



Reference:

P. Lionnet, *Space activity in an environmental context*, 4th ESA REACH Workshop, ESA HQ Daumesnil, Paris, 18th October 2022

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Space activity in an environmental context

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4th ESA REACH Workshop – 18 October 2022

18/10/2022

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Space as an infrastructure

- The Space industry is an infrastructure industry.
 - Infrastructure industry builds roads, bridges, high speed trains, telecoms networks.
 - Space industry builds space infrastructure, where it rolls out **satellites, launches** them in orbit and sets out a **ground network of stations and terminals** to upload/download data from them and, and keep them in operations.
- What is so special with space infrastructure is that differently than all other major human built infrastructures, **it resides in outer space, outside Earth boundaries and atmosphere. And with very few exceptions, it stays there until it ends its useful life**, at which point in time it must be disposed of.

Economic value

- The space infrastructure has a very high recognised social and economic value
- You will often see the Global space economy figure of 400B+++, but beyond that value, space services are provided as a free public infrastructure for 80% of it.
 - Meteorology, PNT (GPS/Galileo), resources monitoring, disaster assessment, rescue and relief, support to warfare and intelligence...
 - Satellite applications are now part of our daily life. They are everywhere.
 - So many things are dependent on them, **and the majority of them are provided as free services by public institutions.**
 - >80% of satellite infrastructure is operated as a public service worldwide.
 - There is also a business dimension to space: with private operators providing satellite services. Most of that business is generated by telecommunications applications with TV broadcast making the most of it.

Space systems: A complex technology mix

- The spacecraft are very **complex** products, a **technology mix** with advanced materials and structures, lots of electronics, a power systems (solar cells, batteries, power electronics), a propulsion system, many antennas, cameras, gyroscopes etc.
- **The launch infrastructure is very special too** (most of them are used once, with a use cycle of only a few handful of minutes)
 - it is supported by a large ground infrastructure for launch operations with tons of **concrete**, tons of **metal**, a lot of **energetic** requirements, **and a lot of stored energy to accelerate the spacecraft to the orbit.**
 - A **launcher is mostly propellant** (95% of its mass) and a little structure, using **metals, composites, electronic components** power systems etc. Again a very complex technology mix, but where most of the mass is propellant.
 - The huge mass of propellant required to do an orbital launch is a major concern for the sustainability of space activities.
 - But the fact that expendable launchers are expended over the oceans and in the lower orbits should be a concern too.
- **One shall not forget the importance of the industrial facilities required to build and assemble satellites and launchers.**
 - And the heavy machinery involved, such as **white rooms, vacuum chambers, vibration benches, large wrenches, huge milling machines, great additive manufacturing autoclaves units** etc. Producing satellites and launchers are highly energetic processes.
- **The ground segment** is the least 'space' part of the infrastructure, it is composed mostly of telecommunications equipment, and human tended control centres. Basically a mix between a data centre and a control room.

How big is the space infrastructure

Space industry is not that big.

- An industry of 50k workers in Europe, and about 700k worldwide
 - 8,7B€ consolidated sales in Europe, vs 37B\$ in the USA
 - The USA, China and Russia produce about 85% of the total space infrastructure worldwide.
- Comparison points:
 - The Aeronautic industry in Europe has 550k employees, and about 1,5 million worldwide
- The space sector worldwide produces an average of 400 to 800 tons worth of spacecraft (150 large and 1000 of small/very small), and uses about 50-60 times that amount in propellant for about 100 to 200 launch events in the year.
 - The aero sector produces 4000 aircraft a year,
 - That's 160k tonnes of Aircraft/year. 200 to 300 times more than spacecraft and launcher production
 - Airlines consume more than 2,5 million barrels of jet fuel per day, or 390 million tonnes/day
 - In contrast the launch sector burns about 44 million tons/year. SpaceX alone is about 40% of the total in 2022

Compliance to environmental law

- The space sector is complying to the environmental regulations... even when they don't make any sense
 - E.g. Waste management, considering that Satellites never become waste for instance, but we still have to comply and produce information to recycle.
- The compliance effort is substantial, despite the low volumes of materials, the variety of technologies used by space creates a lot of regulatory uncertainties.
- Examples:
 - Chromates: the Euro space industry uses 2-3 tons/year where the Aero uses 100 – but we face the same compliance effort
 - Hydrazine: the Euro space industry uses a few tens of tonnes/year, where the other sectors (energy, water treatment, pharma and agri) consume 160k tons, but we face the same compliance effort (side note: hydrazine not yet banned, guess why?)
 - Lead: space sector minimal usage (tribology and soldering) is deeply affected, and must comply, in a world where Lead production is 4 million tons/year.
- Furthermore, the environmental efforts of the sector exceed the Earth rules, to abide to specific environment protections rules:
 - debris, a growing problem that needs to be addressed with best practices and regulation, growing increasingly restrictive.
 - The 25 year rule of ESA
 - the 5 year rule of the FCC
 - planetary protection: we must protect the planets we explore, to avoid contaminating them with Earth bacteria and we must protect earth from sample
 - light pollution: with the deployment of Starlink (and other LEO) the problem of satellites reflecting in the night sky disturb astronomical observation.

Space environmental footprint

- Today the environmental footprint of space activities remains quite limited, due to the small size of the activity globally. Not because the activity is inherently low impact, on the contrary.
 - But things may change if space activity grows exponentially as some like to predict (and others like to believe)
- Europe in particular is a small scale player, with less than 10% of the global production output.
 - And Europe is at the forefront of environmental assessment.
- The subject is addressed by ESA Cleanspace for more than 10 years.
- The situation is complex, and the implications are many.
- Papers and studies are increasing, so we increasingly know what's happening.
- Most of the focus is now on launchers, due to the high perceived environmental impact, but a lot is still unknown.
 - Some say that the environmental toll of launch activity is so unique, and critical, that it is hard to envisage a future with an exponential expansion of space activity.
- Full life cycle analysis of Space systems production and operations is needed now.