(dBW/m2/4	-117.3	-113.3	-121.9	-123.8
	Rx E/S Antenna Diameter	(m)	**0.45**	**0.45**	0.45	0.45
	Rx E/S Antenna efficiency		**0.80**	**0.80**	0.80	0.80
	Rx E/S Antenna Gain	(dB)	34.0	34.0	34.0	34.0
	Squint loss	(dB)	1.0	1.0	1.0	1.0
	Rx E/S G/T	(dB/K)	12.6	12.6	13.6	13.1
	Received Signal Power	(dBW)	-127.3	-123.2	-130.9	-132.7
	System (LNA+Sky) Noise Temp.	(K)	110	110	110	125
	(C/T) Thermal Downlink	(dBW/K)	-147.7	-143.6	-151.3	-153.7
Overall						
	Information Bit Rate	(kbps)	26,700	39,558	19,834	45,000
	Symbol rate	ksps	15,000	15,000	15,000	15,000
	FEC Rate	(fraction)	**.600**	**.667**	**0.667**	**0.500**
	Modulation Type (BPSK, QPSK, 8PSK, 16QAM)	(? PSK)	**8PSK**	**16APSK**	**qpsk**	**QPSK**
	Rx filter "alpha" factor	(%)	**20.0**	**20.0**	20.0	20.0
	Carrier Noise Bandwidth	(kHz)	**18,000**	**18,000**	**18,000**	**18,000**
	(C/N) - Thermal Uplink	(dB)	21.3	20.3	16.7	20.4
	(C/N) - Thermal Uplink	(dB)	21.3	20.3		
	(C/N) - Thermal Downlink	(dB)	8.4	12.4	4.7	2.4
	(C/N) - Thermal Downlink	(dB)	8.4	12.4		
	(C/I) - Intermodulation Noise	(dB)	99.0	99.0	99.0	99.0
	(C/I) - Cross-Polar Interference	(dB)	25.0	25.0	25.0	25.0
	(C/I) - Multi-Beam Effects	(dB)	20.0	25.0	20.0	20.0
	(C/I) - interchannel interference	(dB)	25.0	25.0	25	
	(C/N+I) - Total Actual	(dB)	7.7	11.2	4.3	2.2
	(Es/No) - Total Actual	(dB)	8.5	12.0	5.1	3.0
	Desired BER		QEF	QEF	QEF	QEF
	Es/No required, coded	(dB)	5.50	8.97	3.10	1.00
	implementation margin	(dB)	1.0	1.0	1.0	1.0
	Excess Margin	(dB)	2.0	2.0	1.0	1.0

Table 3.9-4: Inbound Link Budget (10.7-11.2 GHz downlink)

Virtual Geo Link Budget

26-Jul-17

User-to-Gateway (14/11 GHz)

Earth stations: Tx (0.45m) to Rx (6m)

3251 Kbps / 0.8 FEC rate / QPSK Modulation / Alpha = 0.2

Link Parameters		Clear Sky Edge	Clear Sky Nominal	Uplink Fade	Downlink Fade
Link Geometry:					
GW slant range to satellite	(km)	27,677	27,677	27,677	27,677
UT slant range to satellite	(km)	27,744	27,744	27,744	27,744
Uplink (per carrier):					
Carrier Frequency	(MHz)	14,250	14,250	14,250	14,250
Tx E/S Antenna Diameter	(m)	0.45	0.45	0.45	0.45
Tx antenna efficiency		0.80	0.80	0.80	0.80
Tx E/S Power to Antenna	(W)	3.365	1.026	3.998	4.000
Tx E/S PSD to Antenna - per 4 kHz	(dBW/4kH	-22.6	-27.8	-21.9	-21.9
Tx E/S PSD to Antenna - per Hz	(dBW/Hz)	-58.6	-63.8	-57.9	-57.9
Tx E/S Antenna Gain (60% eff.)	(dB)	35.6	35.6	34.3	34.3
Tx E/S EIRP per Carrier	(dBW)	40.8	35.7	40.3	40.3
Atmospheric and Other Losses	(dB)	0.5	0.5	6.0	0.5
Free Space Loss	(dB)	204.4	204.4	204.4	204.4
Spreading Loss	(dB)	159.8	159.8	159.8	159.8
Satellite:					
Total power flux at Satellite	(dBW/m2)	-119.5	-124.7	-125.5	-120.0
Satellite Rx Gain towards Tx E/S (beam edge)	(dBi)	35.0	40.0	35.0	35.0
Effective Aperture of Receive Antenna	(dB-m2)	-9.5	-4.5	-9.5	-9.5
Received Signal Power	(dBW)	-129.0	-129.2	-135.0	-129.5
Received Signal Power	(dBW)	-129.0	-129.2		
Satellite Receive System Noise Temperature	(K)	600	600	600	600
Satellite G/T towards Tx E/S	(dB/K)	7.2	12.2	7.2	7.2
(C/T) Thermal Uplink	(dBW/K)	-156.8	-157.0	-162.8	-157.3
Satellite Channel Gain	(dB)	109.0	109.0	109.0	109.0
Satellite Tx Power	(Watts)	0.010	0.010	0.003	0.009
Satellite Tx Gain towards Rx E/S	(dBi)	40.2	40.2	40.2	40.2
Satellite Tx EIRP towards Rx E/S	(dBW)	20.2	20.0	14.2	19.7
Downlink (per carrier):					
Carrier Frequency	(MHz)	10,950	10,950	10,950	10,950
Atmospheric and Other Losses	(dB)	0.5	0.5	0.5	7.0
Free Space Loss	(dB)	202.1	202.1	202.1	202.1
Spreading Loss	(dB)	159.9	159.9	159.9	159.9
PFD at Earth's Surface (in 4 kHz)	(dBW/m2/	-165.1	-165.2	-171.1	-172.1
Rx E/S Antenna Diameter	(m)	6.00	6.00	6.00	6.00
Rx E/S Antenna Gain (60% eff.)	(dB)	54.5	54.5	54.5	54.5
Rx E/S G/T	(dB/K)	34.1	34.1	34.1	33.6
Received Signal Power	(dBW)	-127.9	-128.0	-133.9	-134.9
System (LNA+Sky) Noise Temp.	(K)	110	110	110	125
(C/T) Thermal Downlink	(dBW/K)	-148.3	-148.5	-154.3	-155.8
Total Link:					
Information Bit Rate (before channel coding)	(kbps)	3,251	3,251	1,617	3,046
Symbol rate	ksps	2,048	2,048	2,048	2,048
FEC Rate	(fraction)	0.800	0.800	0.400	0.750
Modulation Type	(? PSK)	QPSK	QPSK	qpsk	QPSK
Rx filter "alpha" factor	(%)	0.20	0.20	0.2	0.2
Carrier Noise Bandwidth	(kHz)	2,458	2,458	2,458	2,458
(C/N) - Thermal Uplink	(dB)	7.9	7.7	1.9	7.4
(C/N) - Thermal Uplink	(dB)	7.9	7.7		
(C/N) - Thermal Downlink	(dB)	16.4	16.2	10.4	8.8
(C/N) - Thermal Downlink	(dB)	16.4	16.2		
(C/I) - Intermodulation Noise	(dB)	22.0	22.0	22.0	22.0
(C/I) - Cross-Polar Interference	(dB)	25.0	25.0	25.0	25.0
(C/I) - Multi-Beam Effects	(dB)	20.0	25.0	20.0	20.0
(C/N+I) - Total Actual	(dB)	6.9	6.9	1.2	4.8
(Es/No) - Total Actual	(dB)	7.7	7.7	2.0	5.6
Es/No required, coded	(dB)	4.68	4.68	0.00	4.03
implementation margin	(dB)	1.0	1.0	1.0	1.0
Excess Margin	(dB)	2.0	2.0	1.0	0.6

Table 3.9-5: Inbound Link Budget (3.7-4.2 GHz downlink)

Virtual Geo Link Budget

26-Jul-17

User-to-Gateway (14/6 GHz)

Earth stations: Tx (0.45m) to Rx (6m)

3251 Kbps / 0.8 FEC rate / QPSK Modulation / Alpha = 0.2

Link Parameters		**Clear Sky Edge**	**Clear Sky Nominal**	**Uplink Fade**	**Downlink Fade**
Link Geometry:					
GW slant range to satellite	(km)	27,677	27,677	27,677	27,677
UT slant range to satellite	(km)	27,744	27,744	27,744	27,744
Uplink (per carrier):					
Carrier Frequency	(MHz)	14,250	14,250	14,250	14,250
Tx E/S Antenna Diameter	(m)	0.45	0.45	0.45	0.45
Tx antenna efficiency		0.80	0.80	0.80	0.80
Tx E/S Power to Antenna	(W)	3.365	1.026	3.998	4.000
Tx E/S PSD to Antenna - per 4 kHz	(dBW/4kH	-22.6	-27.8	-21.9	-21.9
Tx E/S PSD to Antenna - per Hz	(dBW/Hz)	-58.6	-63.8	-57.9	-57.9
Tx E/S Antenna Gain (60% eff.)	(dB)	35.6	35.6	34.3	34.3
Tx E/S EIRP per Carrier	(dBW)	40.8	35.7	40.3	40.3
Atmospheric and Other Losses	(dB)	0.5	0.5	6.0	0.5
Free Space Loss	(dB)	204.4	204.4	204.4	204.4
Spreading Loss	(dB)	159.8	159.8	159.8	159.8
Satellite:					
Total power flux at Satellite	(dBW/m2)	-119.5	-124.7	-125.5	-120.0
Satellite Rx Gain towards Tx E/S (beam edge)	(dBi)	35.0	40.0	35.0	35.0
Effective Aperture of Receive Antenna	(dB-m2)	-9.5	-4.5	-9.5	-9.5
Received Signal Power	(dBW)	-129.0	-129.2	-135.0	-129.5
Received Signal Power	(dBW)	-129.0	-129.2		
Satellite Receive System Noise Temperature	(K)	600	600	600	600
Satellite G/T towards Tx E/S	(dB/K)	7.2	12.2	7.2	7.2
(C/T) Thermal Uplink	(dBW/K)	-156.8	-157.0	-162.8	-157.3
Satellite Channel Gain	(dB)	120.0	120.0	120.0	120.0
Satellite Tx Power	(Watts)	0.125	0.121	0.031	0.112
Satellite Tx Gain towards Rx E/S	(dBi)	31.3	31.3	31.3	31.3
Satellite Tx EIRP towards Rx E/S	(dBW)	22.3	22.1	16.3	21.8
Downlink (per carrier):					
Carrier Frequency	(MHz)	3,950	3,950	3,950	3,950
Atmospheric and Other Losses	(dB)	0.2	0.2	0.2	5.0
Free Space Loss	(dB)	193.2	193.2	193.2	193.2
Spreading Loss	(dB)	159.9	159.9	159.9	159.9
PFD at Earth's Surface (in 4 kHz)	(dBW/m2/	-162.7	-162.8	-168.7	-168.0
Rx E/S Antenna Diameter	(m)	6.00	6.00	6.00	6.00
Rx E/S Antenna Gain (60% eff.)	(dB)	45.7	45.7	45.7	45.7
Rx E/S G/T	(dB/K)	25.3	25.3	25.3	24.7
Received Signal Power	(dBW)	-125.5	-125.6	-131.5	-130.8
System (LNA+Sky) Noise Temp.	(K)	110	110	110	125
(C/T) Thermal Downlink	(dBW/K)	-145.9	-146.1	-151.9	-151.7
Total Link:					
Information Bit Rate (before channel coding)	(kbps)	3,251	3,251	1,617	3,046
Symbol rate	ksps	2,048	2,048	2,048	2,048
FEC Rate	(fraction)	0.800	0.800	0.400	0.750
Modulation Type	(? PSK)	QPSK	QPSK	qpsk	QPSK
Rx filter "alpha" factor	(%)	0.20	0.20	0.2	0.2
Carrier Noise Bandwidth	(kHz)	2,458	2,458	2,458	2,458
(C/N) - Thermal Uplink	(dB)	7.9	7.7	1.9	7.4
(C/N) - Thermal Uplink	(dB)	7.9	7.7		
(C/N) - Thermal Downlink	(dB)	18.8	18.6	12.8	12.9
(C/N) - Thermal Downlink	(dB)	18.8	18.6		
(C/I) - Intermodulation Noise	(dB)	22.0	22.0	22.0	22.0
(C/I) - Cross-Polar Interference	(dB)	25.0	25.0	25.0	25.0
(C/I) - Multi-Beam Effects	(dB)	20.0	25.0	20.0	20.0
(C/N+I) - Total Actual	(dB)	7.1	7.1	1.4	6.0
(Es/No) - Total Actual	(dB)	7.9	7.9	2.2	6.8
Es/No required, coded	(dB)	4.68	4.68	0.00	4.03
implementation margin	(dB)	1.0	1.0	1.0	1.0
Excess Margin	(dB)	2.2	2.2	1.2	1.7

Table 3.9-6 For 1m User Terminals

Virtual Geo Link Budget

26-Jul-17

Gateway-to-User (14/12 GHz)

Earth stations: Tx (6m) to Rx (1m)

89002 Kbps user bit rate; 0.75 FEC / 16APSK Modulation / Alpha = 20

Link Parameters		Clear Sky Edge of Beam apogee	Clear Sky nominal apogee	Uplink Fade	Downlink Fade
Link Geometry:					
GW range to satellite	(km)	27677	27677	27677	27677
UT range to satellite	(km)	27744	27744	27744	27744
Uplink (per carrier):					
Carrier Frequency	(MHz)	13900	13900	13900	13900
Tx E/S Antenna Diameter	(m)	**6.0**	**6.0**	6.0	6.0
Tx E/S Power to Antenna terminals	(W)	**0.486**	**0.528**	2.7	1.001
Tx E/S PSD to Antenna - per 4 kHz	(dBW/4kH	-42.7	-42.3	-35.2	-39.5
Tx E/S PSD to Antenna - per Hz	(dBW/Hz)	-78.7	-78.3	-71.2	-75.6
antenna efficiency		0.6	0.6	0.6	0.6
Tx E/S Antenna Gain (60% eff.)	(dB)	56.6	56.6	56.6	56.6
Tx E/S EIRP per Carrier	(dBW)	53.5	53.8	61.0	56.6
Atmospheric and Other Losses	(dB)	0.5	0.5	7.0	0.5
Free Space Loss	(dB)	204.1	204.1	204.1	204.1
Spreading Loss	(dB)	159.8	159.8	159.8	159.8
Satellite:					
Total Power Flux at Satellite	(dBW/m2)	-106.9	-106.5	-105.9	-103.7
Satellite Rx Gain towards Tx E/S (beam edge)	(dBi)	**42.3**	**42.3**	42.3	42.3
Diameter of Rcv antenna	m	1.0	1.0	1.0	1.0
antenna efficiency		0.8	0.8	0.8	0.8
Received Signal Power	(dBW)	-108.9	-108.5	-107.9	-105.7
Satellite Receive System Noise Temperature	(K)	**600**	**600**	600	600
Satellite G/T towards Tx E/S (beam edge)	(dB/K)	14.5	14.5	14.5	14.5
(C/T) Thermal Uplink	(dBW/K)	-136.7	-136.3	-135.6	-133.5
Net Satellite Channel Gain	(dB)	**115.0**	**115.0**	115.0	115.0
Satellite Tx Power	(Watts)	**4.10**	**4.46**	5.17	8.44
Satellite Tx Gain towards Rx E/S	(dBi)	**35.0**	**40.0**	35.0	35.0
Satellite Tx EIRP towards Rx E/S	(dBW)	41.1	46.5	42.1	44.3
Downlink (per carrier):					
Carrier Frequency	(MHz)	11950	11950	11950	11950
Atmospheric and Other Losses	(dB)	0.5	0.5	0.5	6.0
Free Space Loss	(dB)	202.9	202.9	202.9	202.9
Spreading Loss	(dB)	159.9	159.9	159.9	159.9
PFlux at Earth's Surface	(dBW/m2/	-119.2	-113.9	-118.2	-121.6
Rx E/S Antenna Diameter	(m)	**1.00**	**1.00**	1.00	1.00
Rx E/S Antenna efficiency		**0.80**	**0.80**	0.80	0.80
Rx E/S Antenna Gain	(dB)	41.0	41.0	41.0	41.0
Squint loss	(dB)	1.0	1.0	1.0	1.0
Rx E/S G/T	(dB/K)	19.6	19.6	20.6	20.0
Received Signal Power	(dBW)	-122.2	-116.9	-120.2	-123.6
System (LNA+Sky) Noise Temp.	(K)	110	110	110	125
(C/T) Thermal Downlink	(dBW/K)	-142.7	-137.3	-140.7	-144.6
Total Link:					
Information Bit Rate	(kbps)	59,419	89,002	79,116	45,000
Symbol rate	ksps	30,000	30,000	30,000	30,000
FEC Rate	(fraction)	**.667**	**.750**	**0.667**	**0.600**
Modulation Type (BPSK, QPSK, 8PSK, 16QAM)	(? PSK)	**8PSK**	**16APSK**	**16APSK**	**8PSK**
Rx filter "alpha" factor	(%)	**20.0**	**20.0**	20.0	20.0
Carrier Noise Bandwidth	(kHz)	**36,000**	**36,000**	**36,000**	**36,000**
(C/N) - Thermal Uplink	(dB)	16.4	16.7	17.4	19.5
(C/N) - Thermal Uplink	(dB)	16.4	16.7		
(C/N) - Thermal Downlink	(dB)	10.4	15.7	12.4	8.5
(C/N) - Thermal Downlink	(dB)	10.4	15.7		
(C/I) - Intermodulation Noise	(dB)	99.0	99.0	99.0	99.0
(C/I) - Cross-Polar Interference	(dB)	25.0	25.0	25.0	25.0
(C/I) - Multi-Beam Effects	(dB)	20.0	25.0	20.0	20.0
(C/I) - interchannel interference	(dB)	25.0	25.0	25	
(C/N+I) - Total Actual	(dB)	8.8	12.4	10.5	7.8
(Es/No) - Total Actual	(dB)	9.6	13.2	11.3	8.6
Desired BER		QEF	QEF	QEF	QEF
Es/No required, coded	(dB)	6.62	10.21	8.97	5.50
implementation margin	(dB)	1.0	1.0	1.0	1.0
Excess Margin	(dB)	2.0	2.0	1.3	2.1

Table 3.9-7: TT&C L

VIrtual Geo Link Budget

26-Jul-17

TT&C Uplink and Downlink

Earth stations: Tx & Rx (5m)

32Kbps / 1/2 FEC / QPSK Modulation / Alpha = 25

Link Parameters		Lower Uplink	Upper Uplink	Lower Downlink	Upper Downlink
Link Geometry:					
Tx E/S Range to Satellite (max)	(km)	31,150	31,151	31150	31150
Rx E/S Range to Satellite (max)	(km)	31,150	31,151	31150	31150
Uplink (per carrier):					
Carrier Frequency	(MHz)	5,926	6,424		
Tx E/S Antenna Diameter	(m)	5.0	5.0		
Tx E/S Power to Antenna	(W)	5.0	5.0		
Tx E/S PSD to Antenna - per 4 kHz	(dBW/4kHz)	-3.0	-3.0		
Tx E/S PSD to Antenna - per Hz	(dBW/Hz)	-39.0	-39.0		
Tx E/S Antenna Gain (60% eff.)	(dB)	47.6	48.3		
Tx E/S EIRP per Carrier	(dBW)	54.6	55.3		
Atmospheric and Other Losses	(dB)	2.0	2.0		
Free Space Loss	(dB)	197.8	198.5		
Spreading Loss	(dB)	160.9	160.9		
Satellite:					
Total PFD at Satellite	(dBW/m2)	-108.3	-107.6		
Satellite Rx Gain towards Tx E/S (beam edge)	(dBi)	0.0	0.0		
Effective Aperture of Receive Antenna	($dB-m^2$)	-36.9	-37.6		
Received Signal Power	(dBW)	-145.2	-145.2		
Received Signal Power	(dBW)	-145.2	-145.2		
Satellite Receive System Noise Temperature	(K)	350	350		
Satellite G/T towards Tx E/S (beam edge)	(dB/K)	-25.4	-25.4		
(C/T) Thermal Uplink	(dBW/K)	-170.6	-170.6		
Satellite Channel Gain	(dB)				
Satellite Tx Power	(Watts)			1.5	1.5
Satellite Tx Gain towards Rx E/S (beam edge)	(dBi)			0.0	0.0
Satellite Tx EIRP towards Rx E/S (beam edge)	(dBW)			1.8	1.8
Downlink (per carrier):					
Carrier Frequency	(MHz)			3,701	4,199
Atmospheric and Other Losses	(dB)			2.0	2.0
Free Space Loss	(dB)			193.7	194.8
Spreading Loss	(dB)			160.9	160.9
PFD at Earth's Surface (in 4 kHz)	($dBW/m^2/4kHz$)			-168.1	-168.1
Rx E/S Antenna Diameter	(m)			5.00	5.00
Rx E/S Antenna Gain (60% eff.)	(dB)			43.5	44.6
Rx E/S G/T	(dB/K)			23.1	24.2
Received Signal Power	(dBW)			-150.4	-150.4
System (LNA+Sky) Noise Temp.	(K)			110	110
(C/T) Thermal Downlink	(dBW/K)			-170.8	-170.8
Total Link:					
Information Bit Rate (w/o coding)	(kbps)	32.0	32.0	32.0	32.0
FEC Rate	(fraction)	1/2	1/2	1/2	1/2
Modulation Type	(? PSK)	QPSK	QPSK	QPSK	QPSK
Rx filter "alpha" factor	(%)	25.0	25.0	25.0	25.0
Carrier Noise Bandwidth	(kHz)	40	40	40	40
(C/N) - Thermal Uplink	(dB)	12.0	12.0		
(C/N) - Thermal Downlink	(dB)			11.8	11.8
(C/I) - Intermodulation Noise	(dB)	22.0	22.0	22.0	22.0
(C/I) - Cross-Polar Interference	(dB)	25.0	25.0	25.0	25.0
(C/I) - Multi-Beam Effects	(dB)	25.0	25.0	25.0	25.0
(C/N+I) - Total Actual	(dB)	11.2	11.2	11.0	11.0
(Eb/No) - Total Actual	(dB)	12.2	12.2	12.0	12.0
(Eb/No) - Total Required	(dB)	8.0	8.0	8.0	8.0
Excess Margin	(dB)	4.2	4.2	4.0	4.0

3.10 PFD Limits

See Schedule S for details

3.10.1 TT&C PFD Limits

The Virtual Geo satellite's TT&C downlinks will operate below –160 $dBW/m^2/4kHz$ at all times. At most times, at the higher altitudes and longer slant ranges, these downlinks will operate at PFDs at significantly lower levels, reaching –168 $dBW/m^2/4kHz$ at apogee for low elevation angles, as shown in the TT&C link budgets. Virtual Geo will be constrained to remain always below the mandated PFD levels as cited in Section 3.10 above.

3.11 TRANSMIT-RECEIVE CONNECTIVITY

The connectivity of the uplink and downlinks of the Virtual Geo system are incidentally given in Sections 3.4.2.1, 3.4.2.2 and 3.4.2.3 above, where the frequency plans of the system are described. All uplinks from gateway beams are connected to downlinks in user beams, and vice versa. The only exception to this is for sub-channels originating from or destined to either user or gateway beams, which have the option of being switched through the ISL's to connect with active Virtual Geo satellites in other regions of the world (the exact configuration of the ISL-switchable channels has not yet been defined).

Although the frequency plan and beam configuration define the apportionment of spectrum to gateway and user beams, the use of active phased array satellite antennas in the Virtual Geo system means that the particular location of the uplink and downlink beams on the Earth's surface is fully flexible. Therefore it is not, for example, possible to uniquely define which 750 MHz portions of the user downlink spectrum will be transmitted towards a particular point on the Earth's surface.

3.12 INTRA-SYSTEM INTERFERENCE

Intra-system interference arises within the Virtual Geo system from a variety of sources, most of which are the same as in conventional GSO satellite systems. These GSO-like sources of intra-system interference are as follows:

- Intermodulation noise resulting from the use of multiple carriers within the operating bandwidth of the satellite channel, which although extremely linear, is not perfect in this respect. The use of solid-state power amplifiers within the satellite active phased array antenna means that this system degrader is minimized. The effect is also minimized by careful setting of the relative carrier power levels, which is achieved by the management control of the gateways for both outbound and inbound transmissions. Allowance is made for intermodulation noise in the link budgets given in Section 3.9.
- Cross-polar interference arises from the use of orthogonal polarizations within overlapping frequency bands (in the case of the Virtual Geo system these are left-hand circular and right-hand circular polarizations). All antennas, both satellite and earth station, achieve only a finite rejection of the orthogonal polarization. In the case of the user terminal beams, only a single polarization is used within a beam, but the adjacent beams, in some cases, will be co-frequency and cross-polar. Therefore, the worst cross-polar interference will occur for the user beams at certain parts of the edges of those beams. The situation for the user beams is therefore somewhat better than for a conventional dual polarization GSO satellite system. The gateway beams, on the other hand, operate co-frequency with dual orthogonal polarizations.

Allowance is made for cross-polar interference in the link budgets given in Section 3.9.

- Adjacent channel interference arises due to out-of-band emissions producing interfering signal energy within the receive bandwidth of adjacent channels. In the case of the Virtual Geo system, which uses wideband satellite channels, this effect is controlled by ensuring adequate channel filtering of the signals by the transmitting earth stations, operation of the satellite channel in a linear mode (so that spectrum re-growth is minimized) and by the use of adequate guard bands between transmissions. This effect is generally catered for by the above allowances for intermodulation and cross-polar degradation effects.

In addition to the above GSO-like sources of intra-system interference, the use of multiple co-frequency spot beams in the Virtual Geo system gives rise to additional effects, as follows:

- On the downlink the sidelobes of the other co-frequency co-polar downlink spot beams produce interference into the wanted downlink spot beam. On the uplink the transmissions from uplink earth stations operating in other co-frequency co-polar uplink spot beams produce interference into the sidelobes of the wanted uplink spot beam. These effects are controlled in the Virtual Geo system by ensuring the best possible sidelobe performance of both receive and transmit spot beams is achieved, together with appropriate geographic spacing of simultaneously operating co-frequency co-polar spot beams. Nevertheless, the resulting link degradation due to this effect is significant, particularly for links at the edges of the spot beams, and has been taken account of in the link budgets given in Section 3.9.

3.13 INTER-SYSTEM INTERFERENCE

The Virtual Geo system provides significant benefits, compared to other proposed NGSO FSS systems, in terms of its spectrum sharing capability with other services. The key differentiating factors, which derive from the novel design of the satellite constellation, are discussed and quantified in this section.

3.13.1 GSO FSS

The world satellite community went through a lengthy debate in the ITU concerning the operation of NGSO satellite systems in frequency bands used, or planned to be used, by GSO satellite systems. This keen interest in accommodating NGSO systems originated at WARC-92 and WRC-95 with U.S.-led initiatives, and culminated at WRC-97 with the introduction of provisional EPFD and APFD limits into the ITU Radio Regulations that are intended to protect GSO systems against unacceptable interference from NGSO systems. The Commission adopted rules to reflect sharing requirements following WRC-2000.[10]

The Virtual Geo system will readily comply with those requirements. The use of elliptical inclined orbits (see Section 3.2) with active arcs near to their apogee creates a completely different sharing environment with respect to GSO satellite systems. By careful design of the Virtual Geo satellite constellation, it has been possible to achieve a

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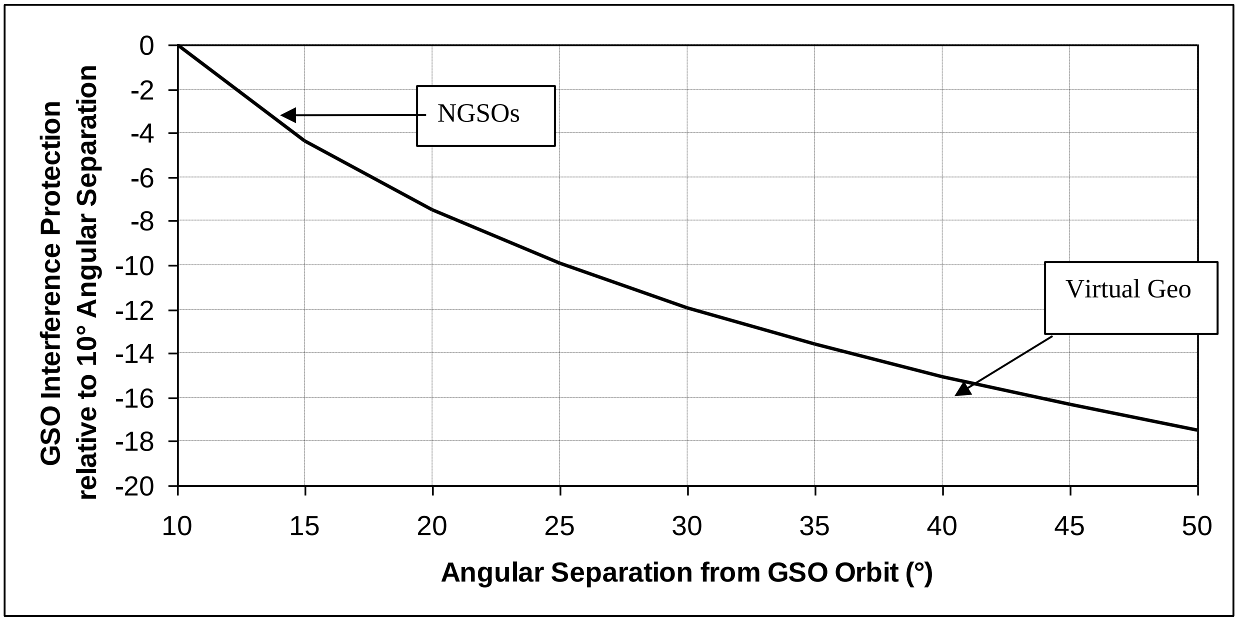
10 Amendment of Parts 2 and 25 of the Commission's Rules to Permit Operation of NGSO FSS Systems Co-Frequency with GSO and Terrestrial Systems in the Ku-band Frequency Range, *First Report and Order and Further Notice of Proposed Rulemaking*, 16 FCC Rcd 4096 (2000) (*First Report and Order*).

large angular separation between the active Virtual Geo satellites and the GSO orbit, which never drops below 40°.

Figure 3.13.1-1 demonstrates the additional interference protection that arises from increased angular separation from the GSO orbit. The data in this diagram is based on the "25log(θ)" roll-off of the GSO and Virtual Geo earth station antenna gain characteristics, which is typically valid out to the 48° off-axis point. The reference point in Figure 3.12.1-1 is the 10° GSO orbit avoidance situation, as proposed by some NGSO systems (others have proposed even less than 10°). Relative to this reference, the increase to 40° GSO orbit avoidance provides an additional 15 dB of interference protection. This additional protection is to the benefit of both the GSO and NGSO system operators, as it reduces the interference in both directions. *This 15 dB reduction in NGSO-to-GSO interference (as well as in GSO-to-NGSO interference) effectively means that there is no interference problem between the Virtual Geo system and existing or planned GSO systems operating co-frequency and co-coverage*.

Figure 3.13.1-1:
Additional Interference Protection with Respect to GSO Systems Arising from Increased Angular Separation of the Active NGSO Satellite from the GSO Orbit



An equally important advantage of the Virtual Geo system design results from the fact that no communications transmissions to or from the Virtual Geo satellites take place when a Virtual Geo satellite is closer to the GSO orbit than 40°, unlike the potential operating mode of other circular orbiting NGSO proposals. NGSO systems have to maintain transmissions to and from other beams in their coverage area, even presumably while passing through the GSO exclusion zone for a particular set of beams. If this were not the case their satellites would be unusable for a significant portion of their orbits, a situation made worse by the fact that their satellites would actually be unusable in parts of their orbit where they are most needed for communications traffic (equatorial and moderate latitudes). Such operations could cause high levels of downlink interference from the NGSO satellite antenna sidelobes to GSO systems for short periods of time as the NGSO satellite passes through the line-of-sight between GSO satellites and their associated earth stations (the so-called "short-term" interference). There is no such interference effect from the Virtual Geosatellite system into GSO systems. *In short, the Virtual Geo system simply does not cause any in-line interference events into GSO satellite networks* and therefore will easily meet the short-term interference criteria adopted by the ITU.

Tables 3.13.1-1 to 3.13.1-3 give simple, yet accurate, assessments of the downlink interference from a Virtual Geo satellite into a GSO receive earth station. The analysis pessimistically assumes three simultaneously interfering Virtual Geo satellites because there may be satellites from three Virtual Geo sub-constellations visible to a GSO earth station at a time within each region, although it is very unlikely that all three satellites will be at the minimum separation angle of 40 degrees assumed here. The only situation where the number of simultaneously active and visible Virtual Geo satellites might increase to four is as follows:

- During the brief handover from a "setting" to a "rising" Virtual Geo satellite, which will occur for several seconds once every 4.8 hours. During this time the chances of both Virtual Geo satellites being at the minimum 40° GSO separation angle as viewed from the GSO earth station is exceedingly small. Even if such a situation were to occur it would give rise to an increase of less than 1.3 dB compared to the situation where three visible Virtual Geo satellites are assumed, which would still maintain the aggregate Virtual Geo interference levels to a very low level.

In Tables 3.13.1-1 to 3.13.1-3 the analysis starts with the maximum downlink PFD of the Virtual Geo satellite, as given in Section 3.6 above. Note that the maximum downlink PFD occurs only in the 11.2-12.7 GHz user terminal band only. In the gateway downlink bands the maximum PFD, and hence the potential interference to GSO systems, is considerably less. Then based on the minimum 40° GSO orbit avoidance angle, the gain of the GSO receive earth station antenna is calculated based on the 32-25log(θ) mask of 25.209 of the FCC rules (as well as in ITU-R Recommendation S.465-5). This gives a GSO earth station antenna gain towards the Virtual Geo satellite of less than –8.1 dBi for all frequency bands. This gain is converted to an Effective Aperture (in dB-m^2) using an appropriate receive frequency. The use of the Effective Aperture then allows a simple calculation of the received interfering signal power, in a 4 kHz bandwidth, from a single Virtual Geo satellite. After allowing for three simultaneously visible Virtual Geo satellites, and adjusting to a reference bandwidth of one Hz, this aggregate interfering signal power is compared to the inherent noise power of the GSO receiver. In this case we have used very optimistic assessments of the likely GSO receive system noise temperatures for the various frequency bands (*i.e.*, 125 K at Ku-band and 80 K at C-band), which is to the benefit of the GSO system. Based on this the interference-to-noise power density ratio (I_0/N_0) is calculated, which is also expressed as an equivalent ΔT/T degradation to the GSO receive earth station performance.

The results in Tables 3.13.1-1 to 3.13.1-3 clearly show that the effect of the Virtual Geo satellite interference is completely unnoticeable. In fact it is questionable whether I_0/N_0 ratios as low as those calculated could even be measured. The interfering signal power is less than one three-hundredth of the noise power due to the LNA (Low

Noise Amplifier) of the GSO receive earth station, and in some cases is lower than one two-thousandth.

Table 3.13.1-1: Analysis of Worst-Case Downlink Interference from Virtual Geo Satellite Into GSO Earth Station in the 11.2-12.7 GHz Frequency Band

Maximum PFD of Virtual Geo satellite in 4 kHz	**-151**	**dBW / m^2 / 4kHz**
GSO orbit avoidance angle	**40**	**°**
GSO Rx Earth Station gain towards Virtual Geo satellite	-8.1	dBi
Frequency	12000	MHz
Effective Aperture of GSO Rx Earth Station towards Virtual Geo satellite	-51.1	dB-m^2
GSO Rx Earth Station Interfering Signal Power in 4 kHz (per Virtual Geo satellite)	-202.1	dBW / 4kHz
GSO Rx Earth Station Interfering Signal Power Spectral Density (per Virtual Geo satellite)	-238.1	dBW / Hz
Increase in interference due to 3 simultaneously visible Virtual Geo satellites	4.8	dB
GSO Rx Earth Station Interfering Signal Power Spectral Density (3 Virtual Geo satellites)	-233.3	dBW / Hz
GSO Rx Earth Station System Noise Temperature	**125**	**K**
GSO Rx Earth Station System Noise Power Spectral Density	-207.6	dBW / Hz
I_0/N_0 at GSO Rx Earth Station Input	**-25.7**	**dB**
ΔT/T Degradation to GSO Rx Earth Station	**0.271%**	

Table 3.13.1-2: Analysis of Worst-Case Downlink Interference from Virtual Geo Satellite Into GSO Earth Station in the 10.7-11.2 GHz Frequency Band

Maximum PFD of Virtual Geo satellite in 4 kHz	**-160**	**dBW / m^2 / 4kHz**
GSO orbit avoidance angle	**40**	**°**
GSO Rx Earth Station gain towards Virtual Geo satellite	-8.1	dBi
Frequency	11000	MHz
Effective Aperture of GSO Rx Earth Station towards Virtual Geo satellite	-50.3	dB-m^2
GSO Rx Earth Station Interfering Signal Power in 4 kHz (per Virtual Geo satellite)	-210.3	dBW / 4kHz
GSO Rx Earth Station Interfering Signal Power Spectral Density (per Virtual Geo satellite)	-246.3	dBW / Hz
Increase in interference due to 3 simultaneously visible Virtual Geo satellites	4.8	dB
GSO Rx Earth Station Interfering Signal Power Spectral Density (3 Virtual Geo satellites)	-241.5	dBW / Hz
GSO Rx Earth Station System Noise Temperature	**125**	**K**
GSO Rx Earth Station System Noise Power Spectral Density	-207.6	dBW / Hz
I_0/N_0 at GSO Rx Earth Station Input	**-33.9**	**dB**
ΔT/T Degradation to GSO Rx Earth Station	**0.041%**	

Table 3.13.1-3: Analysis of Worst-Case Downlink Interference from Virtual Geo Satellite Into GSO Earth Station in the 3.7-4.2 GHz Frequency Band

Maximum PFD of Virtual Geo satellite in 4 kHz	**-165**	**dBW / m^2 / 4kHz**
GSO orbit avoidance angle	**40**	°
GSO Rx Earth Station gain towards Virtual Geo satellite	-8.1	dBi
Frequency	4000	MHz
Effective Aperture of GSO Rx Earth Station towards Virtual Geo satellite	-41.5	dB-m^2
GSO Rx Earth Station Interfering Signal Power in 4 kHz	-206.5	dBW / 4kHz
GSO Rx Earth Station Interfering Signal Power Spectral Density	-242.6	dBW / Hz
Increase in interference due to 3 simultaneously visible Virtual Geo satellites	4.8	dB
GSO Rx Earth Station Interfering Signal Power Spectral Density (3 Virtual Geo satellites)	-237.8	dBW / Hz
GSO Rx Earth Station System Noise Temperature	**80**	**K**
GSO Rx Earth Station System Noise Power Spectral Density	-209.6	dBW / Hz
I_0/N_0 at GSO Rx Earth Station Input	**-28.2**	**dB**
ΔT/T Degradation to GSO Rx Earth Station	**0.152%**	

It is useful to compare the Ku-band EPFD levels (according to the definitions in ITU-R S.22) of the Virtual Geo system with the provisional S.22 EPFD limits adopted at WRC97, as shown in Table 3.13.1-4. The Virtual Geo EPFD levels in this table are derived for the user terminal frequency band 11.2-12.7 GHz, where the downlink PFD levels are the greatest. The results in the gateway downlink band 10.7-11.2 GHz would be 9 dB better because of the use of lower downlink PFD for gateway beams. In this table both the long-term and short-term provisional WRC97 EPFD limits are given, together with an indication of whether these apply in the BSS or FSS allocations. The

Virtual Geo EPFD levels are given for two cases of three or four Virtual Geo satellites simultaneously visible.

In Column A of Table 3.13.1-4 the case of three visible Virtual Geo satellite can be compared against the long term WRC97 limits, and the “delta” –value is also given. Note that the Virtual Geo system meets the long-term provisional EPFD limits with margins ranging from 6.3 to 19.0 dB, depending on the GSO earth station size considered. Note that more detailed analyses or simulations, taking into account the actual off-axis angle to each Virtual Geo satellite, will result in long-term EPFD levels below those indicated in Table 3.12.1-4.

In Column B of Table 3.13.1-4, the situation of four visible Virtual Geo satellites is considered, but this time for the case of very short periods of time during handover between the “setting” and the “rising” Virtual Geo satellites. In this case the resulting EPFD levels can be compared against the short term WRC97 limits. In this case the Virtual Geo system meets the short-term provisional EPFD limits with margins ranging from 13.0 to 42.8 dB, depending on the GSO earth station size considered. As noted above for the long-term case, more detailed analyses or simulations, taking into account the actual off-axis angle to each Virtual Geo satellite, will result in short-term EPFD levels below those indicated in Table 3.13.1-4.

The overall conclusions from Table 3.13.1-4, together with the analyses of Tables 3.13.1-1 to 3.13.1-3, reinforce the fact that the Virtual Geo system is an ideal spectrum sharing partner for GSO systems.

Table 3.13.1-4: Comparison of Worst-Case EPFD from Virtual Geo System in the 11.2-12.7 GHz * Frequency Band with WRC-97 EPFD Limits

WRC97 Provisional EPFD Limits						Column A		Column B	
GSO Rx E/S Diameter (meters)	Service	Long-term		Short-term		VIRGO EPFD (3 satellites)		VIRGO EPFD (4 satellites)	
		EPFD	% Time	EPFD	% Time	EPFD	Δ rel. to WRC97 Long-Term Limits	EPFD	Δ rel. to WRC97 Short-Term Limits
0.3	BSS R1/3	-172.3	99.7	-169.3	100	-183.6	-11.3	-182.3	-13.0
0.45	BSS R2	-174.3	99.7	-165.3	100	-187.1	-12.8	-185.9	-20.6
0.6	FSS	-179.0	99.7	-170.0	100	-189.6	-10.6	-188.4	-18.4
0.6	BSS R1/3	-183.3	99.7	-170.3	100	-189.6	-6.3	-188.4	-18.1
0.9	BSS R1/3	-186.8	99.7	-170.3	100	-193.1	-6.3	-191.9	-21.6
1	BSS R2	-186.3	99.7	-170.3	100	-194.0	-7.7	-192.8	-22.5
1.2	BSS R2	-187.9	99.7	-170.3	100	-195.6	-7.7	-194.4	-24.1
1.8	BSS R2	-191.4	99.7	-170.3	100	-199.2	-7.8	-197.9	-27.6
3	FSS	-186.0	99.97	-170.0	100	-203.6	-17.6	-202.3	-32.3
10	FSS	-195.0	99.97	-170.0	100	-214.0	-19.0	-212.8	-42.8

* Note that the results in the frequency band 10.7-11.2 GHz will be 9 dB better than those given in this table.

Tables 3.13.1-5 to 3.13.1-8 provide very conservative analyses of potential uplink interference from the transmitting Virtual Geo earth stations into a GSO satellite. These tables each show two analyses: one for the clear-sky condition and one for rain conditions where the uplink power control causes the maximum available increase in transmit power to overcome the rain fade. In fact the clear-sky calculation provides the most realistic assessment of the uplink interference situation because, for the rain fade condition, the interfering signal path can also be assumed to be faded by approximately the same amount as the wanted signal path in the Virtual Geo system. The interference levels shown in the rain condition could only occur if the line-of-sight from the Virtual Geo transmitting earth station to the GSO satellite was unfaded while the line-of-sight to the Virtual Geo satellite was fully faded. Such a condition would be extremely rare, and if it ever existed at all would be of extremely short duration.

In Tables 3.13.1-5 to 3.13.1-8 the calculation methodology is similar to that used for the downlink (Tables 3.13.1-1 to 3.13.1-3) and described above. The transmit power spectral density values represent the maximum that will be transmitted in the Virtual Geo system, and are somewhat higher than those shown in the representative link budgets of Section 3.9 above. However there are some very conservative assumptions made in these uplink interference analyses. Firstly, the GSO satellite is assumed to be using a very high gain spot beam with 45 dBi gain (Ku-band) towards the Virtual Geo earth station, as well as having a satellite receive system noise temperature as low as 600 K (the assumed C-band GSO satellite spot beam gain is 40 dBi). Because of the use of such high gain for the GSO satellite antenna, only two co-frequency interfering Virtual Geo earth stations are taken account of (assuming that there might be near-collocated Virtual Geo earth stations, each transmitting to one of the Northern Hemisphere Virtual Geo sub-constellations. In addition the Virtual Geo transmit earth station antenna is only assumed to meet 36-25log(θ) off-axis gain mask at 40° off axis.

The resulting I_0/N_0 ratios and ΔT/T values, although somewhat higher than for the downlink interference, are still at least five times lower than the normal criteria used to initiate coordination between two GSO systems (ΔT/T of 6%). The only exception to this is in the extremely rare instance where the fading on the interfering signal path is not comparable to the wanted Virtual Geo transmission path (as explained above). Even in this unlikely case the interference is still only just over one hundredth of the inherent noise of the GSO satellite receiver.

It is interesting to compare the PFD at the GSO orbit, as given in Tables 3.13.1-5 to 3.13.1-8 with the S.22 APFD levels that were adopted at WRC97 for the 13.8-14.5 GHz band. The APFD limit in this band is –170 dBW/m^2/4kHz for 100% of the time (*i.e.*, never to be exceeded). However, this limit is the aggregate for all co-frequency NGSO uplink transmissions from a single NGSO system. As there are 28 equivalent fully occupied uplink user beams in the Virtual Geo system operating with a 1-in-4 frequency re-use pattern, there could potentially be up to seven co-frequency, co-polar Virtual Geo uplinks within a region. In addition, there could be twice this number of co-frequency, co-polar transmitting earth stations because of the visibility of two Virtual Geo sub-constellations from large parts of a region. Therefore the aggregate PFD at the GSO orbit could be up to 11.5 dB higher than the single-terminal PFD numbers. Taking this factor into account the worst-case numbers, which are in Table 3.13.1-5, are 2.8 dB within the APFD limits for this frequency band.

Table 3.13.1-5: Analysis of Worst-Case Uplink Interference from Virtual Geo Transmitting Earth Station Into GSO Satellite Receiver in the 14.0-14.5 GHz Frequency Band

Maximum PFD of Virtual Geo satellite in 4 kHz	**-151**	**dBW / m^2 / 4kHz**
GSO orbit avoidance angle	**40**	**°**
GSO Rx Earth Station gain towards Virtual Geo satellite	-8.1	dBi
Frequency	12000	MHz
Effective Aperture of GSO Rx Earth Station towards Virtual Geo satellite	-51.1	dB-m^2
GSO Rx Earth Station Interfering Signal Power in 4 kHz (per Virtual Geo satellite)	-202.1	dBW / 4kHz
GSO Rx Earth Station Interfering Signal Power Spectral Density (per Virtual Geo satellite)	-238.1	dBW / Hz
Increase in interference due to 3 simultaneously visible Virtual Geo satellites	4.8	dB
GSO Rx Earth Station Interfering Signal Power Spectral Density (3 Virtual Geo satellites)	-233.3	dBW / Hz
GSO Rx Earth Station System Noise Temperature	**125**	**K**
GSO Rx Earth Station System Noise Power Spectral Density	-207.6	dBW / Hz
I_0/N_0 at GSO Rx Earth Station Input	**-25.7**	**dB**
ΔT/T Degradation to GSO Rx Earth Station	**0.271%**	

Table 3.13.1-6: Analysis of Worst-Case Uplink Interference from Virtual Geo Transmitting Earth Station Into GSO Satellite Receiver in the 12.75-13.25 and 13.8-14.0 GHz Frequency Bands

Maximum PFD of Virtual Geo satellite in 4 kHz	**-160**	**dBW / m^2 / 4kHz**
GSO orbit avoidance angle	**40**	**°**
GSO Rx Earth Station gain towards Virtual Geo satellite	-8.1	dBi
Frequency	11000	MHz
Effective Aperture of GSO Rx Earth Station towards Virtual Geo satellite	-50.3	dB-m^2
GSO Rx Earth Station Interfering Signal Power in 4 kHz (per Virtual Geo satellite)	-210.3	dBW / 4kHz
GSO Rx Earth Station Interfering Signal Power Spectral Density (per Virtual Geo satellite)	-246.3	dBW / Hz
Increase in interference due to 3 simultaneously visible Virtual Geo satellites	4.8	dB
GSO Rx Earth Station Interfering Signal Power Spectral Density (3 Virtual Geo satellites)	-241.5	dBW / Hz
GSO Rx Earth Station System Noise Temperature	**125**	**K**
GSO Rx Earth Station System Noise Power Spectral Density	-207.6	dBW / Hz
I_0/N_0 at GSO Rx Earth Station Input	**-33.9**	**dB**
ΔT/T Degradation to GSO Rx Earth Station	**0.041%**	

Table 3.13.1-7: Analysis of Worst-Case Uplink Interference from Virtual Geo Transmitting Earth Station Into GSO Satellite Receiver in the 17.8-18.6 GHz Frequency Band

Maximum PFD of Virtual Geo satellite in 4 kHz	**-165**	**dBW / m^2 / 4kHz**
GSO orbit avoidance angle	**40**	**°**
GSO Rx Earth Station gain towards Virtual Geo satellite	-8.1	dBi
Frequency	4000	MHz
Effective Aperture of GSO Rx Earth Station towards Virtual Geo satellite	-41.5	dB-m^2
GSO Rx Earth Station Interfering Signal Power in 4 kHz	-206.5	dBW / 4kHz
GSO Rx Earth Station Interfering Signal Power Spectral Density	-242.6	dBW / Hz
Increase in interference due to 3 simultaneously visible Virtual Geo satellites	4.8	dB
GSO Rx Earth Station Interfering Signal Power Spectral Density (3 Virtual Geo satellites)	-237.8	dBW / Hz
GSO Rx Earth Station System Noise Temperature	**80**	**K**
GSO Rx Earth Station System Noise Power Spectral Density	-209.6	dBW / Hz
I_0/N_0 at GSO Rx Earth Station Input	**-28.2**	**dB**
ΔT/T Degradation to GSO Rx Earth Station	**0.152%**	

Table 3.13.1-8: Analysis of Worst-Case Uplink Interference from Virtual Geo Transmitting Earth Station Into GSO Satellite Receiver in the 5.925- 6.425 GHz Frequency Band

	Clear Sky	**Rain**	
Maximum PSD into Virtual Geo Earth Station Antenna in 4 kHz	**-25.0**	**-21.8**	**dBW / 4kHz**
GSO orbit avoidance angle	**40**	**40**	°
Virtual Geo Tx Earth Station gain towards GSO Satellite	-4.1	-4.1	dBi
Virtual Geo Tx Earth Station EIRP Spectral Density towards GSO Satellite in 4 kHz	-29.1	-25.9	dBW / 4kHz
PFD at the GSO Satellite in 4 kHz	-191.2	-188.0	dBW / m^2 / 4kHz
Frequency	6325	6325	MHz
Assumed Gain of GSO Satellite Rx towards Virtual Geo Earth Station	**40**	**40**	**dBi**
Effective Aperture of GSO Satellite Rx towards Virtual Geo Earth Station	2.5	2.5	dB-m^2
GSO Satellite Rx Interfering Signal Power in 4 kHz	-188.6	-185.4	dBW / 4kHz
GSO Satellite Rx Interfering Signal Power Spectral Density (one Virtual Geo earth station)	-224.7	-221.5	dBW / Hz
GSO Satellite Rx Interfering Signal Power Spectral Density (two Virtual Geo earth stations)	-221.7	-218.5	dBW / Hz
GSO Satellite Rx System Noise Temperature	**600**	**600**	**K**
GSO Satellite Rx System Noise Power Spectral Density	-200.8	-200.8	dBW / Hz
I_0/N_0 at GSO Satellite Rx Input	**-20.8**	**-17.6**	**dB**
ΔT/T Degradation to GSO Satellite Rx	**0.824%**	**1.721%**	

3.13.2 NGSO FSS

The Virtual Geo satellite is a virtual-geostationary system which means that the active Virtual Geo satellites always appear in the same portion of the sky as seen from the Earth. This is very different from the types of NGSO systems that are proposed to operate in circular orbits, particularly those in Low Earth Orbit ("LEO"). These LEO NGSOs must operate almost from horizon to horizon, as viewed from their earth stations, in order to ensure full-time service with a manageable and affordable number of satellites in the constellation. With larger numbers their active arcs could be reduced allowing higher elevation angles but reducing system efficiency. New techniques must be devised to emulate the avoidance of these NGSOs as Virtual Geo does for the GEOs. NSS and Virtual Geosatellite are currently working on such novel methods and will present results during the coordination proceedings.

This fundamental advantage of a virtual geo system compared to a circular orbiting NGSO system gives rise to a situation where many virtual geo systems can operate co-frequency and co-coverage, without necessarily making the virtual geo systems identical to each other. In this approach, the different virtual geo systems are designed so that each one operates with its active satellites in a part of the sky separated in angle, as viewed by their earth stations, from the others. There are many possibilities to explore with such a sharing approach between NGSO and virtual geo systems.

In addition, it is possible to also interleave virtual geo satellites of different systems within the same orbit planes to further increase the sharing potential between them. This approach, which is similar to that proposed by the circular orbiting LEO NGSO systems, requires a coordinated design approach between the NGSO system operators in order to create homogenous systems.

Sharing between the Virtual Geo system and the proposed circular orbiting NGSO systems can be achieved by exploiting the inherent satellite diversity of these latter systems. In the same way that these systems switch between active satellites to avoid the GSO arc, they are also capable of switching active satellites to avoid alignment situations between the Virtual Geo satellites and Virtual Geo earth stations.

Clearly the issue of sharing between NGSO systems is a complex one, and Virtual Geo is committed to work with the Commission and other licensees to ensure that viable sharing schemes are established. But given the uncertainty as to how many or which of the proposed systems will be authorized and launched, any attempt to speculate on the details of such sharing would be premature at this point in time.

3.13.3 Inter-Satellite Links

Due to the extremely narrow beamwidth of optical ISL transmit and receive antennas, there should be no sharing problems associated with Virtual Geo's use of the optical ISL frequencies.

Virtual Geo is committed to working with the Commission and other optical ISL users to develop any sharing conditions that might be necessary for the implementation of the Virtual Geo optical ISLs.

3.13.4 Fixed Service

The orbit parameters of the Virtual Geo system, as described in Sections 3.2 and 3.3 above, have been deliberately selected to ensure that the active Virtual Geo satellite operates only at high elevation angles as viewed from the Virtual Geo earth stations. Not only does this provide excellent link quality in the Virtual Geo system, with low probabilities of signal blockage and reduced signal attenuation due to rain, it also makes the Virtual Geo system an excellent sharing partner with co-frequency terrestrial Fixed

Services ("FS"). The gain of the transmitting and receiving Virtual Geo earth stations is very low in directions towards terrestrial FS transmitters and receivers and so the interference coupling, in both directions, is correspondingly reduced. This advantage is shown in Figure 3.13.4-1 where the additional FS interference protection is calculated as a function of the minimum operational elevation angle of the Virtual Geo earth stations, relative to the 5° elevation case which is the typical minimum elevation angles of some GSO and circular orbiting NGSO systems.

Figure 3.13.4-1:

Interference Protection with Respect to FS Systems as a Function of the Minimum Operational Angle of Separation between the Active Virtual Geo Satellite and the GSO Arc

Anywhere within US territory the minimum operational elevation angle is 45°, which gives an improvement factor of 23 dB. Even at the extremes of the Virtual Geo service area the minimum operational elevation angle will always be maintained in excess of 40°, which gives a minimum improvement factor of over 22 dB.

In the United States, frequency overlap with the FS occurs only within the 10.7-11.7 GHz and 12.2-12.7 GHz downlink bands of the Virtual Geo system. The 11.7-12.2 GHz downlink band is not used by the FS in the USA. Of these shared bands, only the 11.2-11.7 GHz and 12.2-12.7 GHz bands are proposed for use by user terminals in the Virtual Geo system. In the event that particular user terminals are found to be in locations where they are subject to FS interference, downlink transmissions destined for these terminals will take place only in the unshared 11.7-12.2 GHz band. The Virtual Geo RNCC will establish a database of any user terminals affected by interference in this way, and assign appropriate frequencies for their use.

The gateway downlink in the 10.7-11.2 GHz band is shared with the FS. For this reason the Virtual Geo gateways, of which there are only four per region, will be located well away from any co-frequency FS links, and frequency coordinated using well established procedures.

In the Virtual Geo uplink frequency bands co-frequency operation with the FS occurs only in the 12.75-13.25 GHz and 17.7-17.8 GHz bands. The 14.0-14.5 GHz uplink band used by Virtual Geo user terminals is not shared with the FS so no coordination problem exists for transmitting Virtual Geo user terminals. In the above listed shared uplink bands, which are only used by Virtual Geo gateway terminals, the same approach will be used as for the gateway downlink to avoid interference into the FS. The gateways will be located well away from any co-frequency FS links, and frequency coordinated using well established procedures.

The potential interference from the Virtual Geo satellite downlink into the FS receivers is addressed by means of the Commission's (and ITU's) PFD limits in the various downlink bands where FS sharing exists. As stated in Section 3.10 the downlink transmissions of the Virtual Geo satellites are below the PFD limits that apply, even ignoring the angle of incidence to the Earth's surface. If the high elevation angles of the active Virtual Geo satellites are taken into account, there is at least a 10 dB margin with respect to these PFD limits.

Finally, it is expected that interference from terrestrial FS transmitters into the Virtual Geo satellite receivers will not be a problem, again due to the high elevation angles from the Virtual Geo beam coverage areas to the active Virtual Geo satellites.

3.13.5 Ka Downlinks

The 17.8-18.6 GHz frequency band is proposed by most applicants for NGSO systems. NSS will coordinate with those to ensure proper operation and optimum resource utilization. NSS is committed to work with the Commission and with potential BSS operators in this band to ensure that mutually satisfactory sharing conditions are implemented to adequately protect both systems.

3.13.6 Earth Exploration-Satellite and Space Research Services

The Virtual Geo satellite system avoids using the 13.75-13.8 GHz band which is used by NASA for the TDRSS operations. Therefore no interference to this service will occur.

3.13.7 U.S. Government Radiolocation Service

The U.S. Government radiolocation service ("RLS") in the 13.75-14.0 GHz is a potential source of interference into the 13.8-14.0 GHz gateway uplink band proposed to be used by the Virtual Geo system. By careful siting of the Virtual Geo gateway uplink sites, and hence the positioning of the Virtual Geo satellite gateway uplink beams, the interference from the RLS should be manageable.

Virtual Geo is committed to work with the Commission and the NTIA to coordinate the Virtual Geo gateway uplinks in these bands to avoid unacceptable interference.

3.13.8 Mobile Service

There are existing terrestrial Mobile services in the 12.75-13.25 GHz and 17.7-17.8 GHz bands. Both of these bands are proposed to be used in the Virtual Geo system for gateway uplinks only. Therefore, because of the use of only four Virtual Geo gateway terminals per region, the fact that the gateway sites must be located well away from metropolitan centers, and the use of high operational elevation angles to the Virtual Geo satellites, there should not be any unacceptable interference to these mobile services. Conventional frequency coordination of the gateway terminals will be used to ensure there is no problem in this respect.

3.13.9 Radio Astronomy Service

The Radio Astronomy Service (“RAS”) has existing operations in the 10.6-10.7 GHz band which is immediately adjacent to the proposed Virtual Geo gateway downlink band. Interference protection of the RAS will be achieved by a combination of the above:

- The downlink EIRP spectral density in the adjacent 10.7-11.2 GHz gateway downlink band is already 9 dB lower than that proposed in the user terminal downlink band 11.2-12.7 GHz, because of the use of large gateway receive earth station antennas. The beam peak in-band PFD in the adjacent 10.7-11.2 GHz band is defined in Section 3.6.2 above.

- The gateway downlink spot beams will be directed only towards the gateway downlink sites, of which there are four per region. Depending on the eventual selection of these gateway sites, this may give additional attenuation of the downlink signals due to the roll-off of the Virtual Geo satellite transmit beam gain.
- The Virtual Geo downlink transmissions will be adequately filtered to further reduce the out-of-band emissions in the 10.6-10.7 GHz band and provide the additional signal attenuation required to adequately protect the RAS in this band.

Virtual Geo is committed to work with the Commission and with the RAS community to ensure that the RAS sites that use the 10.6-10.7 GHz frequency band are adequately protected.

3.14 SATELLITE DESCRIPTION

3.14.1 General Description (47 C.F.R. § 25.114 (d)(1))

The spacecraft manufacturer for the Virtual Geo satellites has not yet been selected, and Virtual Geo does not wish to show preference by providing any data specific to any one manufacturer in this application. The design of the satellite has been based around the known characteristics of the latest spacecraft available from all major US, Canadian and other suppliers Therefore the feasibility of implementing the Virtual Geo satellite system is assured.

Virtual Geo will ensure that the particular physical characteristics of the spacecraft will not adversely affect its orbital debris analyses.

3.14.2 Power and Mass Budgets

The Virtual Geo satellite communications payload requires approximately 10.5 kW d.c. end-of-life power, which is within the capability of all candidate suppliers, including sufficient margin at end of life and full eclipse capability. Beginning-of-life power will be approximately 14 kW. The communications payload mass will be approximately 1058 kg. The total spacecraft mass in turn should be around 3030 kg at launch. The satellite operational lifetime will be approximately 12 years, including stationkeeping fuel requirements and required reliability.

Table 3.14.2-1: Virtual Geo Satellite Power Budget

	Maximum (W)	Average (W)
Forward	11503	
Return	3395	
Total Payload	14898	9900
Bus		693
Total Spacecraft		10593

Table 3.14.2-2: Estimated Virtual Geo Satellite Mass Budget

Subsystem	**Mass (kg)**
Payload	1058
Spacecraft Bus	
Propulsion, Attitude Control	212
TT&C	32
Prime Power (array, drive, batteries, PC&DU)	936
Support (structure, thermal, harness, balance)	540
Total Bus	1720
Total Dry Mass	**2778**
Propellant	252
Launch Mass	**3030**

3.14.3 Communications Payload

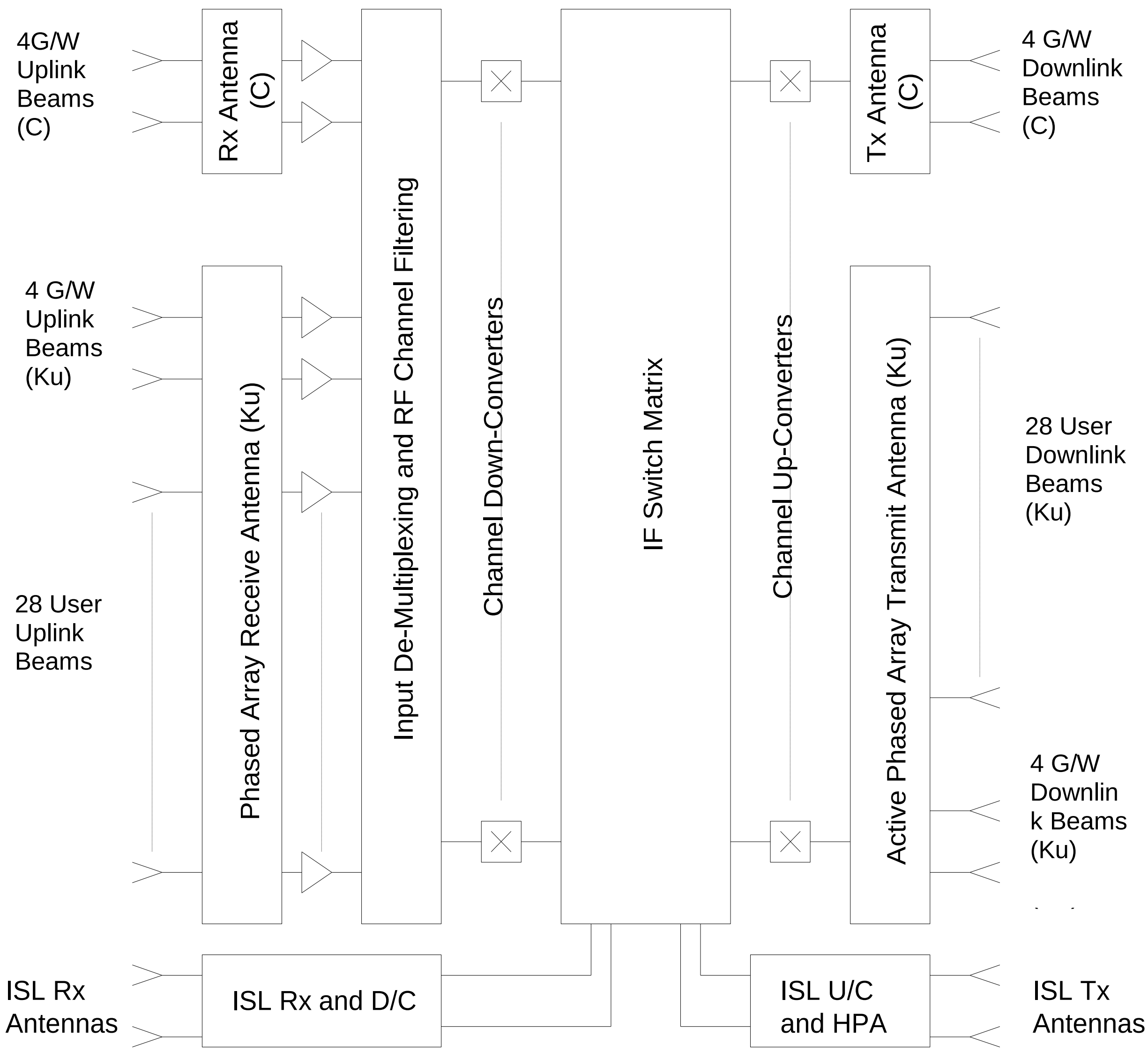
The Virtual Geo satellite communications payload uses phased array antennas in order to be able to configure the beam coverages, in real-time, to give near-constant geographic coverage. These antennas generate all the Ku-band beams for both the user terminal beams and the gateway terminal beams.

At the output of the receive antennas the signals are first amplified and then de-multiplexed and channelized before being down-converted to an IF frequency. A switch matrix is then used to connect appropriate uplink channels to downlink channels, as well as to allow for some sub-channel connectivity to the inter-satellite links. At the output of the IF switch matrix the signals are up-converted and sent to the inputs of the active phased array transmit antenna.

The functions described above are shown in the payload schematic of Figure 3.14.3-1.

The aggregate RF transmit power capability of the Ku-band active phased array antenna is approximately 2.5 kW. The aggregate C-band gateway downlink RF transmit power is approximately 100 Watts.

Figure 3.14.3-1 Virtual Geo Satellite Communications Payload Schematic



3.14.4 TT&C System

The Tracking, Telemetry, and Command (TT&C) subsystem will utilize a small portion of the feederlink frequency band for both on-station operation and transfer orbit or abnormal operation with use of omni antennas. The subsystem will provide the reception, storage, and distribution of commands for control of spacecraft bus and communication systems using a 32 kbps command uplink with authentication protocol.

The subsystem will also collect and process telemetry and data, store and format the date, and transmit the information to the ground TT&C stations with a 32 kbps downlink stream. The TT&C subsystem will be fully redundant and will autonomously switch over to backup hardware in the event of a hardware or software failure as detected.

The spacecraft is designed to have at least 12 years of the active service life. Within its lifetime, the spacecraft on-station position can be maintained within the tolerances shown in Table 3.14.4-1.

Table 3.14.4-1: Virtual Geo Orbital Maintenance Tolerance

Inclination	**Pointing**	**Altitude**	**In Track**
±0.05°	±0.2°	±10 km	±1° MA

3.14.5 Attitude and Orbit Control Subsystem ("AOCS")

The spacecraft will employ a three-axis stabilized system with momentum wheels and small monopropelled thrusters for momentum dumping as well as on orbit control and station-keeping. The satellite will employ a GPS receiver and use on-board processing for orbit determination. Each satellite will employ absolute station-keeping, and will autonomously compute and execute (subject to on-ground monitoring) the corrective maneuvers to maintain the satellite within specified values for the orbital parameter limits. Key characteristics of the Virtual Geo spacecraft are provided in Table 3.14.5-1below.

Table 3.14.5-1: Virtual Geo Spacecraft Key Characteristics

Stabilization:	3 axis
Mission Life:	> 12 years
Positioning Sensor:	GPS
Communication Payload:	See Section 3.14.3
TT&C:	Omni antennas Command and Telemetry: C-band; Link calculations for the TT&C are given in Table 3.9-7
Attitude Control & Station Keeping:	Monopropellant hydrazine thrusters and reaction wheels (considering electric propulsion)
Thermal Control:	Passive design with heaters
Solar Array:	Gallium Arsenide
Battery:	Nickel Hydrogen, 600 A-hours
Bus Dimension:	4.6 x 2.8 x 1.0 meters
Average DC Power:	10593 W
Launch Mass:	3030 kg

3.15 LAUNCHER DESCRIPTION

The Virtual Geo spacecraft will be compatible with a several commercially available launch vehicles. A decision on the actual launcher to be used has not yet been made, as this is heavily influenced by the selection of spacecraft supplier.

3.16 GROUND SEGMENT AND OPERATIONS

3.16.1 User Terminals

These small and low-cost earth stations will be deployed in vast numbers throughout the service areas of the Virtual Geo system. Within the main service areas the user terminal antenna size will be equivalent to 45 cm in diameter, although somewhat larger antennas will be available for situations where transmit power is at a premium (such as for a wide-band uplink). The baseline user terminal design will be a phased array capable of tracking both the “rising” and the “setting” Virtual Geo satellites, although transmissions to and from the Virtual Geo satellites will only take place when the satellites are at latitudes above 40°. The user terminals will automatically switch between the active Virtual Geo satellites to provide continuity of service, under the control of the gateway terminals via the order wire links. This satellite switching, which occurs only once every 4.8 hours, will be completely transparent to the user and will not degrade the circuit performance.

All user terminals will be equipped with beacon tracking capability to enable them to accurately track the required Virtual Geo satellite. In addition, the user terminals will have the "intelligence" through built-in software to initially acquire the active Virtual Geo satellite by being able to predict the orbit path based on a knowledge of the approximate latitude and longitude of the terminal location, which is entered by the installer of the terminal. Once this orbit path has been established the user terminal will scan the orbit track until it locates an active Virtual Geo satellite by means of its downlink beacon signal. When the first Virtual Geo satellite has been acquired in this way the user terminal will continue to track the entire Virtual Geo constellation based on the known orbit parameters. With communications established in this way the ephemeris data for the entire Virtual Geo constellation is transmitted to each user terminal via the order wire link, and updated on a regular basis, by the SOCC/RNCC/gateway. With this data the user terminal is able to accurately "free-wheel" through any periods of time during which it might temporarily lose tracking of the active Virtual Geo satellite. The use of these techniques results in a highly reliable satellite tracking capability without incurring significant expense in the user terminals.

It is expected that most data/Internet user terminals will have two-way (i.e., transmit/receive) capability, but applications that make use of receive-only user terminals, such as video DTH receivers will be addressed.

User terminals with transmit capability will be equipped with uplink power control to ensure that the receive signal level at the satellite is accurately set. Not only does this allow the uplink to overcome rain fades and thereby maintain link quality without causing unnecessary interference to other users of the spectrum, it also ensures that the transmitted signal does not consume more satellite power than is necessary which would reduce the overall capacity of the system and possibly increase intermodulation noise. This feature also compensates for the variation in distance between the user terminals and the Virtual Geo satellite as it passes through the active part of its orbit. The setting of uplink power control is under the control of the gateway terminal with which the user terminal is communicating. The gateway monitors the corresponding downlink signal and, taking account of downlink rain fades by means of observing the beacon signal fading, determines whether the transmitting earth station needs to adjust its uplink power. Any need for adjustments are transmitted by the gateway to the user terminal via the order wire links.

3.16.2 Gateway Terminals

Each gateway terminal will consist of two conventional large tracking earth station antennas plus associated communications electronics and processing capability. The gateway antennas will be at least 5 meters in diameter. Each gateway operates over the ranges of C-band and Ku- and Ka-bands frequencies given in Section 3.4.2.2 above in order to be able to serve the large numbers of user terminals within the user beams that it supports.

The gateway terminals will be capable of performing all the satellite tracking functions described above for the user terminals. They will also operate uplink power control to overcome rain fades based on observing beacon signal fading. In addition a small amount of uplink power control will be applied to compensate for the variation in distance between the user terminals and the Virtual Geo satellite as it passes through the active part of its orbit.

All gateway terminals will have full-time land-line connections to both the RNCC and the primary SOCC.

3.16.3 Regional Network Control Centers

There will be three Regional Network Control Center ("RNCC"), each located to serve three Virtual Geo service areas (two in the northern hemisphere and one in the southern hemisphere). This facility will be connected by land-line to the Spacecraft Operations Control Center ("SOCC") and to the gateway terminals within the same regional service area. One of these gateway terminals (designated the "master gateway") will be used by the NCC to transmit the network control information to the user terminals. The RNCC manages the satellite resources for the region and responds to requests from user terminals for satellite capacity. It also monitors usage of the system and prepares billing data. The RNCC acts as the contact point within the region on all interference issues that might arise, and works in conjunction with the SOCC to resolve them.

3.16.4 Spacecraft Operations Control Center and TT&C Earth Stations

There will be a single primary Spacecraft Operations Control Center ("SOCC") in the Virtual Geo system and it will be located in the United States. In addition there will be a back-up SOCC in the event of a catastrophic failure of the primary facility. The location of the back-up SOCC has not yet been determined.

The primary SOCC will be connected via land-lines to TT&C earth stations in each of the regional service areas that have line-of-sight visibility of the Virtual Geo satellites during the active part of their orbit, and for portions of their orbit either side of the active period. These TT&C earth stations will simply act as "RF pipes" for the tracking, telemetry and command data that passes between the Virtual Geo satellites and the SOCC. The TT&C earth station function may be collocated with one of the regional gateways.

The primary SOCC will be responsible for the control of the entire Virtual Geo satellite constellation, including both operational and spare satellites, and will take over this responsibility upon contractual handover from the satellite system supplier shortly after launch of the satellites. All satellite housekeeping and maintenance will be performed from the SOCC. The detailed status of each of the satellites will be monitored and appropriate commands will be generated. The full ephemeris data of the entire constellation will be maintained at the SOCC.

4 NON-COMMON CARRIER STATUS (47 C.F.R. § 25.114(C)(11))

Virtual Geo elects under Section 25.114(c)(11) of the Commission's rules to provide all capacity on its proposed Virtual Geo system on a non-common carrier basis. Virtual Geo will tailor services to meet the needs of individual customers.

5 Schedule of Implementation

NSS' proposed scheduling milestones for the deployment of the Virtual Geo system are shown with schedule dates referenced to the date of final Commission approval of the instant application:

ISED Approval	**Month 0**
Commence construction	Month 12
Complete construction Virtual Geo Satellite A1	Month 36
Complete construction Virtual Geo Satellite A2	Month 38
Complete construction Virtual Geo Satellite A3	Month 40
Launch Virtual Geo Satellites A1-A2	Month 41
Complete construction Virtual Geo Satellite A4	Month 42
Complete construction Virtual Geo Satellite A5	Month 43
Complete construction Virtual Geo Spare SA1	Month 44
Launch Virtual Geo Satellites A3-A4	Month 45
Launch Virtual Geo Satellites A5-SA1	Month 47
Complete construction Virtual Geo Satellite B1	Month 47
Commence AURORA I™ Service	**Month 48**
Complete construction Virtual Geo Satellite B2	Month 48
Complete construction Virtual Geo Satellite B3	Month 49
Complete construction Virtual Geo Satellite B4	Month 50
Launch Virtual Geo Satellites B1-B2	Month 51
Complete construction Virtual Geo Satellite B5	Month 51
Complete construction Virtual Geo Spare SB1	Month 52
Launch Virtual Geo Satellites B3-B4	Month 53
Complete construction Virtual Geo Satellite C1	Month 53
Complete construction Virtual Geo Satellite C2	Month 54
Launch Virtual Geo Satellites B5-SB1	Month 55
Complete construction Virtual Geo Satellite C3	Month 55
Commence AURORA II™ Service	**Month 56**
Complete construction Virtual Geo Satellite C4	Month 56
Launch Virtual Geo Satellites C1-C2	Month 57
Complete construction Virtual Geo Satellite C5	Month 57
Complete construction Virtual Geo Spare SC1	Month 58
Launch Virtual Geo Satellites C3-C4	Month 59
Launch Virtual Geo Satellites C5-SC1	Month 61
Commence AUSTRALIS™ Service	**Month 62**
Complete Worldwide Virtual Geo Service	**Month 62**

Note that service from the sub-constellations is independent from each other.

6 Public Interest Considerations (47 C.F.R. § 25.114(d)(6) and § 25.137(a))

The grant of NSS' instant application for a Declaratory Ruling for the Virtual Geo system will promote the public interest in several distinct ways.

Initially, NSS observes that the United States has a national interest in promoting broad band telecommunications access both domestically and internationally. Such policies not only benefit U.S. companies by helping them sustain their global leadership in telecommunications, they also contribute substantially to the growth and strength of the global economy. Broadband satellite communications historically have proceeded through exploitation of the geostationary plane and associated frequencies. Both that plane and those frequencies are increasingly congested. The national interest, accordingly, lies in the promotion of technologies and orbital architectures that can efficiently convey broadband services and use spectrum which has been allocated for FSS services without interfering with existing geostationary satellites. NSS' proposed Virtual Geo system, with its transparency to existing and future geostationary satellites, as well as its compatibility with existing terrestrial users, ably fits this bill.

In addition, Virtual Geo will both fan the flames of demand for high-efficiency, affordable broadband capacity, the new universe of Content Delivery Networks and video streaming and help meet that demand. Virtual Geo will provide a wide and wide open range of affordable digital services, including high-speed Internet access and direct-to-home data and video streams, to small user terminals in most of the populated areas of the world.

The number of homogeneous virtual geostationary systems that can potentially operate on a co-frequency basis likely exceeds the limited number of homogeneous low-Earth NGSO satellite systems that other applicants have suggested could co-exist. Virtual Geo thus provides valuable opportunities for competitive multiple entry in a manner that does not impact negatively on existing or future geostationary satellite operations.

Although sharing between NGSO satellite systems of the Virtual Geo design and low- and medium-Earth circular orbit systems is somewhat more complex, Virtual Geo nevertheless believes that it should be possible to achieve co-frequency sharing between disparate types of NGSO FSS systems in certain instances analogous to that achieved in the MSS industry feeder link sharing arena. NSS is prepared to undertake a comprehensive examination of the situation in all appropriate fora. However, it would not be a useful exercise to attempt to conduct any analyses of the current applications, because it is not clear which or how many of those systems will actually become operational.

In addition, Section 25.137(a) of the Commission's Rules, following the *DISCO* decisions, 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.[11] The NSS satellites in the Virtual Geo constellation will be operated under authority of

11 *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*").

Canada, which is a member of the WTO, and thus presumptively further the public interest.

In sum, the Virtual Geo system proposed herein by Virtual Geo offers tremendous public interest benefits with regard to its ability to operate co-frequency with geostationary systems, fixed service systems, and homogeneous nongeostationary systems. Virtual Geo will also satisfy the exponentially growing demand for state-of-the-art, affordable satellite services. The Commission should, on these bases, readily find that grant of NSS' application to establish Virtual Geo is consistent with the public interest.

7 U.S. and International Interference Coordination

NSS will comply with all applicable domestic and international requirements in coordinating the proposed system. Such coordination will be undertaken under the auspices of the Canadian government, as the licensing Administration.

8 Legal Qualifications

NSS is legally qualified to be licensed by the Commission, as demonstrated in the FCC Form 312 separately filed electronically with the Commission.

9 Orbital Debris Information (47 C.F.R. §§ 25.114(d) (14))

Responsibility for orbital debris mitigation will lie with Canada, as the licensing Administration for the Virtual Geo system. Nevertheless, NSS is providing the information below to demonstrate that it will comply with the Commission's orbital debris mitigation requirements.

9.1 Spacecraft Hardware Design:

NSS has assessed and will continue to assess the degree to which debris will be released during the course of normal operations, and will continue to take steps to ensure that the spacecraft design is such that no debris is released during normal operations.

NSS has not yet engaged a spacecraft house to design in detail the Virtual Geo spacecraft. However, the Virtual Geo design team under NSS's leadership will employ standard industry practices to ensure that all system space operations will minimize contributions to orbital debris, including measures to estimate and limit the probability of collision with known objects during the in-orbit lifetime of the system's spacecraft. These practices will include the elimination of any object in the design that would be released in normal operations, including deployment, operation, and retirement. The orbital debris mitigation plan that NSS implements will also consider, and to the extent practicable, limit the probability that collisions with items smaller than one centimeter in diameter could cause a loss of control, and thereby prevent intended means of post-mission disposal.

All spacecraft will use redundant control, sensor, and thruster subsystems. Power subsystems will use a design approach that at the minimum permits fallback to partial power in the event of the failure of any one element in the subsystem or on the power buses. The communications payload will also feature electronic sparing (most amplifiers and control devices) or a fail-soft design (such as, it is expected, within the antenna, RF power amplifiers, and beam forming assemblies). Spacecraft control systems will be mounted within the satellite so as to shield them with structure and other masses, such as batteries and fuel tanks. Fuel tank design and location will take small debris damage failure modes into consideration. No electronic housing surface will form any portion of the satellite exterior surface. Instead, outer structural surfaces, standing off from any electronics modules, will act as a shielding layer to isolate the latter from small debris penetration. The satellite and its launch adaptors will use non debris-generating release mechanisms, and will minimize or if possible eliminate pyrotechnic devices for that purpose.

NSS will use qualified launch vehicles adhering to U.S. policy for minimizing the generation of debris.

In short, NSS has assessed and limited the amount of debris that would be released in a planned manner during normal operations, and has assessed and limited the probability of the space stations of the Virtual Geo system becoming a source of debris following collisions with small debris or meteoroids that could cause loss of control and prevent post-mission disposal. No debris is planned to be released during the course of normal operations.

The Virtual Geo satellites will carry the necessary fuel and kick motor to execute a reentry maneuver. Virtual Geo satellites will not normally use these motors for normal station keeping or attitude control. The considerations described above with regard to steps taken regarding placement of components and shielding to limit the effects of collisions with debris or meteoroids smaller than one centimeter in diameter were analyzed with respect to this sub-system, and similar practices will be followed.

9.2. Minimizing Accidental Explosions:

NSS has been assessing and will continue to assess the design of its spacecraft to ensure its design is such as to minimize the possibility of accidental explosions over the course of the satellites' lifetimes and subsequent disposal. NSS has made this assessment by means of a failure-mode verification analysis.

The Virtual Geo satellites will contain means to safe the satellites at end of life, including fully discharging the batteries, disconnecting power sources from their loads, and releasing all unused fuel, prior to placing them in any final storage regime. NSS will take steps to ensure that kinetic energy stored in momentum wheels is limited at end of life.

These measures will in any case be available should they be needed. However, NSS now plans on reentering its satellites at end of life, and therefore would not normally need to employ all the above measures prior to reentry.

NSS will ensure that its launch partners also follow these guidelines to ensure that upper stages and related components are safed after use. Where possible, NSS will assess mission profiles to determine if a practical means exists for controlled reentry of upper stages after use, rather than abandoning them in transfer orbit. The elliptical orbits of

Virtual Geo satellites, with their relatively low apogees, may offer practical options of this nature.

Debris will not be generated from the conversion of energy sources on board the spacecraft into chemical, pressure or kinetic energy that fragments the spacecraft.

9.3 Safe Flight Profiles:

NSS also evaluated and limited the probability of its satellites becoming a source of debris as the result of collision with large debris and with satellites of other known and relevant NGSO constellations (those operating within the same altitude regime as the Virtual Geo satellites) with the following results. Supporting calculations are given in Figures 9.4-1 and 9.4-2. NSS used current satellite tracking data as its data source for the cited constellations.

a. **Globalstar**. Globalstar operates its satellites with an inclination of 52 degrees at an altitude of 1414 kilometers. Virtual Geo satellites are always above Globalstar's altitude.

b. **GPS**. Virtual Geo satellites pass through the GPS satellite orbital altitude of 20,200 kilometers as they rise above and later fall below that altitude. NSS assessed the probability of collision with a GPS satellite using conservative (large) figures for the area of a GPS satellite and a Virtual Geo satellite. Calculations revealed an overall probability of one collision between any Virtual Geo satellite and any GPS satellite over the 15-year lifetime of the Virtual Geo satellites to be around 7 in 100 million.

c. **Galileo**. Galileo will operate its satellites in circular orbits at an inclination of 56 degrees and an altitude of 23,222 kilometers. This orbit remains outside the space occupied by the Virtual Geo satellites, which do not rise to this altitude until attaining a declination of 56.5 degrees. Similarly, when Virtual Geo satellites have a declination of 56 degrees or less, they have an altitude of 22,974 kilometers or less, or some 248 kilometers below the altitude of Galileo satellites. Consequently, with nominal stationkeeping tolerances, Galileo and Virtual Geo satellites should never intersect.

NSS nonetheless evaluated the probability of collision between Galileo and Virtual Geo satellites assuming an intersection, and found the probability of collision to be approximately $8x10^{-8}$, or a little less than one in 10 million, that any Virtual Geo satellite would collide with any Galileo satellite over the lifetime of the Virtual Geo satellites (assuming complete overlap of Galileo and Virtual Geo lifetimes).

d. **Glonass**. Likewise NSS evaluated the probability of collision with a satellite in the GLONASS constellation and obtained a chance of around 2.4 in 100 million. GLONASS has fewer satellites than GPS at this time.

e. **Molniya and similar**. An evaluation of collision probability at any time among any of the Molniya and any Virtual Geo satellite resulted in a figure of 1 in a million. There are presently 30 Molniya satellites, according to tracking data.

> The higher probability of collision results from the lower altitude of encounter (resulting in a smaller uncertainty zone within which to collide), the number of Molniya satellites, and the obliquity (fine intersection included angle) of the intersection of the orbits, which results in a larger intersection area.
>
> The probability of collision with any satellite of any further N-satellite constellation of a Molniya type would generally follow the probability of N/30*10-6*(area of new satellite)/(area assumed for Molniya).

Many LEO constellations, such as Iridium, Orbcomm, and others, operate below the minimum altitude for Virtual Geo satellites and are therefore of no factor, since Virtual Geo satellites never go there. Likewise, Virtual Geo satellites do not approach GEO altitude, and so pose no threat to GEO satellites.

In general, NSS finds that there is a vanishingly small probability of collision with other constellations within the Virtual Geo operating envelop. These probabilities are much smaller than the permitted 0.001 probability cited by NASA guidelines for strikes with large debris.[12]

Nonetheless, NSS will maintain a watch on all satellites in intersecting orbits for any impending near approach, and will implement drift maneuvers to ensure safe passage when warranted.

NSS plans on maintaining its satellites in orbit to the following tolerances:

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12 Procedures for Limiting Orbital Debris, NSS 1740.14, August 1995, page 5-1.

Orbital Element	Tolerance
Semi-major axis	200 meters
Apogee	500meters*
Perigee	500 meters*
Inclination	0.1 degree
Longitude of the Ascending Node**	0.2 degree
Mean Anomaly	0.2 degree

NOTES:

* Subject to constraint on semi-major axis

** Rather than providing tolerance information on the Right Ascension of the Ascending Node, NSS has instead provided tolerance information for the Longitude of the Ascending Node, and urges acceptance of this substitution for the following reasons: RAAN refers to the location where an orbit passes the equator going northward expressed in terms of its location in reference to the backdrop of the stars. Longitude of the Ascending Node expresses the same thing (location of the northward equator crossing) in terms of earth's longitude where it occurs. The two can be related by the position of the Greenwich meridian in relation to the stars at the time of measurement. The plane of an orbit tends to remain relatively stationary with respect to the stars in many cases (the satellite once in orbit is unaware that the earth rotates, and the stellar reference frame is a much more inertial, or non-rotating, one), so RAAN is often used in the satellite industry, even though RAAN typically drifts with time due to perturbations from the earth's equatorial bulge, for example. However, in the Virtual Geo system case, the orbits are deliberately designed to maintain a constant longitude of the ascending node over the long term, in order to maintain a frozen ground track. But NSS does not strive to maintain a frozen RAAN. As a result, designating the LAN of the orbit is more meaningful in the Virtual Geo system's case than designating the RAAN of the orbit. NSS would control the orbit to maintain the LAN tolerances, which is equivalent to maintaining tolerances on the ground track location. Each Virtual Geo orbit contains only one satellite. These tolerances together with orbit maintenance enable burns no more frequent than at estimated two-week intervals. They will in turn permit maintenance of accurate satellite positioning to a degree consistent with a deployment of additional interleaved satellites within the Virtual Geo orbits at some future date.

9.4 Satellite Post-Mission Disposal:

At the end of the mission lifetime for its satellites (mission lifetime is targeted for a minimum of 12 years), NSS will deorbit the satellites using a series of maneuver burns. Virtual Geo satellites' elliptical orbits with LEO perigees give an opportunity to reenter the satellites with a practical amount of fuel, and permit a controlled reentry, by using an apogee maneuver to drop the perigee to an altitude within the atmosphere, where local reentry can be guaranteed. The two northern Virtual Geo tracks have perigees in the Southern Hemisphere in three locations each. In the case of each of the two tracks, a perigee is available where the satellite can be reentered to fall safely in the far southern Pacific Ocean. A fuel Mass fraction (*i.e.*, the ratio of the needed fuel weight to the total satellite launch mass) of around 0.042 (*i.e.*, approximately 127.26 kilograms) is sufficient for this maneuver, yielding a ΔV of around 128 meters per second to drop the perigee as described. Figures 9.4-3 through 9.4-9 illustrate the parameters used to evaluate these options together with maps depicting breakup and impact zones.

In the case of the Virtual Geo track containing the southern active arcs, the northern perigees occur over land and do not permit safe disposal off-shore. However, a small maneuver at apogee to drop the perigee by 10 kilometers starts an eastward drift in the ground track of the relevant satellite. Such a maneuver requires 1.15 meters/second of velocity change, corresponding to a mass fraction of 4/100 of a percent.

At such a time that the orbit apogee has drifted to the appropriate location, a second apogee retro-burn will drop the perigee so that the orbit intersects the earth at the desired reentry point. This reentry burn requires a 203-meters/second velocity change at apogee, using a fuel mass fraction of 6.6 percent including the small first burn above to drift the orbit to the appropriate location for initiating reentry.

Note that all reentries are controlled reentries, timed to ensure that satellite debris falls safely offshore into deep water greater than 200 nautical miles away from any populated areas. Since all reentries are therefore controlled, they do not fall under the requirements of Guideline 7.1 *Limit the risk of human casualty* in NSS 1740.14, which requires that for uncontrolled reentry, total satellite debris area surviving reentry shall not exceed 8 square meters. NSS notes that casualty risk assessments for the controlled-atmospheric-re-entry case do not call for an estimate of the probability of human casualty resulting from surviving components/fragments of the satellite; such estimates are required only in casualty risk assessments done for the uncontrolled re-entry case. *See Re-Entry Notice, supra.*

NSS will provide appropriate notifications to maritime and aviation interests before a planned reentry to minimize the risks to such interests operating in these areas.

Virtual Geo satellites will carry the necessary fuel and kick motor to execute this maneuver. Virtual Geo satellites will not normally use these motors for normal station keeping or attitude control.

NSS presently plans to have Virtual Geo satellites use a separate fuel supply for thrusting (with options for cross connection as a redundancy and safety measure in the event it uses similar fuels for both purposes). This design approach minimizes gauging uncertainty in allowing adequate fuel for the reentry maneuver. It also reduces the likelihood of reentry fuel loss during normal on-orbit operations. NSS will compensate for any uncertainty in fuel gauging arising out of satellite launch and operations.

NSS will not be its own prime contractor for construction of its Virtual Geo system. To the extent that it can, NSS will request that its contractor, pursuant to NASA Safety Standard 1740.14, prepare two debris assessment reports during program development. The initial report would be prepared at PDR, and a final assessment will be prepared 45 days prior to CDR. The purpose of the report submitted at PDR would be to identify debris issues early in the development cycle. The report submitted prior to CDR will document the position of the program relative to the guidelines to limit orbital debris generation.

SUPPORTING FIGURES

Constellation	Glonass	GPS	Molniya	Galileo
Altitude	19200	20200		23222
Max degrees, orbit inclination	64.7	55	63.435	56
lat of intersection	47.9	50.1	15	
Number of satellites in constellation	11	32	30	30
Size of satellite				
Max dimension	30	30	30	20
dimension orthog 1	3	3	3	3
dimension orthog 2	2	2	2	2
Avg area of satellite	75	75	75	50
Size of Virgo satellite				
Max dimension	40	40	40	40
dimension orthog 1	4	4	4	4
dimension orthog 2	3	3	3	3
Avg area of intersecting satellite	140	140	140	140
2-D convolved area sq m	490	490	490	420
eccentricity	0	0	0.75	0
sma	25510	26559	26559	29994
semiminor axis			17567.13	

Figure 9.4-1, Data used for calculating probability of impact.

	Glonass	GPS	Molniya	Galileo
intersecting latitude	47.9	50.1	16	56
altitude from center of earth at intersection	25510	26559	8820	29994
radius of annulus North of earth at stated lat	17102.58305	17036.26076	8478.328158	16772.43195
Width of anulus = max intersection dim	70	70	70	60
area of annulus of all possible orbit intersctn pts	7522108897	7492938833	3728963484	6323057878
intersection area	490	490	490	420
orbit inclination	64.7	55	63.435	56
ratio of intersecting area to annulus area	6.51413E-08	6.53949E-08	1.31404E-07	6.64236E-08
Number of intersections per orbit	2	2	2	2
P(orbits intersect)	1.30283E-07	1.3079E-07	2.62808E-07	1.32847E-07
circumference of orbit, meters	160284057.2	166875118.6	139454873.9	119976000
area of target orbit (intersctn dim*circumf) m^2	11219884003	11681258300	9761841171	7198560000
intersection included angle, deg	40	40	5	45
corrected target interesctn area due to obliquity of intersection	762.3046752	762.3046752	5622.11949	593.9696962
Intersection area to orbit area ratio	6.79423E-08	6.52588E-08	5.75928E-07	8.25123E-08
P(orbits intersect & tgt sat at intersctn | V sat at intrsctn)	8.8517E-15	8.53518E-15	1.51358E-13	1.09615E-14
Number of Virgo revs per day	3	3	3	3
Number of Virgo sats	15	15	15	15
Number of target sats	11	32	30	30
Number of years of Virgo life	15	15	15	15
total probability of collision, any Virgo sat with any Target sat	2.39892E-08	6.72914E-08	1.11873E-06	8.10193E-08

Figure 9.4-1, Calculations supporting probability of satellite impact. Note that normally Galileo does not intersect the Virtual Geo orbits, missing by around 250 kilometers. Calculations here are for the case of an intersection due to deviations from nominal orbit parameters, and assume in the Galileo case that the orbits intersect for the lifetime of the satellites.

altitude upper limit	Flux, impacts/ m^2/yr	times	Fraction of orbit duration within zone	Product of duration and flux
		10:22:00 PM		
1160	1.80E-06	10:24:15 PM	0.009375	1.69E-08
1320	1.00E-06	10:27:08 PM	0.011979	1.20E-08
1570	1.50E-06	10:29:41 PM	0.010677	1.60E-08
1630	9.00E-07	10:30:11 PM	0.002083	1.87E-09
1730	5.60E-06	10:31:00 PM	0.003385	1.90E-08
1880	2.30E-07	10:32:07 PM	0.004622	1.06E-09
2000	1.20E-07	10:32:57 PM	0.003515	4.22E-10
2110	6.00E-08	10:33:41 PM	0.003060	1.84E-10
2220	3.00E-08	10:34:22 PM	0.002865	8.59E-11
2330	1.50E-08	10:35:03 PM	0.002799	4.20E-11
2440	7.50E-09	10:35:42 PM	0.002734	2.05E-11
2550	3.75E-09	10:36:21 PM	0.002669	1.00E-11
2660	1.88E-09	10:36:57 PM	0.002539	4.76E-12
2770	9.38E-10	10:37:34 PM	0.002540	2.38E-12
2880	4.69E-10	10:38:09 PM	0.002474	1.16E-12
2990	2.34E-10	10:38:45 PM	0.002474	5.80E-13
3100	1.17E-10	10:39:20 PM	0.002408	2.82E-13

Figure 9.4-2, Data used for calculating the probability of large debris impact. Debris Flux taken from Figure 5-1 of NSS 1740-14 following instructions there.

Percent of time below 3100 km	7.22%
Total annual dose	6.75E-08
Number of years	15
Total P(strike) per unit area	1.01E-06
Total sfc area	73
Overall P(strike)	0.0000740
Limited to <2K	
Total annual dose	6.72E-08
Number of years	15
Total P(strike) per unit area	1.01E-06
Total sfc area	73
Overall P(strike)	0.0000736

Figure 9.4-3, Calculation of Overall Probability of Strike by Large Debris

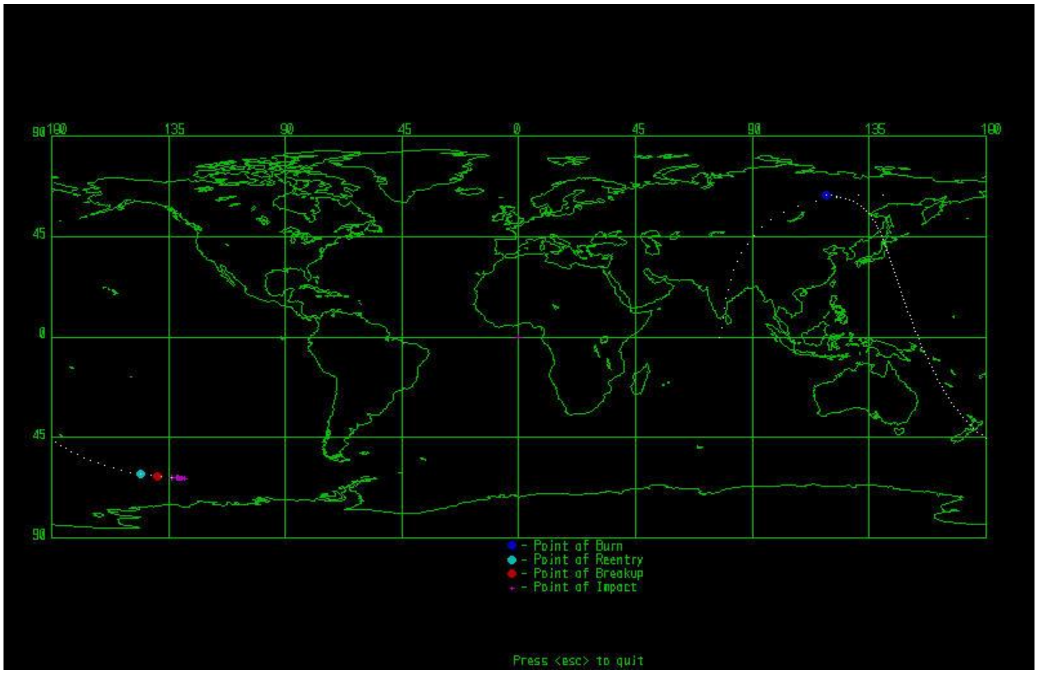

Figure 9.4-4, Reentry and impact of Aurora I Satellites per DAS. Retro burn at apogee to depress perigee to 60 kilometers, causing satellite to reenter at perigee into the Southern Pacific Ocean as shown. This is a controlled reentry that avoids any populated area. All Aurora I satellites will use this track.

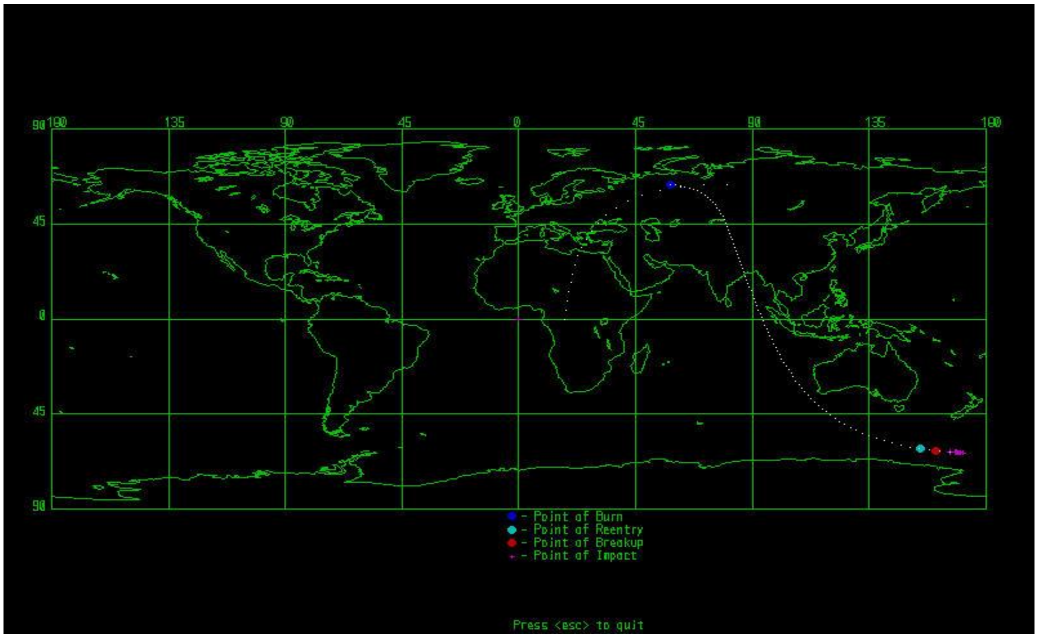

Figure 9.4-5, Reentry and impact of Aurora II Satellites per DAS. Retro burn at apogee to depress perigee to 60 kilometers, causing satellite to reenter at perigee into the Southern Pacific Ocean as shown. This is a controlled reentry that avoids any populated area. All Aurora II satellites will use this track.

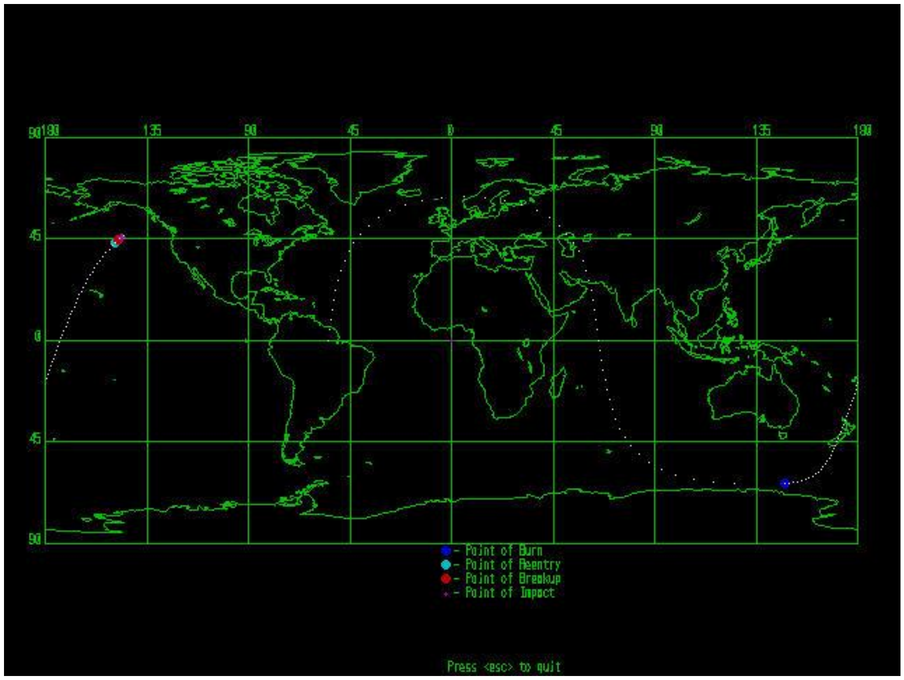

Figure 9.4-6, Reentry and impact of Australis Satellites per DAS after drift maneuver to shift apogee to the desired point to yield reentry into water. Retro burn at apogee to depress perigee to -500 kilometers, causing satellite to reenter at perigee into the North Pacific Ocean as shown. This is a controlled reentry that avoids any populated area and remains well clear (>200 nautical miles per NASA guidelines) of any landmass. All Australis satellites will use this track.

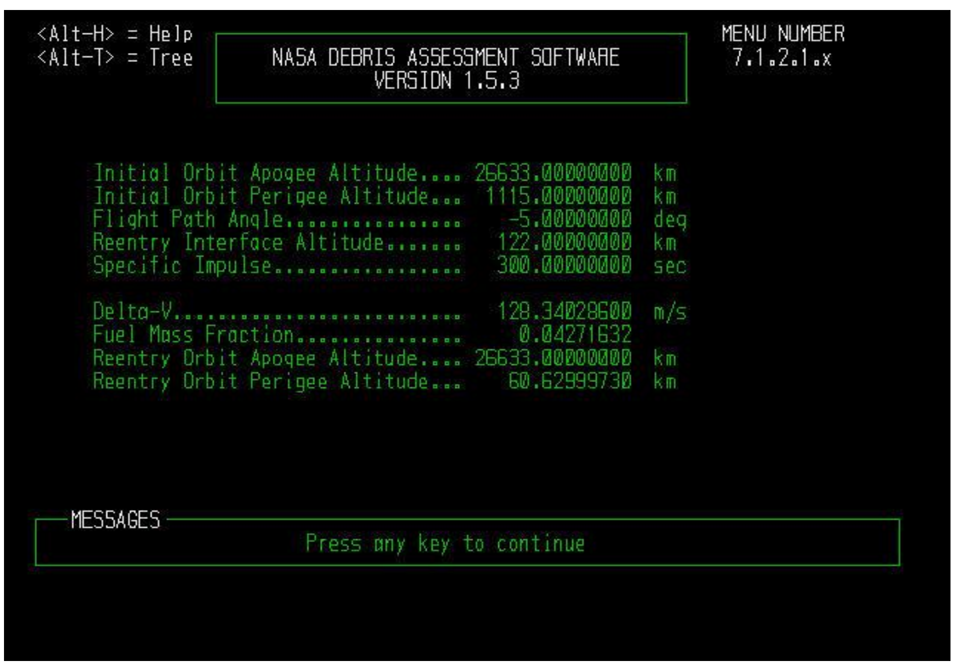

Figure 9.4-7, Reentry Delta-V requirements per DAS from the Aurora operational orbits.

Figure 9.4-8, Reentry data for Australis satellites

10 Requested Waivers of the Commission's Rules

NSS requests a waiver of Section 25.210 of the Commission's Rules, 47 C.F.R. § 25.210. This rule contains technical requirements that apply generally to fixed-satellite service spacecraft. The particular provisions of this rule, however, are tailored to the typical design specifications of geostationary satellites, and are technically inapplicable to nongeostationary satellites (which are inherently incapable of meeting the specific requirements set forth in Section 25.210). Notwithstanding the facial inapplicability of the rule, NSS's Virtual Geo system is consistent with the purpose of Section 25.210 to the extent that they maximize the efficient use of the spectrum in which its satellites will operate.

11 CONCLUSION

The Virtual Geo satellite system is an innovative concept that will be capable of providing affordable and highly desirable satellite services to businesses and end users in most of the heavily populated areas of the world. Virtual Geo is a model of how the orbital/spectrum resource can be shared on a co-frequency basis by multiple services in order to maximize efficiency, and will help maintain U.S. leadership in commercial satellite technology.

For all of the reasons set forth in this application, NSS respectfully urges the Commission to grant this application and authorize it to operate the Virtual Geo system in the United States, so that the promised public interest benefits will be realized as rapidly as possible.

Respectfully submitted,

New Spectrum Satellite, Ltd

By: /s/
David Castiel
Managing Director

Dated: July 26, 2017

Of Counsel:

Stephen L. Goodman
Butzel Long
1909 K Street, NW Suite 500
Washington, D.C. 20006

REQUIRED CERTIFICATIONS

Pursuant to Section 304 of the Communications Act (47 U.S.C. § 304), New Spectrum Satellite, Ltd ("NSS") waives any claim to the use of any particular frequency or of the electromagnetic spectrum as against the regulatory power of the United States because of the previous use of the same, whether by license or otherwise.

The undersigned further certifies, under penalty of perjury, that neither NSS nor any party to this application is subject to denial of federal benefits pursuant to Section 5301 of the Anti-Drug Abuse Act of 1988, 21 U.S.C. § 862.

The undersigned certifies under penalty of perjury, individually and for NSS, that the statements made in this application are true and correct to the best of his knowledge and belief, and are made in good faith.

By: /s/
David Castiel
Managing Director
New Spectrum Satellite, Ltd

July 26, 2017

Technical Certificate

The undersigned hereby certify, under penalty of perjury, that we are the technically qualified persons responsible for the preparation of the technical information contained in the foregoing application, that we are familiar with Part 25 of the Commission's Rules, and that I have either prepared or reviewed the technical information in the foregoing application and found it to be complete and accurate to the best of my knowledge and belief.

/s/
John W. Brosius
Acting Chief Technical Officer

New Spectrum Satellite, Ltd

July 26, 2017

ATTACHMENT: OWNERSHIP INFORMATION
New Spectrum Satellite, Ltd

FCC Form 312, Question 40
July 26, 2017

1. NSS is currently a wholly-owned subsidiary of Virtual Geosatellite, LLC. NSS's Directors are:

   David Castiel 5335 Wisconsin Avenue, NW Suite 640
   Washington, DC 20015
   Linda Awkard 5335 Wisconsin Avenue, NW Suite 640
   Washington, DC 20015
   Elie Castiel 1200 McGill College Avenue, Suite 1100
   Montreal Quebec, Canada H3B 4G7

2. Virtual Geosatellite, LLC is a wholly-owned subsidiary of Ellipsat, Inc.
   David Castiel is Managing Director, same address as above

3. The following shareholders control and/or hold 10% or more of Ellipsat, Inc.

David Castiel	30.02%
John Q. Piper	11.14%
Global Spectrum Investment Partnership, LLC	10.75%

All the above are US citizens and/or entities controlled by US citizens. Each of these shareholders can be reached at:

c/o Virtual Geosatellite, LLC
5335 Wisconsin Avenue, N.W.
Suite 640
Washington, DC 20015

The Officers of NSS are:

David Castiel President/Managing Director
Linda Awkard Secretary, Chief Counsel
John W. Brosius Acting Chief Technical Officer

New Spectrum Satellite, Ltd

FCC Form 312, Question 36
July 26, 2017

ADVERSE ACTIONS CONCERNING FCC LICENSES OR APPLICATIONS

New Spectrum Satellite, Ltd's affiliate, Virtual Geosatellite LLC, itself had an affiliate relationship with Mobile Communications Holdings, Inc. ("MCHI"). In 1997, MCHI was licensed in to operate Ellipso, a 1.6/2.4 GHz Mobile-Satellite Service ("MSS") System. *See Mobile Communications Holdings, Inc.*, 12 FCC Rcd 9663 (1997). As a result of the adverse impact on the market for MSS due to the Iridium bankruptcy, MCHI failed to satisfy an implementation milestone and the International Bureau declared this authorization null and void. *See Mobile Communications Holdings, Inc.*, 16 FCC Rcd 11766 (IB 2001), *recon. denied*, Memorandum Opinion and Order, 17 FCC Rcd 11898 (Int'l. Bur. 2002), *rev. denied*, Memorandum Opinion and Order, 18 FCC Rcd 11659 (2003).

In 2001, MCHI was also licensed to operate "Ellipso 2G," a 2 GHz MSS system. *See Mobile Communications Holdings, Inc.*, 16 FCC Rcd 13794 (Int'l. Bur/OET 2001). In 2003, the International Bureau likewise declared MCHI's Ellipso 2G authorization null and void on the ground that the licensee had failed to satisfy an implementation milestone included in its authorization. *Applications of Mobile Communications Holdings, Inc. and ICO Global Communications (Holdings) Limited for Transfer of Control, Constellation Communications Holdings, Inc. and ICO Global Communications (Holdings) Limited for Transfer of Control, Mobile Communications Holdings, Inc. for Modification of 2 GHz License, Constellation Communications Holdings, Inc. for Modification of 2 GHz License*, Memorandum Opinion and Order, 18 FCC Rcd 1094 (Int'l. Bur. 2003), *rev. denied sub nom. Joint Application for Review of Constellation Communications Holdings, Inc., Mobile Communications Holdings, Inc. and ICO Global Communications (Holdings) Limited*, Memorandum Opinion and Order, 19 FCC Rcd 11631 (2004).