Hands-on strategy
& competitive solutions

May 2023

The space industry's path to a sustainable future

Our point of view on the stakes of the industry and the solutions

Executive summary

Space industry actors must act now towards sustainability. Because the market is set to triple by 2040, its environmental footprint will explode and increasing regulatory pressure is to come. Succeeding in this market tomorrow means hastening the deployment of eco-design and sustainable innovation levers considering the significant time it takes to develop them.

The good news is that **the starting point is known.** By prioritizing the launch and space segments - which account for the majority of these impacts - and striving towards the development of low-footprint components and cleaner propulsion technologies, the industry can effectively become sustainable.

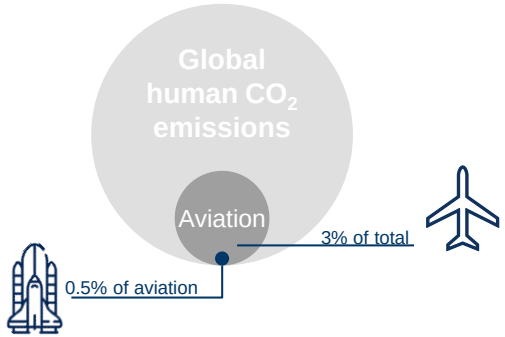
Developing a sustainable space industry is achievable if these **three challenges are addressed in the short-term:**

1. Strengthen the measuring and understanding of its impacts
2. Accelerate deployment of sustainable innovation and eco-design
3. Anticipate the evolution of normative and customer requirements

While the footprint of the space industry is relatively small compared to other sectors, environmental sustainability will become a necessity based on future trends

The (currently) low CO2 emissions of the space sector are just the tip of the iceberg

A small CO_2 footprint(2) …



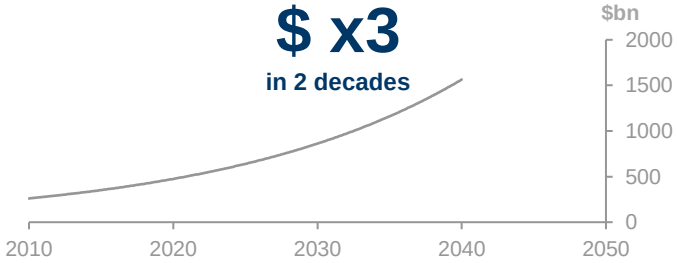
But a high radiative forcing:

The space industry represents **10%** of the total radiative forcing of the aerospace industry

98% of the GWP comes from particles emitted at high altitude – looking only at CO_2 is a bias

The sector is exponentially ramping up

$ x3
in 2 decades



Global space market projection(1)

(incl. new sectors: space tourism, asteroid mining, moon bases...)

x4
by 2030

Number of operational satellites

It's time to act on sustainability for space industry players

The sector has the sword of Damocles hanging over its head and should expect:

Significant increase of WW climate impact:
Space sector could reach **2.5%** of the global contribution(3)

New regulations

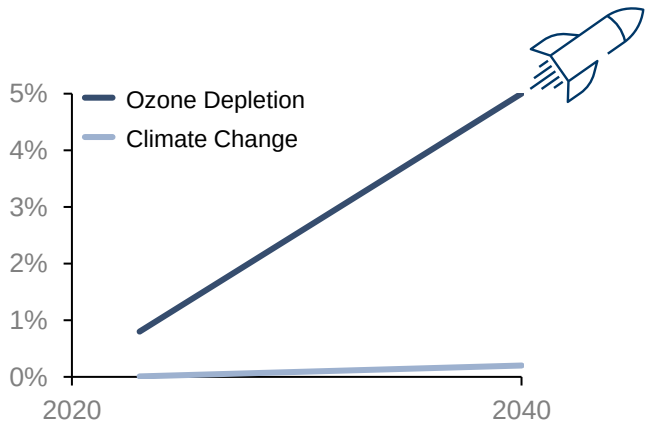
to frame the growth, reflecting governmental targets of both space industry development and climate impact mitigation

Sources: IAC research, Article by Loïs Miraux, ESA
(1) Citi, McKinsey Chart Growth of Space Industry, by Ryan Duffy, 2022
(2) "What's the Impact of the Space Industry on Climate Change?" The Aerospace Corporation, 2022
(3) "Ecospheric life cycle impacts of annual global space activities", by Andrew Ross Wilson et. Al, 2022

The space sector has its own specific environmental impacts, requiring customized countermeasures

Climate change is not the only impact to be taken into account

Impacts:
- Stratospheric Ozone Depletion
- Contribution to climate change (CO_2 eq)
- Mineral resources depletion
- Air acidification
- Impacts of objects reentry

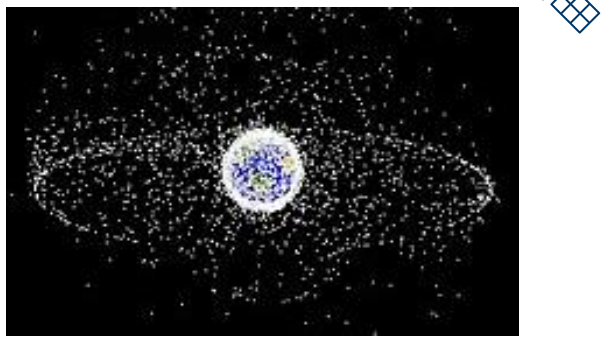


2040 projection of the global contribution of the space sector to three impact categories

Space debris are endangering the space industry itself

Impacts:
- Damages to satellites / spacecrafts
- Kessler syndrome: exponential growth of debris and collisions

- **Speed:** 8 km/s ~15x bullet speed
- **Size:** from 1 mm to a tennis ball size



Space debris and human spacecraft seen from the geosynchronous orbit

Overcrowded space pollutes the night-sky

Impacts:
- Longer exposures through telescopes to study the cosmos
- Reduce the detection limits of sky surveys, and (harmful) object detection
- By 2040, there will be half as many visible stars

~100,000 satellites in orbit around Earth by 2030

Reducing its environmental impact is the only way for the space industry to avoid climate change-related risks

Space sector remains too dependent on specific rare-earth material and energy resources

- High dependency on few geographies for critical raw materials: 98% of REEs used in EU are imported from China in 2021[1]
- Lack of substitutes as of now

China has a quasi-monopoly on REEs transformation

Climate change endangers the industry: rising waters jeopardize up to 2/3 of NASA's infrastructure

- Historical facilities remain too close to sea level – roads should be raised as well
- Sea-level measurements & predictions lack accuracy

Flooding damage to the Sonny Carter Training Facility at the Johnson Space Center

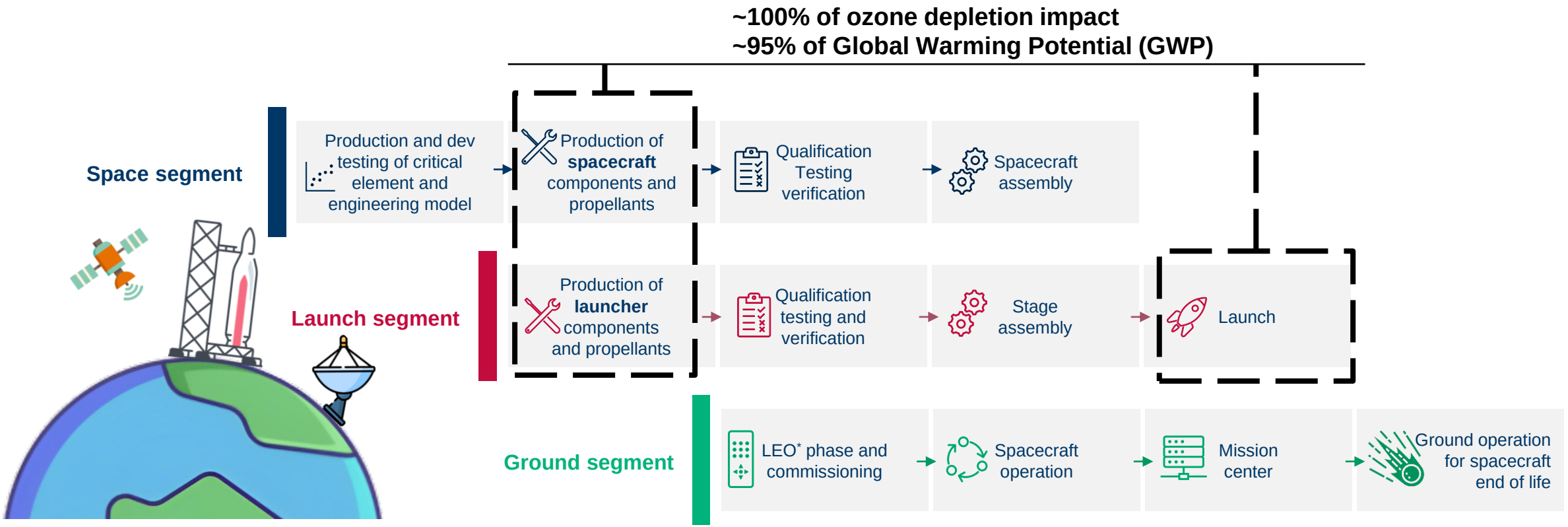
Geopolitical conflicts[3] are shaking the industry's foundations

- Emerging conflicts are endangering the access to raw materials and energy resources
- More and more restrictions on the transfer and development of technologies, while the space industry historically relies on international collaboration

15 nations were involved in the ISS, including United States and Russia

1) China dominates the Rare Earth Market, Martin Armstrong, January 2023
2) NASA watches sea level rise from space, and it's center's windows, Lara Streiff, November 2020
3) Les événements géopolitiques et leur impact sur l'économie spatiale, Nouvelle économie Spatiale, Avril 2023

The space sector is divided into 3 segments: space, launch and ground with the space and launch accounting for most of the GWP and ozone depletion



Sources: Ecospheric life cycle impacts of annual global space activities, by Andrew Ross Wilson et. Al, 2022
* Launch and early orbit

All 3 segments have their own challenges and sustainability levers to activate

Ground segment

Main drivers:

Ground segment is driven by **energy consumption** and **equipment manufacturing**

Levers

1. **Reduce energy consumption**
2. Set up **sustainable energy** production and **battery storage** for peak management
3. Performance vs impact **trade-off for specific equipment** (e.g., antenna)

Launch segment

Main drivers:

Launch stage **drives most of the impact**, followed by the **propellant manufacturing**

Levers

1. Use gases with less **SOD* impact**
2. Ban propellants with a high **GW** impact** (less particle-emitting)
3. Include **afterburning impact** into LCA
4. Explore **reusable launchers**

Space segment

Main drivers:

High mineral depletion due to the **production** of both polluting propulsion means and components, especially solar panels

Levers

1. **Optimize R&D operations,** limiting the environmental impact of tests
2. Implement **low-carbon propulsion technologies**
3. **Develop space debris reduction strategies** (e.g., account for enough fuel to retrieve waste)

*Stratospheric Ozone Depletion
**Global Warming

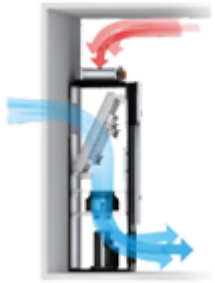
An LCA on Ground Segment infrastructure and operations enables hotspot highlighting, cost saving, and reduced waste & energy consumption

Scope — **Identified areas of investigation** — **Levers for the space industry**

Installation of free cooling in server rooms

- **Performance:** Up to **90% cooling** energy reduction
- **Implementation:** Applicable on every server rooms, **High TRL**[1]

- 38%



Different antenna design solution

- **Performance:** 10m/55tons vs. 11m/18 tons
- **Implementation:** Only applies to future antennas, **High TRL***

- 60%
- 50%

1. Assess reduction measures of **electrical consumption** (e.g., data centers)
2. Investigate means of **sustainable electrical production**
3. Use batteries for **peaks management**

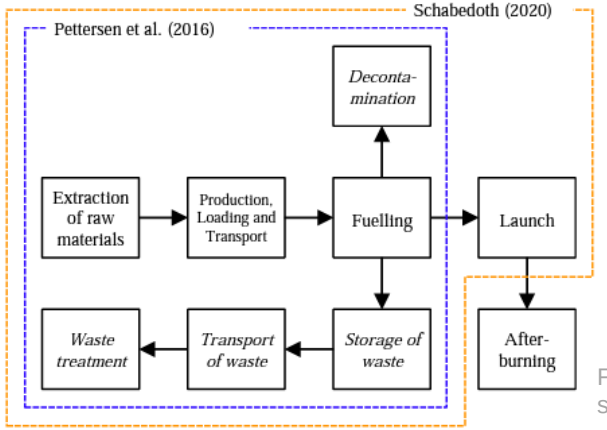
Source: LCA Ground Segment CSID Conference 2021
*Technology Readiness Level

The GWP and SOD of a rocket launch confirm the pressing need for a thorough LCA on segments of the space industry

Scope

Identified areas of investigation

- Highest environmental impacts:
  - **Launch stage, then**
  - **Propellant manufacturing**
- **Global SOD*** impact is more significant than **GW** impact**
- Current contribution to SOD of rocket launches: **0.39% of the global emissions of ozone depleting substances**
- The **use of CH_4 and H_2** should be emphasized to avoid the growth of GW and SOD



For a complete LLCA, the after-burning stage needs to be investigated

Levers for the space industry

1. Next generation rockets should rely on gases with **lower SOD impact**
2. Ban propellants with **a high GW impact**
3. An **investigation of afterburning impact** is essential to draw the whole picture

Source: Life cycle assessment of rocket launches and the effects of the propellant choice on their environmental performance by Paul Erik Schabedoth, 2020
*Stratospheric Ozone Depletion
**Global Warming Potential

An LCA on a complete space mission highlights the two most impactful phases on the environment: launch & use phase

Scope

Identified areas of investigation

- The launcher represents 99% of the mass: the environmental impacts of **the launcher are a major concern for all impact categories**

- **PV system** generates **100% of the impact on mineral resource depletion potential**

- Without considering launch segment, **utilization phase of the spacecraft** contributes to **60% of the environmental impacts**
- During this phase, major contributors are **electricity consumption of the data center and servers**

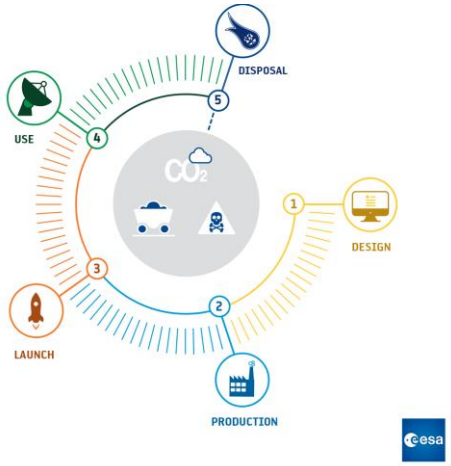
Levers for the space industry

1. **Using renewable energy** is a key element to decrease the impact of space activities on climate change
2. **R&D** has a major contribution to the environmental impact of the satellite mission

Source: Consideration of space debris in the life cycle assessment framework (hal.science), 2019

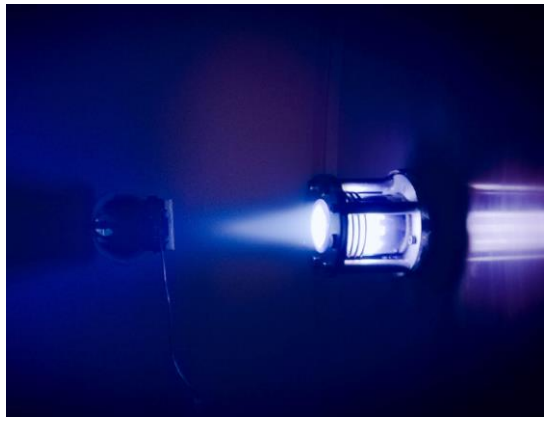
Space industry actors are now facing three challenges

1 Strengthen the measuring and understanding of the environmental footprint



By adapting the LCA methodology to the space sector specificities and implementing efficient measurement tools & data

2 Deploy eco-design and sustainable innovation



By establishing the right organization & methods along with management & trade-off tools

3 Anticipate the evolution of normative and customer requirements

esa

2018 → 2023

First Green Technologies development

Eco design **implementation in ESA projects**

By capturing and integrating them into technological and strategic roadmaps

Source: (1) Integrating life cycle assessment of space systems into the concurrent design process, Andrew Ross Wilson and Massimiliano Valise, 2017

INNOVATE. ACCELERATE. CHALLENGE.

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