# Preserving Space for Generations: Inclusivity in a Common Framework for the Space Sustainability Rating

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Figure 1. Re-entry of Jules Verne ATV over the Pacific Ocean. (ESA, 2008).

Spacecraft re-entry can look like beautiful shooting stars. However, recent studies found they don't only pollute land and water but also, the Earth's atmosphere.

The Jules Verne ATV in Figure 1 pioneered seemingly sci-fi technologies for collision avoidance and controlled re-entry. Despite advancements, the effects of its atmosphere burn and breakup in the South Pacific Ocean are unknown.

Nowadays, several technologies are being developed to further avoid space debris, however, challenges remain to reduce terrestrial pollution. To address this, holistic ideas to improve the newly established Space Sustainability Rating (SSR, 2019) are proposed with a focus on accounting for terrestrial impact, inclusivity, and implementation strategies.

## Introduction

The exponential growth of space activities brings opportunities alongside critical challenges, notably the threat of orbital debris and an increasingly complex operational landscape. To ensure space remains accessible and sustainable for future generations, a consortium led by Rathnasabapathy et al. (2019) and Letizia et al. (2021) responded to a call during the 2018 World Economic Forum to establish the Space Sustainability Rating (SSR). Since then, a framework has been published and an organization established with the EPFL Space Centre (eSpace) operating the SSR (David and Saada, 2022). While significant attention has been directed towards addressing space debris, the terrestrial impact of space launches remains a pressing concern. Moreover, although a SSR certification can be considered an incentive in and of itself, it will be important to have more tangible incentives and ensure that countries most affected by terrestrial pollution are included in such discussions. This essay discusses the potential of 1) establishing a terrestrial impact index, 2) promoting inclusion, and 3) incentivizing the adoption of SSR to improve its implementation.

## Establishing a Terrestrial Impact Index

The initial version of the SSR eliminated elements related to assessing terrestrial pollution (e.g. material selection, ozone depletion, land/water contamination) due to their perceived complexity and contentiousness (Rathnasabapathy et al. 2019). Other related elements (e.g. acoustic suppression system assessment, greenhouse gas emissions, re-entry burn and plume) have also been excluded. However, several studies have been conducted that can be useful in estimating such terrestrial impact during pre-launch, launch, and post-launch (Wilson 2019; Suikkanen and Nissinen 2020; Antoniadou and Basubas et al. 2021; Ryan et al. 2022; Murphy et al. 2023; Shareefdeen and Al-Najjar 2024; Koffler 2024). Methods and frameworks, such as product environmental footprint (PEF) and life cycle sustainability assessments (LCSA), already exist. Still, implementation is still not widespread as it could be tedious to conduct such assessments for every mission.

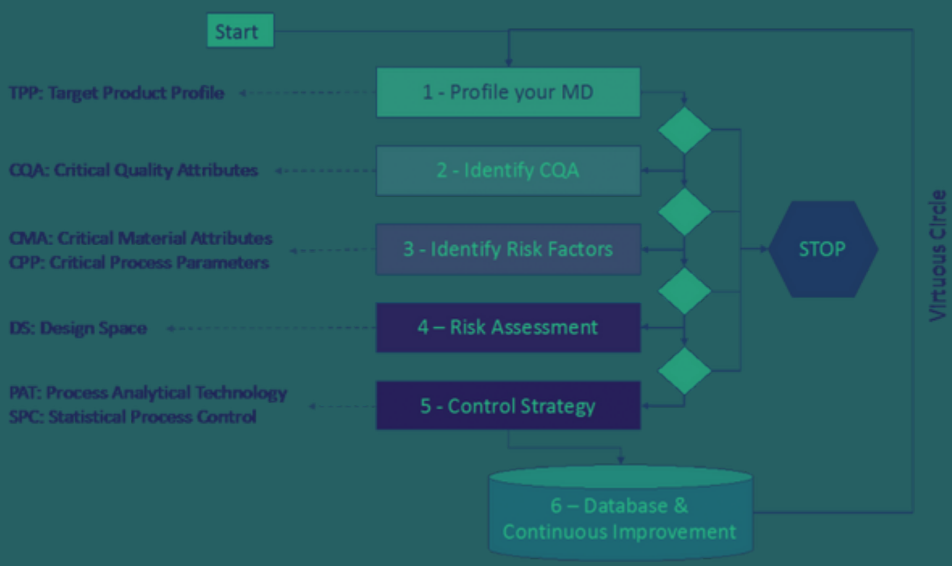


Figure 2. Quality by Desgn. (TBMED EU, 2020).

Applying a Quality by Design (QbD) framework (see Figure 2) could potentially address this by allowing organizations to establish a system that will allow them to identify materials and processes as critical quality attributes (CQA). To do this, a Terrestrial Impact Index (TII) can be developed and integrated into the Design Space to quantify terrestrial impact of CQAs while maintaining the quality of space operations. Patterned after the newly developed space debris index (Colombo et al. 2023), the TII can be the sum of the terrestrial impact during pre-launch (e.g., materials, assembly, testing), launch (e.g., acoustic suppression system assessment, propellant, fuel, combustion), and post-launch (e.g., land, water, and atmospheric contamination during re-entry). Although, it might seem difficult to initially set up and adopt QbD in space operations, QbD has been widely used in various manufacturing industries, including pharmaceuticals, automotive, and green chemistry (Jurjeva and Koel 2022). Organizations certifying SSR can abstract from the regulatory strategies of the U.S. FDA (2009), E.U. EMA (2017), and ICH's experience in harmonizing standards (2009). Creating a database of critical quality attributes (CQA) and their terrestrial impact might be a potential challenge, however, ESA LCA Working Group (2016) already has recommended environmental impact categories and the studies mentioned above has some data on some materials and processes. Artificial intelligence technologies can also be utilized to mine and organize such data and then develop a model for the calculation of TII, creation of the design space, and even identifying better material and process combinations. Nevertheless, establishing a TII and utilizing QbD can guide research and future standards to improve efficiency and keep a balance between quality and sustainability.

## Promoting Inclusion

The current lack of tangible actions to quantify and be aware of terrestrial impacts also underscores inequality in current space sustainability frameworks. This is because terrestrial pollution by space activities are more likely to directly affect small island nations, which are near sites of re-entry (see Figure 3). Indirect negative externalities of terrestrial pollution (e.g., global warming, climate change, rising sea levels) are also more likely to affect such nations. In addition to the SSR certification level, space operators are able to get bonus points for additional standards (David and Saada, 2022). To encourage inclusion, missions addressing climate or helping emerging space nations should get bonus points. More importantly, small island nations should be consulted by regulatory bodies and the SSR consortium in continuing to improve the SSR

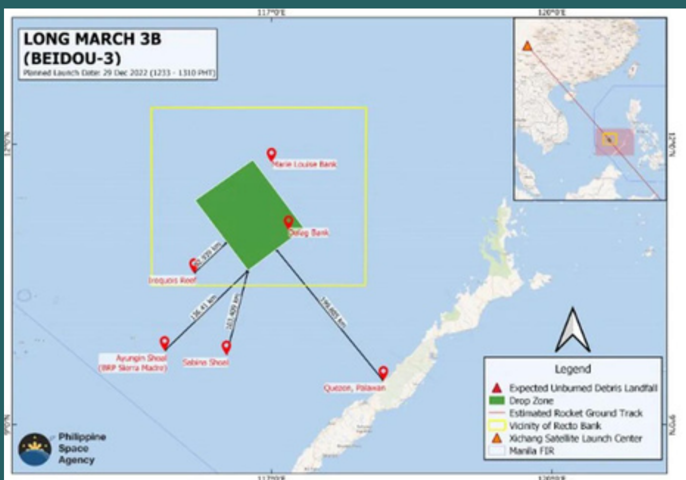


Figure 3. Tracking potential rocket debris falling around West Philippine Sea, contaminating and potentially causing marine damage. (Philippine Space Agency, 2022).

## Incentivizing Sustainability

Space debris and terrestrial pollution are concerns beyond complete control that will be difficult to regulate and penalize. Although SSR certification can be a good motivation for space operators to adopt sustainable practices, more tangible incentives should be awarded. Just like how open science and data sharing are now being required or incentivized in funding opportunities, organizations with SSR certification and sustainable practices can be given bonus points in funding opportunities. Public-private partnerships and international cooperation in monitoring, avoiding, and reducing terrestrial pollution should be particularly highlighted. Additionally, establishing an international award, akin to a Sustainability Award which can be given by the International Astronautical Federation (IAF) during annual IACs, can further recognize organizations and companies achieving a consistently high average annual SSR and demonstrating sustainable practices.

## Conclusion

In an ideal world, sustainability should be a requirement for space operations just like how we require FDA approval for medicines, credit scores for finances, and ISO for data security and quality management. However, requiring SSR certification might face strong resistance, necessitating a gradual approach focused on establishing a culture of sustainability within the spacefaring community. By actively promoting and incentivizing an inclusive space sustainability framework that addresses both space and terrestrial pollution, the space industry can propel responsible space exploration on a global scale, ensuring a future where humankind's cosmic ambitions can coexist with the preservation of planetary health and resources.

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