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FILED ELECTRONICALLY VIA IBFS

Mr. Jose P. Albuquerque
Chief, Satellite Division- International Bureau
Federal Communications Commission
445 12th Street, S.W.
Washington, DC 20554

Re: Telesat Canada, IBFS File No. SAT-LOI-20170301-00023 (Call Sign S2991)

Dear Mr. Albuquerque:

In response to your June 22, 2017 letter requesting additional information in evaluating Telesat Canada's ("Telesat") above referenced petition for declaratory ruling, Telesat provides the following answers to your questions below. The questions are formatted in italics with Telesat's responses in plain text. Footnote references in the Commission's letter to Telesat are removed for clarity:

1. Telesat describes its V-band NGSO constellation as a "second-generation overlay" to its proposed Ka-band NGSO constellation. Please provide more information about the relationship between Telesat's proposed V-band and Ka-band constellations, including whether the V-band NGSO constellation will be composed of entirely new satellites or if Telesat intends to host V –band payloads on the satellites of its Ka-band NGSO constellation.

> Telesat's proposed second generation V-band satellites will be separate from the Ka-band satellites for which Telesat has requested U.S. market access in the Commission Ku/Ka-band processing round. The V-band constellation is designed to provide additional communications capacity for Telesat's NGSO service. While current plans do not call for it to do so, it is possible that the V-band fleet may host some Ka-band capacity in addition to its V-band capacity. In either case, the constellations are designed to be interoperable, with interface capability via Inter-Satellite Links (ISL).

2. Section 25.114(d)(1) of the Commission's rules requires that applicants provide an explanation of how the uplink frequency bands would be connected to the downlink frequency bands on their proposed satellite system. In order to better understand the beam and channel connections on the Telesat V-band NGSO constellation, we request that Telesat supplement its petition with a showing (e.g., a strapping table, chart, or spreadsheet) that clearly presents this information. If Telesat is using dynamic channel allocation, please describe the algorithm that will be used for the connections.

> Each satellite of the V- band LEO Constellation will provide a minimum of 16 steerable User beams and two dual-polarization steerable Gateway beams with the use of Direct Radiating

Arrays (DRA). RF signals will be digitized, demultiplexed and demodulated; regenerating each signal on-board for packet switching. In addition, each satellite will have a maximum of four Inter-Satellite Link (ISL) terminals to redirect traffic when Gateways are not available or when traffic is required to be transmitted to a specific Gateway. Therefore, the switching capability on board the satellite will maximize connectivity, *i.e.*, Gateway-User, User-User, User-Gateway, User-ISL, Gateway-ISL and ISL-ISL. With the use of on-board regenerative payloads and ISLs, the satellites are no longer limited to the pre-determined typical uplink/downlink channel connectivity of bent-pipe payloads.

As shown in the proposed frequency plan (Figure 1), any uplink frequency band can be connected to any downlink frequency band. At a specific instant, if no Gateway is available, *i.e.*, over water, all spectrum can be used for user uplink and downlink. Similarly, for Gateways located in the North, with a limited number of users, most of the spectrum can be used for the Gateways. The LEO Constellation design will allow maximum flexibility and efficiency.

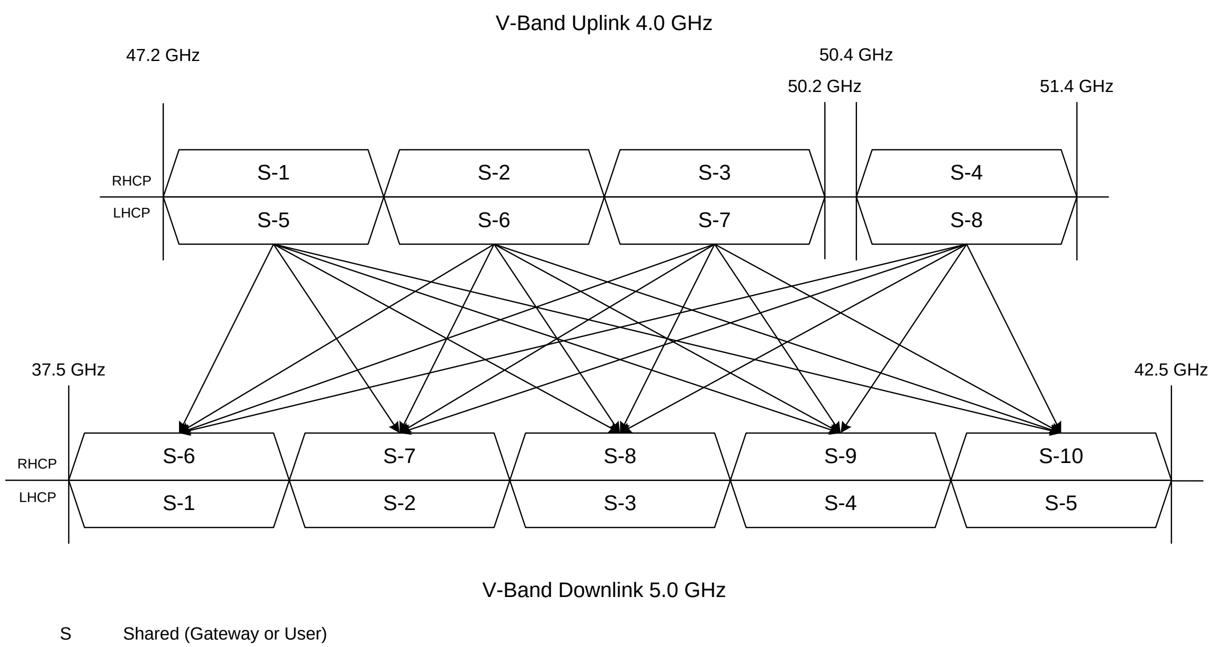

Figure 1 Telesat LEO V-Band Constellation Polarization and Frequency Plan

Telesat's V-band constellation will not be using a dynamic channel allocation algorithm for switching. Resource management will be done at system level with some distributed functionality on-board each satellite.

3. Please provide the minimum elevation angle at which gateway and user terminals will be operated.

Ten degrees.

4. Please indicate the date by which Telesat anticipates that its V-band NGSO constellation will be operational.

Telesat's V-band NGSO constellation will be operational within the time frame established by the FCC's milestone requirements.

If in response to Question 1 Telesat indicates that the V -band NGSO constellation will be composed of new satellites separate from Telesat's proposed Ka-band NGSO constellation, please respond to the following additional questions:

5. A statement concerning whether it is Telesat's intent to seek registration of the Telesat V-band NGSO constellation by Canada consistent with the Convention on the Registration of Objects Launched into Outer Space.

Yes, Telesat will seek registration of the V- band NGSO constellation by Canada consistent with the Convention on the Registration of Objects Launched into Outer Space.

Telesat takes this opportunity to note the following related information: In its Petition, Telesat stated that it provided the Canadian licensing authority, Innovation, Science and Economic Development Canada ("ISED") (formerly Industry Canada), with documentation to initiate the coordination process for the V-band LEO Constellation. Telesat also noted that it was not able to file an application for authorization with ISED at that time because of ISED's moratorium on new commercial NGSO systems. Telesat stated that it would submit an application to ISED once the moratorium was lifted. That moratorium was lifted on June 26, 2017 and on the same day, Telesat filed its V-band NGSO constellation application with ISED, an application that conforms to the documentation submitted by ISED to the ITU.

6. Commission rules require petitioners requesting U.S. market access for non-U.S. licensed space stations to provide a narrative description of the design and operational strategies that will be used to mitigate orbital debris. Alternatively, an applicant seeking market access for a non-U.S. licensed system can satisfy this requirement "by demonstrating that debris mitigation plans for the space station(s) for which U.S. market access is requested are subject to direct and effective regulatory oversight by the national licensing authority." Telesat states that it satisfies this requirement because the operations of its V-band NGSO constellation are subject to direct and effective regulatory oversight by the Canadian licensing authority - Innovation, Science and Economic Development Canada (formerly Industry Canada). Telesat states that Canadian regulations require that space debris mitigation measures be implemented "in accordance with best industry practices so as to minimize adverse effects on the orbital environment," and that Telesat's pending Canadian approval will ultimately specify the same condition. Telesat also disclosed certain information concerning its orbital debris mitigation plans pursuant to section 25.114(d)(14) of the Commission's rules. In order to assist in our assessment of whether Telesat has demonstrated that it is subject to direct and effective regulatory oversight, or alternatively, to permit analysis of the debris mitigation plans for the constellation, we request the following additional information:

a. Any additional information concerning the scope of oversight to which Telesat is subject, supported if possible by publicly available materials discussing the criteria applied by the Canadian regulatory authority. If an Orbital Debris Assessment Report or other documentation for the Telesat constellation has been prepared for or submitted to ISED, please submit a copy of that report.

The applicable Canadian regulation is contained in CPC-2-6-02, Issue 4, Licensing of Space stations, issued June 2017 available at http://www.ic.gc.ca/eic/site/smt-gst.nsf/eng/sf01385.html.

The relevant excerpt from CPC-2-6-02, Issue 4, is provided at Attachment 1 to this letter. The relevant excerpt from Telesat's Canadian license application with respect to the commitment to debris mitigation is provided in Attachment 2 to this letter.

b. The accuracy within which the space station orbital parameters will be maintained for any orbit in which Telesat V -band NGSO satellites will operate, including apogee, perigee, inclination, and the right ascension of the ascending node(s).

The space station orbit parameters will be maintained as follows:

Apogee or Perigee Altitude ±300 meters

This value is in relation to the target apogee and target perigee, not mean altitude.

Inclination ±0.04 degrees

This value is in relation to the target mean inclination, not osculating inclination.

Right Ascension of the Ascending Node ±1 deg

This value is in relation to the target ascending node. For Walker constellation this is referenced to the key satellite, not a particular RAAN (0-360 deg).

Target values are determined by Walker orbit design and phasing for the inclined constellation. Target values are determined by initial polar orbit deployment and phasing for the polar constellation, as this configuration is sun synchronous.

c. Whether or not Telesat's assessments of collision risk, including the stated "minimum close approach of 10 km with other satellites," takes into account the satellites in Te1esat's proposed Ka-band NGSO constellation.

Yes, Telesat's assessments of collision risk, including the stated "minimum close approach of 10 km with other satellites," take into account the satellites in Te1esat's proposed Ka-band NGSO constellation.

d. The intended orbital parameters of the "Decaying Lower Orbit" to be used for end-of-1ife disposal, or, if range of possible orbits depending on available fuel is intended, a characterization of the likely distribution of satellites within that range.

Telesat will use highly elliptical orbits of approximately 750 km x 150 km for end-of-life disposal. Telesat notes that the use of a highly elliptical orbit for end of life disposal reflects an update in its post-mission disposal plans designed to reduce fuel usage, time in the disposal orbit and risk of debris generation.

e. Please provide an analysis of collision risk for satellites during the passive disposal phase, i. e., after all propellant is consumed, for a 117 satellite deployment, assuming 100% reliability. As part of that analysis, please take into account the satellites of the proposed Telesat Ka-band NGSO constellation and provide an assessment of how many conjunctions and/or collision avoidance maneuvers might be required of the International Space Station, assuming it is in operation throughout the period in which disposals occur. To the extent replenishment or deployment rates can be expected to involve more than 117 satellites through 2035, please also provide an analysis assuming such rates.

Each of Telesat's Ka-band and V-band constellations will have a minimum of 117 satellites, plus spares. Using the NASA DAS (Debris Assessment Software) for the probability of collision with an object of greater than 10 cm, the collision risk, per satellite, rounded to five decimals, is 0.00000. Given that the probability of collision is less than the resolution of the DAS software, the aggregate risk for 234 satellites, plus spares would be near zero.

At the time of entry into disposal phase, Telesat will custom design disposal orbit parameters that minimize probability of collision with all known high value assets in the lower orbits. Telesat is experienced in eccentricity and inclination collocation and probability of collision avoidance strategies. At the planned eccentricity, even a passive disposal strategy, with properly chosen argument of perigee and orbital parameters, will create significant separation. Telesat continues to review and assess other de-orbit strategies as part of its system level engineering trades.

Currently, ISS debris avoidance maneuvers are less than one or two per year with more than 100 catalogued debris objects within a +/- 20 km altitude range. It is expected that the decommissioned satellites with fast decaying orbits from the Telesat constellations during the passive phase of the deorbit will have an insignificant impact on the ISS collision avoidance activities.

f. Please provide an analysis of collision risk, assuming rates of satellite failure resulting in the inability to perform collision avoidance procedures of 10, 5, and 1 percent. This analysis should include a study performed assuming all failures occur at the mission altitude and should take into account the satellites of the proposed Te1esat Ka-band NGSO constellation. The analysis may also include additional studies specifying alternative assumptions concerning the other orbital locations (such as injection altitude) at which failures might occur.

The risk of collision with debris of diameter ≥10 cm is 0.0019, 0.0076, and 0.0145 for the combined Ka-band and V-band polar constellations over 12 years assuming rates of satellite failure resulting in the inability to perform collision avoidance procedures of 1, 5, and 10 percent respectively. The risk of collision is much less for the inclined constellations at 0.00009, 0.00045, and 0.00081.

It should be noted, moreover, that while this response addresses the Commission's hypothetical of uncontrolled orbit failures of up to 10%, Telesat fully expects the actual probability of a failed satellite, especially a failure that results in a loss of any maneuver control, to be substantially less. Such reliability will be produced, among other ways, in the redundancy of critical subsystems, including in propulsion, mechanisms, sensors, spacecraft computer and power subsystems, as well as best practices in satellite operation by experienced and well-trained engineering personnel. During 45 years of operating geosynchronous spacecraft, Telesat has always successfully maneuvered its spacecraft from the operation orbit to the disposal orbit at the end of life despite multiple bus system failures.

With regard to other Telesat satellites that would still be in service, given the maneuver capability and other means that Telesat has to identify and avoid collisions with large space objects, based upon Telesat's operational experience, Telesat regards any additional risk as negligible.

A collision probability analysis of satellite injection orbit failures will be carried out once the mission design requirements have matured. Currently it is intended to launch into the vicinity of the final orbits, with the same inclinations and minor altitude differences to allow for nodal regression to the right ascending node where the orbit will be adjusted to final parameters. Any failures in such orbits are expected to be consistent with the collision probability estimates above. More specific analyses will be carried out as part of the final mission design.

g. Any additional information you may wish to provide concerning human casualty risk resulting from satellite disposal, such as outcomes based on higher fidelity analysis, or any risk or loss mitigation strategies under development.

One of the critical requirements for the satellite design is to ensure the materials, processes and assemblies are selected, designed, and integrated such that the probability of survival of spacecraft components through the re-entry into earth's atmosphere is extremely remote. The design will be assessed using NASA DAS program and modified as required to ensure that the human casualty risk resulting from the de-orbiting of the satellites is less than 1 in 10,000, in accordance with the applicable guidelines. Such requirements for design and analysis needs will be discussed and agreed as part of the selection of the spacecraft supplier.

h. Any information or analysis you may wish to provide with respect to treatment of this application under the Commission's environmental processing ru1es.

Telesat has imposed as one of the critical requirements for the satellite design that the materials, processes and assemblies are selected, designed and integrated such that the probability of survival of any component through re-entry into earth's atmosphere is extremely remote. Therefore, the risk that a component not only survives but strikes an environmentally protected target is infinitesimal.

7. For optical inter-satellite links, please provide the wavelength, power, duty cycle, beam diameter at emitter, and beam divergence. In addition, please provide the power margin at the receiver at maximum operating distance.

The specific design is yet to be finalized, however the following parameters are under consideration:

• Candidate Laser wavelength(s): 1060, 1065, 1070, 1075 and 1550 nm.
• Laser radiated power (for respective candidate wavelengths noted above): 4.0, 4.0, 4.0, 4.0 and 8.0 Watts, respectively for the 5 wavelengths noted above.
• Duty cycle: will vary from continuous link, to intermittent connection of various periods.
• Beam diameter at emitter: 10 cm.
• Beam divergence (for respective candidate wavelengths noted above): 21.1 urad (1/e^2, full angle), 21.2 urad (1/e^2, full angle), 21.3 urad (1/e^2, full angle), 21.4urad (1/e^2, full angle), and 30.8 urad (1/e^2, full angle).
• Power margin at the receiver at maximum operating distance (for respective Candidate wavelengths noted above, at 6000 km): 6.20 dB, 6.13 dB, 6.06 dB, 5.98 dB, and 7.00 dB.

8. Please indicate whether optical inter-satellite links will be coordinated with other systems proposed in FCC applications and with the U.S. Department of Defense's laser clearing house, and, if such coordination has commenced, please address the status of coordination.

The optical inter-satellite links will have very narrow beams directed between Telesat's satellites. As such the potential to cause interference is expected to be very low to nil. Nevertheless, coordination will be conducted with operators of other systems using optical links if and to the extent required by the International Bureau. Telesat is discussing with the Bureau the scope of coordination requirements involving the U.S. Department of Defense's laser clearing house. If and to the extent that such coordination is required, it will also be undertaken. These coordinations have yet to be initiated.

Should the Commission need additional information, I can be reached at eneasmith@telesat.com or 1-613-748-8700 x3279.

Very truly yours,

/s/_______________________

Elisabeth Neasmith
Director, Spectrum Management and Development

ATTACHMENT 1
EXCERPT OF CPC-2-6-02, Issue 4
(Relates to Question 6.a.)

3.3 Other requirements

3.3.3 Space debris mitigation plan

For all satellites (GSO and NGSO), a plan must be submitted that describes, in operational detail, how the satellite(s) will be de-orbited, and what other measures will be implemented to mitigate the possibility of orbital debris.

For NGSO satellites, the plan must be consistent with the guidelines issued by the Inter-Agency Space Debris Coordination Committee, including the requirement for the satellite(s) to de-orbit within 25 years of end of operational life.

These requirements are derived from the broader United Nations (UN) space debris mitigation guidelines, which cover many elements, including:

- limiting debris released during normal operations;
- minimizing the potential for break-ups during operational phases;
- limiting the probability of accidental collision in orbit;
- avoiding intentional destruction and other harmful activities;
- minimizing potential for post-mission break-ups resulting from stored energy;
- limiting the long-term presence of spacecraft and launch vehicle orbital stages in the low-Earth orbit region after the end of their mission; and
- limiting the long-term interference of spacecraft and launch vehicle orbital stages with the geosynchronous Earth orbit region after the end of their mission.

ATTACHMENT 2
EXCERPT FROM TELESAT'S CANADIAN APPLICATION
REGARDING ORBITAL DEBRIS MITIGATION
(Relates to Question 6.a.)

Space Debris Mitigation Plan
Telesat has been operating GSO satellites for more than 40 years during which multiple generations of its satellites have been retired and duly disposed of in the appropriate (graveyard) orbit to avoid adding debris to the GSO orbit. Telesat also takes LEO orbital debris mitigation very seriously, as it plans to be a major operator of satellites in LEO orbits. Debris control and mitigation are stated requirements in our spacecraft design specifications. Telesat has always met the requirements of the relevant regulatory bodies and the LEO-V Constellation will fully meet the ITU recommendations regarding atmospheric destruction of components. Telesat will implement mitigation measures in accordance with guidelines established by the Inter-Agency Space Debris Coordinating Committee.

Post-Mission Disposal Plans
At the end of life, each satellite will be de-orbited by re-entering the satellite into the earth's atmosphere and burning.
The de-orbiting has two phases. In the first phase, the satellite will be moved from its operational orbit to a planned lower orbit, the "Decaying Lower Orbit". The Decaying Lower Orbit will be an orbit with an apogee of less than 1,000 km and a perigee of not more than 550 km. Once the satellite is moved to this lower orbit, all stored energy sources onboard the satellite will be removed by venting the remaining propellant and the remaining helium pressurant. All propulsion lines and latch valves will be vented and left open. All battery chargers will be turned off and batteries will be left in a permanent discharge state. All momentum storage devices will be switched off. These steps will ensure that no buildup of energy can occur and eliminate the risk of explosion after the satellite has stopped operating.
In the second phase, the satellite will be left in the Decaying Lower Orbit which, within 25 years, will result in the re-entry of the satellite into the Earth's atmosphere and burning of the satellite. (The design will be consistent with the requirement 4.7.-1 of NASA-STD 8719.14- Process for Limiting Orbit Debris.) Sufficient (worst case 3 sigma) propellant will be budgeted for the de-orbit maneuvers to insert the spacecraft into the Decaying Lower Orbit, which will ensure re-entry into the Earth's atmosphere and burning of the satellite.
One of the critical requirements for the satellite design will be to ensure that the materials, processes and assemblies are selected, designed, and integrated such that the probability of survival of spacecraft components through the re-entry into the earth's atmosphere is extremely limited. The design will be assessed using NASA DAS (Debris Assessment Software) and modified as required to ensure that the human casualty risk resulting from the de-orbiting of the satellites is less than 1 in 10,000, in accordance with the applicable guidelines.
Design and Operational Strategies that are used to Mitigate Orbital Debris
No Intentional Destruction

Telesat will avoid the intentional destruction on orbit of any LEO-V satellite.

Debris Release Assessment

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

Accidental Explosion Assessment

Telesat will review failure modes for all equipment to assess the possibility of an accidental explosion on board the spacecraft.

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

Assessment Regarding Collision with Larger Debris and Other Space Stations

Telesat has been operating geostationary satellites for decades and has been performing the station-keeping for its satellite fleet from its Satellite Control Centre in Ottawa. Telesat also has experience of operating non-geostationary LEO satellites. Specifically, since 2007 Telesat has been operating Radarsat-2 for MacDonald, Dettwiler and Associates Ltd. (MDA). Radarsat-2 is a non-geostationary LEO satellite at an altitude of 798 km. Telesat will use its highly developed and tested station-keeping methodologies to maintain the orbital parameters of the LEO-V Constellation satellites with a level of accuracy sufficient to avoid collision with other non-geostationary satellites. In order to protect against collision with other orbiting objects, Telesat has been sharing ephemeris data with the Canadian Space Agency (CSA), the Joint Space Operations Center (JSpOC), MIT Lincoln Laboratory and the Space Data Center (SDC). The JSpOC and the CSA provide notifications to Telesat for any object they see approaching a Telesat satellite, together with assessments of whether avoidance maneuvers are required, and Telesat will maneuver its satellites accordingly.

In the case of the LEO satellite Radarsat-2, Telesat has been working with the Canadian Space Agency to use Probability of Collision (PoC) analysis to determine the need for collision avoidance maneuvers. Telesat will coordinate with other non-geostationary satellite networks to minimize the risk of collision between Telesat LEO-V Constellation satellites and any other NGSO satellite. To further limit the potential for future collision, Telesat will continue to monitor new satellite launches to ensure that future satellites do not present a danger to the LEO-V Constellation satellites.

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

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

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

The spacecraft will be designed with redundancy so that individual unit faults will not cause the loss of control of the spacecraft. On board fault protection will ensure the isolation of the affected unit(s) and the replacement with the back-up hardware/systems. As this process will occur within the spacecraft, it will also afford protection from command link failures (on the ground).