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STRENGTHENING AUSTRALIA'S CRITICAL SPACE INFRASTRUCTURE

Strategies for growth and resilience.

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Introduction:

The growing reliance on space-based assets for essential services such as communication, navigation and weather monitoring means that space infrastructure has become critical to the effective functioning of Australian society. The *Security of Critical Infrastructure Act 2018* (Cth) recognises 'space technology sector' as a critical infrastructure sector.[1]

Critical space infrastructure (CSI) are components that are fundamental for enabling space activities including position, navigation, space weather, communications, tracking, and remote sensing earth observation services. The complexity of CSI goes beyond physical assets, extending to social, legal, security and geopolitical frameworks. Substantial damage or disruption to CSI for a significant period of time or during a time of critical necessity may have severe consequences across numerous sectors, including telecommunications, navigation, and various defence capabilities.

To ensure the sustainability and security of CSI, it is crucial to protect and maintain these components. Fostering cooperation and governance among the diverse actors and stakeholders within the space community to address the evolving threats and challenges that CSI encounters is imperative. Such an approach is essential for reinforcing its resilience and capacity to serve the needs of modern society.

This paper outlines 8 recommendations which addresses the question of how Australia could develop resilient space infrastructure that supports civilian, commercial and national security demands. The recommendations have been categorised into three topics; Socio-Cultural, Technology, Legal and Policy, and International Interest.

Methodology

This paper was written by participants in the Astra Program from Team Casuarina over the course of four months. The Casuarina team members started the process of preparing this paper by first conducting individual research into the problem statement, in particular, developing a personal definition for CSI. Our team then engaged in discussions to formulate a combined definition of CSI.

Our team then conducted further research and consulted various sources such as academic papers, reports published by institutions, news articles, and legislation and regulations in order to brainstorm preliminary recommendations for the paper. We received feedback on our preliminary recommendations from Subject Matter Experts from prominent industry organisations, including Airbus, Azimuth Advisory and iLAuNCH. Our team considered their feedback when editing and finalising this paper.

Topic 1: Socio-Cultural

The recent Looking Up from Down Under survey (LUFDU) showed that Australians have low awareness of, but a positive interest in, Australia's space activities.[2] For government organisations, justifying public spending requires support and trust, afforded when the government can "make effective decisions and take our interests into account".[3] Additionally, the public expects the government to provide fundamental rights such as food, health, and safety - all enhanced by CSI. Therefore, by communicating that CSI supports these provisions, the government can increase trust and support.

Recommendation 1: The Australian Space Agency (the Agency), the Australian Centre for Space Governance, and the Australian Space Diversity Alliance should help raise the profile of, and support for, the Australian space industry in the minds of the Australian public, by increasing the proportion of marketing and communications roles in the national space industry to 5% by 2030.

By turning data and insights from the LUFDU survey into targeted action points, the Agency can foster a more informed and supportive public via:

Enhancing Public Awareness: Develop targeted awareness campaigns focusing on the Agency's existence and activities.
Improving Education on Space: Tailor engaging materials to address specific gaps in understanding, emphasising the practical applications of space technologies, and invoke curiosity.
Highlighting Tangible Benefits: Connect to tangible, real-world applications like weather forecasting, disaster management, agriculture, financial systems, communications, GPS.
Clarifying Policy Direction: Communicate policy decisions transparently to involve the public in discussions around space priorities and Australia's future direction in space.
Promoting Diversity and Inclusivity: Showcase success stories and emphasise the positive impact of a diverse workforce on space-related projects.
Addressing Concerns About Funding: Demonstrate the value and necessity by highlighting the societal benefits of space investments, drawing attention to areas where public support is high.

Additionally, certain areas receive notably higher levels of support, and present opportunities for strong public connection, such as: Astronaut Programs, Satellite Deployment, Space R&D, International Space Collaboration, Space Industry Growth, and Earth Observation.

While the LUFDU survey could be repeated annually to track the themes above, it didn't measure trust. The Edelman Trust Barometer[4] is a leading measure of consumer trust used by organisations globally, and could also be used to track trust over time.

Quantitative and qualitative market research should be conducted to identify and understand the thoughts and feelings of the Australian public at a deeper level than the LUFDU survey provided. Armed with these insights, audience segmentations can be targeted with appropriate messages via appropriate channels.

Bringing more marketing and communications professionals into the industry will be necessary to strategise and execute the aforementioned messages, and are proven to be very impactful in improving perceptions of brands and organisations.[5] The Agency's goal is to increase the number of jobs in the space industry to 30,000 by 2030.[6] It needs to be considered what proportion of these is allocated to marketing and communications, as there has been a dominant, albeit necessary, focus on STEM roles to date. For example, marketing makes up 5% of the Canadian space sector workforce.[7] Additionally, women make up 61% of the Australian marketing workforce, so by hiring more from this field the sector can increase gender diversity, as women only account for 15% of those in STEM fields.[8]

Topic 2: Technology

Technological advancements are required to ensure resilient CSI . This section of the paper explores Human-Computer Interface, guidelines for the mission lifecycle, launch and satellite industry growth, and space debris management.

Recommendation 2: The Agency should promote research in Human-Computer Interactions (HCI) in space explorations.

Human-Computer Interaction (HCI) is a multidisciplinary field focusing on computer technology designs and the interaction between humans and computers.[9] In space exploration, HCI is crucial for addressing challenges and ensuring astronaut well-being as there is potential for wearable technology, human-robot interaction, and trust in autonomous systems. Advances in aerospace engineering and accessible space exploration by companies like SpaceX open opportunities for HCI projects, like exoskeletons, which would contribute to human living and working in space.[10]

NASA's 'The New Challenges of Deep Space Exploration' emphasises that communication delays and limited crew size necessitate a revolution in spaceflight human-systems integration, making HCI vital.[11] The identified focus areas for HCI align with challenges in deep space exploration, like technology for space health, cognitive load, cooperative work, augmented/mixed reality, smart vehicles/habitats, and digital fabrication.

The current state of advanced HCI research in space exploration centres around collaborative initiatives, such as the SpaceCHI 2.0 workshop. This event brings together researchers from diverse disciplines to envision the future of human space exploration and address challenges through HCI. SpaceCHI 1.0 identified key areas like human-machine collaboration, space health, humanising space, and mission operations.[12] Therefore, it is evident that the involvement of HCI in the challenging nature of space exploration requires innovative and interdisciplinary approaches.

It is recommended that the Agency implements the following strategies to foster resilience in Critical Space Infrastructure (CSI) through advancements in the area of HCI for space exploration. The Agency should allocate resources to the development of HCI systems that enhance both the physical and intellectual performance of astronauts. This includes exploring the implementation of virtual and augmented reality for interplanetary exploration and creating zero-gravity musical interfaces to address the psychological well-being of individuals during extended space missions. Further, the Agency should prioritise User-Centric Design for Human-Automation/Robotic Integration (HARI) by emphasising a user-centric approach when

designing interfaces and interactions for operational environments involving a combination of automation and robotics.[13] Focus on clarity, adaptability, and ease of use to enhance user understanding, facilitate effective collaboration, and address the dynamic and complex nature of space exploration contexts. Lastly, attention should be directed towards an integration of effective automation and robotics. Following the example of NASA's Human Research Program, the Agency should concentrate efforts on understanding and addressing challenges in HARI for successful space exploration by evaluating the current state, identify challenges, and explore opportunities for advancements in HARI to ensure seamless collaboration between human operators and automated systems.

Recommendation 3: The Agency should advocate for the consistent use of international standards to harness supply chain efficiencies, improve interoperability, and create a resilient space infrastructure network.

Defence Aviation Safety Regulations were adopted in 2016 by Defence and Industry to satisfy the requirements of the Work Health and Safety Act 2011.[14] These were adapted from the European Military Airworthiness Regulations which are used by over 30 countries.[15] This enabled Australia to easily nest into the global supply chain; increase interoperability with partner nations; improve mutual recognition of approvals and certifications in addition to driving sustainment and aircraft costs down.[16] The Australian Defence Force has seen a significant decline in accidents and asset loss for aircraft since the introduction of airworthiness boards and technical regulations.[17] This is also due to the elimination of prescriptive regulations and moving towards intent-based regulations that enables organisations to be flexible and innovative to achieve mission objectives while remaining safe. Australia should consider a similar approach for the security and resilience of space critical infrastructure.

The Agency should establish a set of national guidelines that supports academic and commercial space operators on how to implement resilient systems in their assets as seen in the success of the Cubesat form factor,[18] This would aim to ensure non-government operations have a “best practice” to follow and create a resilient Australian space infrastructure network.

The implementation of these national guidelines would be beneficial for smaller teams which may lack industry knowledge. The guidelines would also be a reference for larger space operations, ensuring all Australian space operators are equipped to create and maintain resilient assets. As the whole industry will be compliant or striving to be compliant with a best practice standard, this will prevent potential failure points for critical infrastructure, maintaining infrastructure network robustness and therefore resiliency.

Recommendation 4: The Australian government should support its launch industry by investing in spaceport infrastructure, and providing domestic launch contracts by 2027.

Australia's geography presents unique opportunities for robust launch infrastructure developments. Despite this, lack of funding and government policy has prevented historic attempts at establishing a domestic launch industry. To ensure the success of Australia's launch industry, especially in the context of international competition, it is recommended that financial assistance be aimed at supporting existing spaceport attempts. Similarly, Australian rocket companies should be supported by sending government payloads from Australian launch companies. These mirror the policies of most spacefaring nations. In line with expected private sector developments such as the launch of three suborbital rockets from Equatorial Launch Australia's Arnhem Space Centre in 2022, the development of the Whalers Way Orbital Launch Complex by Southern Launch, and Gilmour Space Technologies' first launch in April of this year, such a support is to complement and enhance these efforts.

Lack of investments in spaceport infrastructure has meant that Australia has yet to capture its geographic competitive advantage in the launch market. Significant examples of Australian spaceports which failed due to lack of funding include the failed Cape York proposal and the failed bid to host Kistler Aerospace launches in the late 1990s.[19] Contrastingly, nations with independent launch capabilities have governments fund and operate spaceports, for example the European Space Agency's (ESA) launch facility in French Guiana and the United States (US) Space Force's launch sites at Cape Canaveral Space Force Base and Vandenberg Space Force Base. However, this complete government operation is not ideal for Australia since private spaceports are already being built at ideal geographic locations. Instead, it is advisable that the Agency provides financial grants and regulatory assistance to spaceport projects and proposals. The benefits of providing such funding would first address the lack of government support as expressed by domestic space companies, and would enable the Space Agency to leverage Australia's unique geography to overseas firms looking to launch in Australia.

We also recommend that the Agency mandates Australian government payloads be launched from Australian launch providers unless there is a technical or safety reason in opposition. Other spacefaring nations have enacted similar mandates to encourage growth of their local space industries including the US.[20] While the absence of a mandate previously made sense because of a lack of local launch capability, it is now outdated. Such a mandate would also enable Australia to more effectively safeguard sensitive payloads under a framework similar to the US International Traffic in Arms Regulations where other countries' citizens, even those of allied

nations, are prohibited from viewing or accessing American space technology except for some narrow exemptions.

To keep up with industry developments and to ensure that government assistance is most effectively passed to industry stakeholders, it is advisable that this support is provided by 2027. This would be in line with developments such as the successful launch of three suborbital rockets from Equatorial Launch Australia's Arnhem Space Centre in 2022 and Gilmour Space Technologies' expected launch of its Eris rocket in April of this year.

Recommendation 5: The Agency should incentivise the development of micro to medium satellites by supporting infrastructure for integration and testing with the objective of attaining sovereign satellite capability by 2035 for critical applications.

Australia has a rich diversity of startups and established firms specialising in satellite technology. Common to most of these firms is a focus on cubesats, a standard of nanosatellites consisting of blocks with a size of 10 x 10 x 10cm. These satellites have become increasingly capable for a range of applications like imaging of other satellites, internet of things, and technology demonstrators.

Despite these capabilities, technical limitations of cubesats on key components such as power generation, lenses, high gain antennas, and others have meant that Australia is considerably reliant on overseas satellites for essential services. Examples include use of the American Wideband SATCOM constellation for military communications, Chinese and Japanese satellites for weather forecasting, and overseas built satellites for the NBN.[21] Such a reliance on overseas vendors has led to instances of degraded service such as outdated imagery in bushfires between 24 to 72 hours, while also exposing Australian space data consumers to geopolitical risk.[22]

While Australia has yet to possess the capacities to build large medium earth orbit or geostationary earth orbit satellites due to a lack of experience and a lack of suitable testing facilities, micro to medium satellites may be progressive efforts towards these larger satellites. Additionally, the production of these satellites may also allow Australia to enter a niche which until recently has been underutilised with most satellites until 2016 being in the nano or very large categories of satellites as shown in fig. 1 of the appendix.[23]

Australia does have a limited number of facilities able to support the integration, testing, and operation of micro to medium satellites, defined as 10 to 100 kg and 500 to 1000 kg respectively.[24] These include the Australian National University's National Space Test Facility, CSIRO's Infrastructure Technologies vibration test facility at CSIRO's Clayton North campus, and a

proposed space test facility at UNSW.[25] The first of these is the most well known of the facilities and consists of a range of assets such as a vacuum chamber called the Space Simulation Facility, otherwise known as Wombat, being capable of testing satellites up to 500 kg with volumes of 1.6m x 1.6m x 2.25m,[26] radiation, and vibration testing facilities along with an experimental laser ground station for communicating with laser equipped satellites in orbit. While these capabilities are more than sufficient to support a cubesat industry, for scaling up to medium and large satellites they are currently insufficient. In comparison, overseas facilities are much larger with an example being the UK's proposed National Satellite Test Facility, capable of complete testing of satellites up to 7 tonnes with a budget of £116 million ($225 million AUD).[27]

Improving Australian facilities to match analogous facilities internationally requires investment. These investments would be directed towards institutes with proven existing space heritage with the intention of complementing existing expertise in various aspects of integration and testing. Upgrades should be completed by 2035 with the aim of providing Australia sufficient sovereign satellite services to meet critical sectors such as defence and intelligence, weather forecasting, and search and rescue. Such a date also focuses on meeting expected challenges in climate change, ensuring Australian access to weather satellite information regardless of political tensions in the Asia Pacific, and complementing other Defence priorities such as increased naval spending.

Recommendation 6: iLAuNCH and the Australian Centre for Space Governance should collaboratively develop comprehensive outcomes-based guidelines on the technological and legal aspects of space debris management in order to enhance the security of CSI.

Space debris is defined as "all non-functional, artificial objects" in Earth's orbit or re-entering Earth's atmosphere.[28] Space debris commonly originates from in-orbit break-ups, with a small portion of debris from collisions.[29] The concern around space debris is largely around avoiding the occurrence of the Kessler syndrome which refers to a hypothesised phenomenon where collisions in space would cause a chain reaction of further collisions due to an abundance of space debris.[30] ESA has stated that long-term simulations of the space debris environment suggest that the Kessler syndrome could become a reality within the following decades of space activities.[31]

Recent history shows that several entities within the space industry have been working on this issue. In 2002, the Inter-Agency Space Debris Coordination Committee (IADC), composed of the space agencies of 10 countries as well as the ESA, achieved consensus on a set of guidelines designed to mitigate space debris development.[32] The United Nations' Committee on the

Peaceful Uses of Outer Space (COPUOS), through adopting the IADC's guidelines, also completed their work on mitigation guidelines in 2007, and were endorsed by the General Assembly of the United Nations.[33] Meanwhile the ESA offers strategic support to missions on manoeuvring to avoid collision. If a mission's risk threshold would be exceeded, the Space Debris Office would inform mission control and advise on optimal strategies on how to potentially minimise collision risk.[34] In 2022, the ESA published their Space Debris Mitigation Requirements, which established eight recommendations with a goal to reach zero debris by 2030.[35]

Australia has a strong history of impacting the global community and being a norm entrepreneur, including as a pioneer and advocate for the non-proliferation of nuclear weapons of mass destruction.[36] Australia should continue its legacy in norm entrepreneurship by using soft power through funding and supporting research organisations to research Space Debris Management technology and strategies, we can instil the norm of all space actors to minimise and reduce space debris. This will enable a long term solution to reducing risk to CSI in space from space debris. This also enables free movement of launch vehicles in space and space structures such as the ISS from conducting debris avoidance manoeuvres.[37]

iLaunch is recommended to provide support through its Core Commercialisation Projects to research space debris management technologies. While Active Debris Removal (ADR) activities are difficult and inherently risky, they provide an effective method for space debris removal. For example, Astroscale, a Japanese company, is researching ADR with a satellite-satellite manoeuvre to remove defunct satellites from their orbits. iLAuNCH and the ACSG have an opportunity for innovation on this front, having a dual-pronged approach to address space debris management with both technological and regulatory perspectives.

Topic 3: Legal and Policy

Space policy, laws and regulations govern the development and use of space technologies and space related activities. Effective space policy, laws and regulations ensure that space related activities are conducted in a responsible and sustainable manner.[38]

Recommendation 7: The Australian government should develop a whole-of-government space policy that aligns civilian, commercial and defence interests.

Australia currently has a Civil Space Strategy published by the Agency and a Defence Space Strategy published by Defence, which are not aligned in their roadmaps.[39] The Space Industry Association of Australia refers to this as "disjointed space priorities, policy and funding".[40] The

current fragmented approach to space policy is hindering Australia's progress in its space related activities.[41]

Ensuring the sustainability and security of Australia's CSI requires a unified approach between industry and Defence to ensure that critical assets and systems are protected and maintained, advancements in space technologies benefit the country as a whole, and Australia's space capabilities are sustainable in a congested and competitive environment.[42]

Developing a whole-of-government space policy that aligns civilian, commercial and defence interests would have the benefit of: a single national voice on space endeavours, more efficient use of government budget, improved coordination between industry and Defence, improved coordination between different government departments, and greater sharing opportunities.[43] A whole-of-government space strategy would increase public awareness and support for Australia's space activities as one national vision and roadmap will be more marketable to the public than two separate policies.

A whole-of-government space policy does not need to be developed from scratch as there are commonalities between the civil and defence space strategies that can be aligned. For example, both strategies recognise the importance of enhancing space capabilities but have different focus areas.

Other countries that have released a whole-of-government space policy include the United States, United Kingdom and New Zealand, with their policies setting out a national commitment to lead the constructive use of space for civil, commercial and defence interests.[44] For example, the US National Space Policy recognises that American space activities encompass "three distinct but independent sectors: commercial, civil, and national security" and sets out cross-sector policies alongside sector-specific guidelines.[45] The US National Space Policy recognises that a variety of stakeholders have interest in space but also acknowledges that government direction is necessary for those areas to overlap.[46] We recommend the Australian government look to these other countries as best practice to develop a whole-of-government space policy that aligns civilian, commercial and defence interests.

Topic 4: International Interest

In strengthening Australia's Critical Infrastructure, it is vital that Australia considers its place in the international space industry. Having a strong international position will enable us to grow and learn from bigger competitors, so that Australia can ensure the resilience of our CSI. In doing so, Australia can also satisfy its national security demands that it faces due to cyber-attacks, which are "one of the main risks affecting space systems".[47]

Recommendation 8: The Agency should endeavour to nurture current and new international space partnerships to boost Australia's CSI.

The Agency should build on new and existing international relationships to ensure the success of our space industry. This will enable us to learn from more developed space industries to improve our CSI resilience. In doing so, it will "open the door for Australian innovators and grow a connected, respected and globally competitive space industry in Australia."[48]

Some of the current partnerships that Australia has are:

- The Space Bridge Framework Arrangement with the UK
- An in-principle agreement on a Technology Safeguards Agreement with the USA
- The Australian-French Space Research Collaboration Initiative 2024
- The Memoranda of Understanding with South Korea and India
- The ISI India Projects

Another impactful engagement was the signing of the Artemis Accords in October 2020. In becoming one of eight founding signatories,[49] the Agency committed to transparent dissemination regarding space policies and exploration plans.[50] This can be seen in the collaboration between NASA's Search and Rescue office and Australia's SmartSat Cooperative Research Centre, which aimed to "advance distress-related communications and navigation technology benefiting the U.S. and Australia",[51] which produces benefits to the global emergency response efforts. This is especially important because of growing cybersecurity threats to satellites, which would significantly impact these emergency services which receive a call every 11 seconds.[52] Thus, it is evident that Australia has the skills and resources to assist the US in a way that will satisfy our national security demands and ensure the resilience of our CSI in times of emergency.

It is recommended the Agency expand upon the Statement of Intent with the ESA, creating a proper partnership that produces tangible results. This is essential, as this statement was signed in 2019, and stated that both parties will consider "multiple opportunities offered by recent

respective developments and by the growth of their space sectors".[53] While the ESA is working with SmartSat and with CSIRO on Earth-observation research, there is not a lot of involvement with the Agency, other than the New Norcia project.[54] This would be very beneficial, as Europe could tap into Australia's public sector to assist them with knowledge transfer, technology growth, and demonstration of best practices.

By building on these partnerships, there is room for many opportunities, such as:

- The Government, The Agency and science organisations should be more actively involved and aware of island nation conferences, specifically the Space for Island Nations Conference (SINC), as this is an area deeply valued by Indigenous Australians.
- The development of an international critical infrastructure council. Currently, Australia's Critical Infrastructure Advisory Council is comprised of industry representatives, the Australian Government and state and territory government representatives,[55] but it does not consider an international standpoint.

Ensuring the resilience of CSI is a global effort in a world where cybersecurity threats are increasing. While each country has its own needs for space infrastructure, there are many benefits to collaboration with other space agencies to satisfy our industry and national security demands.

Recommendations

Recommendation 1: The Australian Space Agency (the Agency), the Australian Centre for Space Governance, and the Australian Space Diversity Alliance should help raise the profile of, and support for, the Australian space industry in the minds of the Australian public, by increasing the proportion of marketing and communications roles in the national space industry to 5% by 2030.

Recommendation 2: The Agency should promote research in Human-Computer Interfaces (HCI) in space explorations.

Recommendation 3: The Agency should advocate for the consistent use of international standards to harness supply chain efficiencies, improve interoperability, and create a resilient space infrastructure network.

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Recommendation 6: iLAuNCH and the Australian Centre for Space Governance should collaboratively develop comprehensive outcomes-based guidelines on the technological and legal aspects of space debris management in order to enhance the security of CSI.

Recommendation 7: The Australian government should develop a whole-of-government space policy that aligns civilian, commercial and defence interests.

Recommendation 8: The Agency should endeavour to nurture current and new international space partnerships to boost Australia's CSI.

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Appendix

Fig. 1: Satellite weight classifications from 2006 - 2016 - From Recommendation 5

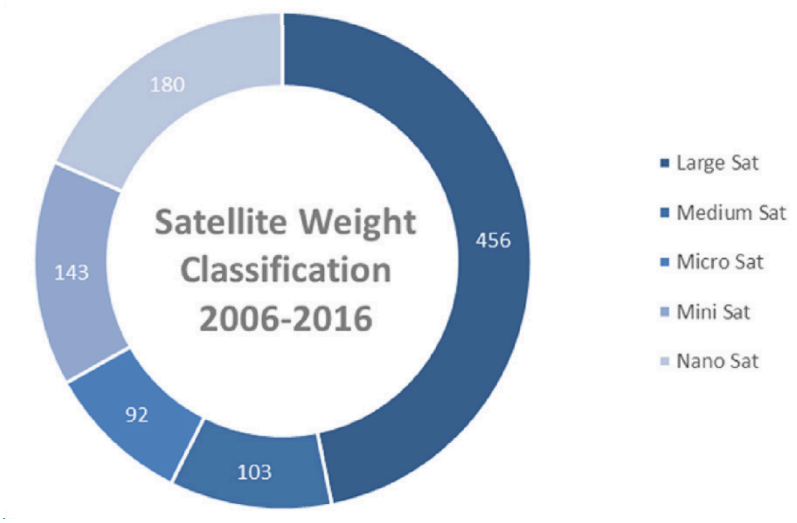

Fig. 2 - COPUOS and ESA guidelines on space debris mitigation - From Recommendation 6:

COPUOS guidelines on space debris mitigation	ESA guidelines on space debris mitigation
1. Limit debris released during normal operations 2. Minimise the potential for break-ups during operational phases	8. Guarantee successful disposal of space objects 9. Improve orbital clearance

3. Limit the probability of accidental collision in orbit 4. Avoid intentional destruction and other harmful activities 5. Minimise potential for post-mission break-ups resulting from stored energy 6. Limit the long-term presence of spacecraft and launch vehicle orbital stages in the low-Earth orbit region after the end of their mission 7. Limit the long-term interference of spacecraft and launch vehicle orbital stages with the geosynchronous Earth orbit region after the end of their mission	10. Avoid in-orbit collisions 11. Avoid internal break-ups 12. Prevent the intentional release of space debris 13. Improve on-ground casualty risk assessment 14. Guarantee dark and quiet skies 15. Extend protected regions

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