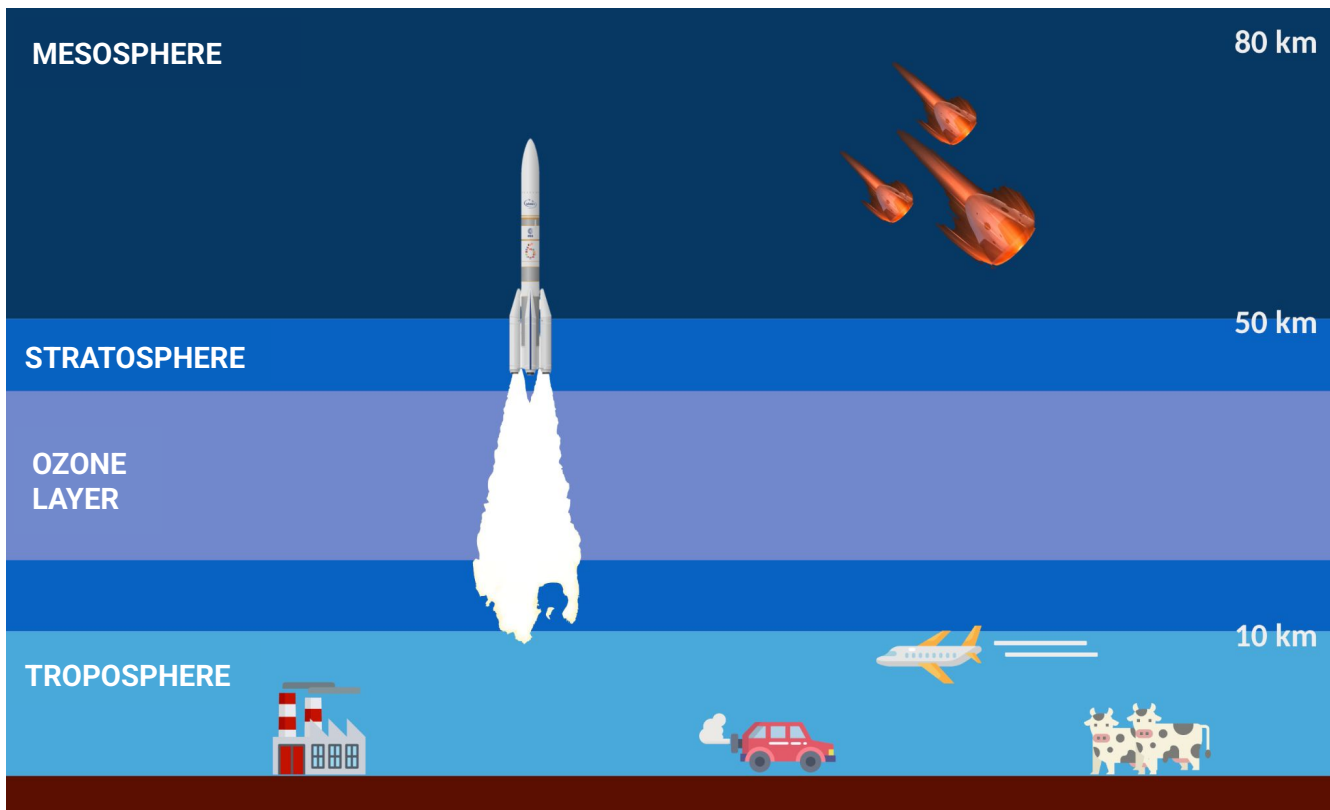




- Analyze
- Suggest
- Communicate

# ➤ The only activity impacting all layers of the atmosphere

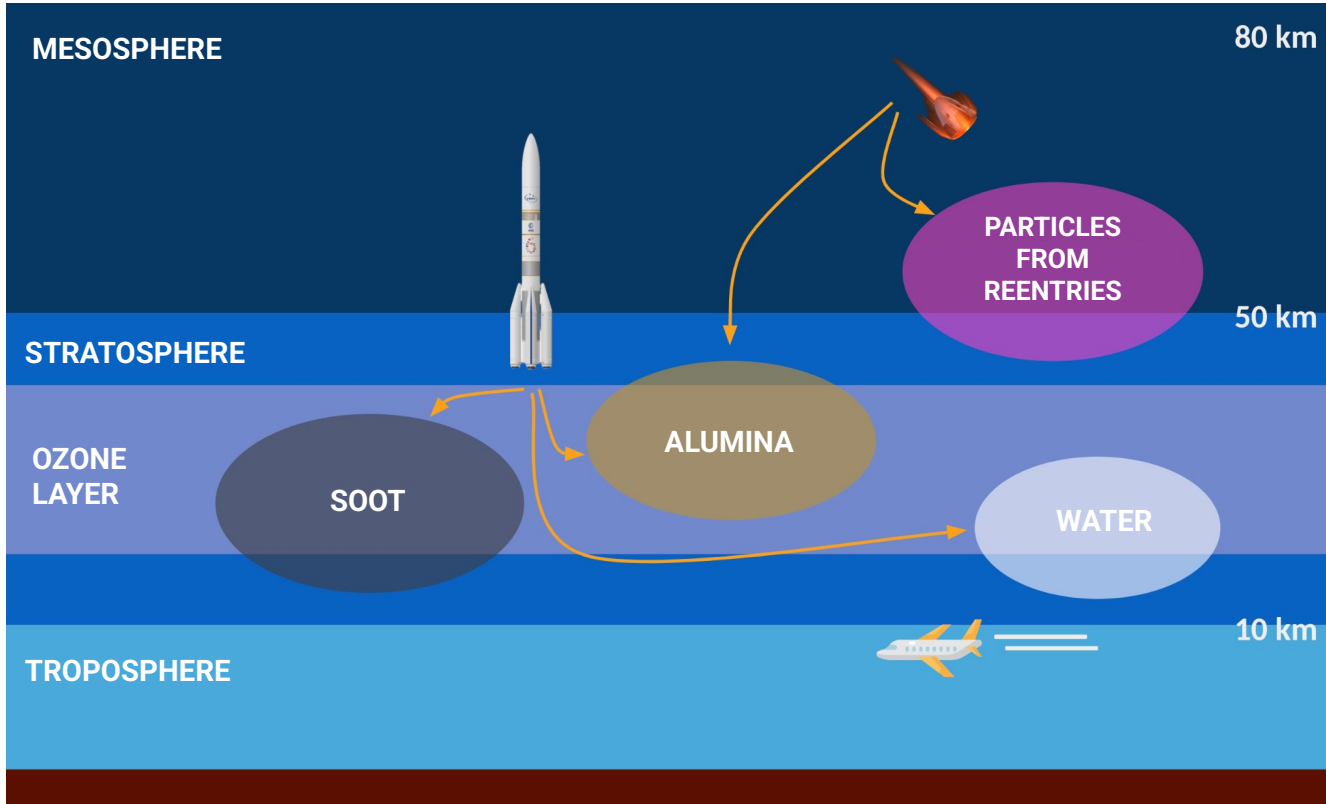


## Detailed models and abundant scientific results

Some uncertainties remain in specific areas, but overall impacts are well characterized.



## Climate impacts beyond the troposphere...

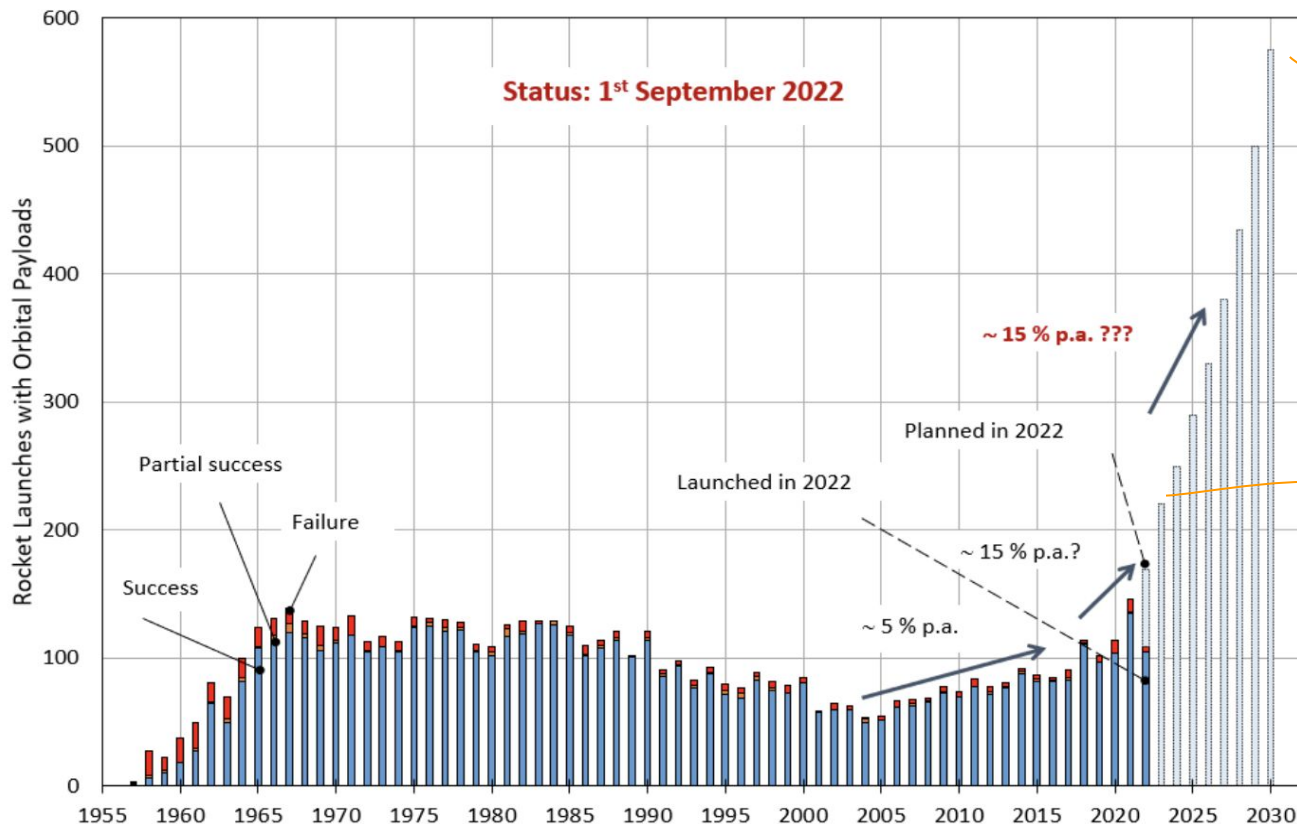


- Soot may significantly contribute to radiative forcing (500 times more than at aircraft altitudes)
  - $11 \text{ mW/m}^2$  (Ross et al. 2014)
  - $4.4 \text{ mW/m}^2$  (Ryan et al. 2022)

*This represents between 0.1% and 0.5% of total anthropogenic radiative forcing.*



# A sector on its launchpad...

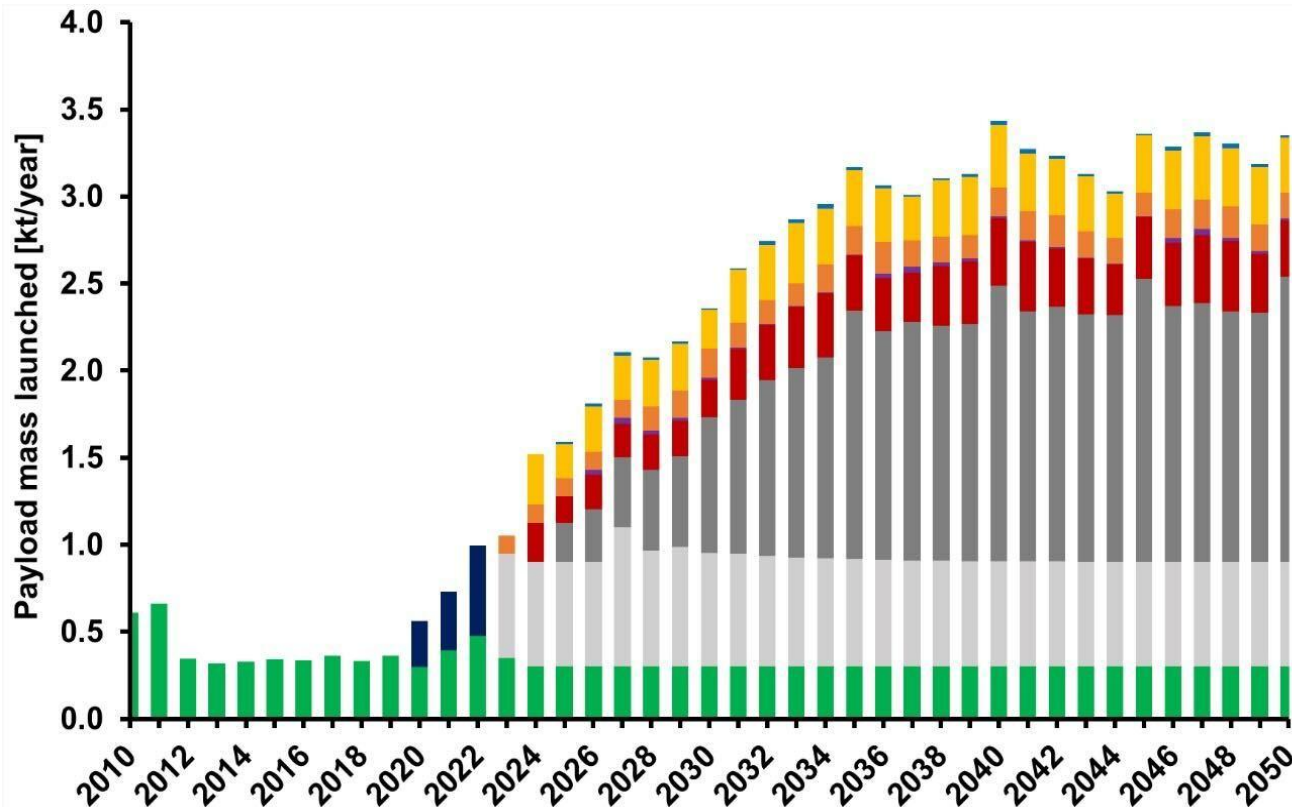


x5 between  
2020 and 2030

223 attempted  
launches in 2023



...which is expected to stay in orbit



Source : adapted from Miraux et al. 2022

Internet

x5 increase in orbital mass between  
2020 and 2030  
(and a x10 increase in the number  
of satellites)

## Summary

- **Uncertainties about the impact, not about the existence, of the non-Co2 effects (particles).**
- **Non-CO<sub>2</sub> effects have an impact both during launch and during re-entry.**
- **Space activities impact the climate and the ozone.**
- **Significant increase in the number/mass of satellites in orbit over the last decade despite the previously mentioned uncertainties.**

# Questions and reactions

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*Convinced, skeptical, motivated?*

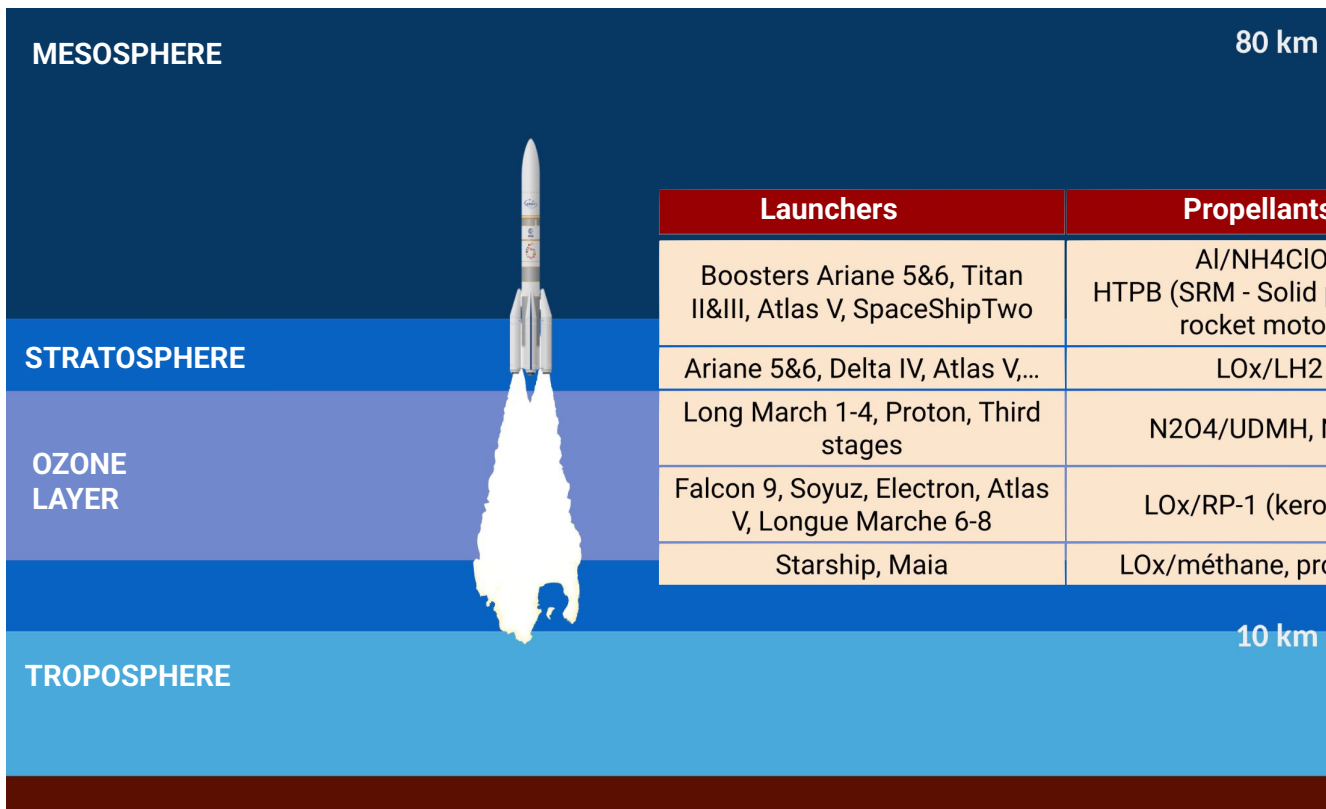
*Let's talk about it!*

*Contacts*

[jdoche@ensc.fr](mailto:jdoche@ensc.fr)



# Launch-related emissions



**Greenhouse gases**  
**Particles**  
**Harmful to the ozone layer**

Emission levels vary depending on **altitude** and **launcher type**.

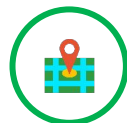




# Towards new metrics?



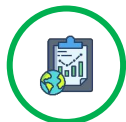
International cooperation



Critical applications



Law enforcement and monitoring



Earth observation



Space debris



Direct emissions



Optical pollution



Ozone depletion



Resource scarcity



Energy scarcity

Indicator dimensionless

Few objective methods available

**[Social utility]**

**[Environmental impact]**

Multidimensional indicator

Quantifiable but little-known impacts!



# The impacts of space: diverse, overlooked, and hard to see?

Consider the full value chain!

**Consider all impacts!**  
Even the less visible or less direct ones should be taken into account for a sustainable future.

Upstream activities

Core sector activities

Downstream activities

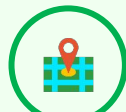
## Positive aspects



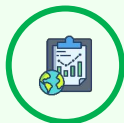
International cooperation



Law enforcement and monitoring



Critical applications



Earth observation



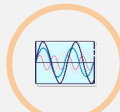
Space debris



Direct emissions



Reentries



Frequency scarcity



Optical pollution



Downstream data processing



Energy pressure



Water stress



Ozone depletion



Launch emission uncertainties



Resource scarcity

**The stars of the space sector's impacts!**

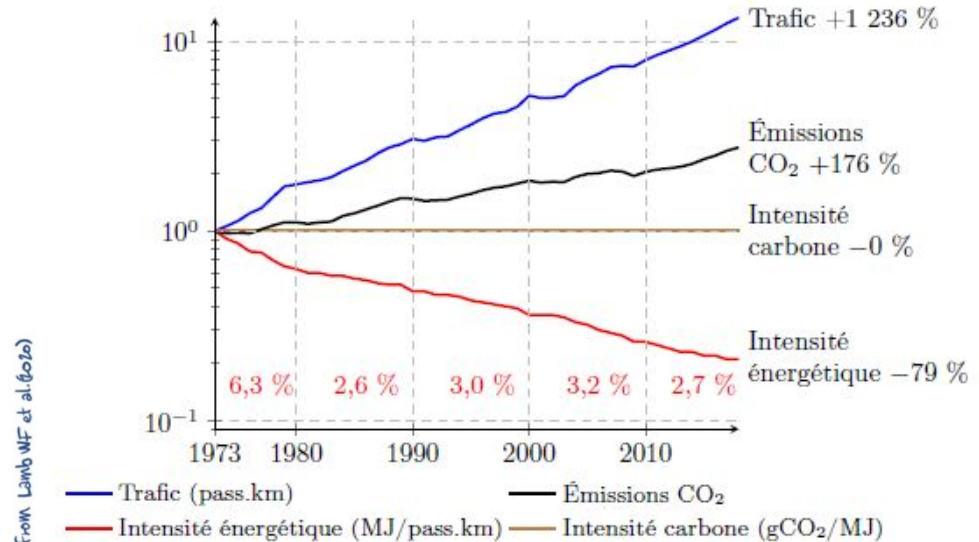
**The land of the forgotten...**



# TECHNO-OPTIMISME: CONTREDIT PAR LE PASSÉ



## Contredit par les tendances historiques : l'exemple de l'aérien



Évolution des termes de la décomposition de Kaya (3.2) des émissions de l'aviation entre 1973 et 2018. Base 1 en 1973. L'échelle des ordonnées est logarithmique. (Référentiel Aviation-Climat ISAE-SUPAERO)