## BOW AFF

### 1AC---Plan

#### The appropriation of outer space by The Boeing Company and The OneWeb Group is unjust.

### 1AC---Debris ADV

#### Boeing is on track to deploy mega-constellations---contributes to massive debris---mitigation fails.

Foust 16 (, J., 2016. The Space Review: Mega-constellations and mega-debris. [online] Thespacereview.com. Available at: <https://www.thespacereview.com/article/3078/1> [Accessed 13 December 2021] Jeff Foust is an aerospace analyst, journalist and publisher. A senior aerospace analyst with the Futron Corporation in Bethesda, Maryland, he is the editor and publisher of The Space Review and has written for Astronomy Now and The New Atlantis. He is the writer of the blog Space Politics.)-rahulpenu

Mega-constellations and mega-debris

Two current **trends** **in** space operations are on a **collision** **course** with each other. One is the concern about the growth of space debris, particularly in low Earth orbit. Events like the 2009 collision between an Iridium satellite and a Russian Cosmos spacecraft, as well as China’s infamous 2007 test of an anti-satellite weapon, have sharply increased the amount of debris in LEO. The growing population of debris raises fears of more collisions creating yet more debris, a cascade that, in a worst-case scenario known as the **Kessler** Syndrome, make **LEO** **unusable**.

“The **concern** for mega-constellations is **not** **about** the **spacecraft** themselves, but **rather**, it is the potential for **debris** **generation** from the explosion of or collisions involving the mega-constellation spacecraft,” said Liou.

The second trend is growing interest in so-called “mega-constellations” of satellites in low Earth orbit. OneWeb, for example, is developing a constellation of initially 648 satellites in LEO to provide broadband communications services globally. Other proposed systems, also primarily in the communications realm, are even larger: Boeing has filed with the US Federal Communications Commission (FCC) plans for a satellite system of between 1,400 and 3,000 satellites, while SpaceX is studying a system of about 4,000 satellites.

At last month’s International Astronautical Congress (IAC) in Guadalajara, Mexico, a panel discussion examined the implications of such mega-constellations on the orbital debris environment. The implication from the session’s title—“Projection and Stability of the Orbital Debris Environment in the Light of Planned Mega-Constellation Deployments”—suggested that those systems could exacerbate the orbital debris problem. But even as one company argued it would take steps to be a good citizen in LEO, it was clear that those measures alone won’t be enough to alleviate the problems those systems could create.

The threat posed by orbital debris, particularly objects too small to track—and thus maneuver to avoid—is not academic. On August 23, an object about one centimeter across struck ESA’s Sentinel-1A Earth observation spacecraft. Before-and-after images provided by a camera on the satellite showed a ring about 40 centimeters across on one solar array, created when the particle hit the back of the array.

“Since August 23rd, nobody else can tell better than ESA that we are operating in a risky environment,” said Holger Krag, head of ESA’s Space Debris Office, at the panel. The impact, he said, caused a partial power loss and a “significant momentum exchange” to the spacecraft, although the long-term effects on the spacecraft are minimal. Analysis of the direction and velocity of the impact led ESA to conclude the object was a piece of debris, and not a micrometeoroid.

“In some sense, we were lucky, because we can continue the mission without major constraints,” he said. “But if the object had arrived a few microseconds later, it would have hit the main body with certainly more significant consequences.”

Debris experts are worried about an increase in collisions as the number of spacecraft increase, creating even more debris. “The concern for mega-constellations is not about the spacecraft themselves, but rather, it is the potential for debris generation from the explosion of or collisions involving the mega-constellation spacecraft,” said Jer-Chyi Liou, NASA’s chief orbital debris scientist.

The US and many other nations have adopted guidelines for mitigating the generation of new orbital debris. Those measures include recommendations that spacecraft in LEO be deorbited no more than 25 years after the end of their mission, so they don’t pose a risk for debris-generating collisions.

For satellites low enough in LEO, that deorbiting can be accomplished naturally, through atmospheric drag. Above about 650 kilometers, though, drag alone is not enough to deorbit a typical satellite within the 25-year guideline. Those spacecraft need to lower their orbit, typically through on-board propulsion, in order to deorbit within 25 years.

“But if the object had arrived a few microseconds later, it would have hit the main body with certainly more significant consequences,” said Krag of the object that hit Sentinel-1A.

Krag said **simulations** of the debris environment **indicate** that **at** **least** **90** **percent** **of** LEO **satellites** **need** **to** **deorbit** within 25 years in order to control to growth of debris. The record is discouraging, though: he said **today** **only** about **20** **percent** of satellites above 650 kilometers even **attempt** to deorbit. That practice, if continued by a mega-constellation, could result in a catastrophic increase in debris: too much, he said, for even his models to handle. “If I had done the simulation with 20 percent instead of 90 percent, that wouldn’t even work with our numerical tools. It would be overloaded with the amount of debris,” he said.

At those higher altitudes, the debris that would be created would be long-lived because of the lack of atmospheric drag. Liou said that many **mega**-**constellations** are **planning** satellites **for** altitudes of **1,100 to 1,200 kilometers**. “Any **debris** generated **in** **that** **region** **will** **exist** **for** **thousands** **of** **years**,” he warned. “We need to be extra-sensitive about the potential for collision cascading in that region.”

Those concerns have put constellation developers like OneWeb on the defensive. Tim MacLay, director of mission systems engineering for OneWeb and the one person on the panel representing constellation developers, said his company is very aware of the orbital debris risks and is taking steps to mitigate the development of orbital debris.

“OneWeb designed its mission to minimize collision risks,” he said. That includes, he said, inserting the satellites after launch into an initial orbit above the International Space Station but below many other operational satellites. Those satellites will eventually move up to an altitude of 1,200 kilometers, which, despite concerns about the longevity of debris created there, is relatively unpopulated today.

MacLay said the satellites will provide accurate position information, which OneWeb will make available to other satellite operators as well as the US Air Force’s Joint Space Operations Center (JSpOC) to aid in analyses to calculate any potential collisions. The spacecraft will also have “a high degree of collision avoidance agility,” he said, to maneuver in the event of a collision risk.

OneWeb also plans to swiftly deorbit its satellites at the end of their lives. “At OneWeb, the ability to deorbit is specified as the highest reliability function in the spacecraft, even above the payload itself,” MacLay said. Each spacecraft will have enough fuel to lower its perigee “all the way to reentry” at the end of their lives, “and are committed to being out of orbit within five years of decommissioning.”

That emphasis on reliability is important, Liou said, calling “high design reliability” of spacecraft one of the most important factors in mitigating debris creation. “A second key element, which is applicable to all space missions, is post-mission disposal,” he said.

**Even** **if** OneWeb and other mega-constellation **operators** **take** strong **efforts** **to** **avoid** **collisions** and other debris-generating events, their **development** **will** still **pose** **challenges** for efforts to avoid satellite collisions in general, as the number of **operations** satellites dramatically **increase**.

Liou noted that while there are currently about 1,400 operational satellites in Earth orbit, mega-constellations could increase that to as many as 7,000 to 8,000. “It can be a non-trivial challenge for JSpOC to extend the conjunction assessment coverage to the mega-constellation spacecraft,” he said.

OneWeb founder Wyler, MacLay recalled, “said that he doesn’t want it on his tombstone that he messed up space.”

It’s also not clear if that responsibility will remain with JSpOC in the long term. At the direction of Congress, the Department of Transportation recently completed a report assessing whether the FAA could take on the role of providing “safety-related” space situational awareness data, like collision warnings. While the Air Force would continue to collect the bulk of the data, the FAA would take over the role of analyzing it and providing collision warnings. That report concluded the FAA could handle that role, provided it obtained legislative authority to do so.

In any case, both debris experts and mega-constellation developers are aware of the additional risks that hundreds or thousands of new satellites could pose for a region of space where the amount of debris continues to grow even with the current population of satellites.

MacLay, near the end of the panel, invoked the name of OneWeb’s founder, Greg Wyler. “From the very beginning, Greg Wyler has recognized the environmental issues associated with launching constellations,” he said. “In one of his interviews, he said that he doesn’t want it on his tombstone that he messed up space.”

#### Boeing is opposing the final FCC rule.

FCC 20 (,Federal Communications Commission, 2020. Mitigation of Orbital Debris in the New Space Age - A Rule by the Federal Communications Commission. [online] federalregister.gov. Available at: <https://www.federalregister.gov/documents/2020/08/25/2020-13185/mitigation-of-orbital-debris-in-the-new-space-age> [Accessed 13 December 2021] The Federal Communications Commission regulates interstate and foreign communications by radio, television, wire, satellite, and cable. It is responsible for the orderly development and operation of broadcast services and the provision of rapid, efficient nationwide and worldwide telephone and telegraph services at reasonable rates. Its responsibilities also include the use of communications for promoting safety of life and property and for strengthening the national defense.)-rahulpenu

CSSMA and LeoSat oppose a requirement that the collision analysis include analysis with respect to planned systems, arguing that planned systems change frequently and not all systems are known. We clarify that the rule will require a disclosure identifying potential systems of concern, but does not require that the applicant's calculated collision risk include such systems (which would go beyond what can be assessed using the NASA Debris Assessment Software). It is important, however, that applicants assess planned systems, what impact such systems may have on their operations, and what coordination can be completed with the operators of such systems. While not all planned systems may come to fruition and there may be systems that would be unknown to applicants, such as foreign or government systems, we expect applicants to make best efforts to analyze the environment in which their satellites will be operating [8] and specify how they plan to coordinate, to the extent possible, with other operators to ensure safe operations. **Boeing** **asks** that we **clarify** that the **disclosure** must specify **only** those other **NGSO** satellite systems “the **normal** **operation** of which” **pose** a **risk** **of** **collision**. **We** concur with Boeing's clarification of the rule, but **decline** **to** **change** the rule language since we believe that it is self-evident that an operator can only take into consideration the planned or normal operations of another operator's system.

Orbit Selection and Other Orbital Characteristics. In the NPRM, the Commission also proposed that any applicants planning an NGSO constellation that would be deployed in the LEO region above 650 km in altitude specify why the applicant had chosen the particular orbit and describe other relevant characteristics of the orbit. The Commission reasoned that missions deploying above 650 km altitude may represent a greater risk from a long-term orbital debris perspective, since satellites that fail above that altitude will generally not re-enter Earth's atmosphere within 25 years, and depending on the deployment altitude, may be in orbit for centuries or longer. The Commission also sought comment on whether it should require a statement concerning the rationale for selecting an orbit from operators of satellites that will remain in orbit for a long period of time relative to the time needed to perform their mission.

After review of the record, we decline to adopt these proposals. We conclude after further consideration that the long-term risks associated with deployments above 650 km are sufficiently addressed through our other rules, such as collision risk assessment, and reliability of post-mission disposal and that therefore the additional statement is not necessary. Indeed, application of the Commission's other orbital debris mitigation rules may in some instances result in an operator deciding to deploy below 650 km. While SpaceX, for example, supported the proposed disclosure regarding rationale for selecting a particular orbit, we conclude that concerns the Commission may have about risks associated with operations in a particular orbit can be adequately addressed through other measures addressed in this proceeding.

We do adopt our proposal, however, that NGSO systems disclose information regarding other relevant characteristics of the chosen deployment orbit not already covered, such as the presence of a large concentration of existing debris in a particular orbit. **Boeing** **states** that the **Commission** **should** **not** **adopt** **regulation** **in** **this** **area**, because **operators** are adequately **incentivized** **to** **select** initial **orbits** that are sufficiently **free** **of** **hazards**, or invest in other measures to facilitate the safety of their satellites. We find that this disclosure will help to ensure that operators have considered all the characteristics of the deployment and operational orbits, and are fully aware of the risks associated with operations in the particular orbit. This may not always be the case, particularly with smaller operators or operators who use a rideshare launch. If an orbit is particularly congested with debris, for example, an operator may want to consider modifying its operations slightly to avoid having to perform a large number of collision avoidance maneuvers.

4. ORBIT VARIANCE AND ORBIT SELECTION FOR LARGE NGSO SYSTEMS The Notice sought comment on whether the Commission should adopt Start Printed Page 52429an upper limit for variances in orbit for NGSO systems. “Variance” refers to the range of altitude, such as “1025 km plus or minus 10 km,” in which a satellite or constellation of satellites will operate. The Commission asked whether variance in altitude should be limited in an NGSO system in order to enable more systems to co-exist in LEO without overlap in orbital altitude, and if so, how an appropriate limit should be set. We received a number of comments related to orbital variance for large NGSO systems, and even more comments on the related topic of whether, and how, the Commission should assign orbital altitude ranges for large constellations of NGSO satellites, such that the altitudes do not overlap. The question of whether two satellite systems can coexist in a given region of space, such as a circular LEO orbit, depends on multiple factors, including the number and size of satellites, the capabilities of the satellites such as maneuverability, costs of maneuvering (such as interruption of service), availability and timeliness of data on satellite parameters (both from telemetry and from radar or optical observations), planning cycles for maneuvers, and the time required to coordinate operations between systems, etc. Larger deployments of satellites into circular LEO orbits have been into separate orbital “shells.” As a practical matter, in cases where two planned systems propose use of the same shell, coordination typically results in one or both systems adjusting planned orbital altitudes, so that the constellations are separated, rather than in the operators coordinating their operations at the same or overlapping altitude ranges. While some commenters urge that we adopt specific requirements for separation of orbits, others argue that coordination, data sharing, and collision avoidance practices should be sufficient to avoid collisions, or that limits are not practicable for the regions in which some operators operate, particularly small satellite operators. ORBCOMM states that the operational availability of NGSO orbits appears likely to become an increasingly scarce resource, but states that it is premature to try and set rules on maximum altitude variance and orbit selections. Other commenters argue, particularly with respect to systems proposing large orbital variances, that the Commission must consider the impact of such systems on the rational, efficient, and economic use of orbital resources. At this time, we decline to adopt a maximum orbital variance for NGSO systems and decline to adopt a required separation between orbital locations, and will instead continue to address these issues case-by-case. There are a wide range of considerations in such cases, and while we are concerned about the risk of collisions between the space stations of NGSO systems operating at similar orbital altitudes, as the Commission has previously stated, we think that these concerns are best addressed in the first instance through inter-operator coordination. As part of the disclosure of system characteristics, we note that some applicants for large systems may be asked to provide a description of the planned orbital variance, and the relationship of that variance to the system's technical capabilities and operational requirements (e.g., ability to avoid collisions). Such applicants may also need to address how their system operations will accommodate spacecraft transiting through the system and other systems, large or small, operating in the same region. If operators require a large orbit variance for their system, particularly if this might substantially constrain operations by other systems, they should plan to describe why and explain whether other less impactful alternatives were considered.5. PROTECTION OF INHABITABLE SPACECRAFT The Commission proposed in the NPRM that for any NGSO space station deployed above the International Space Station (ISS) and that will transit through the ISS orbit either during or following the space station's operations, the applicant provide information about any operational constraints caused to the ISS or other inhabitable spacecraft [9] and strategies used to avoid collision with such spacecraft. The Commission explained that normal operations of the ISS could be disrupted or constrained by collision avoidance maneuvers that the ISS would need to perform to avoid satellites transiting through the ISS orbit. We conclude that it is in the public interest to adopt the proposed disclosure requirement.[10] The statement must describe the design and operational strategies, if any, that will be used to minimize the risk of collision and enable the operator to avoid posing any undue operational constraints to the inhabitable spacecraft. Commenters agree that special protections should be afforded to inhabitable spacecraft. We find that requiring this information will help to ensure that the applicant has taken into consideration the inhabitable spacecraft, and will provide information in the public record to help the Commission and other interested parties, such as NASA, determine if there are any potential issues with the applicant's operations vis-à-vis the ISS or other inhabitable spacecraft. NASA states that disruption to ISS operations may be lessened if a spacecraft in the process of disposal through atmospheric reentry remains active and able to maneuver until the apogee is below ISS altitude. We conclude that the benefits in assuring the safety of human life in space and minimizing disruption to the operations of inhabitable spacecraft outweighs any additional cost to applicants in preparing such a disclosure. 6. MANEUVERABILITY Disclosure. Maneuverability can be an important component of space debris mitigation, both by enabling space stations to engage in collision avoidance and by facilitating spacecraft disposal. The Commission proposed in the NPRM that applicants disclose the extent of maneuverability of the planned space stations. The Commission noted this could include an explanation of the number of collision avoidance maneuvers the satellite could be expected to make, and/or any other means the satellite may have to avoid conjunction events, including the period both during the satellite's operational lifetime and during the remainder of its time in space prior to disposal. The Commission tentatively concluded that this information could assist in the Commission's public interest determination, particularly regarding any burden that other operators would have to bear in order to avoid collisions and false conjunction warnings. Most commenters addressing this topic agree with the maneuverability disclosure, and we adopt this disclosure. LeoSat disagrees with the proposal, arguing that specific information related to satellite maneuverability is proprietary and competitive in nature, that public disclosure of this information as part of an application could prompt a “race to the bottom” among satellite operators, and that any information initially disclosed in an application will become stale and inaccurate as the operator's satellites age and their propulsion capacity is consumed. It does not appear that LeoSat has support among fellow Start Printed Page 52430satellite operators for its proposition that satellite maneuverability information is proprietary and competitive. Further, even if such information has some potential “competitive” value, such information would likely need to be shared with another operator in the event of a potential conjunction, and all operators will be better able to make informed decisions if they have a baseline understanding of the maneuvering potential of other satellites in orbit. Moreover, it is not clear to us how disclosure would cause a “race to the bottom,” and even if information became outdated as some spacecraft were no longer able to maneuver, having initial information on what capabilities the satellites were designed with could still assist the Commission in its review of the system and also assist other operators. We find that the benefits of having information regarding maneuverability as part of the record outweigh these commenters' generalized competitive concerns. Boeing also **disagrees** in some respects **with** the proposed **disclosure** on the basis that the **Commission** has **not** **provided** **guidance** on the number of avoidance maneuvers that would be presumptively deemed acceptable. We plan to consider the maneuverability disclosure as factual information, and at this time do not establish a presumptive number of avoidance maneuvers that would trigger concern. We believe that on balance, this area is an appropriate one for a disclosure and provides useful information, including to other operators. We encourage operators to submit as much information as they reasonably can regarding maneuverability, ideally providing the type of information mentioned by NASA in its comments, including maneuver methods and capabilities, as well as any other mechanisms to mitigate conjunction likelihood (e.g., cross-sectional area modulation). This would also include information regarding the propulsive technology itself (i.e., ion thrusters, traditional chemical thrusters, etc.), thrust level, and a description of the guidance and operations scheme for determining maneuvers, where applicable. Generally speaking, operators should submit a written description of the space stations' expected capabilities, including, if possible, the expected time it would take the space station to modify its orbital location by a certain distance to avoid a collision.

Propulsion or Maneuverability Above a Certain Altitude. The Commission also sought comment in the NPRM on whether it should require all NGSO satellites planning to operate above a particular altitude to have propulsion capabilities reserved for station-keeping and to enable collision avoidance maneuvers, regardless of whether propulsion is necessary to de-orbit within 25 years, and if so, what altitude should be adopted. A number of commenters supported some requirement along these lines, with some identifying 400 km as an altitude above which propulsion or other maneuvering capabilities should be required, generally based on the approximate operational altitude of the ISS. Other commenters disagreed with this suggestion. We seek to expand the record on this potential requirement in the Further Notice. C. Tracking and Data Sharing In the NPRM, the Commission observed that the successful identification of satellites and sharing of tracking data are important factors in the provision of timely and accurate assessments of potential conjunctions with other spacecraft. We continue to believe that improvements in the ability to track and identify satellites may help to reduce the risk of collisions. These factors can help to enable effective collision avoidance through coordination between operators, and improve the accuracy of conjunction warnings, whether those warnings are from a public or private entity specializing in space situational awareness and space traffic management. The Commission made several specific proposals in the Notice related to trackability, identification, and sharing of tracking data, which are discussed below. We adopt a number of our proposals in this area, while ensuring that our rules provide flexibility for the continued advancement of space situational awareness and space traffic management functions, including any transition of certain activities in the United States to a civilian entity, and the accommodation of non-governmental associations and other private sector enterprises engaged in these functions. We also received several comments addressing improvements to the U.S. space situational awareness and space traffic management functions more generally. In this proceeding, the Commission has not considered other activities related to space situational awareness and space traffic management, such as maintaining a comprehensive catalog of space objects or providing conjunction warnings. These functions as a general matter are well beyond the type of analysis that we have historically addressed through our rules and licensing process, but we suggest that these comments be filed for consideration in the proceeding currently underway in the Commerce Department, if they have not been already, so that the comments can be taken into consideration in that context. Relatedly, the Commerce Department notes that its Request for Information on Commercial Capabilities in Space Situational Awareness Data and Space Traffic Management Services (RFI), issued last year, will have bearing on the Commission's proposals in this proceeding, and asked us to take their RFI into consideration in this proceeding. We have reviewed the comments filed in response to the RFI, and note that in some instances they are the same in part, or similar to comments submitted to the docket file for the instant proceeding. Other comments to the RFI focus on space situational awareness and space traffic management functions, such as development of an open architecture data repository, that are not directly germane to the Commission's proposals. 1. TRACKABILITY AND SATELLITE IDENTIFICATION Trackability. The Commission proposed in the NPRM to require a statement from an applicant regarding the ability to track the proposed satellites using space situational awareness facilities, such as the U.S. Space Surveillance Network. The Commission also proposed that objects greater than 10 cm by 10 cm by 10 cm in size be presumed trackable for LEO. For objects with any dimension less than 10 cm, the Commission proposed that the applicant provide additional information concerning trackability, which will be reviewed on a case-by-case basis. Commenters generally support the proposed approach to size as it relates to trackability. NASA recommends that the term “satellite trackability” be interpreted to mean that an object is trackable if, through the regular operation of space situational awareness assets, it can be tracked and maintained so as to be re-acquirable at will, and that the object's orbital data is sufficient for conjunction assessments. According to NASA, this will typically mean that the object possesses trackability traits (e.g., sufficient size and radar/optical cross-section) to allow it to be acquired routinely by multiple space situational awareness assets in their regular modes of operation. Several commenters agree that in LEO, a 10 x 10 x 10 cm cube should meet this standard. We agree, and adopt the proposed rule stating that Start Printed Page 52431space stations of this size in LEO are deemed presumptively trackable, modified slightly to cover space stations that are 10 cm or larger in their smallest dimension.[11] We clarify that this presumption covers those space stations that are 10 cm or larger in their smallest dimension excluding deployable components.[12] CSSMA proposes that the Commission require applicants to simply certify that they can be tracked reliably by widely available tracking technology. Swarm similarly suggests that the rules permit smaller satellite form factors pursuant to an affirmative demonstration that such spacecraft can be accurately tracked, and that size should be merely one factor in assessing trackability. Although there may be future improvements in standard space situational awareness tracking facilities, at this time we believe it is in the public interest to adopt the presumed trackable approach for space stations in LEO larger than 10 cm in the smallest dimension, and for other cases, including where a satellite is planning to use deployable devices to increase the surface area, we conclude that operators should provide more information to support their conclusion that the space station will be reliably trackable. For a spacecraft smaller than 10 cm x 10 cm x 10 cm, for example, some of the standard space situational awareness tracking facilities may no longer be able to track the satellite. In these instances, part of a demonstration supporting a finding of trackability may be a showing that the operator has taken on the cost of bringing the trackability back up to the level it would be for a larger spacecraft, perhaps by enlisting a commercial space situational awareness provider. CSSMA and others argue that the Commission should permit operators flexibility to choose appropriate solutions, and that ground-based space situational awareness capabilities may improve significantly in the future. We find that our approach provides operators with flexibility to satisfy the Commission's rule, because it permits a case-by-case assessment of trackability where the space station is smaller than 10 cm in the smallest diameter. Global NewSpace Operators argues that we should provide further detail on what information we are looking for in the disclosure, for example, to what accuracy and how often should tracking occur, and whether we will ask for verification from the space situational awareness provider that they can indeed track the proposed satellites. We decline to provide additional detailed guidance in our rules on this topic, as an acceptable disclosure could vary significantly depending on the trackability solution that will be used by the applicant. We expect, however, that applicants will specify the tracking solution and provide some indication of prior successful demonstrated use of the technology or service, either as part of a commercial or government venture. This would include addressing reliability of deployment of any deployable spacecraft parts that are being relied on for tracking. Tracking solutions that have not been well-established or previously demonstrated will be subject to additional scrutiny, and applicants may need to consider a back-up solution in those instances. In addition, our rule provides flexibility for trackability demonstrations above LEO, where Aerospace states that it is not clear that a 10 cm x 10 cm x 10 cm object could be reliably tracked. Aerospace states that the assumed size for reliable tracking in the GEO region by the current Space Surveillance Network is one meter, done primarily with optical sensors. The Commission will address the trackability demonstration on a case-by-case basis for satellites that would operate above the LEO region, including in the GEO region, and we do not see the need at this time to include a specific size value in our rules for those space stations. In the NPRM, the Commission inquired whether there were hardware or information sharing requirements that might improve tracking capabilities, and whether such technologies are sufficiently developed that a requirement for their use would be efficient and effective. Aerospace suggests that hardware such as transponders or other signature enhancements and data sharing would benefit trackability, but it is not clear that any commercial transponder hardware or comprehensive data sharing methods currently exist. Aerospace states that a potential rule could drive development in this area, and consider enhancements such as radar reflectors for small objects in orbits well above LEO. NASA cautions against relying on active tracking assistance that would no longer occur once the spacecraft is unpowered, and observes that at the present time, on-board tracking improvement methods such as beacons or corner cube reflectors are not sufficiently supported by space situational awareness assets to enable significant and reliable tracking improvements. Keplerian Tech suggests that the Commission should mandate the use of an independent transponder solution, such as the space beacon that it has developed. Swarm suggests that trackability can be improved through the use of active or passive signature enhancements, such as the passive radar retro reflectors that would be used by Swarm's proposed satellites. CSSMA opposes a specification of any particular type of tracking technology, and suggests that mandating use of an independent tracking solution would impose unnecessary costs on operators. According to CSSMA, the level of trackability needed to maintain a safe orbital environment can already be attained by well-established active or passive tracking methods. We conclude that the provision of position data in addition to standard space situational awareness data, through radiofrequency identification tags or other means, may ultimately be a way to support a finding that a spacecraft smaller than 10 cm x 10 cm x 10 cm is trackable, but until the establishment of the commercial data repository, reliance on most alternative technologies does not appear to be readily implementable. A number of commenters oppose the adoption of any rule that would specify a particular type of tracking technology. We agree. While we encourage operators to use various means to ensure that their spacecraft is trackable and to help ensure that accurate positioning information can be obtained, we believe it is premature to require that operators use a particular tracking solution, such as an independent transponder. As technologies for obtaining spacecraft positioning information continue to evolve, however, we may revisit this issue in the future. We do adopt the disclosure proposed in the NPRM that applicants specify whether space station tracking will be active (that is, with participation of the operator by emitting signals via transponder or sharing data with other operators) or passive (that is, solely by ground based radar or optical tracking of the object. This disclosure, in connection with the other descriptive disclosures discussed in this section, will provide a way for the Commission and any interested parties to understand the extent to which the operator is able to obtain satellite positioning information separately from information provided by the 18th Space Control Squadron or other space situational awareness facilities. We believe this Start Printed Page 52432requirement presents minimal costs, since an operator will readily have access to this information based on the basic characteristics of its spacecraft (for example, will it be transmitting its Global Positioning System location information via transponder?). Operators are likely to select either active or passive means of tracking depending on the mission specifications, but it is useful for the Commission to understand as part of its holistic review of the application, the overall trackability and ability to identify the satellite.

Relatedly, we also adopt the NPRM proposal that operators certify that their space station will have a unique telemetry marker allowing it to be distinguished from other satellites or space objects. This is the same as the certification we have previously adopted for small satellites applying under the streamlined process, and is unlikely to pose any additional costs for most operators, since the vast majority of operators already distinguish their satellite's signal from other signals through use of unique signal characteristics. Few commenters addressed this issue, and some expressed support or sought clarification. As we clarified in the Small Satellite Order, we expect that when a spacecraft transmits telemetry data to the ground it will include in that transmission some marker that allows the spacecraft to be differentiated from other spacecraft. This signal-based identification marker, which should be different from those of other objects on a particular launch, can assist with identification of a satellite for space situational awareness purposes. **Boeing** **argues** that the **Commission** **does** **not** **need** **to** **verify** **whether** an active telemetry **marker** **will** **be** **unique** **since** satellite **operators** **have** **adequate** **incentives** to distinguish their own telemetry beacons from those of other satellites, but **we** **disagree**, because smaller-scale operators may not have these incentives or know that they should implement this type telemetry marker to help identify their satellite.

Identification. Additionally, the Commission sought comment on whether applicants should be required by rule to provide information about the initial deployment to the 18th Space Control Squadron or any successor civilian entity. We noted that, as an example, communications with the 18th Space Control Squadron may be particularly important in the case of a multi-satellite deployment to assist in the identification of a particular satellite. We adopt a rule requiring that applicants disclose how the operator plans to identify the space station(s) following deployment, for example, how the operator plans to obtain initial telemetry.[13] We expect that for most operators this disclosure will be fairly straightforward, but requesting this information, alongside the other information requested on satellite trackability, will help the Commission and any other interested parties to understand whether the satellite poses a risk of being misidentified following deployment, for example, in the case of a multi-satellite deployment. As Global NewSpace Operators suggests, we will consider favorably in an application the use of radiofrequency transponder tags or other unique telemetry markers that can support the identification of objects once in orbit. Overall, we want to emphasize the importance of operators planning for satellite identification in advance so that they are able to troubleshoot potential issues, particularly for multi-satellite deployments. Also, as the Secure World Foundation suggests, we encourage additional research in this area on how identification aids may help distinguish one satellite from another early after payload separation. We also adopt a requirement that applicants must disclose whether the satellite will be registered with the 18th Space Control Squadron or successor civilian entity. At this time, the typical registration process for new operators includes contacting the 18th Space Control Squadron via email with information on the satellite common name, launch date and time window, launch location and launching agency, the satellite owning organization and operating organization, the contact information for the operations center, and any usernames for the website Space-Track.org. A number of established operators also maintain ongoing relationships with the 18th Space Control Squadron, either directly or through intermediary organizations, such as the Space Data Association, and routinely exchange information about upcoming launch activities. It is possible that this process may change in the future, but we adopt a disclosure requirement broad enough to accommodate “registration” generally, even if the process changes. We conclude that the costs associated with the disclosure, to the extent they are not already routinely followed by most established operations, are outweighed by the importance of operators sharing information with a central entity that can provide space situational awareness support. Additionally, the operators themselves benefit from the services that are provided at no charge by the 18th Space Control Squadron, and so the burden of operators disclosing whether they are in fact benefiting from these services is minimal. 2. ONGOING SPACE SITUATIONAL AWARENESS Sharing Ephemeris and Other Information. In addition to the sharing of information related to initial identification of a satellite included in the NPRM, the Commission also proposed that space station operators share ephemeris and information on any planned maneuvers with the 18th Space Control Squadron or any successor civilian entity. The Commission sought comment on whether this should be a requirement implemented through a rule. The Commission also sought comment on whether NGSO operators should be required to maintain ephemeris data for each satellite they operate and share that data with any other operator identified in its disclosure of any operational space stations that may raise a collision risk. The Commission observed that this requirement would help to facilitate communications between operators even before a potential conjunction warning is given. Most commenters agreed with the goals of the proposed requirements. Some commenters argue that data sharing exchanges should respect owner/operator intellectual property and proprietary information and should be limited to only the information necessary to describe explicit maneuvers, initial deployment, or conjunction avoidance. Several commenters also seek flexibility to share maneuverability and status data using any reasonable method identified by the providing operator. After consideration of the record on this issue, we adopt a disclosure requirement regarding sharing of ephemeris and other data. Specifically, we adopt a rule stating that applicants must disclose the extent to which the space station operator plans to share information regarding initial deployment, ephemeris, and/or planned maneuvers with the 18th Space Control Squadron or successor entity, or other entities that engage in space situational awareness or space traffic management functions, and/or other operators. This also includes disclosure of risk thresholds for when an operator will deem it appropriate to conduct a collision avoidance maneuver. This disclosure provides an opportunity for the Commission to assess the extent to Start Printed Page 52433which the operator is actively engaging with space situational awareness facilities, keeping in mind that the need for such engagement may vary depending on the scale of the system.[14] We observe that for certain types of systems, for example, those using electric propulsion, sharing of ephemeris data is particularly critical in preventing collisions, and so we would look for a detailed description of those plans when assessing the application for those systems. The disclosure will also assist other operators in understanding how they may be able to best coordinate with the applicants' system and provide flexibility for operators to demonstrate how their plans for sharing information will facilitate space safety. As one example, a particular operator may decide to share ephemeris information with the private Space Data Association, which would be indicated in its disclosure. This also addresses any operator's concerns regarding proprietary information and security, since operators concerned with these issues could take them into consideration as part of their plan for how to share ephemeris.[15] We also extend this disclosure to experimental and amateur systems at the authorization stage. As with the rule updates discussed above, we believe the benefits of this disclosure in encouraging space safety and coordination outweigh any costs to the operator in specifying the extent to which, and how, it will share ephemeris and other information during operations. Tyvak suggests that requiring licensees to submit information pertaining to planned maneuvers is not conducive to the flexibility of agile space, but we do not see how submission of information in advance of planned maneuvers would have any significant impact on an operator's ability to perform such spacecraft maneuvers, and may provide other operators with useful information about the planned scope of operations that will facilitate coordination. Although we are adopting a disclosure requirement rather than an operational requirement, if this information changes during the course of the system's operations, the operator will need to update the file for its license or grant by specifying how it has changed. We conclude that this disclosure is more beneficial than a more specific requirement, as it provides flexibility for operators to use a combination of different resources, including private sector space situational awareness resources, as well as accommodate potential changes in the U.S. entity responsible for space situational awareness and space traffic management functions relevant to non-Federal operators. In the near term, we encourage all operators to engage with the 18th Space Control Squadron, either directly or through intermediary organizations, and avail themselves of the space situational awareness and space traffic management functions that the 18th Space Control Squadron provides. At this time, we do not adopt a separate operational requirement regarding sharing of information with the 18th Space Control Squadron or other operators whose systems may pose a collision risk. We conclude that requirement is unnecessary given the application disclosure requirement we adopt here as well as the separate certification that upon receipt of a space situational awareness conjunction warning, the operator will review and take all possible steps to assess the collision risk, and will mitigate the collision risk if necessary—and that the assessment and potential mitigation should include, as appropriate, sharing ephemeris data and other relevant operational information. Conjunction Warnings. The Commission proposed that applicants for NGSO space stations certify that, upon receipt of a conjunction warning, the operator of the satellite will take all possible steps to assess and, if necessary, to mitigate collision risk, including, but not limited to: Contacting the operator of any active spacecraft involved in such warning; sharing ephemeris data and other appropriate operational information directly with any such operator; and modifying spacecraft attitude and/or operations. The Commission also sought comment on whether any different or additional requirements should be considered regarding the ability to track and identify satellites in NGSO or respond to conjunction warnings. As discussed below, based on the record, we adopt the proposal from the NPRM. We believe this certification will enhance certainty among operators, and thereby help to reduce collision risk. Most commenters addressing this issue agreed generally with the Commission's proposal, although some commenters had varying views on implementation of the proposed requirement. NASA and Aerospace recommend that applicants submit information outlining plans that they intend to follow operationally in order to minimize collision risk. Global NewSpace Operators suggests that the Commission simply require the applicant to have an operational procedure and process for a conjunction warning, rather than a certification. We see the potential benefits of having applicants outline operational steps to minimize collision risk, but we believe that the information that would be included in this type of submission is already addressed by other aspects of the rules. As described above, we will request information on maneuverability of the satellites, and applicants will be required to disclose how they have coordinated or plan to coordinate with other operators whose satellites may pose a collision risk, as well as disclose how they plan to share ephemeris and other information during the course of the spacecraft operations.

Other commenters suggest modifications to the language of the proposed rule to provide operators with some additional flexibility when responding to conjunction warnings. The Commission's proposed rule stated that the space station operator “must certify that upon receipt of a space situational awareness conjunction warning, the operator will review the warning and take all possible steps to assess and, if necessary, to mitigate collision risk, including, but not limited to: Contacting the operator of any active spacecraft involved in such a warning; sharing ephemeris data and other appropriate operational information with any such operator; modifying space station attitude and/or operations.” Several commenters, including SIA, Telesat, and others, were concerned that the use of the term “all possible steps” would not give operators enough flexibility to decide how to respond, and proposed the language “appropriate steps” instead. Taking into consideration the concerns expressed in the record, we adopt a slightly different formulation of the certification. Specifically, the rule we adopt states that the space station operator must certify that upon receipt of a space situational awareness conjunction warning, the operator will review and take all possible steps to assess the collision risk, and will mitigate the collision risk if necessary. As appropriate, steps to assess and mitigate the collision risk should include, but are not limited to: Contacting the operator of any active spacecraft involved in such a warning; sharing ephemeris data Start Printed Page 52434and other appropriate operational information with any such operator; and modifying space station attitude and/or operations. We believe that the terms “if necessary” and “as appropriate” provide sufficient flexibility for operators to determine what is appropriate in individual cases. Finally, **Boeing** **suggests** that this **requirement** may be **unnecessary**, because **operators** already **have** sufficient **incentives** **to** **avoid** **collision** risks. We conclude, however, that this certification is useful in ensuring that all space actors, in particular new space actors, are aware of and have planned responses to conjunction warnings, consistent with responsible space operations.

We also encourage operators to reference industry-recognized best practices in addressing conjunction warnings. NASA, for example, notes that there are currently industry-recognized best practices of submitting ephemerides to the 18th Space Control Squadron for screening, examining and processing all resultant conjunction warnings from each conjunction screening, mitigating high-interest events at a level consistent with the mission's risk mitigation strategy, and explicit conjunction avoidance screening by the 18th Space Control Squadron of ephemerides that include any risk mitigation maneuvers prior to maneuver execution. D. Topics Related to Creation of Debris During Operations The Commission's existing orbital debris rules require disclosure of debris released during normal operations. This has been a longstanding requirement, and is consistent with the revised U.S. Government Standard Practices objective regarding “Control of Debris Released During Normal Operations.” The Commission observed in 2004 that communications space stations do not typically involve the release of planned debris. Although there are some unique experiments on space stations today that do potentially involve the planned release of debris, we observe that most communications space stations still do not typically release debris absent some type of anomaly. Where there is a planned release of debris, however, we examine such plans on a case-by-case basis. Accordingly, the Commission did not propose to update our general rule in this area, as it has functioned well for the past 15 years. In the Notice, the Commission did propose to update its rules, however, in two specific areas related to the release of debris, discussed below, which reflect evolving satellite and launch technologies. 1. DEPLOYMENT DEVICES In the NPRM, the Commission observed that in several instances applicants sought to deploy satellites using deployment mechanisms that detach from or are ejected from a launch vehicle upper stage and are designed solely as a means of deploying a satellite or satellites, and not intended for other operations—and that once these mechanisms have deployed the onboard satellite(s), they become orbital debris. In one example, the Commission received applications for communications with deployment devices designed to deploy smaller spacecraft after the devices separating from the launch vehicle. In another example, the Commission received an application for an experimental satellite that would be released from a tubular cylinder deployer, using a spring mechanism. There are also more well-established uses of deployment devices, such as a separation ring used to facilitate the launch of geostationary satellites. Several commenters explain the advantages of use of deployment devices such as rings or other deployment vehicles, sometimes referred to as “free-flyers,” stating, for example, that such devices can allow safe, reliable deployment of multiple spacecraft. Spaceflight posits that deployment devices contribute to a safe space environment, where such devices allow spacecraft to be placed into orbit using well-established launch services and well-designed and planned deployment missions. The Commission proposed in the NPRM to require disclosure by applicants if “free-flying” deployment devices are used to deploy their spacecraft, as well as requiring a specific justification for their use. We adopt our proposal, and require that applicants for a Commission license disclose whether they plan to have their spacecraft deployed using a deployment device. This includes disclosure of all devices, defined as separate deployment devices, distinct from the space station launch vehicle, regardless of whether they will be authorized by the Commission.[16] Although in some instances it is difficult to draw a clear line between a launch vehicle and deployment device, for purposes of this rule, as explained below, we consider a deployment device to be a device not permanently physically attached to or otherwise controlled as part of the launch vehicle. For purposes of this discussion, we distinguish between consideration of orbital debris mitigation issues involving such free-flying deployment devices and consideration of orbital debris mitigation issues involving multi-satellite deployments generally, including use of deployment devices that are part of or remain attached to the launch vehicle. We have considered the arguments of Eutelsat, University Small-Satellite Researchers, and Boeing, who suggest that it would be burdensome for space station applicants to disclose information regarding free-flying or uncoupled deployment devices. Eutelsat states that satellite operators are not responsible for launch procedure and do not choose the specific deployment device used for launch of their satellite, which may not be determined until after the space station application is submitted. Some commenters suggest that information regarding a free-flying deployment device should be outside the scope of the Commission's purview, either for jurisdictional or practical reasons. We disagree with these points. It is reasonable to consider objects with limited purpose, other than launch vehicles, as part of the deployment or operations of a Commission-licensed spacecraft. Free-flying deployment devices are, in terms of their effect on the orbital debris environment, indistinguishable from lens covers, tie-down cables, and other similar devices, in that they fulfill a limited function and then become debris. In some instances, the required disclosure may be as straightforward as incorporating by reference the information contained in a separate Commission application that has been submitted by the operator of the deployment device. In other instances, the space station operator will need to obtain the information regarding the deployment device from the operator and/or manufacturer of that device. The space station operator will be able to obtain this information, since the space station will be using the deployment device. Second, our experience has been that FAA launch-related analyses do not include consideration of free-flying or separated deployment devices, since such devices are not considered part of the launch vehicle. In this sense, depending on the factual scenario, the devices can be considered either “spacecraft” or “operational debris” related to the Start Printed Page 52435authorized space stations.[17] Our goal is to avoid a regulatory gap in which the orbital debris issues associated with a particular deployment device are not under review by any government entity. We will continue to coordinate with the FAA as needed, and in any case where an applicant believes that the deployment device would be under the FAA's authority, the applicant should make us aware so we can coordinate with the FAA in the particular case and avoid overlapping review. Eutelsat points out that in some instances the launching entity may not even be within U.S. jurisdiction or regulatory authority. In these instances, the operator should still provide information regarding use of any free-flying or separated deployment devices, consistent with our policy to require same information related to orbital debris mitigation from market access applicants as from U.S. license applicants. For example, it would not be in the public interest for us to authorize market access for a non-U.S.-licensed satellite where the satellite meets our orbital debris mitigation requirements, but will be deployed by a free-flying device that has a 200-year on-orbit lifetime and presents a significant collision risk. Although, as Eutelsat states, market access may be requested long after the satellite is launched, that fact has not prevented us from applying our orbital debris regulations to such satellites in the past.

We will continue to largely assess these on a case-by-case basis at this time, since the individual facts can vary widely and so it is difficult to assess specific disclosure rules for each different type of device that may be used.[18] Consistent with the NPRM proposal, we will require that applicants disclosing the use of a deployment device also provide an orbital debris mitigation disclosure for any separate deployment devices. The information provided by applicants should address basic orbital debris principles, such as the orbital lifetime of the device, and collision risk associated with the device itself. Where applicable, the information should also address the method, sequencing, and timing by which the spacecraft be deployed into orbit. **Boeing** **opposes** the adoption of an information **disclosure** requirement absent “clear and objective criteria articulating when the use of such devices is permissible.” There are a variety of facts to assess in connection with use of deployment device and potential for contribution to the orbital debris environment. In some uses, a deployment device may become debris, but serve to decrease the collision risk associated with the individual deployed objects. In the case of well-established deployment practices, such as use of a detachable separator ring for a GSO deployment, the disclosure should be relatively straightforward, and we would not expect operators to provide significant detail regarding utilization of such a deployment practice. In other instances, use of a deployment device may increase the risk of collision among satellites deployed from the device, as compared to other means of deployment, even where the device itself may present a low risk. The different factual scenarios presented here illustrate the difficulty in making a “one-size-fits-all” rule when it comes to determining what is an acceptable use of a deployment device. We conclude the more effective approach at this time is to adopt a disclosure requirement, and to continue to assess the specific uses on a case-by-case basis. Disclosure in this instance provides flexibility to address new developments in space station design and facilitates the Commission identifying facts to support decisions to grant, condition, or deny an authorization in a manner consistent with the Communications Act.

We also received a number of comments related to the best means in which to evaluate collision risk specifically associated with the deployment of multiple satellites from a deployment device (e.g., re-contact analysis). We expect that recontact analysis will be conducted by operators, and that information will be provided to the Commission, but we do not adopt specific rules in this Order on how to conduct a re-contact analysis in the instance where a deployment device is deploying multiple satellites. Free-flying deployers releasing multiple satellites are still relatively new, and there is not consensus on what constitutes an adequate analysis of re-contact risk, and the extent to which re-contact risk is different from typical collision risk in terms of likelihood of creating debris. Accordingly, we will continue to assess this issue on a case-by-case basis in the context of a particular mission profile. In addition to compiling information regarding collision risk, however, we encourage operators of free-flying deployment devices to adopt practices that will help reduce risks associated with multi-satellite deployments—including formulating a deployment sequence that minimizes re-contact risks and making other operators with satellites nearby aware and updated on the scope of the deployment.[19] Additionally, we do not adopt rules in this Order related to multi-satellite launches more generally, i.e. multi-satellite launches not involving separate, free-flying deployment devices. In the Notice, the Commission also sought comment on whether we should include in our rules any additional information requirements for satellite applicants that will be part of a multi-satellite launch. A number of commenters suggested that these issues should be handled by the launch licensing authority and/or that there would be other difficulties involved in requiring additional information regarding launch and deployment from an FCC applicant. We observe that there are a number of established practices for multi-satellite deployment that are associated with low risk of re-contact, or otherwise a low risk of debris creation since any recontact would occur at low velocities. While we decline to adopt any rules related to this topic at this time, we may revisit this issue in the future. 2. MINIMIZING DEBRIS GENERATED BY RELEASE OF PERSISTENT LIQUIDS In the NPRM, the Commission proposed to update the rules to cover the release of liquids that, while not presenting an explosion risk, could nonetheless, if released into space, Start Printed Page 52436cause damage to other satellites due to collisions. Specifically, the Commission proposed to include a requirement to identify any liquids that if released, either intentionally or unintentionally, will persist in droplet form. The Commission observed that there has been increasing interest in use by satellites (including small satellites) of alternative propellants and coolants, some of which would become persistent liquids when released by a deployed satellite. The NPRM also stated our expectation that the orbital debris mitigation plan for any system using persistent liquids should address the measures taken, including design and testing, to eliminate the risk of release of liquids and to minimize risk from any unplanned release of liquids. Some commenters addressing this issue disagreed with the Commission adopting a rule to address this issue, with most expressing concern that there was not sufficient evidence that release of certain propellants, for example, would result in persistent droplets or create any additional risk in the orbital environment. Along these lines, Aerospace states that it is important to distinguish between releases that could result in droplets or solids that could be a collision threat and those that dissipate or are too small to cause damage on impact. Aerospace points out, for example, that there are a number of beneficial operations including venting or using excess propellant and oxidizer that constitute release of liquids that are less likely to cause impact damage. Aerospace recommends that the Commission's proposed rule be clarified to explicitly permit the venting of volatile liquids and pressurants that could create future risk of fragmenting the spacecraft if not released, but will not form hazardous droplets. We agree that it is important to distinguish between those releases that could result in a long-term risk to the orbital environment and those that are unlikely to create any significant additional risks, such as release of volatile propellants that are soon dispersed through natural processes. Additionally, we have long recognized the importance of operators limiting the risk of accidental explosions, including by venting pressurized systems at a spacecraft's end of life.[20] We adopt our proposed disclosure requirement, but clarified to require that applicants must specify only the release of those liquids that may in fact persist in the environment and pose a risk.[21] Thus, the applicant will determine whether any liquids have a chemical composition that is conducive to the formation of persistent droplets. If so, then the applicant will disclose that fact to the Commission.[22] The main consideration in making this determination is whether the liquid, if released into space, will disperse through evaporation, or remain in droplet form, as is typical of some ionic liquids, such as NaK droplets. If the applicant determines that released liquids will not persist due to evaporation or chemical breakdown, for example, then the applicant need not address the release of such liquids.[23] We conclude that asking applicants—who have the most information regarding the operational profile of the mission and characteristics of the potentially released substances—to assess the risk will address the commenters' concerns that such a requirement may be overinclusive or premature. We clarify that this rule would apply to any liquids, not just propellants. In addition, we clarify that this rule will apply equally to release of liquids throughout the orbital lifetime. We further conclude that the benefit of identifying potential risks associated with use of certain liquids, if such liquids could become long-term debris objects, outweighs any costs to operators in assessing the chemical composition of any liquids to determine the physical properties of such liquids following release into the orbital environment. E. Post-Mission Disposal Post-mission disposal is an integral part of the mitigation of orbital debris, and the commercial space industry has increasingly recognized the importance of not leaving defunct objects in orbit after their useful life. In 2004, the Commission established specific rules for GSO space station disposal based on U.S. and international guidance, and in the absence of an anomaly, Commission-authorized space station operators have complied with those rules. In this Order, we adopt specific rules for disposal of NGSO space stations, and address reliability of post-mission disposal for NGSO space stations as well. As in 2004, we base these rules on updated sources of guidance, including the revised ODMSP, adapted for the commercial and otherwise non-governmental context. The orbital lifetime of a particular space station affects the collision risk it presents and reduction in post-mission orbital lifetime reduces collision risk. Spacecraft that are unable to complete post-mission disposal, particularly when left at higher altitudes where they may persist indefinitely, will contribute to increased congestion in the space environment over the long-term and increase risks to future space operations.Start Printed Page 52437 1. POST-MISSION ORBITAL LIFETIME In the NPRM, the Commission inquired whether the 25-year benchmark for completion of NGSO post-mission disposal by atmospheric re-entry remains a relevant benchmark, as applied to commercial or other non-Federal systems. The 25-year benchmark has been applied in Commission licensing decisions for NGSO systems. The NASA Standard and ODMSP specify a maximum 25-year post-mission orbital lifetime, with the revised ODMSP stating that for spacecraft disposed of by atmospheric reentry, the spacecraft shall be “left in an orbit in which, using conservative projections for solar activity, atmospheric drag will limit the lifetime to as short as practicable but no more than 25 years.” Most commenters supported a reduction in the 25-year benchmark as applicable to non-Federal systems, but disagreed on the length of time, and on whether a single benchmark was appropriate for all missions. As a practical matter, space stations that conduct collision avoidance maneuvers would achieve the main goal of limitations on orbital lifetime—avoiding collisions with large objects. Even with no maneuver capability, spacecraft deployed to and operating below 400 km generally re-enter Earth's atmosphere as a result of atmospheric drag within, at most, several years. For such satellites, when functioning normally, specification of a maximum post-mission orbital lifetime may be unnecessary. We examine in the Further Notice a maneuverability requirement for satellites operating above 400 km. Given the practical reality that satellites with maneuvering capabilities are likely to meet the objectives of limitations on post-mission orbital lifetime, the need to incorporate a separate provision into our rules regarding post-mission orbital lifetime will depend on whether we adopt a maneuverability requirement, and therefore will be addressed in the Further Notice. At this time, we will require that applicants planning disposal by atmospheric re-entry specify the planned time period for post-mission disposal as part of the description of disposal plans for the space station. We maintain the Commission's existing rule requiring a statement detailing post-mission disposal plans for the space station at end of life. The Commission also sought comment on whether we should account for solar activity in our rules or grant conditions. We note that the NASA Debris Assessment Software takes into consideration solar flux that may affect atmospheric drag, among other environmental factors. To the extent that the operator plans to rely on atmospheric drag for re-entry, reliance on NASA Debris Assessment Software or a higher fidelity assessment tool will meet the requirement on specifying the time period for post-mission disposal.

The Commission also sought comment on whether operators planning disposal through atmospheric re-entry should be required to continue obtaining spacecraft tracking information, for example by using radio facilities on the spacecraft to the greatest extent possible following the conclusion of the primary mission. **Boeing** **argues** that satellite **operators** should **not** be **required** **to** **maintain** **communication** links and active tracking with the satellite following the end of the missions unless they had initially indicated in the application that active tracking, rather than passive tracking, would be used to monitor the location of the spacecraft. Boeing also states that satellite operators should be required to continue to obtain spacecraft tracking information for retired satellites only if the satellite operator's original calculations regarding acceptable collision risk as the satellite's orbit decays depend upon the operator's ability to conduct collision avoidance. Iridium, on the other hand, suggests that satellites should be controlled all the way through atmospheric re-entry. We do not adopt a specific regulation specifying the extent to which an operator should be required to maintain communications links or otherwise obtain spacecraft tracking information following the conclusion of the satellite's main mission at this time, since absent any particular requirements to maintain maneuvering capabilities, for example, operators are likely to have a wide range of capabilities in this area such that it would not be reasonable to adopt a “one-size-fits all” rule absent other requirements such as requiring active tracking capabilities, which we decline to adopt above. We do, however, encourage all operators to maintain communications links for tracking, control, and collision avoidance purposes for as long as possible following the conclusion of the spacecraft's primary operations, even below 400 km, and to continue to provide location information to the 18th Space Control Squadron and other operators for as long as possible, in accordance with the operators' plan for sharing ephemeris.

2. RELIABILITY AND POST-MISSION DISPOSAL In the NPRM, the Commission considered whether to add to the rules a specific metric for reliability of disposal in order to help us better evaluate the applicant's end-of-life disposal plan. The Commission proposed to require that applicants provide information concerning the expected reliability of disposal measures involving atmospheric re-entry, and the method by which the expected reliability was derived. The Commission also sought comment on whether we should specify a probability of no less than a certain standard, such as 0.90, and whether the evaluation should be on an aggregate basis if an operator plans to deploy multiple satellites, for example, in an NGSO constellation. The Commission also asked whether, for large constellation deployments, a more stringent metric should apply. The revised ODMSP states that the probability of successful post-mission disposal should be no less than 0.9, with a goal of 0.99 or better, and further states that each spacecraft in a large constellation of 100 or more operational spacecraft should have a probability of successful post-mission disposal at a level greater than 0.9 with a goal of 0.99 or better. The majority of commenters addressing the issue agree with the Commission revising its rules to incorporate a standard for reliability of disposal. While the Commission sought comment on a broader design and fabrication reliability standard as well, many commenters suggest that focusing on disposal reliability is a more effective way to minimize the long-term impact of failed satellites on the orbital environment. With respect to the specific metric, NASA notes that it currently employs a 0.9 disposal reliability for individual spacecraft not part of a constellation, and, consistent with the revisions to the ODMSP, states that inter-agency discussions have concluded that constellations (100 or more spacecraft) should have a post-mission disposal reliability of greater than 0.9. NASA goes on to state that large constellations (1000 or more spacecraft) should have a post-mission disposal reliability goal of 0.99 or better. A number of commenters agree with a tiered approach to reliability, specifically, with a 0.9 reliability for individual satellites and a higher reliability for individual satellites that are part of a constellation. We conclude that a baseline post-mission disposal reliability of 0.90 is appropriate for individual NGSO space stations, and that larger systems will be evaluated on a case-by-case basis for whether a higher per-spacecraft disposal reliability standard is necessary to avoid significant long-term impacts to the Start Printed Page 52438orbital environment. The rule adopted specifies that NGSO applicants provide a demonstration that the probability of successful post-mission disposal is 0.9 or greater for any individual space station.[24] Consistent with the general approach taken in the revised ODMSP, the rule further states that for space systems consisting of multiple space stations, the demonstration should include additional information regarding efforts to achieve a higher per-spacecraft probability of successful post-mission disposal, with a goal of 0.99 or better for large systems. Under this approach, particular scrutiny will be given to larger deployments, including consideration of factors such as mass, collision probability, and orbital location. We believe this method will avoid some of the concerns associated with arbitrary cutoffs of numbers of space stations. and will allow assessment of acceptable post-mission disposal reliability taking into account all relevant factors. Many commenters disagree with applying a disposal reliability standard in the aggregate. NASA recommends the use of a reliability metric expressed on a per-satellite basis. For purposes of post-mission disposal reliability, we agree that the target probability of successful post-mission disposal is best expressed on a per-satellite basis rather than in the aggregate. However, and as recognized in the ODMSP, consideration of the risks presented by deployment of large numbers of satellites supports higher per-satellite reliability, particularly for deployments involving larger numbers of satellites. For purposes of calculating the probability of successful post-mission disposal, we define successful post-mission disposal for spacecraft in LEO as re-entry into the Earth's atmosphere within 25 years or less following completion of the spacecraft mission. We recognize that consistent with the discussion above on post-mission lifetime, 25 years will in almost all instances be a longer period than the planned post-mission lifetime of the spacecraft.[25] We believe this is an appropriate balance, however, by giving operators options to meet a performance-based post-mission disposal reliability standard while mitigating the long-term impact of spacecraft failures on the orbital environment. Absent unusual circumstances, this would allow spacecraft and systems deployed at low altitudes to achieve a 100% probability of successful post-mission disposal even if the satellites themselves fail immediately upon deployment. We observe that at lower deployment altitude, however, a high percentage of failed satellites could result in a high collision risk for a system as a whole. Global NewSpace Operators suggests the Commission should not be prescriptive in how applicants meet post-mission disposal reliability requirements but should instead encourage innovative approaches to how this problem is solved. We agree and expect operators would include in their demonstration, for example, a description of any backup mechanisms or system redundancies that should be factored into assessment of post-mission disposal reliability. We note that at some point, a very high level of reliability becomes difficult to achieve absent extraordinary cost and effort. We also note that in some instances, development of the spacecraft is likely to be a rapidly iterative process, involving more in-orbit testing than ground testing. In these scenarios, lower deployment altitudes may be required in order to achieve a post-mission disposal reliability consistent with the public interest. In other cases, where the applicant has demonstrated significant ground-based testing commensurate with a high reliability, the lower deployment altitudes may not be as significant a consideration. Operators of large constellations replenishing on a regular basis or otherwise deploying a system through multiple launches should strive to improve reliability with each successive deployment, since it appears such improvements may have significant impact on the longer-term debris environment. Related to this point, Iridium suggests the Commission require all operators of space stations above 400 km to notify the Commission of any on-orbit satellite failures, whether such failures occur before or during operations. According to Iridium, once an operator makes such a notification, the Commission should require the operator to identify and correct the root causes of failure on the ground prior to launching any additional satellites. Other commenters similarly request the Commission address how it will verify compliance with operator disclosures on post-mission reliability and other issues. In instances where an applicant for a system consisting of multiple satellites submits information that the expected total probability of collision, post-mission disposal reliability, or casualty risk is close to the acceptable threshold, the Commission will require, as an initial condition of the license, that, in case a rate of failure that would result in values above the risk threshold(s) described in the application is observed, such occurrence be reported to the Commission. The Commission could also require reporting as a result of information that comes to the attention of the Commission during the licensee's operations. In appropriate circumstances, the Commission could subsequently modify the license in accordance with section 316 of the Communications Act to address a rate of failure that departs materially from the expected reliability level, since that departure would affect the public interest assessment underlying grant of the license. A. DEPLOYMENT ORBIT Initial Deployment Below 650 km. The Commission sought comment on whether applicants for space stations in LEO certify that the satellites that will operate at an altitude of 650 km or above would be initially deployed into an orbit at an altitude below 650 km and then, once it was established that the satellites had full functionality, they could be maneuvered up to their planned operational altitude. The Commission reasoned this may help to ensure that if satellites are found to be non-functional immediately following deployment, the satellites would re-enter the atmosphere within 25 years. Commenters addressing this issue generally disagree with the NPRM proposal. NASA recommends that a post-mission disposal reliability metric be adopted rather than requiring an initial deployment altitude below 650 km, stating that the lower deployment would add to the complexity of the deployment of spacecraft and not significantly reduce risk. Other commenters suggested that this would create additional difficulties in development of a constellation and meeting of milestones, without significant benefits, and that the goal of reducing dead-on-arrival satellites could be met by other means. We decline to adopt a uniform requirement that NGSO satellites deploy first to 650 km and then raise their orbits to deployment altitude. We conclude that reliability of post-mission disposal and collision risk standards we adopt here more effectively address the same underlying issues regarding the long-term impact of non-functional satellites on the orbital Start Printed Page 52439environment. It should be noted, however, that in order to achieve post-mission disposal reliability objectives, the use of this strategy may be necessary, particularly for deployments involving larger numbers of satellites.

Testing. The Commission also sought comment on whether applicants for large NGSO constellations should be required to test a certain number of satellites in a lower orbit for a certain number of years before deploying larger numbers of satellites, in order to resolve any unforeseen flaws in the design that could result in the generation of debris. Several commenters pointed out that operators of new constellations of NGSO satellites have conducted testing of a few satellites to verify their performance before launching larger numbers. **Boeing** **suggests** that the **Commission** **should** **not** **dictate** the length of such **test** **operations**, since operators are usually able to determine fairly quickly whether satellites are operating as intended or whether any anomalies are apparent that may necessitate an extended period of monitoring. Other commenters agree that operators should be able to set their own timelines for in-orbit testing. Boeing **further** **argues** that **operators** **have** sufficient **incentives** **to** **employ** a **testing** **approach** **to** **avoid** the significant **costs** **that** **would** **result** **from** an **unanticipated** **fault** affecting a large number of satellites. OneWeb contends that required testing could impact an operator's ability to comply with the Commission's NGSO milestone rules.

#### But approvals are still rolling in---here’s the most recent.

Howell 11-4 (, E., 2021. Boeing gets FCC approval for 147-satellite constellation. [online] Space.com. Available at: <https://www.space.com/boeing-satellite-constellation-fcc-approval> [Accessed 5 January 2022] Elizabeth Howell, Ph.D., is a contributing writer for Space.com since 2012. As a proud Trekkie and Canadian, she tackles topics like spaceflight, diversity, science fiction, astronomy and gaming to help others explore the universe. Elizabeth's on-site reporting includes two human spaceflight launches from Kazakhstan, and embedded reporting from a simulated Mars mission in Utah. She holds a Ph.D. and M.Sc. in Space Studies from the University of North Dakota, and a Bachelor of Journalism from Canada's Carleton University. Her latest book, NASA Leadership Moments, is co-written with astronaut Dave Williams. Elizabeth first got interested in space after watching the movie Apollo 13 in 1996, and still wants to be an astronaut someday.)-rahulpenu

**Boeing** **gets** FCC **approval** **for** 147-satellite **constellation**

Boeing has until 2027 to begin building the new broadband constellation.

Boeing has the **green** **light** **to** **launch** a planned broadband constellation that will place 147 satellites in orbit.

The Federal Communications Commission granted the aerospace giant permission on Wednesday (Nov. 3), which **places** **Boeing** **into** an increasingly **crowded** **market** for service against giants such as SpaceX's Starlink and Amazon's planned Kuiper constellations.

"As detailed in its FCC application, Boeing plans to provide broadband and communications services for residential, commercial, institutional, governmental, and professional users in the United States and globally," the FCC said in its announcement approving the license.

The **FCC** also **rejected** a **claim** **from** **SpaceX** that the new constellation would cause interference with Starlink.

"SpaceX provides no basis on this particular issue to warrant departure from the established framework already in place to address concerns regarding interference between NGSO [non-geostationary satellite orbit] systems, and to adopt a special condition on this grant," the FCC stated in its documentation, adding that all operators must "coordinate in good faith the use of commonly authorized frequencies."

**Starlink** operates in the Ka- and Ku-band frequencies, but is **moving** **into** a more rarely used higher set of frequencies known as the **V-band**, **where** **Boeing** also **plans** **to** **operate**. Ars Technica, noting that competitor objections are common in megaconstellation applications, pointed to a recent SpaceX-Amazon dispute as one example of such objections.

"SpaceX recently blasted Amazon for objecting to Starlink plans, saying that Amazon was using an 'obstructionist tactic' to delay a competitor," Ars Technica reported. "Amazon pointed out that SpaceX itself 'routinely raises concerns with respect to its competitors' currently filed plans, including with respect to interference.' "

The FCC also rejected Boeing's proposal to delay its launch plans beyond typical standards of 50% completion by 2027 and full launch 2030. The commission said Boeing did not provide adequate justification as to why it plans to launch the full system in 12 years, which would require a waiver of the typical FCC requirement. But the FCC said it is open to more discussion on that point in future applications.

Broadband satellite constellations aim to offer service in rural and otherwise hard-to-reach regions that previously, had poor Internet access. SpaceX plans to deploy up to 42,000 satellites (it has more than 1,600 operational today), Amazon hopes to have 3,200 after its first launch in 2022, and OneWeb is more than halfway to its target of 648 satellites.

Such megaconstellations will likely have a **negative** **effect** on astronomy as the bright machines leave trails in long-exposure photography required for asteroid hunting or to image very faint objects, astronomers have warned. The companies and scientists continue to talk with each other about possible mitigation measures.

#### Predictive analysis concludes that OneWeb’s mega-constellations ensure catastrophic space debris.

Radtke et al. 17 (, J., Kebschull, C. and Stoll, E., 2017. Interactions of the space debris environment with mega constellations— Using the example of the OneWeb constellation. [online] Acta Astronautica. Available at: <https://www.sciencedirect.com/science/article/abs/pii/S009457651630515X?via%3Dihub> [Accessed 15 December 2021] Christopher Kebschull - Lead scientist specialised on developing Space Surveillance & Tracking applications and cross platform interfaces. Experience in using databases and web development for front-end UIs. Enrico Stoll - Head of the Institute of Space Systems, TU Braunschweig System Engineer at RapidEye/Blackbridge Lecturer at FU Berlin Visiting Researcher at University Putra, Malaysia Postdoc at Massachusetts Institute of Technology, USA Dr.-Ing. at the Institute of Astronautics, TU München Studies in Mathematics at TU München and University of Hagen Studies in Aerospace Engineering at TU Dresden, MAI (Russia) and UNSW (Australia).)-rahulpenu

ABSTRACT

Recently, several announcements have been published to deploy satellite constellations into Low Earth Orbit (LEO) containing several hundred to thousands of rather small sized objects. The purpose of these constellations is to provide a worldwide internet coverage, even to the remotest areas. Examples of these mega-constellations are one from SpaceX, which is announced to comprise of about 4000 satellites, the Norwegian STEAM network, which is told to contain 4257 satellites, and the OneWeb constellation, which forms one of the smaller constellations with 720 satellites. As example constellation, OneWeb has been chosen. From all announced constellation, OneWeb by far delivered most information, both in regards to constellation design and their plans to encounter space debris issues, which is the reason why it has been chosen for these analyses.

In this paper, at first an overview of the planned OneWeb constellation setup is given. From this description, a mission life-cycle is deduced, splitting the complete orbital lifetime of the satellites into four phases. Following, using ESA-MASTER, for each of the mission phases the flux on both single constellations satellites and the complete constellation are performed and the collision probabilities are derived. The focus in this analysis is set on catastrophic collisions. This analysis is then varied parametrically for different operational altitudes of the constellation as well as different lifetimes with different assumptions for the success of post mission disposal (PMD). Following the to-be-expected mean number of collision avoidance manoeuvres during all active mission phases is performed using ARES from ESA's DRAMA tool suite. The same variations as during the flux analysis are considered. Lastly the characteristics of hypothetical OneWeb satellite fragmentation clouds, calculated using the NASA Breakup model, are described and the impact of collision clouds from OneWeb satellites on the constellation itself is analysed.

1. Introduction

Providing a continuous space-based service to a certain on-ground area is generally a trade-off between the altitude of the system and the number of satellites needed to reach the desired on-ground coverage. The advantage of placing satellites in high altitudes is that less objects are needed to achieve a high coverage (cf. Fig. 3). As one example, using super-synchronous orbits with periods of 48 and 96 h, a continuous global coverage is possible with only four satellites [5]. On the other hand, lower altitudes have the advantage of much lower signal delay times and require less power to transmit a signal, but require a considerably larger number of satellites to provide the onground coverage. Nevertheless, the signal delay time and power requirements are compelling enough that several communication system concepts accept the large number of satellites required. During the 1990s,a first wave of announcements for constellations ranging from tens to hundreds of satellites were made. This included amongst others Teledesic, Celestri, M-Star Iridium, Globalstar and OrbComm. From these, only the latter three became operational, most of the others only in a very reduced form. The impact of these constellations on the space debris environment has been analysed in some publications during that time, which include Rossi et al. [16], Wegener et al. [20], Reynolds et al. [15] and Walker [19]. Furthermore, the impact of the space debris environment on some of these constellations has been analysed in Rossi et al. [17]. In these studies, it was found that as long as the number of constellations perform a post mission disposal at high success rates (thus not leaving too many objects on orbit over the long-term), the number of objects in single constellations does not get too large and the spatial density in the orbital altitude of the constellation is not already critical, the space debris environment can sustain such constellations. Walker [19] states that in orbital regions with low spatial densities, constellations with 300–900 members can be sustained, whereas in altitudes with high spatial densities, even constellations with 300 might lead to a critical increase in the number of objects.

New constellation announcements have been made during the last two years. These include for example a SpaceX constellation, one from Samsung, and the OneWeb constellation. In comparison to those from the first wave, these constellations are planned to be released into higher altitudes with lower spatial densities. However, they will be constituted of many more objects (between 720 for OneWeb and up to 4200 for Samsung).1 Therefore, it is uncertain if the findings from the studies from the turn of the century are still valid for this new type of constellation. First investigations have been published to investigate impact of such very large constellations on the long-term environment. Bastida Virgili and Krag [3] and Bastida Virgili et al. [2] coincide with the other studies that the most critical parameter of a sustained environment is to limit the number of objects that stay on orbit over the very long-term, for example by performing an end-of-life disposal at a very high success rate.

In this paper, the interactions between the space debris environment and the OneWeb constellation are investigated. This accounts for both the impact of the environment on the constellation itself but also the criticality such a constellation poses for the overall space debris environment. The OneWeb constellation was chosen only for the trivial reason that it appears to be closest to become operational from all announced new constellations and therefore sufficient details are available in comparison to other constellations. It is not meant to emphasize this constellation to be more risky than others. Actually, to the current date, OneWeb shows a very commendable approach towards space debris issues (also compare Section 2). The paper is structured as follows. The relevant facts (to date) of the OneWeb constellation are presented in Section 3. The section also contains the four phases in which the simulations are structured. Section 4 describes the variation of the constellation over different operational altitudes. The collision flux, collision avoidance manoeuvres and reentry analysis simulations, described in Sections 5 and 6, have been performed using MASTER-2009 and the Assessment of Risk Event Statistics (ARES) and Orbital Spacecraft Active Removal (OSCAR) tools of the Debris Risk Assessment and Mitigation Analysis (DRAMA) tool suite respectively.

2. The OneWeb constellation

As of today, the characteristics in terms of orbital parameters and satellite properties have not been finalized. Nevertheless, the basic roadmap seems to be decided and left unchanged during the last year. All information stated here is based on statements from the official OneWeb website2 as well as Lindsay [10] and Azzarelli [1]. From there it is taken that the final constellation will consist of 720 satellites, which will be distributed along 40 orbital planes leading to 18 satellites per plane. The operational altitude of the constellation will be at 1200 km, the inclination of the planes 87.9°. Each satellite will have a mass of about 150 kg and will be equipped with an electric propulsion system. For the concept of operations it is planned to first inject the satellites into a 500 km circular orbit, from where it spirals up to the final mission altitude independently. The time needed for the manoeuvre had not been specified when the shown analyses were performed. After its active mission, the satellites will shift to an active de-orbit phase, which will take between 6 and 24 months. The final disposal orbit will be at 1100 km× 200 km, leading to a total postmission orbital lifetime below 5 years. From all communications so far, OneWeb aims on minimising their impact on the LEO environment. For this, the following measures and activities have been stated [10]: • Data sharing agreement in place with USSTRATCOM/JSpOC to decrease orbit determination uncertainties. • Collision avoidance foreseen from the active phase (from injection to end-of-disposal), with the aim to be able to keep the satellites active during the complete orbital lifetime. • An orbital lifetime after end-of-mission (EOM) of 5 years. • A success rate for the end-of-life (EOL) disposal of ≥90%. • All satellites will be equipped with a grapple fixture to allow future active debris removal operations. All these points show that OneWeb understands the high responsibility that comes with introducing hundreds of satellites into the LEO environment, which furthermore will cross the highly populated regions between 700 and 900 km twice. While this is a very positive signal, still many open questions remain on how OneWeb will be able to fulfill these self-imposed requirements. While these information already contain many important points for the following analyses, the actual mission duration for a single satellite has not been stated yet. Therefore, a rather arbitrary value of 5 years has been chosen, which is in line with Bastida Virgili et al. [2], and appears reasonable, considering the long orbit raising and de-orbit lifetimes before and after the actual mission. The times needed for the orbit raising and active disposal are not counted to the actual mission lifetime.

3. The OneWeb constellation in this paper

For the following analyses, the mission of the constellation satellites is split into four different phases: 1. Release at 500 km and 6 months spiraling to final altitude of 1200 km at 87.9° inclination.3 2. Active mission for 5 years at nominal orbit. 3. Active disposal to 1100×275 km orbit taking 2 years using the electrical engine in two steps: First, lowering the orbit to a circular 1100×1100 km orbit followed by an eccentric disposal to the final orbit.

4. Passive re-entering of the object.

The 275 km as perigee altitude were chosen to account for an ambiguity in the current OneWeb statements, which emerge from the disposal to a 1100×200 km orbit and a disposal lifetime of about 5 years. One very large unknown of the final satellites is the electrical engine to be used. Therefore, the engine has been “reverse”-engineered from the stated assumptions. For all the manoeuvres, it is assumed that they are performed with a thrust-efficiency of 100%. During the manoeuvre of Phase 1, an altitude change of 700 km needs to be performed. For this, a total ΔV of 0.36 km/s is needed, when applying the simplified relation in Eq. (1) for spiral orbits with r 1 = 6878 km, r2 = 7578 km and the standard gravitational parameter defined as μ = 398, 599 km /s E 3 2 . Under the assumption that the engine fires continuously the complete 6 months and the mass of the satellite remains constant, this leads to a needed constant acceleration of 2.3187·10−5 m/s2 , or a needed thrust of about 3.5 mN: V μ r μ r Δ= − E E 1 2 (1) During the third phase, the active disposal phase, it is assumed that the engine has still the same characteristics as in the beginning. The first step, the lowering to a 1100 km circular orbit, needs in a total ΔV of

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0.0484 km/s and takes 24.2 days. The second step is the eccentric disposal. For this one it is assumed that the engine fires always 15% of the orbital period around the apogee, again not accounting for any losses. The ΔV needed for this is 0.2366 km/s, leading to a total burning time of 118 days, split over little more than two years. The same thrust as for the spiral-up manoeuvre has been assumed. These manoeuvres have been modeled within the analytical propagator FLORA to propagate the complete evolution of the orbit over time for the use within MASTER. This propagator considers all major perturbations (Geopotential, third body, atmospheric drag and solar radiation pressure), with atmospheric density calculations based on the NRLMSIS-2000E atmosphere model. The evolution of the apogee and perigee altitudes are shown in Fig. 1. For the shape of the satellites, it is assumed that they have an orbital cross section of a randomly tumbling object of 2.7 m2 for the propagation. This is based on an assumption of a central box-shaped body with an edge length of 1 m and two solar panels with an edge length of 1.12 m. The cross section computation has been done using CROC from DRAMA 2.0 [7]. 4. Variation of the constellation size and altitude To perform some parametric variation, the operational altitude of the constellation has been varied. In general, constellations need less objects when operating at higher altitudes. For the variations performed here, it is assumed that the constellation provides the same service (providing the same overall bandwidth and availability) on different altitudes. In addition it is assumed that the maximum grazing angle ε (refer to Fig. 2) in each configuration will remain the same so that the on-ground hardware (user terminals) configuration can beDiagram, engineering drawing

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Table

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used. Furthermore, it is assumed that the satellite bus stays identical for all altitude variations. For the following analysis equations are taken from [21]. From the initial OneWeb configuration the grazing angle ε needs to be determined. This can be achieved using ε η ρ cos = sin sin . (2) Based on the altitude H, the angular radius of the Earth ρ can be derived in ρ R R H sin = + . E E (3) The nadir angle η, measured from the nadir of the satellite's ground track to the user terminal, is then calculated using η ρ λ ρ λ tan = sin ·sin 1 − sin ·cos (4) To derive λ, an assumption is made that 18 OneWeb satellites are equally distributed along a single orbital plane, each covering 20.0° of the Earth's surface along their ground swath. This leads to an angle λ of 10.0°. The results are summarized in Table 1. Holding the grazing angle constant, Eqs. (2)–(4) are used to determine the number of satellites needed when moving the constellation to different altitudes. The relation in Eq. (5) is used to retrieve an integer number of satellites per orbital plane based on the Earth central angle λ : ⎡ ⎢ ⎢ ⎤ ⎥ N ⎥ λ = 360.0° 2· . (5) Fig. 3 shows the number of satellites necessary to provide coverage when moving the constellation to different altitudes.

5. Space debris flux analysis

At first, a flux analysis for single constellation satellites is performed. The analysis is done for each of the phases of the satellite stated in Section 2. The flux analysis has been performed using ESA'sChart, bar chart

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MASTER model [6]. Next to describing the risk for OneWeb satellites posed by the space debris environment, the risk that one OneWeb satellite catastrophically collides is analysed. A catastrophic collision is understood as a collision, in which the target object is completely shattered. The generally used criterion to distinguish a catastrophic collision in simulations is the Energy-to-Mass (EMR) ratio, which is defined as M v M EMR = · 2· . imp rel tar 2 (6) Mimp describes the mass of the impactor, which is the smaller object. vrel is the impact velocity between the objects and the target mass Mtar. If the EMR exceeds a threshold of 40 000 J/kg, the collision is assumed to be catastrophic [11]. From the mass for a OneWeb satellite of 150 kg and assuming that collisions with relative velocities of up to 14.5 km/s can occur, the impactor mass for catastrophic collisions can be estimated. This is shown in Fig. 4: Objects with masses larger than 0.056 kg fulfill the criterion. Assuming a medium density of space debris objects similar to that of aluminium of 2.8 g/cm3 [13] and furthermore assuming the objects to be spheres, which is reasonable for small objects, the threshold for catastrophic collisions is reached for diameters of about 3 cm. **This size falls below the generally assumed threshold of 10 cm for the observability of object and therefore cannot be avoided using available collision avoidance techniques**. From the flux (F), which is returned directly from MASTER, the mean number of collisions (N) can be determined via: N FA T = · ·. c (7) Here, T is the timeframe, which is different for each analysis. Ac is the collision cross section, which can be computed from the radii of both the impactor and target objects: A πr r = ·( + ) . c target impactor 2 (8) From the mean number of collisions, the probability for (n) impacts can be calculated using Poisson statistics: P N n = e ! · . i n n N = − (9) Thus, the probability for no impact is determined via: P e i = N =0 − (10) and the probability of one or more impacts is P e =1− . i N ≥1 − (11) The complete calculation and correct derivation of the probabilities can be found in Klinkrad [9].

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5.1. Phase 1: Spiraling from 500 km to 1200 km

The flux on a OneWeb satellite from objects ≥3 cm during Phase 1 is shown in Fig. 5. It moves between 1.9·10−5 m−2 a−1 in the beginning, a little less than 5.0·10−5 m−2 a−1 while crossing highly populated regions in 800–1000 km altitude and ends at 1.2·10−5 m−2 a−1 for the final operational altitude. The fluxes together with their numbers of impacts and collision probabilities for single objects and the complete population are stated in Table 2. As shown already in Section 4, of greatest interest is the flux from impactors larger than 3 cm. The according impact probability for a single object is 0.01%, whereas the probability to experience an impact for the entire constellation of 720 objects is 4.11%. 5.2. Phase 2: Operational time at 1200 km During the second phase, the constellation satellites are at their operational altitude of 1200 km. Five years are assumed as operational lifetime. T**he evolution of the flux on OneWeb satellites from objects ≥3 cm over time is shown in Fig. 6. Due to the constant altitude, the flux from objects ≥3 cm oscillates between 9.0·10−6 m−2 a−1 and 1.0· 10−5 m−2 a−1 , with a slightly increasing trend**. These variations in the flux are only due to the changing background population over time. The fluxes, numbers of impacts and probabilities for one or more impacts over different diameter classes are shown in Table 3. The probability of an impact with an object larger or equal to 1 cm is therefore at 51.83%, for the complete constellation over the operational lifetime of five years. For collisions against objects larger than 3 cm the probability is 13.45%.

[Omitted All Tables and Graphs from Page 58-60]

5.3. Phase 3: “active” disposal lifetime

The third phase is the active disposal phase. The evolution of the flux on OneWeb satellites from objects ≥3 cm over time is shown in Fig. 7. It moves from a value of 1.5·10−5 m−2 a−1 in the beginning of the disposal, towards 4.0·10−5 m−2 a−1 , when the perigee altitudes lies in between 800 and 900 km, to about 2.3·10−5 m−2 a−1 , when the final eccentric disposal orbit is reached. Table 4 shows the results for the fluxes, numbers of impacts and probabilities for one or more impacts over different diameter classes for single constellation objects and the complete constellation. For most critical objects, those larger than 3 cm, the probability is 0.02%, for the complete constellation it is 15.15%.

5.4. Phase 4: passive disposal lifetime

The fourth phase is the passive disposal lifetime. During this time, the object's orbit is propagated. The evolution of the flux from objects ≥3 cm is shown in Fig. 8. It starts at a comparably high number of 2.3· 10−5 m−2 a−1 and decreases while the object reenters to 2.0· 10−5 m−2 a−1 just before the re-entry. The fluxes, numbers of impacts and probabilities for one or more impacts over different diameter classes for both single objects and the complete constellation are shown in Table 5. The probability of an impact for the complete constellation during the passive re-entry phase with an object ≥1 cm is therefore 27.16%, for an impact with an object ≥3 cm it is 7.24%.

5.5. Variation of the constellation's size and altitude

A sensitivity analysis for a constellation at different orbital altitudes and thus different numbers of objects has been performed based on the parameters stated in Section 4. The flux analysis has additionally performed for two of these constellations: One at 800 km, which consists of 1000 satellites, and one at 1400 km, which contains 680 satellites. Again, the complete mission life cycle of the single objects was considered by splitting it into the four known phases. These phases are summarized in Table 6. For the computation of these parameters, it was aimed to keep as many parameters constant as possible. This includes the injection altitude of 500 km, the duration of the operational mission of 5 years and the acceleration of the electrical engine. For the disposal orbit it was again assumed that satellites spiral down onto a circular orbit 100 km below the mission orbit and then perform an eccentric disposal with a remaining passive disposal which leads to an identical complete disposal time of 3.5 years. This of course is only one out of many possible solutions for a disposal orbit.

As results, only the complete collision probabilities are shown and compared to the OneWeb reference case. The fluxes over time for all constellations are shown in Fig. 9. From the results, the sensitivity to the orbital altitude is obvious: For the low constellation, the largest flux is during the active mission time, as the overall spatial density in this orbital region is highest. During the spiral-up and disposal, the objects spend large amounts of time in low orbital altitudes with low spatial densities. For the higher constellations, the results are comparable, although on different levels: The highest flux is during the initial spiral-up and the disposal phases. An evaluation, which of the different layouts is better in terms of creating new space debris is difficult, as it highly depends on operational parameters of the constellation: Assuming the possibility of a strict collision avoidance against all objects ≥3 cm during all active phases (Phases 1–3), the solution at the highest altitude is the best, with lowest collision probabilities in the passive phase. This is accounted to the fact thought that the combined active lifetime for this constellation is longer than that of the lower constellations. If on the other hand assuming strict collision avoidance during the actual mission only (thus Phase 2), which is of identical length for the three concepts, the constellation at 800 km appears to be preferable due to less time spend in spiraling orbits.

Considering the overall risks though, the assumed OneWeb design shows to be the best choice. For overview, the complete collision probabilities for the complete constellations over the different missions phases and the complete orbital lifetime are shown in Table 7. 5.6. Variation of the constellation's operational lifetime In the prior sections, it was assumed that the constellation is operational for five years only, without considering any replenishment. Furthermore, only the flux from background objects was considered. In this section, additionally to size and altitude, the operational lifetime of the constellation is varied: Once to 10 years and once to 20 years. Over these extended lifetimes, objects from the constellation accumulate in the population, especially those that were not disposed successfully after end-of-life. Therefore, the success rate for end-of-life disposal is also varied three times: 50%, 75% and 90%, leading to nine different constellation setups.

The constellation setup for the simulations shown is as follows: At first, it is build-up over three years. As soon as the build-up is complete, the operational phase starts, lasting for the stated timeframe. Satellites still operational at the end of the constellation operational time stay in orbit until their operational lifetime of five years is over and are deorbited afterwards, according to the rules valid for that constellation. This helps avoiding disposing a constellation of up to 1000 objects at once. In the flux analysis, now four different sources of constellation objects are considered: Satellites during Phase 1, the spiral-up, Phase 3, the active disposal, Phase 4, the passive disposal, and those that are left in the operational altitude because the disposal failed. All active objects in the operational constellation are not considered as due to constellation design they cannot encounter, at least during the short time frames considered here.

The results presented in Fig. 10 are valid for the complete mission lifecycle of the complete last generation of the constellation. Shown is the complete collision probability (top) and that from constellation objects only (bottom). It has to be noted that the shown collision risks are mostly due to encountering failed objects during the active phase of the constellation satellites (Phase 2), which is between 3.14% for a constellation at 1400 km altitude and 90% disposal success after 10 years and 92% for a constellation at 1200 km altitude and 50% disposal success after 20 years of operations.

Starting with a constellation at 800 km altitude and thus 1000 objects, the probability that one object of the second generation constellation catastrophically collides with any other object is between 85% for a high PMD of 90% and 97% for a low PMD of 50%. For one object of the fourth generation, the numbers stay almost identical. The reason for this is that constellation objects failing at that altitude decay Table 5 Fluxes, numbers of impacts and probability for one or more collisions for constellation objects during Phase 4. Values for numbers of impacts and collision probabilities are valid for a Phase 4 of 1.5 years duration. Values with index 720 stand for the total constellation. Class Flux/ 1/m2 /a N P≥1 (%) N720 Pi≥1720 (%) d > 1 cm 8.65E −05 4.40E−04 0.04 3.17E−01 27.16 d > 3 cm 1.60E −05 1.04E−04 0.01 7.52E−02 7.24 d > 10 cm 4.76E −06 5.28E−05 0.01 3.80E−02 3.73 d > 1 m 7.98E −07 2.59E−05 0.00 1.87E−02 1.85 Table 6 Mission phases of the alternative constellations for the space debris flux analysis. Phase 800 km constellation 1400 km constellation 1 Release at 500 km, spiral-up to 800 km, duration: 80 days Release at 500 km, spiral-up to 1400 km, duration: 454 days 2 5 years mission at 800 km 5 years mission at 1400 km 3 Spiral down to 700 km circular orbit, disposal to a perigee of 380 km, duration 323 days spiral down to 1300 km circular orbit, disposal to a perigee of 250 km, duration 923 days 4 2.6 a passive disposal 1 a passive disposal Fig. 9. Evolution of flux from different sources and semimajor axes over time for all three altitude variations of the constellation. For the background population, the MASTER scenario “intermediate mitigation” including objects ≥3 cm is chosen. J. Radtke et al. Acta Astronautica 131 (2017) 55–68 60 fast enough to reach an equilibrium between failing and decaying objects short after the beginning of the constellation's operational lifetime. The variations found in the results are mostly due to variations in the solar activity used for the constellation propagation. Looking at 1200 km and thus 720 objects, a different behaviour is observed: While the second generation constellation encounters collision probabilities between 54% for high PMD rates and 80% for low PMD rates, the fourth generation constellation has to deal with collision probabilities between 68% and almost 96%. While the flux from the background population also remains fairly constant, the atmospheric drag at this altitude is so low that failed constellation satellites remain very close to the operational constellation altitude and therefore have a large impact on the constellation's collision probabilities. A similar, but less strong effect, can be found for the 1400 km constellation with 680 objects: In here, the collision probabilities from constellation objects roughly double from between 4% and 15% to between 8% and 32%. The lower risks are combined effects from both less objects in the constellation (and thus also less failed objects) and a larger volume available. Over very long times though, the accumulation effect will be strongest at this altitude, as almost no decay of failed objects occurs. For a more comprehensive overview of the number of collisions to be expected for the different constellation, more results on this are presented in the Appendix A.

6. Estimation of collision avoidance manoeuvres

In the next step the number of collision avoidance manoeuvres for OneWeb satellites has been estimated using the ARES (Assessment of Risk Event Statistics) module [14] from ESA's DRAMA tool suite in version 2.0.4. The number of needed collision avoidance manoeuvres has been calculated for all phases, in which the satellites are assumed active. Again, a cross section of 2.7 m2 has been used. This leads to an equivalent radius of 0.9271 m for the use in DRAMA ARES. In the orbital uncertainties section for both the constellation objects and the known space debris population CSM (Conjunction Summary Message) data quality is assumed. This rather optimistic assumption is based on the statement of OneWeb on the data sharing agreement with JSpOC to reduce orbit determination uncertainties. The lower diameter size has been set to 3 cm. The intermediate scenario for the future space debris population has been selected.

6.1. Phase 1: Collision avoidance during spiraling phase

For Phase 1 the simulation starts on January 1, 2018. As a simplification the orbit has been assumed to be an elliptical 500 km ×1200 km orbit with the parameters of 7228 km for the semimajor axis, 0.048 for the eccentricity and 87.9° for the inclination. This assumption suffices for the statistical approach of deriving the collision flux for the movement through the orbital region over a 6 months period. ARES distinguished between the detectable and the whole population. While the detectable fraction of the population can be observed and catalogued there is a none detectable part of the population, which can be derived through modeling the space debris environment, as it is done in MASTER. However, the not detectable fraction of the population is not observable in the manner that they can be maintained in a catalogue. ARES shows the whole population as the detectable and none detectable parts of the population. The flux results for the whole population (subscript w) from ARES, as shown in Table 8, are comparable to the results obtained in the previous section: The Flux\_w value of 3.07·10−5 m−2 a−1 compared to the value of 2.90·10−5 m−2 a−1 in Table 2 yields and error of 5.8%. Fig. 11 shows the mean number of avoidance manoeuvres as a function of the accepted collision probability level (ACPL). The ACPL is a value that is defined by the operator. It is the limit at which a decision in favour of an avoidance manoeuvre is made. A lower ACPL corresponds to a higher number of avoidance manoeuvres due to the fact that many more potential but less likely collisions have to be avoided. Note that in this paper an ACPL value is always applicable for a single satellite, not for the constellation as an entity. Thus the operator optimizes the manoeuvre rate for each satellite. The combined ACPL value for the constellation would be bigger than for the single satellites. The figure shows the mean number of avoidance manoeuvres scaled for all 720 satellites in the constellation and a timeframe of 6 months. Choosing a very low ACPL of 1·10−6 results in a total of about 800 avoidance manoeuvres, which have to be performed. Orientating towards the satellites of the RapidEye constellation, which constitute similarly to OneWeb a privately owned commercial constellation of satellites, a more realistic ACPL appears to be 1·10−4 [18], which results in a reduced number of 23 avoidance manoeuvres.

As a result of a successful avoidance manoeuvre the risk of collision is reduced. This can be observed in Fig. 12. Here the risk reduction, residual risk and the remaining risk are shown as a function of the mean number of avoidance manoeuvres. Note that the term risk is treated as the annual collision probability, so the Poisson statistics as shown in Section 5 has been applied. As expected with an increasing number of manoeuvres the risk reduction rises as the residual risk is lowered to an equal extent. For the number of 23 manoeuvres the risk is reduced by about 1.9 percentage points. However only a fraction of the population is known and avoidance manoeuvres can only be performed to prevent collisions with known objects. The left-over risk is shown as the remaining risk, which stems from none detectable objects, and the risk that is taken into account due to the choice of the ACPL. In the case of 23 performed manoeuvres a remaining risk of about 2.5% is expected. Choosing an ACPL of 1·10−6 and taking into account the resulting 800 manoeuvres decreases the residual risk from the known population to zero. However the remaining risk would still be about 1.8%.

6.2. Phase 2: Collision avoidance during operational lifetime

In the second phase the constellation is in operation at a circular orbit at 1200 km altitude. For the simulations with ARES a semimajor axis of 7528 km and an eccentricity of 0.001 is assumed. The results are scaled to the whole constellation of 720 satellites and a timeframe of five years. The simulation starts on June 1, 2018. ARES gives the results shown in Table 9 for the overall annual collision probability and fluxes of the detectable (d) and whole (w) population. The results from ARES are in agreement to those obtained with MASTER shown in Table 3. The error is at 6.6% (result for MASTER: 9.66·10−6 m−2 a−1 and ARES: 1.03·10−5 m−2 a−1 ). Fig. 13 shows the number of expected manoeuvres. Even though the considered timeframe is ten times longer than in the previous phase, the expected number of avoidance manoeuvres for the whole constellation, with an ACPL of 1·10−4 , is merely increased by a factor of three, to 68 manoeuvres. This number reflects the decreased flux and thus the decreased collision probability in the chosen orbital region as compared to the spiraling phase. After successfully performing 68 avoidance manoeuvres a risk reduction of 4.3 percentage points is achieved, as shown in Fig. 14. The remaining risk for a collision is reduced to about 8.9% for the entire constellation. The maximum risk reduction would be achieved when performing around 900 manoeuvres. The increased effort would lead to a remaining risk of about 7.5%. Compared to the initial risk about 12.2% this means that less than half of the risk can be reduced through avoidance manoeuvres. In turn, more than half of the risk (the remaining risk) results from the none detectable fraction of the population in the given altitude. 6.3. Phase 3: Collision avoidance during disposal lifetime In the third phase each satellite performs manoeuvres to reach the disposal orbit (1100 km×275 km). Because the input in ARES does not allow for manoeuvres a simplifying assumption of an elliptical orbit at 1100 km×275 km orbit is assumed. The ARES output for the given timeframe is shown in Table 10. The flux of the whole population (Flux\_w) is estimated to be 2.704·10−5 m−2 a−1 . The MASTER simulations in the previous chapter show a flux of 2.89·10−5 m−2 a−1 . This results in a deviation of about 6.4%. The simulation starts on May 1, 2023 and ends on May 1, 2025. Fig. 15 shows the required number of avoidance manoeuvres to conform with a given ACPL value. For an ACPL of 1·10−4 about 152 manoeuvres are necessary for the whole constellation in the assumed two year timeframe. Fig. 16 shows that the 152 avoidance manoeuvres lead to a risk reduction of about 8.0%. This leaves the remaining risk at 8.4%. About half of that risk is a contribution by the detectable fraction of the space debris population. The other fraction of the remaining risk, about 3.6%, is caused by the none detectable fraction of the space debris population and cannot be reduced through more avoidance manoeuvres. The lowest possible risk that can be achieved through the maximum number of avoidance manoeuvres remains at about 4.9%.

6.4. Phase 4: Decay phase

In the last phase of the mission the satellite is assumed to be no longer operational. It is in an orbit of 1100×275 km and slowly decaying towards its reentry. It is no longer able to perform any avoidance manoeuvres. It's reentry is simulated using the Orbital Spacecraft Active Removal (OSCAR) of the DRAMA tool suite, starting from May 1, 2025. The cross sectional area is set to 2.7 m2 and the dry mass to 150 kg. In OSCAR no disposal option was selected, so that only the re-entry is simulated. For the solar and geomagnetic activity prediction the Best Case/Worst Case scenario has been chosen. The forecast is based on a modified McNish–Lincoln algorithm [12], which is enhanced by an assumed confidence interval. This results in an upper and lower boundary, where the lower boundary is referred to as the Worst Case (WC) and the Best Case (BC) is the upper boundary. The WC is associated with a longer orbital lifetime, while for most cases the BC is associated with a shorter orbital lifetime [4]. The result of the simulation is shown in Fig. 17. Three different altitude evolutions are visible. The BC and WC scenarios have been derived using confidence intervals of 50%. A given OneWeb satellite, which starts its decay on May 1, 2025 will likely reenter between December 13, 2025 in the Best Case scenario and April 23, 2026 in the Worst Case scenario. The nominal reentry may take place around December 27, 2025. The chosen orbit thus results in a remaining orbital lifetime between 197 and 358 days for the given timeframe.

6.5. Collision avoidance and the variation of the constellation's size and altitude

Corresponding to the sensitivity analysis for the collision flux of different operational altitudes in Section 5.6, the collision avoidance analysis is carried out accordingly. The numbers of collision avoidance maneuvers for constellations at different altitudes are compared in Fig. 18. The ACPL has been set to 1·10−4 . The altitude is varied between 500 km and 2000 km. The number of satellites in the constellation is scaled according to results shown in Fig. 3. The numbers of avoidance manoeuvres in the three different phases of operation: spiral-up, mission time and active disposal phase are considered. The total number of manoeuvres is shown in the solid (violet) bar. It is visible that there are peak values in the lower altitude regions around 800 km as well at higher regions around 1400 km. Each of the peaks are driven by manoeuvres required during the mission lifetime of the satellites, as shown as a dotted a bar (blue). In those regions the spatial density is high, which requires the satellites to perform avoidance manoeuvres. In altitudes between 1100 km and 1300 km as well as between 1600 km and 2000 km the number of collision avoidance manoeuvres required during the disposal phase is higher than during the mission phase itself. This is owed to the fact that the spatial density in the operational orbit is low, leading to fewer manoeuvres. However during the disposal phase the satellites cross different orbits of higher spatial density, so that more manoeuvres are needed as the perigee is lowered. The numbers for the disposal phase are shown as striped bars (green). Fig. 18 also shows that the number of manoeuvres during the spiral-up phase, at the beginning of the mission, does not have a significant impact on the overall numbers of collision avoidance manoeuvres.

6.6. Collision avoidance and the variation of the constellation operational lifetime

In the next analysis the number of avoidance manoeuvres during the mission time after 10 and 20 years of constellation operations are derived. The operational altitudes of 800 km, 1200 km and 1400 km as well as PMD scenarios of 50%, 75%, 90%, and 100% have been analysed. Fig. 19 shows the results. On the left the number of collision avoidance manoeuvres of the entire constellation during their five years of operation are depicted after the constellation has been on orbit for 10 years. The satellites on the 800 km orbit have a high manoeuvre rate (832), even with 100% PMD success rate. This is caused by the high spatial density in the orbital region. When the PMD success rate is reduced additional manoeuvres are needed. These manoeuvres are caused by constellation objects of the previous generations that have failed their post mission disposal goal. For a success rate of 50% the manoeuvre number is increased to 1969 for the 800 km orbit. The effect of inter-constellation collisions becomes more apparent for the 1200 km altitude constellation, which has a very low manoeuvre rate of about 60 when the PMD success rate is at 100%. This number increases rapidly as the success rate decreases. With a 50% success rate the number of collision avoidance manoeuvres is increased to about 1600. This is an increase of 2500%, when compared to the 100% PMD success scenario. The reason for this strong increase is the low drag force that is causing a slower decay of the failed constellation satellites, thus causing them to be potential collision partners. On lower altitudes, like the 800 km orbit, the defective satellites are decaying from the constellation slots more quickly, so their impact on the number of collision avoidance manoeuvres is not as significant.

At the operational altitude of 1400 km the manoeuvre rate increases slowly with a decreasing PMD success rate. However the change of the manoeuvre rate is lower than on the 1200 km altitude as the manoeuvre rate moderately increases from 286 to 345. Thus the impact of the failing satellites is noticeable as the change in the number of expected manoeuvres increases by 121%. The difference in the 1200 km to the 1400 km altitude can be explained by fewer satellites in the 1400 km-constellation and a larger volume of space available. This leads to fewer interactions between the constellation satellites among each other. Fig. 19 also shows the latest generation after 20 years of constellation lifetime. The qualitative development for each altitude and PMD scenario are equal to the 10 year consideration. However, the impact of failed PMD manoeuvres on the 1200 km altitude is even more apparent than before. This leads to the observation that for each satellite that fails its PMD manoeuvre causes about two to three additional avoidance manoeuvres in the 1200 km-constellation.

7. Impact of a collision cloud

Furthermore, the impact of a possible collision cloud of constellation objects is analysed. This is done for two fragmentation cases: First case is the collision of a single constellation object against a small impactor leading to a catastrophic collision, second the collision between two constellation objects. This analysis has only been performed for the nominal case at 1200 km. For the collision between the two constellation objects it is assumed that is happened at the intersection of two orbits which are rotated by 90° in their RAAN. The collision clouds, together with an orbit perpendicular to the orbital planes of the clouds, is shown in Fig. 20. 7.1. Characteristics of the fragmentation cloud In Fig. 21, the area to mass ratio of the objects over their diameter is shown. The cloud has been computed using the NASA Break-Up model [8], as implemented in MASTER-2009. Fig. 22 shows the Gabbard Diagram of the fragmentation cloud for one object directly after the fragmentation in May 2018 and ten years later, in May 2028. Due to the rather high altitude of 1200 km, the shape of the diagram and also the number of objects on orbit does not change much over time.

Last, Fig. 23 shows the distribution of objects along their right ascension of ascending node of the argument of mean latitude at four different times: Once directly after the fragmentation in May 2018 and furthermore three months, five years and ten years later. It takes about five years for an even distribution of the objects along all orbital planes.

7.2. Contribution to the space debris environment

Fig. 24 shows the spatial density of different sources over the orbital altitude for two different times, once directly after the fragmentation in May 2018 and once ten years later, in May 2028 assuming an intermediate mitigation future scenario in MASTER-2009. For the cloud, the spatial density for the collision between two constellation objects is shown.

At both times, the spatial density of the collision cloud is clearly dominating the operational altitude of the constellation. The spatial density in that region is roughly doubled, compared to an projected environment without the collision. As already shown in the prior section, this also does not change much over time.

7.3. Flux on constellation objects

The impact of the fragmentation clouds on the flux on constellation objects has been investigated at three different times: The day after the fragmentation, three months and five years later. This has been done for three different objects from the constellation: One, which is always in the plane of the fragmentation cloud (Object 1), one that is on an orbit which plane is rotated by 90° against the orbit of the fragmentation cloud (Object 2) and one that is on an orbit which is rotated by 180° against the orbit of the fragmentation cloud (Object 3). This has been done to account for different effects on different orbital planes, which are stated in Table 11.

The effect of the flux on all 18 satellites in each corresponding plane from the fragmentation clouds is shown in Fig. 25. From the results, different conclusions can be drawn. First, the impact of a single collision varies highly, depending on both the plane of the fragmented as well as the influenced object. In-plane objects are only very little influenced by a fragmentation (compare Fig. 25 for Object 1 against the single cloud). This is due to the fact that both the constellation object and the fragments move at very similar orbital velocities.

Objects on head-on orbits (thus, the orbital plane of the object is rotated by 180° against the fragmentation cloud) on the other hand experience a very strong impact from the fragmentation cloud (compare Fig. 25 for Object 3 against the single cloud): Here, the fragmentation cloud leads to an increase of the flux of almost a factor of 9, at the day directly after the fragmentation. This very high increase vanishes quickly though, as the orbital planes of the single fragments in the cloud distribute over time (compare Fig. 23), but even after five years a single collision still more than doubles the flux in this plane. Additionally to the extended flux, in head-on planes, the encounters occur with much higher relative velocities between the encountering objects; therefore the probability of a single collision being catastrophic is much higher than for other planes.

The relative velocities for Objects 1 and 3 against the collision fragments from the single cloud are shown in Fig. 26. For Object 1, which is in-plane with the fragmentation cloud, all encounters with fragments occur at relative velocities below 4 km/s. Over time, and with dispersion of the fragments along all orbital planes, the relative velocities trend towards an even distribution. For the object in Plane 3, the effect is opposite: Here, directly after the fragmentation, all encounters with cloud object occur at very high relative velocities, larger than 14.5 km/s. Over time, the distribution also flattens out, but even five years after the event, high velocity encounters are dominating. To this point, only in-plane or head-on encounters have been analysed. Object 2 demonstrates the results for objects in a plane between those two extreme cases. Therefore, this object can be treated as a mean case, representing the overall average in the constellation, when considering only one fragmentation cloud. For the case with two clouds on the other hand, objects in Plane 2 represent the minimum case. All other objects experience a stronger impact, as one of the Table 11 RAANs of constellation objects for flux analysis. For future epochs, only J2 influence has been considered. May 2 2018 August 1 2018 May 1 2023 RAAN, Plane 1/° 359.53 341.38 355.19 RAAN, Plane 2/° 89.53 71.38 85.19 RAAN, Plane 3/° 179.53 161.38 175.19 Fig. 24. Spatial density of the collision clouds (Cloud) in comparison to other sources (explosion fragments (Expl), collision fragments (Coll) and launch and mission related objects (LMRO)) for May 2018 and May 2028. Fig. 25. Fluxes on different objects with one or two or no cloud at all. Top: Object 1, which is in plane with the single cloud and head-on with the second cloud. Middle: Object 2, whose orbital plane is rectangular to both clouds. Bottom: Object 3, which is head-on with the single cloud and in plane with the second cloud. The flux is shown for all 18 satellites in each plane. J. Radtke et al. Acta Astronautica 131 (2017) 55–68 66 clouds is always in parts retrograde to the constellation object under consideration.

8. Summary and conclusion

In this paper, the setup of the OneWeb constellation as of beginning 2016 has been used to perform an analysis of the interactions between the space debris environment and large constellations of satellites. The focus of this analysis is the impact of space debris on the constellation itself. Building on the known properties of OneWeb's satellites, the lifecycle of a single satellites has been split-up into four phases: A spiral-up phase, the operational mission, an active and a passive disposal. Furthermore, it was estimated that an impactor from about 3 cm in diameter would lead to a catastrophic collision of a OneWeb sized satellite.

Using these properties for the satellites, flux analyses for payloads in all different mission phases were performed and scaled for the complete number of satellites, which is 720 for the constellation at 1200 km. The results show that the first generation of such a constellation would have a 35% probability to catastrophically fragment during the described mission lifecycle. The largest flux on the satellites occurs during the spiral-up and active disposal, as highly populated regions between 800 km and 1000 km are crossed. Due to the residence times, the highest collision probabilities occur during the operational mission lifetime and the active disposal phase though. In the next step, the operational altitude of the constellation was varied: One constellation with 1000 objects at 800 km and one with 640 objects at 1400 km were analysed. For both of the varied constellation higher collision probabilities against objects ≥3 cm were calculated: 69.35% for the 800 km constellation and 45.28% for the 1400 km constellation.

For all three constellation altitudes, it was assumed that the operational lifetimes were extended to both 10 years and 20 years, with different assumptions for the post-mission disposal success. This analysis showed the importance of a high post-mission disposal success rate for constellations at high altitudes: While at 800 km quite soon an equilibrium between newly failed and decaying satellites is reached, at higher altitudes defective satellites cumulate and lead to an increasing collision risk: Even when performing post-mission disposal with 90% success, the collision probability against constellation objects increases from 22% after 10 years of operations to over 42% after 20 years of operations for the 1200 km constellation.

Following, the effort to reduce the stated collision probabilities was analysed. During this analysis it was found that orbit of 1200 km altitude chosen for OneWeb is recommendable as it lies within a local minimum of the number of required collision avoidance manoeuvres for the first generation of OneWeb satellites. Only raising the operational altitude to around 1600 km and above will lead to fewer manoeuvres. In further analyses, over a few generations of OneWeb satellites, it becomes apparent that the chosen orbital region is more susceptible to failed post mission disposal (PMD) manoeuvres than other regions. The lower the PMD rate is, the higher will the number of inter-constellation encounters be. Failing to achieve a PMD success rate of at least 50% will lead to a significantly higher number of avoidance manoeuvres that need to be performed. After 10 years the 1500 manoeuvres per year mark will be reached. After 20 years 2500 manoeuvres will be necessary. The effect of this drastic increase in inter-constellation encounters is accounted to the lower atmospheric density, which leads to a slow decay of defective satellites. On lower orbits this effect is much lower because of the higher atmospheric drag removing the defective satellites more quickly from the operational orbit. On higher orbits the cleaning effect is even lower. However, because on higher orbits are also fewer satellites in use and a lot more volume of space available per satellites the chance of encounters is also reduced. In the light of the chosen 1200 km altitude a very high PMD rate will help to keep the orbital region as usable for future satellite generations as it is today. This conclusion is in-line with statements from Bastida Virgili et al. [2] and also the efforts communicated from OneWeb to have the highest system reliabilities in the sub-systems involved in the post-mission disposal.

Last, fragmentation clouds from OneWeb satellites have been described and their impact on constellation payloads themselves has been analysed. This analysis has only been done for the 1200 km case. Due to the low mass of OneWeb satellites, the fragmentation clouds themselves are comparably small. If it comes to a collision in the active altitude of the constellation, the impact is limited to altitudes around the active constellation. The impact of the cloud on satellites within the constellation depends highly on relative attitude of the orbital planes of both constellation satellites and fragmentation cloud and the time since the fragmentation occurred. On the short term, the flux increases up to a factor of nine, if the two orbital planes are rotated against each other by 180°. Due to the very low drag at these altitudes, the cloud stays close to the operational altitude over the long-term and leads to an increase of about 34% in the flux on an average constellation object ten years after the fragmentation event.

#### 1---Missile Radars.

#### Congestion creates rivalrous orbits.

Fabian 19 (Christopher; January 2019; B.S. from the United States Air Force Academy, thesis submitted in partial fulfillment of the requirements for a M.S. from the University of North Dakota, approved by the Faculty Advisory Committee and in coordination with Dr. Michael Dodge, David Kugler, and Brian Urlacher; University of North Dakota Scholarly Commons, “A Neoclassical Realist’s Analysis Of Sino-U.S. Space Policy,” <https://commons.und.edu/theses/2455/>)

b. Defect/Defect The ubiquity of space technology has also yielded the negative externality of overcrowding the space domain. Despite its seemingly unlimited size, there are a limited number of useful earth-centric orbits to optimize terrestrial coverage. It is projected that there are over 300,000 medium sized objects capable of causing catastrophic failure of a satellite upon collision currently in earth’s orbit.159 Of these objects, 20,000 are actively tracked by the comparatively robust space surveillance network (SSN) of the United States Air Force, only 1,000 are active payloads, and even fewer have maneuver capability.160 Recent trends indicate that the problem of orbital congestion will only worsen in the coming decades as the barriers to entry are reduced. Launch service cost is rapidly decreasing due to an increased number of service providers and technology revolutions such as reusable rockets. Also, the miniaturization and simplification of satellite payloads further reduces the cost and infrastructure needed to be a spacefairing nation.161 This is evidenced by the near doubling of state operated satellites from 27 in 2000 to over 50 in 2012, coupled with a near doubling in total space objects from 1997 to 2007.162 The accumulation of space debris is a vital concern to the sustainable development of the space environment due to the increased probability of conjunction between active payloads and all other objects that results from crowded orbits. This increase in collision probability occurs proportionally to the number of objects in a given orbital domain. The tripling of orbital debris projected to occur in the next century, due to routine use and accumulation alone, would cause a tenfold increase in the probability of collision. In the event of a catastrophic collision between two objects, the resulting debris cloud could cause a cascading effect. Each successive collision increases the probability of another occurrence in a given orbit until an instability threshold is reached. At this threshold, debris removal due to decay would be negligible compared to debris created by subsequent collisions. As the propagation of debris continues, the cost of launching a satellite would eventually outweigh the benefits received due to the probability of that asset being destroyed by errant debris, effectively rendering the given orbit unusable. This debris propagation model and the dangers associated with it are colloquially referred to as the Kessler Syndrome. Kessler asserts unstable regions of low earth orbit (LEO) currently exist and that, barring the addition of more debris, a major collision would occur once every 10-20 years. If debris doubles, as it has in the last decade, the collision rate would increase to 2.5 years. Although most models’ time scales are on the order of centuries, it is widely accepted that the current rate of debris accumulation will render critical orbits unusable unless immediate measures are taken to return stability.163 There is near universal acceptance of the danger space debris presents, yet little substantive action has been taken to solve the problem. Current debris accumulation and propagation models show that earth orbiting domains are finite resources. Continued unsustainable development moving forward may preclude future usage, making earth orbits rivalrous goods.164 Furthermore, orbital domains are made a non-excludable good by the OST which states, “Outer space… shall be free for exploration and use by all States without discrimination of any kind.”165 As a non-excludable public good, space succumbs to the tragedy of the commons where the privately beneficial strategy of space utilization differs significantly from the socially optimal strategy promoting orbital stability.166 Understandably, most analysis has focused on solving the problem of orbital instability by addressing the market failure responsible for debris creation. The current reasoning suggests that if actors creating space debris internalize the cost of their actions, a solution can arise. Proposed solutions run the gamut of ideologies from free market tax incentives, to command and control legislation, to restructuring orbital property rights. Scientific solutions have also been proposed, but technological feasibility and cost remain major problems. Furthermore, analogous environments susceptible to the tragedy of the commons have been examined in hopes that they may prove applicable to the problem of orbit instability.167 This analysis is ultimately useful if the problem is to be solved under nominal conditions, but there is an underlying problem that needs to be addressed before any of these proposed solutions can realistically be enacted.

#### That triggers missile radars.

Hoots 15 (Felix; Fall 2015; Distinguished Engineer in the System Analysis and Simulation Subdivision, Ph.D. in Mathematics from Auburn University, M.S. in Mathematics from Tennessee Tech University; Crosslink, “Keeping Track: Space Surveillance for Operational Support,” <https://aerospace.org/sites/default/files/2019-04/Crosslink%20Fall%202015%20V16N1%20.pdf>)

The launch of Sputnik on October 4, 1957, marked the beginning of the Space Age. It also marked the beginning of an intense space race that brought a remarkable rate of rocket launches. In a very short time, the number of objects in orbit grew dramatically. This created a host of strategic challenges, including the need for space surveillance. In particular, the Air Force needed a way to prevent false alarms as satellites came within view of missile-warning radars, while the Navy needed a way to alert deployed units of possible reconnaissance by satellites overhead. These needs led to the establishment of a military mission to maintain a catalog of all Earth-orbiting objects—active payloads, rocket bodies, and debris—along with detailed information about trajectory and point of origin. Such a catalog could be used to filter normal orbital passages from potential incoming missiles and predict the passage of suspected spy satellites. The first catalog was relatively small in comparison with today’s version, which lists more than 22,000 items (as of May 2015). Also, the current version supports much more than the original military mission—and Aerospace is helping to extend its utility even further. The Space Catalog The Space Catalog is maintained by the Joint Space Operations Center (JSpOC) at Vandenberg Air Force Base, part of U.S. Strategic Command. One of the missions of JSpOC is to detect, track, and identify all artificial objects in Earth orbit. A key component of this mission is the Space Surveillance Network, a worldwide system of ground-based radars along with ground-based and orbital telescopes. The radars are used primarily for tracking near-Earth satellites with orbital period of 225 minutes or less, as well as some eccentric orbits that come down to near-Earth altitudes as they go towards their perigee. Ground-based telescopes are used for tracking more distant satellites, with orbital period greater than 225 minutes, and space-based sensors are used to track both near and distant satellites. The JSpOC tasks these sensors to track specific satellites and to record data such as time, azimuth, elevation, and range. This data is used to create orbital element sets or state vectors that represent the observed position of the satellite. The observed position can then be compared with the predicted position. The dynamic models used for predicting satellite motion are not perfect; factors such as atmospheric density variation caused by unmodeled solar activity can cause the predicted position to gradually stray from the true position. The observations are used to correct the predicted trajectory so the network can continue to track the satellite. This process of using observations to correct and refine an orbit in an ongoing feedback loop is called catalog maintenance, and it continues as long as the satellite remains in orbit. Ideally, the process is automatic, with manual inter vention only required when satellites maneuver or get near to reentry due to atmospheric drag. Sometimes, however, more effort is required. For example, a sensor may encounter a satellite trajectory that does not correspond well to anything in the catalog. Such observations are known as partially correlated observations if they are somewhat close to a known orbit or uncorrelated observations (or uncorrelated tracks) if they are far from any known orbit. Also, if a satellite is not tracked for five days, it is placed on an attention list for manual intervention. In that case, an analyst will attempt to match the wayward satellite to one of these partially correlated or uncorrelated tracks. If that effort succeeds, then the element sets are updated, and the object is returned to automatic catalog maintenance. On the other hand, if the satellite cannot be matched to a partially correlated or uncorrelated track, the satellite information continues to age. If it reaches 30 days without a match, the satellite is placed on the lost list. Risk Prediction One of the most visible uses of the catalog is to warn about collision risks for active payloads. This function predicts potential close approaches three to five days in advance to allow time to plan avoidance maneuvers, if necessary. Unplanned maneuvers may disturb normal operations and deplete resources for future maneuvers, so one would like to have high confidence in the collision-risk predictions. The reliability of the predictions depends directly on the accuracy of the orbit calculation, which in turn depends on the quality and quantity of the tracking data, which is limited by the capability of the Space Surveillance Network. Simply put, there are not enough tracking resources in the network to achieve high-quality orbits for every object in the catalog. Furthermore, many smaller objects can only be tracked by the most sensitive radars, and this tracking is infrequent. Most objects in the catalog are considered debris, which can neither maneuver nor broadcast telemetry. On the other hand, some satellite operators depend exclusively on the satellite catalog to know where their satellites are, and users of the satellite orbital data depend on the catalog to know when the satellites will be within view. This situation creates a challenging problem in balancing Space Surveillance Network resources to support the collision-warning task (tracking as many potential hazards as possible) while also providing highly accurate support to operational satellites (tracking the spacecraft as precisely as possible). The practical solution is to perform collision risk assessment using a large screening radius to ensure no close approaches are missed despite lower-quality predictions. Once an object is identified as having a potentially close approach, then the tasking level is raised, with the expectation that more tracking data will be obtained to refine the collision risk calculations. When the danger has passed, the object reverts to a normal tracking level. Collisions and spontaneous breakups do happen. The first satellite breakup occurred on June 29, 1961, when residual fuel in an Ablestar rocket body exploded, creating 296 trackable pieces of debris. Since that time, there have been more than 200 satellite breakups, the most notable being the missile intercept of the Fengyun-1C satellite, which created more than 3300 trackable fragments. In most cases, these breakups are first detected by the phased-array radars in the Space Surveillance Network. When multiple objects are observed where only one was expected, the downstream sensors are alerted, but no tasking is issued because specific debris orbits are not yet established. Tracks are taken and tagged as uncorrelated. Analysts at JSpOC then attempt to link uncorrelated tracks from different sensors to form a candidate orbit. Subsequent tracking improves the orbit to the point that the object can be named and numbered and moved into the catalog for automatic maintenance.

#### Nuclear war.

Rogoway 15 (Tyler; November 12; Defense Journalist and Editor of Time Inc’s The War Zone; Jalopnik, “These Are The Doomsday Satellites That Detected The Explosion Of Metrojet 9268,” <https://foxtrotalpha.jalopnik.com/these-are-the-doomsday-satellites-that-detected-the-exp-1737434876>)

For over 50 years the Pentagon has had early warning satellites in orbit aimed at spotting launches of ballistic missiles, especially the big intercontinental kind that can fly around the globe in less than 30 minutes and bring about nuclear Armageddon. Recently, these satellites have made news for their “secondary capabilities,” spotting the downing of Metrojet Flight 9268 and Malaysian Airlines Flight 17. These are the shadowy satellites that are capable of such amazing feats, and an idea of how they work. In 1960, at the height of the Cold War and at the dawn of the space age, the first Missile Defense Alarm System (MiDAS) satellite was launched into low earth orbit. Six years later there was a constellation of nine of these satellites roaming the heavens, each scanning the Soviet Union for large infrared plumes, the tell-tale sign of a ballistic missile or rocket launch. These fairly crude, low-earth orbit satellites, along with the radar-based Ballistic Missile Early Warning System, would be the basis for a Cold War ballistic missile surveillance system that would become ever more complex and capable as the years went by. If ballistic missile launches were detected and deemed a threat, the decision to retaliate would mean the National Command Authority making the call to do so within half an hour, an act that could bring an the end of humanity’s reign on Earth, permanently. The first really reliable and full coverage space-based ballistic missile early warning capability came with the launch of the first Defense Support Program (DSP) satellite in 1970. These new satellites were much more capable than their MiDAS predecessors. Early DSP satellite design was relatively straight forward, with the satellites’ spinning around their center axis while in geosynchronous orbit. This allows their telescopic infrared sensor to continuously sweep an area of the planet in a relatively brief amount of time, around six times in one minute. If something were detected, the information would immediately be data-linked to controllers on the ground at the 460th Space Wing located at Buckley AFB in in Colorado. A total of 23 of these satellites have been launched over the program’s life, with constant upgrades made along the way. A DSP satellite was launched by the Space Shuttle on STS-44 in 1991, and the last one was launched by a Delta IV Heavy in 2007. Most famously, the Defense Support Program constellation of satellites were used to detect launches of SCUD missiles during Operation Desert Storm.

#### 2---Regionalization.

#### Orbital debris prevents regional space associations.

Gottschalk 16 (, K., Ngcofe, L. and S.Madlanga, 2016. THE SPACE RUSH – THE COST OF BEING A LATE STARTER FROM AN AFRICAN PERSPECTIVE. [online] africanremotesensing. Available at: <http://www.africanremotesensing.org/page-1524987/4136883> [Accessed 5 January 2022] Keith Gottschalk Department of Political Studies, University of the Western Cape, Cape Town, South Africa Luncedo Ngcofe Mr at Department of Rural Development and Land Reform S.Madlanga National Research Foundation: Hartebeesthoek Radio Astronomy Observatory.)-rahulpenu

Abstract

The costs of Africa being a late starter in space include the exponentially accumulating space debris. This threat to space assets is worse in low earth orbit (LEO), where it has already destroyed an Irridium operational US comsat.

The current discussions in international forums about mitigating the creation of new space debris, has not yet gone to the next stage to discuss financial liability for collisions caused by such debris. Late starters in space need to table the responsibility of the historic space powers to seek ways to remove their cumulative debris from orbit, and finance this.

Introduction

The ability to observe the Earth from space has enhanced accurate-up-to-date environmental monitoring, thus overcoming some of the environmental challenges experienced by humankind. Investment in space activities has endless, long term, benefits including diplomatic relations; technological advancement through collaboration with other countries; improving overall economic activities in the global arena, which in turn vastly contributes towards addressing social ills. Acknowledging this Chung et al., (2010) argues that where ground based systems are limited in frequency, continuity and coverage of important ecosystems, satellites can provide essential earth observation data on a continuous basis and over a range of scales, from local, regional, to global. Access to and the development of space technology has historically been a key determinant of a country’s wealth, power, influence, status and prestige. However, space exploration has been an issue of marginal political interest in Africa, thus leading the continent to be the late starter in space matters. Sharpe (2010) shows Africa as the least active continent with regards to space exploration activities. Aganaba-Jeanty (2013) cites a lack of consistent funding as the greatest barrier of the African space technology development. He argues that according to 2009 to 2012 the countries within Africa represent the lowest spending countries in space exploration when compared to developed and developing countries. Africa as a late starter in space might be seen through Abiodun (2012) words of wisdom starting that “the quality and character of a man’s perceptions as well as his subsequent responses are determined in part by limitations imposed by or opportunities available in his environment. If he is to manifest any real growth and reach his higher potentials, his creativity would need nourishment from his environment”. Currently there are recent strides documented in literature showing Africa’s growing interest and participation in space exploration (Ngcofe et al., 2013; Abiodun, 2012; Wood & Wiegel, 2012; Gottschalk, 2010; Martinez, 2008; Mostert, 2008). It is of this view that this paper attempts to examine the impact of being a late starter on space exploration, particularly looking at the issue of space debris and its potential impact on Africa as a developing space fearing nation.

Space debris

The current major threat of space exploration is the risk pertaining to space debris relative to the cost of launching satellites in space. The need to justify expenditure on space-related endeavours competes with other pressing expenditure needs such as provision of food, clean drinking water, housing, electricity, roads infrastructure and other commercial development. Space debris also known as orbital debris, or space junk, or space waste, is the collection of man-made objects that have exceeded its service life and broken down while in orbit around the earth (Interagency Report on Orbital Debris 2005; UN, 1999; Sénéchal, 2007; Colliot, 2002; Glassman, 2009; Griffiths, 2010). These include everything from spent rocket stages, old satellites, and fragments from disintegration erosion and collision. Space debris has vastly increased since the beginning of space travel in 1957 thus leading to orbit congestion (Colliot, 2012; Figure 2). According to NASA (2013), there are 500 000 pieces of debris tracked in orbit on Earth.

Collision at orbital velocity can be extremely dangerous to functioning satellites and space manned missions. Sénéchal (2007) argues that at orbital velocity of more than 28000 km/h, an object as small as 1 cm in diameter has enough kinetic energy to produce significant impact damage, to partially or completely destruct an operational satellite. While an object of 1mm size can cause surface pitting and erosion, with larger objects of about 10 cm totally destroying operational satellites, and may even kill space explorers. According to the Kessler Syndrome space debris model, as the number of debris object increases, collisions become more likely to occur thus creating yet more debris (Griffiths, 2010; Colliot, 2012; Durrieu & Nelson, 2013). This is an immense concern, which threatens safety of future space explorations. Though space is a large environment, satellites are actually concentrated in a few orbits that are currently optimal, namely:

Low Earth Orbit (LEO) – this is the altitude from 160 km to 2000 km above the earth’s surface. LEO is largely used for earth monitoring, military surveillance, and communication satellites, especially around 350 km.

Medium Earth Orbit (MEO) – this is an area from 2000 km to 35 000 km and is mainly used by navigation satellites such as global position system (GPS) networks at around 20 000 km.

Geostationary Orbit (GEO) – this is the belt at 36 000 km and is optimal for communication satellites. However, Griffiths (2010) argues that it is more expensive to launch satellites to this orbit. Hence, many communication satellites are placed at LEO.

High Earth Orbit (HEO) – This is the area above 36 000 km, and used almost only by satellites researching the magnetosphere or other solar-terrestrial physics.

LEO is regarded as the major used space orbit environment and therefore has a larger record of space debris than any other orbit. There has been four accidental collision events up-to-date (Durrieu and Nelson 2003), with a recent collision incident occurring in 2009 where a United States communication satellite collided with a defunct Russian satellite (Glassman, 2009; Griffiths, 2010; Smitham, 2010). These satellites collided at a speed of over 40 000 km/h, causing complete destruction of both satellites. Thus resulting in around 1400 recorded debris objects (Glassman, 2009; Griffiths, 2010; Smitham, 2010). The available computer models based on observation of debris used to predict future growth of the debris population and probability of collision with satellites under different assumptions reveal that in the next 40 years, collisions with objects larger than 10 cm in LEO are expected to occur on average every 5 years (Griffiths, 2010). This statistics coincide with Sénéchal (2007); Williamson (2003); Liou and Johnson (1996) who argued that in LEO the spatial density of objects is above critical point and the continuation of debris in this orbit may render it inaccessible in the future.

Space availability

The vulnerability of space asserts interference and disruption, led to the view, held by the USA security space community, that space is a contested domain. Whoever seizes space has a powerful advantage both for social and economic enhancement together with military applications (Sadeh, 2009). Space asserts provide a persistent view of the earth and offer ability of real or near real time global collection and dissemination of crucial information. Although, recently, there have been vast strides by Africa within the space arena, the continent still lags behind in space matters. Out of 53 countries in Africa, only four countries (Algeria, Egypt, Nigeria and South Africa) have successfully participated in space activities, through the development of their own space agencies which led to launching of their own satellites in space. The development of micro satellite technology and multiple constellations is now making space technology more affordable for developing countries to utilise the space environment (Durrieu & Nelson, 2013). Thus debate about the African Space Agency, which will cater for participation in space activities for Africa’s needs, is gaining momentum. Currently, Africa has an inspiring mission to the moon (http://africa2moon.developspacesa.org). With the vast interest in space activities by the African continent, one wonders, is there still space in space? Rex (1998) on his paper seeking to answer ‘will space run out of space’. He argues that there would be no major risk for space endeavours from current operational satellites only if it were not for space debris. The issue of space availability in space has been, and is still a major area of concern, more especially for Africa. Since the initial space exploration, the United Nations Committee on the Peaceful Uses of Outer Space (UNCOPOUS) was established in 1959 in order to safeguard the use of space and promote space sustainability. This resulted in five UN treaties on Outer Space (http://www.oosa.unvienna.org/oosa/COPUOS/copuos.html) namely:

Outer Space Treaty (1967) - This treaty promotes the international cooperation in the exploration and use of space, however, prohibits the usage of space for any nuclear weapons and / or any kind of weapons of mass destruction. It clearly emphasises that no state can claim sovereignty of or occupy outer space, the moon or any other Celestial Body. This treaty further deals with liability and states responsibility as to inform the UN secretary general and the international scientific community of the nature, conduct, location and results of their activities in outer space.

Rescue Agreement Treaty (1968) - This agreement deals with the rescue of astronauts, the return of astronauts and the return of objects launched into outer space. This agreement has a legal framework for emergency assistance of astronauts and the notification of launching of any space objects which has to return to earth and express who should be responsible for all the cost incurred for such a particular mission.

Liability Convention (1972) - This convention is a pact of international liability for damage caused by space objects. It imposes an international and absolute liability on a launching state, or states as well as on those states who are members of inter-governmental organisations, for any damage caused by their objects. Launching state is defined as the state which launches or procures the launching of a space object or from whose territory or facility a space object is launched, irrespective of the success or not of the launch. Damage includes the loss of life, personal injury or any other impairment or health or loss of damage to property of state or of persons, natural or juridical or property of international, intergovernmental organisations. This also applies to any damage caused by a space object on the surface of the earth or to an aircraft flight.

Registration Convention Treaty (1974) - The treaty obliges states to register all space objects in a register, which is maintained by the UN secretary general since 1962.

Moon Treaty (1979) - The treaty declares that the moon is a global common for all humankind and is not subject to national appropriation and occupation. It further stresses that no private ownership is allowed but all state parties have the right to exploration and use of the moon. In practice, this treaty has no force, because none of the space powers who engage in lunar exploration have ratified it: USA, Russia, China and India.

Although, these treaties exist there has been non-compliance by those leading space faring countries. Since the 1960s, the United States and Russia have conducted dozens of anti-satellite (ASAT) test missions in space, which resulted in most of orbital debris experienced even today (Weeden, 2013). Most recently China has performed an ASAT mission against its aging FY-1C weather satellite at 855 km altitude on the 11/01/2007. It launched a missile, which destroyed the satellite, resulting in 3000 pieces of debris larger than 10 cm in size (Glassman, 2009; Weeden, 2013). This event was further followed by the United States ASAT in 21/02/2008, firing a missile that destroyed one of its military satellites at around 250 km altitude. The US ascertained that the satellite was uncontrollably descending into the atmosphere with nearly fully fuelled tank of toxic hydrazine. Furthermore, its altitude was low enough to ensure swift re-entry of all the resulting space debris, and so, harmless to the space environment. The US delegate fully briefed the UN COPUOS unlike the Chinese. The outcome by the US in destroying its satellite is applaudable. However, ignorance has been shown by the former President George W. Bush when asked what would the people say about the mission? He said “I don’t care what people will say. We’re doing it for the right reason, and it’s transparent” (Oberg, 2008). These clearly are signs of bullying with regard to space matters by space powers with advanced space technologies.

Conclusion

The act of destroying a satellite can damage the space environment by creating dangerous amounts of space debris. Space debris can, therefore, lead to collisions and loss of important satellites, which has tremendous cost effects for Africa’s participation in space activities. Losing a satellite in-orbit due to space debris is no longer hypothetical, but rather a harsh reality and is likely to increase with years to come (Smitham, 2010). Grego (2014) argues that deliberate space debris creation might result in conflict between space fearing nations with unpredictable and dangerous consequences. Such consequences might trigger an arms race which would further divert the economic and political resources from other pressing issues like food security, climate change, health issues, etc. The need to sustain benefits of space for present and future generations and other countries that have not explored space as yet is vital if we are to obtain continuous benefits from space activities. Glassman (2009) suggests that a number of activities and commitments need to be revitalised. Current space best practice, also termed rules of the road, seek to minimize causing new space debris, through careful revision of both design and operational protocols:

· Separation of satellites from their carrier rocket should no longer result in loose bolts and other metal pieces flying off;

· satellites should have some propulsion capability to initiate collision avoidance manoeuvres;

· at the end of their service life, satellites, especially those in geosynchronous orbit (GSO), should be manoeuvred into a “graveyard orbit” at a different altitude;

· and valves should open to discharge any remaining propellant, to prevent overheating and explosive disruptions.

#### Regional space assets are key to cooperation and preventing power conflicts.

Liao 15 (, X., 2015. The Growing Space Regionalization of the Global Space Regime Complex. [online] The Aviation & Space Journal. Available at: <https://www.academia.edu/30520492/The\_Growing\_Space\_Regionalization\_of\_the\_Global\_Space\_Regime\_Complex> [Accessed 5 January 2022] Li-Wen Liao received his PhD from Ghent Institute for International Studies (GIIS), now Ghent Institute for International and European Studies (GIES), Ghent University. His main research focused are international space politics and global space governance. He has published two books, The Regime Complex of Global Space Complex - The International space politics of the 21st Century (2016 in English) and Space Policy, International Politics and Global Governance (2019 in Chinese). The growing regional space cooperation activities and the accelerated strategic space regionalisation are his current studying focuses. In parallel to his academic endeavours, conducting policy research projects for countries’ public services, space sector and research institutes are the services he offers to fulfil his scholarly social economic responsibilities. Regularly he is involved in the international expert groups for sharing his advices to improve national and international space policy and governance. Li-Wen Liao is currently a Guest Researcher at the NCKU R&D Foundation, National Cheng Kung University (NCKU) in Tainan, Taiwan.)

Dynamics of regional astropolitics

Regional spacefaring countries often seek to demonstrate their regional leadership, or to ensure the regional power - balance equilibrium by creating a regional space - related regime under their cooperative supremacy. In order to counter their political adver-saries and strategic competitors in the same geographical region, these regional space regimes provide technological facilities and space applications incentives to involve neighbouring allies into the interdependency of a regional space system. These region-al space regimes determine what would be the centralities for the cooperation net-works. They set up norms, rules or practical arrangements for security, safety, com-mercial and ecological cooperation. When one regional space power starts up a space regionalism process, the other regional powers will duplicate the same action to counter it. Quite often, space regionalism of this kind might not aim to enhance substan-tial regional space cooperation, but aims to counter other space regionalization initia-tives led by other spacefaring countries in the same region. In practice, these regional regimes offer cooperation incentives that are similar to what their counterpart organi-zations offers in order not to loose the overlapping member states that are affiliated with the competing regional space regimes. But, these regional space regimes normal-ly only provide vital exclusive cooperation projects to satisfy the loyal allies who stand historically, ideologically or culturally on the same side of the leading space power. The regional space leaders cautiously release any critical technology or know - how if they are unsure about the possible fair return from or possible leaks lamed by their protégés.

An example, which demonstrates that the dynamics of regional astropolitics sparked duplicate space regionalization processes led by adversary or competitive regional spacefaring states occurred in the 1970s among the Arab League states. In principle, it would be perfect if a unique Arab regional satellite system regulatory and cooperation mechanism can be established in order to efficiently coordinate national satellite communication frequency attribution, avoid transnational radio signal interference, and to disseminate a pooled satellite TV and radio broadcasting program gathered from different Arabic - speaking states for the benefits of the entire Arab League states. But the reality was, when Saudi Arabia was arising during the 1970s oil boom and Egypt endured the subsequent expulsion from the Arab League following its 1979 peace treaty with Israel, the competing space regionalism between Egypt and Saudi Arabia has led to the consequence that the Cairo - led Arab States Broadcasting Union (ASBU) created in the 1960s was heavily challenged by the Riyadh - led Arab Satellite Communication Organization (ARABSAT) founded in 1970s. The two regional satellite related operations organizations, which shared the overlapping membership of the Arab League states, could hardly work together. Further to the ASBU - ARABSAT com-petitive regionalization story in the 1970s, it occurred recently that competition be-tween the Japan - led APRSAF and the China - led APSCO, and perhaps soon the neces-sary addition of an India - led SAARC satellite network, are vying for leading a regional-ism of their own in the Asia - Pacific region. The different regional space regimes with overlapping objectives and membership are created based on the competition be-tween the leading regional spacefaring states. Since the functioning of these regional regimes is highly connected to the regional astropolitics, the regional member states will choose their affiliation by pragmatism to fulfil their own short - term interests, noted as ‘ regime shopping ’. In the case of APRSAF vs. APSCO, the overlapping member states are mostly from the ASEAN countries. These countries take part in both regional space regimes but only pick the issue - relevant cooperation, which fits their respective national interest instead of being fully engaged into any regional astropolitical strate-gic interdependency.

The quest for regional space capacity - building

The collective quest for developing common regional space capacity or a specific or exclusive regional space system ( e.g. for satellite TV and radio broadcasting, disaster mitigation, navigation safety, and Earth Observation) can also stimulate and nourish space regionalisation. The regionalisation is therefore undertaken with actors ’ func-tional or cost - benefit logic. By knowing the fact that developing space capacity and upholding it is an expensive and highly risky business, there is no country, even not the US that can handle it alone. Pooling different material or immaterial resources to de-velop regional space capacity doubtlessly becomes the optimal and legitimate strate-gy for collective and individual prosperity and benefits. Since the space ‘ democratization ’ after the Cold War, emergent industrial countries and developing continents have various ways to continue or to start up their own space capacity. Hence, they are all keen to enjoy the utilities of space technology applications for military, civil or dual - use.

The path of the European space regionalization in pursuit of its collective prosperity and common benefits was a well - known example. Europe started its space regionaliza-tion from the early 1960s by having established two different space agencies. The Eu-ropean Launch Development Organisation (ELDO) to develop a European launcher sys-tem with six member states and one associate member. The other, the European Space Research Organisation (ESRO) with 10 members was created to develop Europe-an spacecraft. Soon after, the ELDO and the ESRO were merged to become the Euro-pean Space Agency (ESA) in 1964. It was only in 1975 the ESA formally and operation-ally replaced the two organisations. One of the reasons for that the European states explored a regional space institutional centrality, such as the ELDO, ESRO and ESA, were based on the aforementioned strategic and functional logics for their respective national interests. These regional space institutions gradually created a interdepend-ent space network which gathered the crucial space capability elements among the intra - regional partners and facilitate the member states to exchange resources, rein-force their own national space capability, share financial burdens and reduce the risks of marketing failure. Additionally, the space regionalization has strengthened European regional political and economic position to on the one hand, reduce the dependen-cy on the US space capacity. It offered the leverage to allow Europe to explore possi-ble space cooperation with the Soviet Union. Until now, the European space regionali-zation is subsequently viewed as the most inspiring model and was duplicated by other regional spacefaring countries that also try to create their respective space regionali-zation.

Another case was the ARABSAT, the ARABSAT established in 1976 was dedicated to answers the regional request for providing satellite services in order to facilitate tele-communication, promote common culture and education programs in the light of the commitments of the Arab League Charter member states. The ARABSAT became the major regional space mechanism for the Arab League member states to coordinate satellite industries and services operators. Similarly, the enthusiast initiatives and debates about a start - up of an expected Latin - American Space Agency (LASA) (Monroy 2010) 10 and the recent kick - off of the 1 st Latin American Satellite Communication and Broadcasting Summit ( Space Mart 2014) 11 , an ASEAN Space Organization (ASO) (Noichim) 12 , or an African Space Agency (ASA) (Martinez 2012 13 ; Aganaba - Jeanty 2013 14 ) took place constantly. These space regionalism initiatives mostly stress indigenous regional space capacity building. Yet, due to a lack of a strong spacefaring nation to continuously lead and carry on these space regionalization initiatives, concrete start - up hardly takes off. In these cases, extra - regional assistance is expected to bring suit-able technology and sufficient means, but this causes worries of triggering an unex-pected regional astropolitics reshuffle that can destabilize the equilibrium of the en-tire regional homo astro ecosystem.

In the Asia - Pacific region, the Japan - led APRSAF and the China - led APSCO are both committed to establish a regional space technology cooperative regime for their over-overlapping Asia - Pacific member states. The APRSAF, claimed as a voluntary regional space agency cooperation mechanism, aims to lead a long - term and mid - term space capacity building regionalization throughout space science and technology coopera-tion activities though the Japanese Space Basic Law, approved by the two Parlia-ments in 2005, explicitly states that ‘ space diplomacy ’ is one of the objectives that Japan shall integrate into its future national space policy. The APSCO, particularly after the launch of the Chinese Beidou (COMPASS) Satellite Navigation System, pro-motes APSCO regional partners e.g. Thailand, Pakistan (and it is expected other ASEAN states) to share the benefits of China ’ s satellite navigation system by hosting the ground network facilities in their territories. Until now, the question whether these two regional space regimes could respond to the quest for regional space ca-pacity needs further observation, particularly since the India - led South Asian Associa-tion of Regional Cooperation (SAARC) ( The Times of India 2014) 15 seems also enthusi-astic to gain the regional space leadership by exploring the similar method with a South Asian approach for proposing a tentative SAARC Satellite Service project.

Necessity of regional space governance

Nowadays, it occurs that the neighbouring states develop their own space systems for national satellite telecommunication, weather monitoring, TV and radio broadcast-ing, and navigation services for military or civil utilities. Subsequently, these systems are not compatible due to the blockage based on the national security concerns or simply caused by technical incompatibility. Throughout the regionalisation process, states negotiate common measures, such as regulations, standards, tariffs, and inter-ference avoidance rules for heterogeneous national space systems within a given geo-graphical region. Especially nowadays, the growing commercialization of space tech-nology for its design, manufacture, launch and operations and its application for tele-communication, TV and radio broadcasting, remote sensing and navigation are in-creasingly taking more ground, the quest of establishing regional common conduct rules and operational standards become more and more important. The necessity for institutionalise such regional space governance architecture is doubtless uncontested. These space regimes are created to respond to these specific needs. Yet, whether the design as well as the perfection path for building any regional space regimes de-pends on whether the desired regime meets its member states ’ strategic calculation and functional concerns. This often made the managerial manoeuvre of a given space regionalisation more complicate and complex.

The aforementioned Arab Satellite Communications Organization (ARABSAT since 1976) that established an Arab Space Communication network, the Asia - Pacific Broad-casting Union (ABU since 1964) - a regional platform for national TV and radio broad-casters (which are mostly state - owned at least from their staring period) the Asia Pacific regional – set up the ABU Emergency Warning Broadcasting Systems (EWBS) to disseminate information to alert people of neighbouring countries before a disaster occurs. Together with ARABSAT and ABU the Regional African Satellite Communica-tions Organization (RASCOM) were all created for the reason of regional space gov-ernance in Africa, and are examples of the space regionalization for improving re-gional space governance. To enable this space governance regionalization, the parties of a regional group seemingly need to posses similar space capacities and the willing-ness to share a common development strategy. Nowadays, as the commercialization of all development steps of satellite technology (production, launch and operations) and all utilities of satellite technology applications (communication, broadcasting, remote sensing and navigation) are growingly taking more ground, which increasingly the quests of coordinating common regional conduct rules and operational standards may become more important but will also become more complex.

Extra - regional inputs

Apart from the intra - regional inputs, the inputs from the extra - regional dimension also offer sounding influences in sparking and to fuelling the rise of space regionalisa-tion. These extra - regional inputs can be perceived from three dimensions of the glob-al space regime complex: (1) the stimuli from extra - regional space powers, (2) the inspiration other regionalisation from other regionalisation ( mirror effect ), and (3) the endorsement from global space related regimes. It is important to state that never a single one of these inputs but always a mix of them results in the activation and the growth of these space regionalisation processes in different regions.

Space powers ’ stimulation

The stimuli from extra - regional space powers, namely from the US, Russia and nowa-days China, India or others, are centripetal forces that congregate various new regional space centralities. These space powers, with their crucial technology know - how and financial supports, push to institutionalise a regional space centrality is either to en-hance their ties with the extent allies, make new friends or attract new followers from non - spacefaring countries in a given region. This outreach toward the regional level is supposed to increase the respective space power ’ s political and strategic in-fluences on both regional and global astropolitics. It is also commercially interesting for the space powers to conquer foreign regional markets more efficiently. As for the choice where to do such space power stretch exercises, it depends on every space power ’ s geopolitical concerns and strategic interests. Furthermore, while sponsoring a given space regionalisation, the space powers do not provide full space capacity assis-tance and do not offer it for free neither. The attractive incentives for the accommodating countries for having and keeping the deals are often accompanied with strict conditions.

The U.S. has supported most of their allies in the Western European and Asia - Pacific regions by sharing American space technologies, know - how , as well providing finan-cial aid to the regional leading states for building their space capacities, though often through bilateral cooperation channel. This bilateral cooperation has indirectly facili-tated the foundation of space regionalization. While building these strategic space interdependencies, Washington usually requires the beneficiary states of American space system and products to behave strictly under the US International Traffic in Arms Regulations (ITAR). The ITAR has unilateral power to decide whether a piece of technology can be sold to the US allies or interested states or companies, but it can also sanction the contractor if contracted project is leaked to a third party. Conse-quently, European states were somehow pushed to seek their independency or at least non - dependency from the US, and therefore wanted to create their own regional space cluster. The Soviet Union was doing the same during the Cold War by forcing the Eastern European socialist states into a closer regional space community. Finally, whether a targeted region has political desires and adequate capacity to host and develop a given space regionalisation sponsored by extra - regional space powers has no co - relationship to the efforts provided by the space powers. The former Soviet Union has incorporated the Eastern European socialist states into a closer regional space community. These days, Russia is doing it again with the Eurasia states via the space related regional cooperation, such as the Russia - Kazakhstan - Belarus formed Eurasia Economic Union (EEU). Russia also claimed to study Armenia ’ s capacity of using space for peaceful purposes under the Russia - Armenia cooperation framework in scientific, technical and industrial areas. However, after the Russia - Ukraine stand-off, Russia cessed the longstanding space cooperation with Ukraine ( Space News 2015) 16 . With a strong geopolitical mind - set, Africa, Latin America, ASEAN and Central Asia became nowadays the new power playground for the US, Russia and China to bid for allies or followers. In this circumstance, non - spacefaring states from a given re-gions often undertake the practice of ‘ regime shopping ’ (Keohane & Victor 2011) by opting the most advantageous regimes in accordance to their functional interests and preferences to gain beneficial issue linkages. The stimuli from the space powers are valuable to help the space regionalization. Yet, it can hardly be the only factor to lead such processes to its final goal.

#### Goes nuclear.

Gallagher 15 “Antisatellite warfare without nuclear risk: A mirage” <http://thebulletin.org/space-weapons-and-risk-nuclear-exchanges8346> (interim director of the Center for International and Security Studies in Maryland, previous Executive Director of the Clinton Administration’s CTBT Treaty Committee, an arms control specialist at the State Dept., and a faculty member at Wesleyan)//Elmer

In recent decades, however, as space-based reconnaissance, communication, and targeting capabilities have become integral elements of modern military operations, strategists and policy makers have explored whether carrying out antisatellite attacks could confer major military advantages without increasing the risk of nuclear war. In theory, the answer might be yes. In practice, it is almost certainly no. Hyping threats. No country has ever deliberately and destructively attacked a satellite belonging to another country (though nations have sometimes interfered with satellites' radio transmissions). But the United States, Russia, and China have all tested advanced kinetic antisatellite weapons, and the United States has demonstrated that it can modify a missile-defense interceptor for use in antisatellite mode. Any nation that can launch nuclear weapons on medium-range ballistic missiles has the latent capability to attack satellites in low Earth orbit. Because the United States depends heavily on space for its terrestrial military superiority, some US strategists have predicted that potential adversaries will try to neutralize US advantages by attacking satellites. They have also recommended that the US military do everything it can to protect its own space assets while maintaining a capability to disable or destroy satellites that adversaries use for intelligence, communication, navigation, or targeting. Analysis of this sort often exaggerates both potential adversaries’ ability to destroy US space assets and the military advantages that either side would gain from antisatellite attacks. Nonetheless, some observers are once again advancing worst-case scenarios to support arguments for offensive counterspace capabilities. In some other countries, interest in space warfare may be increasing because of these arguments. If any nation, for whatever reason, launched an attack on a second nation's satellites, nuclear retaliation against terrestrial targets would be an irrational response. But powerful countries do sometimes respond irrationally when attacked. Moreover, disproportionate retaliation following a deliberate antisatellite attack is not the only way in which antisatellite weapons could contribute to nuclear war. It is not even the likeliest way. As was clearly understood by the countries that negotiated the Outer Space Treaty, crisis management would become more difficult, and the risk of inadvertent deterrence failure would increase, if satellites used for reconnaissance and communication were disabled or destroyed. But even if the norm against attacking another country’s satellites is never broken, developing and testing antisatellite weapons still increase the risk of nuclear war. If, for instance, US military leaders became seriously concerned that China or Russia were preparing an antisatellite attack, pressure could build for a pre-emptive attack against Chinese or Russian strategic forces. Should a satellite be struck by a piece of space debris during a crisis or a low-level terrestrial conflict, leaders might mistakenly assume that a space war had begun and retaliate before they knew what had actually happened. Such scenarios may seem improbable, but they are no more implausible than the scenarios that are used to justify the development and use of antisatellite weapons.

#### Nuclear war causes extinction -- counter-forcing is impossible

Steven Starr, 6/11/2014 (the Senior Scientist for Physicians for Social Responsibility and Director of the Clinical Laboratory Science Program at the University of Missouri. Starr has published in the Bulletin of the Atomic Scientists and the Strategic Arms Reduction (STAR) website of the Moscow Institute of Physics and Technology; “There Can be No Winners in a Nuclear War”, <https://truthout.org/articles/there-can-be-no-winners-in-a-nuclear-war/>) Ngong

Nuclear war has no winner. Beginning in 2006, several of the world’s leading climatologists (at Rutgers, UCLA, John Hopkins University, and the University of Colorado-Boulder) published a series of studies that evaluated the long-term environmental consequences of a nuclear war, including baseline scenarios fought with merely 1% of the explosive power in the US and/or Russian launch-ready nuclear arsenals. They concluded that the consequences of even a “small” nuclear war would include catastrophic disruptions of global climate and massive destruction of Earth’s protective ozone layer. These and more recent studies predict that global agriculture would be so negatively affected by such a war, a global famine would result, which would cause up to 2 billion people to starve to death. These peer-reviewed studies – which were analyzed by the best scientists in the world and found to be without error – also predict that a war fought with less than half of US or Russian strategic nuclear weapons would destroy the human race. In other words, a US-Russian nuclear war would create such extreme long-term damage to the global environment that it would leave the Earth uninhabitable for humans and most animal forms of life. A recent article in the Bulletin of the Atomic Scientists, “Self-assured destruction: The climate impacts of nuclear war,” begins by stating: “A nuclear war between Russia and the United States, even after the arsenal reductions planned under New START, could produce a nuclear winter. Hence, an attack by either side could be suicidal, resulting in self-assured destruction.” In 2009, I wrote “Catastrophic Climatic Consequences of Nuclear Conflicts” for the International Commission on Nuclear Non-proliferation and Disarmament. The article summarizes the findings of these studies. It explains that nuclear firestorms would produce millions of tons of smoke, which would rise above cloud level and form a global stratospheric smoke layer that would rapidly encircle the Earth. The smoke layer would remain for at least a decade, and it would act to destroy the protective ozone layer (vastly increasing the UV-B reaching Earth) as well as block warming sunlight, thus creating Ice Age weather conditions that would last 10 years or longer. Following a US-Russian nuclear war, temperatures in the central US and Eurasia would fall below freezing every day for one to three years; the intense cold would completely eliminate growing seasons for a decade or longer. No crops could be grown, leading to a famine that would kill most humans and large animal populations. Electromagnetic pulse from high-altitude nuclear detonations would destroy the integrated circuits in all modern electronic devices, including those in commercial nuclear power plants. Every nuclear reactor would almost instantly meltdown; every nuclear spent fuel pool (which contain many times more radioactivity than found in the reactors) would boil off, releasing vast amounts of long-lived radioactivity. The fallout would make most of the US and Europe uninhabitable. Of course, the survivors of the nuclear war would be starving to death anyway. Once nuclear weapons were introduced into a US-Russian conflict, there would be little chance that a nuclear holocaust could be avoided. Theories of “limited nuclear war” and “nuclear de-escalation” are unrealistic. In 2002 the Bush administration modified US strategic doctrine from a retaliatory role to permit preemptive nuclear attack; in 2010, the Obama administration made only incremental and miniscule changes to this doctrine, leaving it essentially unchanged. Furthermore, Counterforce doctrine – used by both the US and Russian military – emphasizes the need for preemptive strikes once nuclear war begins. Both sides would be under immense pressure to launch a preemptive nuclear first-strike once military hostilities had commenced, especially if nuclear weapons had already been used on the battlefield. Both the US and Russia each have 400 to 500 launch-ready ballistic missiles armed with a total of at least 1800 strategic nuclear warheads, which can be launched with only a few minutes warning. Both the US and Russian Presidents are accompanied 24/7 by military officers carrying a “nuclear briefcase,” which allows them to transmit the permission order to launch in a matter of seconds. Yet top political leaders and policymakers of both the US and Russia seem to be unaware that their launch-ready nuclear weapons represent a self-destruct mechanism for the human race. For example, in 2010, I was able to publicly question the chief negotiators of the New START treaty, Russian Ambassador Anatoly Antonov and (then) US Assistant Secretary of State Rose Gottemoeller, during their joint briefing at the UN (during the Non-Proliferation Treaty Review Conference). I asked them if they were familiar with the recent peer-reviewed studies that predicted the detonation of less than 1% of the explosive power contained in the operational and deployed US and Russian nuclear forces would cause catastrophic changes in the global climate, and that a nuclear war fought with their strategic nuclear weapons would kill most people on Earth. They both answered “no.” More recently, on April 20, 2014, I asked the same question and received the same answer from the US officials sent to brief representatives of the NGOS at the Non-Proliferation Treaty Preparatory Committee meeting at the UN. None of the US officials at the briefing were aware of the studies. Those present included top officials of the National Security Council. It is frightening that President Obama and his administration appear unaware that the world’s leading scientists have for years predicted that a nuclear war fought with the US and/or Russian strategic nuclear arsenal means the end of human history. Do they not know of the existential threat these arsenals pose to the human race . . . or do they choose to remain silent because this fact doesn’t fit into their official narratives? We hear only about terrorist threats that could destroy a city with an atomic bomb, while the threat of human extinction from nuclear war is never mentioned – even when the US and Russia are each running huge nuclear war games in preparation for a US-Russian war. Even more frightening is the fact that the neocons running US foreign policy believe that the US has “nuclear primacy” over Russia; that is, the US could successfully launch a nuclear sneak attack against Russian (and Chinese) nuclear forces and completely destroy them. This theory was articulated in 2006 in “The Rise of U.S. Nuclear Primacy,” which was published in Foreign Affairs by the Council on Foreign Relations. By concluding that the Russians and Chinese would be unable to retaliate, or if some small part of their forces remained, would not risk a second US attack by retaliating, the article invites nuclear war. Colonel Valery Yarynich (who was in charge of security of the Soviet/Russian nuclear command and control systems for 7 years) asked me to help him write a rebuttal, which was titled “Nuclear Primacy is a Fallacy.” Colonel Yarynich, who was on the Soviet General Staff and did war planning for the USSR, concluded that the “Primacy” article used faulty methodology and erroneous assumptions, thus invalidating its conclusions. My contribution lay in my knowledge of the recently published (in 2006) studies, which predicted even a “successful” nuclear first-strike, which destroyed 100% of the opposing side’s nuclear weapons, would cause the citizens of the side that “won” the nuclear war to perish from nuclear famine, just as would the rest of humanity.

#### 3---China War.

Zenko 14 (, M., 2014. Dangerous Space Incidents. [online] Council on Foreign Relations. Available at: <https://www.cfr.org/report/dangerous-space-incidents?sp\_mid=45655631&sp\_rid=emFjay5iZWF1Y2hhbXBAZ21haWwuY29tS0> [Accessed 5 January 2022] Micah Zenko is an American political scientist. He is Whitehead Senior Fellow on the US and Americas Programme at Chatham House. He is author of two books.)-rahulpenu

A January 2007 direct ascent ASAT test carried out by China against its defunct Fengyun-1C weather satellite instantly increased the amount of space debris in low earth orbit (LEO) by 40 percent. **Debris** is especially **problematic** **in** **LEO**, where half of the world's 1,100 active satellites operate. Space objects—even flecks of paint—travel as fast as eighteen thousand miles per hour and can cause **catastrophic** **damage** to manned and unmanned spacecraft—creating even more debris in the process. The U.S. National Research Council estimates that portions of LEO have reached a "**tipping** **point**," with hundreds of thousands of space debris larger than one centimeter stuck in orbit that will collide with other pieces of debris or spacecraft, thus creating **exponentially** **more** **debris**. Significant growth in the quantity or density of space debris could **render** certain high-demand portions of outer **space** **unnavigable** and inutile. Currently, there are no legal or internationally accepted means for removing existing debris.

China could also test co-orbital antisatellite systems in which an interceptor spacecraft destroys its target by exploding in close proximity, creating even more debris. For several years, Beijing has conducted a series of close proximity maneuvers with its satellites in LEO; the most recent occurred after a July 20, 2013, launch of three satellites on the same rocket, which have since conducted sudden maneuvers toward other Chinese satellites. Human or operating errors during these maneuvers could inadvertently result in a collision that produces harmful debris. While these maneuvers could eventually be used for civilian purposes, most U.S. officials believe these experiments are primarily intended to demonstrate latent ASAT capabilities.

An ASAT test that causes **unintended** **damage** **to** U.S. and ally **satellites** **or** an **accident** in space caused by debris could **trigger** a **major** international **crisis** between the United States and China. The **risk** is **heightened** **by** the fact that both countries have **no** **pre**–**space**-**launch** **notification** **arrangements**, similar to the U.S.-Russia agreement on notifications of intercontinental ballistic missile (ICBM) and submarine-launched ballistic missile (SLBM) launches. **Management** of such a crisis could also be **hindered** by a lack of direct communication between U.S. authorities and the PLA agency that oversees Chinese military space launches.

#### Miscalc goes nuclear.

Kulacki 16 — Gregory Kulacki, China Project Manager in the Global Security Program at the Union of Concerned Scientists, former Associate Professor of Government at Green Mountain College, former Director of External Studies at Pitzer College, former Director of Academic Programs in China for the Council on International Educational Exchange, holds a Ph.D. in Political Theory from the University of Maryland-College Park, holds graduate certificates in Chinese Economic History and International Politics at Fudan University (Shanghai), 2016 (“The Risk of Nuclear War with China: A Troubling Lack of Urgency,” Union of Concerned Scientists, May, Available Online at <http://www.ucsusa.org/sites/default/files/attach/2016/05/Nuclear-War-with-China.pdf>, Accessed 06-28-2016)

No Technical Exit

As long as both sides remain committed to pursuing technical solutions to their unique strategic problems, they are condemned to continue competing indefinitely. But stalemate is not a stable outcome; rather, it is a perpetual high-wire act. Twenty-four hours a day, 365 days a year, the governments of the United States and China are a few poor decisions away from starting a war that could escalate rapidly and end in a nuclear exchange.

Lack of mutual trust and a growing sense that their differences may be irreconcilable incline both governments to continue looking for military solutions—for new means of coercion that help them feel more secure. Establishing the trust needed to have confidence in diplomatic resolutions to the disagreements, animosities, and suspicions that have troubled leaders of the United States and the PRC for almost 70 years is extremely difficult when both governments take every new effort to up the technological ante as an act of bad faith.

The bilateral dialogues on strategic stability aim to manage the military competition, but they do not seek to end it. Although the two governments work very hard at avoiding conflict, they have yet to find a way out of what Graham Allison called their “Thucydides trap”—the risk of conflict between a rising power and an established power invested in the status quo (Allison 2015). Allison’s warning not to minimize the risks of war is sage advice, even if he does not say how the United States and China can escape the trap he describes. [end page 8]

PRC leaders believe it is possible to prosecute a major war without risking a U.S. nuclear attack. The leaders of the United States believe stopping the PRC from prosecuting such a war may depend, in certain contingencies, on a credible threat to use nuclear weapons—a threat U.S. leaders state they are prepared to execute. These mismatched perceptions increase both the possibility of war and the likelihood it will result in the use of nuclear weapons.

Well-informed U.S. officials tend to dismiss the possibility that the United States and the PRC could wander into a nuclear war. For example, Admiral Dennis Blair, a former Director of National Intelligence whose final military post was Commander in Chief of the U.S. Pacific Command, assured a large gathering of U.S. arms-control experts that “the chances of a nuclear exchange between the United States and China are somewhere between nil and zero.” J. Stapleton Roy, a former U.S. ambassador to the PRC, wholeheartedly agreed (Swaine, Blair, and Roy 2015). Similarly, PRC military strategists and arms control experts believe that the risk of nuclear war with the United States is not an urgent concern even if that risk may not be zero (Cunningham and Fravel 2015).

This lack of urgency is troubling. For example, the United States reportedly told the PRC it would risk military escalation to prevent or stop a proposed PRC island reclamation project in the Scarborough Shoal (Cooper and Douglas 2016). The PRC reportedly responded by committing to move ahead with the project later in 2016 (Chan 2016). This particular contest of wills is part of a steadily increasing number of unresolved diplomatic spats that have escalated to the level of overt military posturing reminiscent of U.S.-Soviet jousting during the Cold War.

The United States and the PRC are decades-old enemies, preparing for war and armed with nuclear weapons. Good faith efforts by the leaders of both nations have failed to stop accelerating preparations for war, including new investments in their nuclear forces. Miscommunication, misunderstanding, or poor judgment could spark a conflict that both governments may find difficult to stop.

War between the United States and the People’s Republic of China is not inevitable, but failing to acknowledge the risks is certain to make it more likely. Both governments should confront these risks with a greater sense of purpose. Only then will they devote the same measure of creativity, effort, and resources to the diplomacy of reducing those risks as they now spend preparing for war.

**1AC---Framework**

**The standard is maximizing expected well-being. – we will spec – Hedonistic act Utilitarianism**

**Prefer:**

**Pleasure and pain are intrinsic value and disvalue**

**Blum et al. 18**

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**Pleasure** is not only one of the three primary reward functions but it also **defines reward.** As homeostasis explains the functions of only a limited number of rewards, the principal reason why particular stimuli, objects, events, situations, and activities are rewarding may be due to pleasure. This applies first of all to sex and to the primary homeostatic rewards of food and liquid and extends to money, taste, beauty, social encounters and nonmaterial, internally set, and intrinsic rewards. Pleasure, as the primary effect of rewards, drives the prime reward functions of learning, approach behavior, and decision making and provides the **basis for hedonic theories** of reward function. We are attracted by most rewards and exert intense efforts to obtain them, just because they are enjoyable [10]. Pleasure is a passive reaction that derives from the experience or prediction of reward and may lead to a long-lasting state of happiness. The word happiness is difficult to define. In fact, just obtaining physical pleasure may not be enough. One key to happiness involves a network of good friends. However, it is not obvious how the higher forms of satisfaction and pleasure are related to an ice cream cone, or to your team winning a sporting event. Recent multidisciplinary research, using both humans and detailed invasive brain analysis of animals has discovered some critical ways that the brain processes pleasure [14]. Pleasure as a hallmark of reward is sufficient for defining a reward, but it may not be necessary. A reward may generate positive learning and approach behavior simply because it contains substances that are essential for body function. When we are hungry, we may eat bad and unpleasant meals. A monkey who receives hundreds of small drops of water every morning in the laboratory is unlikely to feel a rush of pleasure every time it gets the 0.1 ml. Nevertheless, with these precautions in mind, we may define any stimulus, object, event, activity, or situation that has the potential to produce pleasure as a reward. In the context of reward deficiency or for disorders of addiction, homeostasis pursues pharmacological treatments: drugs to treat drug addiction, obesity, and other compulsive behaviors. The theory of allostasis suggests broader approaches - such as re-expanding the range of possible pleasures and providing opportunities to expend effort in their pursuit. [15]. It is noteworthy, the first animal studies eliciting approach behavior by electrical brain stimulation interpreted their findings as a discovery of the brain’s pleasure centers [16] which were later partly associated with midbrain dopamine neurons [17–19] despite the notorious difficulties of identifying emotions in animals. Evolutionary theories of pleasure: The love connection BO:D Charles Darwin and other biological scientists that have examined the biological evolution and its basic principles found various mechanisms that steer behavior and biological development. Besides their theory on natural selection, it was particularly the sexual selection process that gained significance in the latter context over the last century, especially when it comes to the question of what makes us “what we are,” i.e., human. However, the capacity to sexually select and evolve is not at all a human accomplishment alone or a sign of our uniqueness; yet, we humans, as it seems, are ingenious in fooling ourselves and others–when we are in love or desperately search for it. It is well established that modern biological theory conjectures that **organisms are** the **result of evolutionary competition.** In fact, Richard Dawkins stresses gene survival and propagation as the basic mechanism of life [20]. Only genes that lead to the fittest phenotype will make it. It is noteworthy that the phenotype is selected based on behavior that maximizes gene propagation. To do so, the phenotype must survive and generate offspring, and be better at it than its competitors. Thus, the ultimate, distal function of rewards is to increase evolutionary fitness by ensuring the survival of the organism and reproduction. It is agreed that learning, approach, economic decisions, and positive emotions are the proximal functions through which phenotypes obtain other necessary nutrients for survival, mating, and care for offspring. Behavioral reward functions have evolved to help individuals to survive and propagate their genes. Apparently, people need to live well and long enough to reproduce. Most would agree that homo-sapiens do so by ingesting the substances that make their bodies function properly. For this reason, foods and drinks are rewards. Additional rewards, including those used for economic exchanges, ensure sufficient palatable food and drink supply. Mating and gene propagation is supported by powerful sexual attraction. Additional properties, like body form, augment the chance to mate and nourish and defend offspring and are therefore also rewards. Care for offspring until they can reproduce themselves helps gene propagation and is rewarding; otherwise, many believe mating is useless. According to David E Comings, as any small edge will ultimately result in evolutionary advantage [21], additional reward mechanisms like novelty seeking and exploration widen the spectrum of available rewards and thus enhance the chance for survival, reproduction, and ultimate gene propagation. These functions may help us to obtain the benefits of distant rewards that are determined by our own interests and not immediately available in the environment. Thus the distal reward function in gene propagation and evolutionary fitness defines the proximal reward functions that we see in everyday behavior. That is why foods, drinks, mates, and offspring are rewarding. There have been theories linking pleasure as a required component of health benefits salutogenesis, (salugenesis). In essence, under these terms, pleasure is described as a state or feeling of happiness and satisfaction resulting from an experience that one enjoys. Regarding pleasure, it is a double-edged sword, on the one hand, it promotes positive feelings (like mindfulness) and even better cognition, possibly through the release of dopamine [22]. But on the other hand, pleasure simultaneously encourages addiction and other negative behaviors, i.e., motivational toxicity. It is a complex neurobiological phenomenon, relying on reward circuitry or limbic activity. It is important to realize that through the “Brain Reward Cascade” (BRC) endorphin and endogenous morphinergic mechanisms may play a role [23]. While natural rewards are essential for survival and appetitive motivation leading to beneficial biological behaviors like eating, sex, and reproduction, crucial social interactions seem to further facilitate the positive effects exerted by pleasurable experiences. Indeed, experimentation with addictive drugs is capable of directly acting on reward pathways and causing deterioration of these systems promoting hypodopaminergia [24]. Most would agree that pleasurable activities can stimulate personal growth and may help to induce healthy behavioral changes, including stress management [25]. The work of Esch and Stefano [26] concerning the link between compassion and love implicate the brain reward system, and pleasure induction suggests that social contact in general, i.e., love, attachment, and compassion, can be highly effective in stress reduction, survival, and overall health. Understanding the role of neurotransmission and pleasurable states both positive and negative have been adequately studied over many decades [26–37], but comparative anatomical and neurobiological function between animals and homo sapiens appear to be required and seem to be in an infancy stage. Finding happiness is different between apes and humans As stated earlier in this expert opinion one key to happiness involves a network of good friends [38]. However, it is not entirely clear exactly how the higher forms of satisfaction and pleasure are related to a sugar rush, winning a sports event or even sky diving, all of which augment dopamine release at the reward brain site. Recent multidisciplinary research, using both humans and detailed invasive brain analysis of animals has discovered some critical ways that the brain processes pleasure. Remarkably, there are pathways for ordinary liking and pleasure, which are limited in scope as described above in this commentary. However, there are **many brain regions**, often termed hot and cold spots, that significantly **modulate** (increase or decrease) our **pleasure or** even **produce the opposite** of pleasure— that is disgust and fear [39]. One specific region of the nucleus accumbens is organized like a computer keyboard, with particular stimulus triggers in rows— producing an increase and decrease of pleasure and disgust. Moreover, the cortex has unique roles in the cognitive evaluation of our feelings of pleasure [40]. Importantly, the interplay of these multiple triggers and the higher brain centers in the prefrontal cortex are very intricate and are just being uncovered. Desire and reward centers It is surprising that many different sources of pleasure activate the same circuits between the mesocorticolimbic regions (Figure 1). Reward and desire are two aspects pleasure induction and have a very widespread, large circuit. Some part of this circuit distinguishes between desire and dread. The so-called pleasure circuitry called “REWARD” involves a well-known dopamine pathway in the mesolimbic system that can influence both pleasure and motivation. In simplest terms, the well-established mesolimbic system is a dopamine circuit for reward. It starts in the ventral tegmental area (VTA) of the midbrain and travels to the nucleus accumbens (Figure 2). It is the cornerstone target to all addictions. The VTA is encompassed with neurons using glutamate, GABA, and dopamine. The nucleus accumbens (NAc) is located within the ventral striatum and is divided into two sub-regions—the motor and limbic regions associated with its core and shell, respectively. The NAc has spiny neurons that receive dopamine from the VTA and glutamate (a dopamine driver) from the hippocampus, amygdala and medial prefrontal cortex. Subsequently, the NAc projects GABA signals to an area termed the ventral pallidum (VP). The region is a relay station in the limbic loop of the basal ganglia, critical for motivation, behavior, emotions and the “Feel Good” response. This defined system of the brain is involved in all addictions –substance, and non –substance related. In 1995, our laboratory coined the term “Reward Deficiency Syndrome” (RDS) to describe genetic and epigenetic induced hypodopaminergia in the “Brain Reward Cascade” that contribute to addiction and compulsive behaviors [3,6,41]. Furthermore, ordinary “liking” of something, or pure pleasure, is represented by small regions mainly in the limbic system (old reptilian part of the brain). These may be part of larger neural circuits. In Latin, hedus is the term for “sweet”; and in Greek, hodone is the term for “pleasure.” Thus, the word Hedonic is now referring to various subcomponents of pleasure: some associated with purely sensory and others with more complex emotions involving morals, aesthetics, and social interactions. The capacity to have pleasure is part of being healthy and may even extend life, especially if linked to optimism as a dopaminergic response [42]. Psychiatric illness often includes symptoms of an abnormal inability to experience pleasure, referred to as anhedonia. A negative feeling state is called dysphoria, which can consist of many emotions such as pain, depression, anxiety, fear, and disgust. Previously many scientists used animal research to uncover the complex mechanisms of pleasure, liking, motivation and even emotions like panic and fear, as discussed above [43]. However, as a significant amount of related research about the specific brain regions of pleasure/reward circuitry has been derived from invasive studies of animals, these cannot be directly compared with subjective states experienced by humans. In an attempt to resolve the controversy regarding the causal contributions of mesolimbic dopamine systems to reward, we have previously evaluated the three-main competing explanatory categories: “liking,” “learning,” and “wanting” [3]. That is, dopamine may mediate (a) liking: the hedonic impact of reward, (b) learning: learned predictions about rewarding effects, or (c) wanting: the pursuit of rewards by attributing incentive salience to reward-related stimuli [44]. We have evaluated these hypotheses, especially as they relate to the RDS, and we find that the incentive salience or “wanting” hypothesis of dopaminergic functioning is supported by a majority of the scientific evidence. Various neuroimaging studies have shown that anticipated behaviors such as sex and gaming, delicious foods and drugs of abuse all affect brain regions associated with reward networks, and may not be unidirectional. Drugs of abuse enhance dopamine signaling which sensitizes mesolimbic brain mechanisms that apparently evolved explicitly to attribute incentive salience to various rewards [45]. Addictive substances are voluntarily self-administered, and they enhance (directly or indirectly) dopaminergic synaptic function in the NAc. This activation of the brain reward networks (producing the ecstatic “high” that users seek). Although these circuits were initially thought to encode a set point of hedonic tone, it is now being considered to be far more complicated in function, also encoding attention, reward expectancy, disconfirmation of reward expectancy, and incentive motivation [46]. The argument about addiction as a disease may be confused with a predisposition to substance and nonsubstance rewards relative to the extreme effect of drugs of abuse on brain neurochemistry. The former sets up an individual to be at high risk through both genetic polymorphisms in reward genes as well as harmful epigenetic insult. Some Psychologists, even with all the data, still infer that addiction is not a disease [47]. Elevated stress levels, together with polymorphisms (genetic variations) of various dopaminergic genes and the genes related to other neurotransmitters (and their genetic variants), and may have an additive effect on vulnerability to various addictions [48]. In this regard, Vanyukov, et al. [48] suggested based on review that whereas the gateway hypothesis does not specify mechanistic connections between “stages,” and does not extend to the risks for addictions the concept of common liability to addictions may be more parsimonious. The latter theory is grounded in genetic theory and supported by data identifying common sources of variation in the risk for specific addictions (e.g., RDS). This commonality has identifiable neurobiological substrate and plausible evolutionary explanations. Over many years the controversy of dopamine involvement in especially “pleasure” has led to confusion concerning separating motivation from actual pleasure (wanting versus liking) [49]. We take the position that animal studies cannot provide real clinical information as described by self-reports in humans. As mentioned earlier and in the abstract, on November 23rd, 2017, evidence for our concerns was discovered [50] In essence, although nonhuman primate brains are similar to our own, the disparity between other primates and those of human cognitive abilities tells us that surface similarity is not the whole story. Sousa et al. [50] small case found various differentially expressed genes, to associate with pleasure related systems. Furthermore, the dopaminergic interneurons located in the human neocortex were absent from the neocortex of nonhuman African apes. Such differences in neuronal transcriptional programs may underlie a variety of neurodevelopmental disorders. In simpler terms, the system controls the production of dopamine, a chemical messenger that plays a significant role in pleasure and rewards. The senior author, Dr. Nenad Sestan from Yale, stated: “Humans have evolved a dopamine system that is different than the one in chimpanzees.” This may explain why the behavior of humans is so unique from that of non-human primates, even though our brains are so surprisingly similar, Sestan said: “It might also shed light on why people are vulnerable to mental disorders such as autism (possibly even addiction).” Remarkably, this research finding emerged from an extensive, multicenter collaboration to compare the brains across several species. These researchers examined 247 specimens of neural tissue from six humans, five chimpanzees, and five macaque monkeys. Moreover, these investigators analyzed which genes were turned on or off in 16 regions of the brain. While the differences among species were subtle, **there was** a **remarkable contrast in** the **neocortices**, specifically in an area of the brain that is much more developed in humans than in chimpanzees. In fact, these researchers found that a gene called tyrosine hydroxylase (TH) for the enzyme, responsible for the production of dopamine, was expressed in the neocortex of humans, but not chimpanzees. As discussed earlier, dopamine is best known for its essential role within the brain’s reward system; the very system that responds to everything from sex, to gambling, to food, and to addictive drugs. However, dopamine also assists in regulating emotional responses, memory, and movement. Notably, abnormal dopamine levels have been linked to disorders including Parkinson’s, schizophrenia and spectrum disorders such as autism and addiction or RDS. Nora Volkow, the director of NIDA, pointed out that one alluring possibility is that the neurotransmitter dopamine plays a substantial role in humans’ ability to pursue various rewards that are perhaps months or even years away in the future. This same idea has been suggested by Dr. Robert Sapolsky, a professor of biology and neurology at Stanford University. Dr. Sapolsky cited evidence that dopamine levels rise dramatically in humans when we anticipate potential rewards that are uncertain and even far off in our futures, such as retirement or even the possible alterlife. This may explain what often motivates people to work for things that have no apparent short-term benefit [51]. In similar work, Volkow and Bale [52] proposed a model in which dopamine can favor NOW processes through phasic signaling in reward circuits or LATER processes through tonic signaling in control circuits. Specifically, they suggest that through its modulation of the orbitofrontal cortex, which processes salience attribution, dopamine also enables shilting from NOW to LATER, while its modulation of the insula, which processes interoceptive information, influences the probability of selecting NOW versus LATER actions based on an individual’s physiological state. This hypothesis further supports the concept that disruptions along these circuits contribute to diverse pathologies, including obesity and addiction or RDS.

**Extinction first –**

**1 – Forecloses future improvement – we can never improve society because our impact is irreversible**

**2 – Turns suffering – mass death causes suffering because people can’t get access to resources and basic necessities**

**3 – Moral obligation – allowing people to die is unethical and should be prevented because it creates ethics towards other people**

**4 – Objectivity – body count is the most objective way to calculate impacts because comparing suffering is unethical**

**5 – Moral uncertainty – if we’re unsure about which interpretation of the world is true – we ought to preserve the world to keep debating about it**