



# Ethical Questions in Space Research: Topics to consider

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# On sustainability

## Rules-based

*("Let's prevent waste")*

**Brundtlandt definition: "Let's use a common-pool resource such that it can also be used in the future"**

## Resilience-based

*("How do we act if there is waste")*

**"The system is sustainable if it returns back to normal after a disturbance."**



Venn diagram for sustainable development



# How is space research carried out in practice

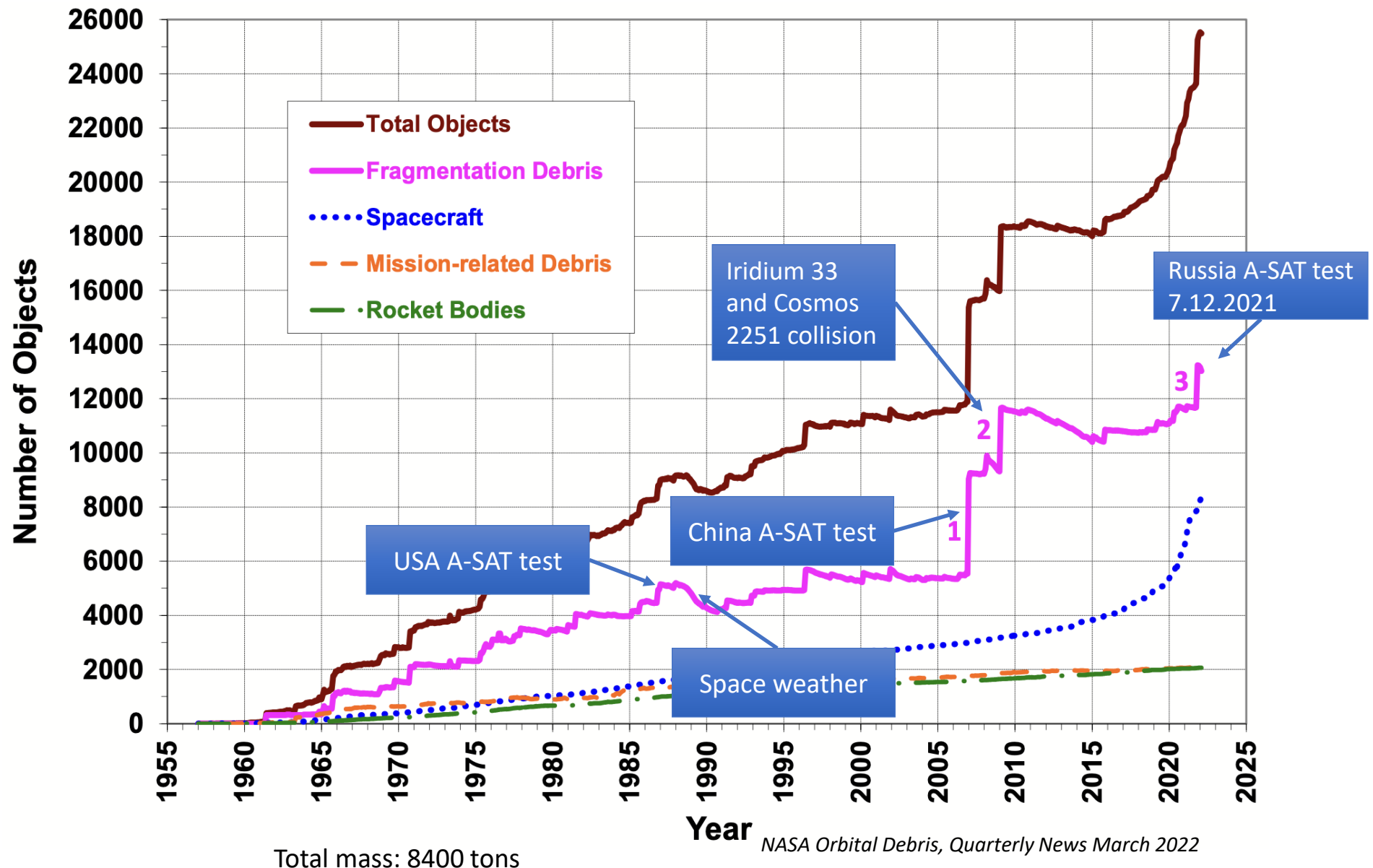
- **Empirical science requires observations**
  - Satellites
    - Design, build, test, launch, calibrate, operate
  - Ground observations
    - Design, build, test, install, calibrate, operate
- **Models**
  - Computers and supercomputers
- **Theory**
  - Paper and pen, computers and supercomputers
- **Ultimate understanding of natural phenomena requires observations**
  - Read Minna's article in Financial times:  
<https://www.ft.com/content/95c62ecd-e0ca-4151-b3cf-8db4ee814137>

# Launching satellites create rocket fuel pollutants

## ROCKET EMISSION TOTALS<sup>[METRIC TONNES]</sup>

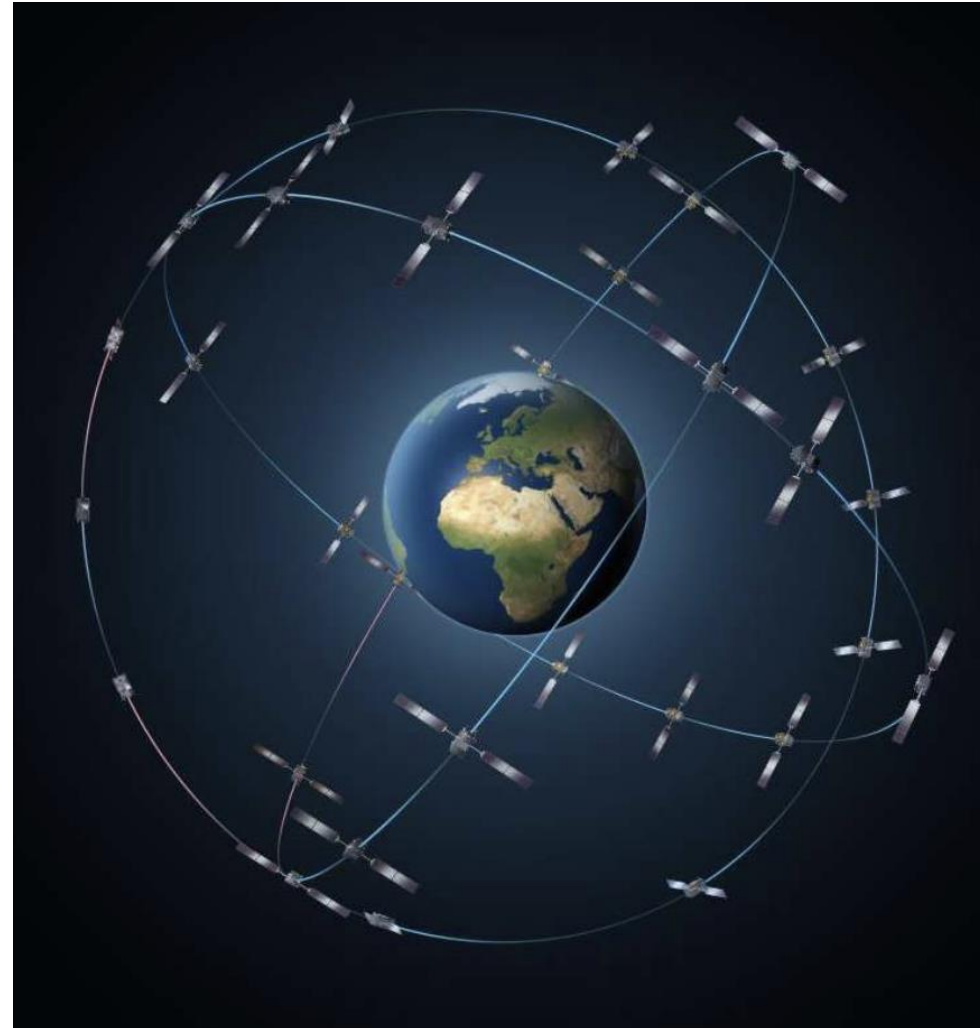
	FUEL	CO <sub>2</sub>	WATER VAPOR	SOOT	NO <sub>x</sub>	INORGANIC CHLORINE	ALUMINA	SULFUR CONTAINING COMPOUNDS
TITAN II	HYPERGOLIC	36	16	0.2	0.3	0	0	0.3
SOYUZ FG	RP-1 + HYPERGOLIC	243	64	13	0.4	0	0	~0
ATLAS V N22	SRB + RP-1 + HYDROGEN	259	111	2.1	0.8	21.4	30	~0
FALCON 9	RP-1	425	152	30	1	0	0	~0
DELTA IV HEAVY	HYDROGEN	~0	632	0	0.5	0	0	0
SPACE SHUTTLE	SRB + HYDROGEN	443	976	4.2	7	250	350	~0
SLS	SRB + HYDROGEN	538	1346	5.1	8.5	302.5	423.5	~0
STARSHIP + SUPER HEAVY	METHANE	2683	2199	0	1.7	0	0	0

# Launching satellites potentially create space debris



# On the other hand:

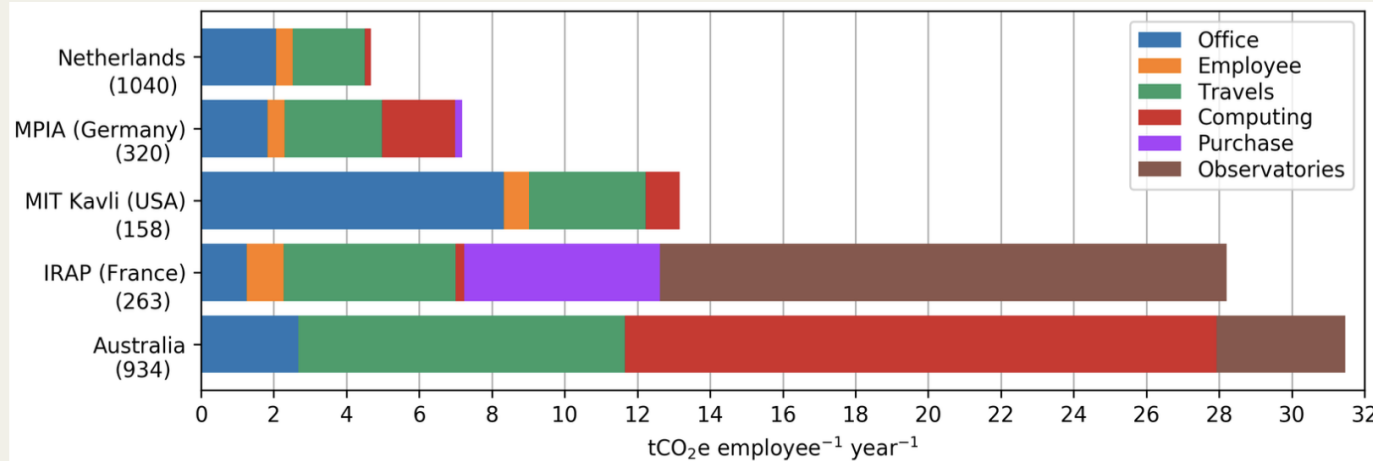
- **Space enables the modern digitised society**
  - Communication & Navigation
  - Weather & Monitoring the planet
  - Digitisation & Green transition
- **Space research has enabled all that**
  - How to go and be there
- **Space research nowadays increases the resilience of the society**
  - Understanding space environment increases safety of satellites and critical societal infrastructure
- **In future**
  - Manned missions to Moon & Mars, perhaps inhabitation
  - Asteroid mining
  - Space tourism





# The carbon footprint of astronomy

Courtesy of J. Knödseder



**Important differences among assessments**

**Most assessments excluded some sources of emissions (purchase, observatories)**

**Knödseder (2023), in: Climate Change for Astronomers (IOP)**

Based on data from:

Van der Tak et al. (2021) – Netherlands

Jahnke et al. (2020) – MPIA

Simcoe et al. (2022) – MIT Kavli

Martin et al. (2022) – IRAP

Stevens et al. (2020) – Australia

**Astronomical observatories (ground- and space-based) make the single largest contribution to the carbon footprint of an astronomer ( $36.6 \pm 14.0 \text{ tCO}_2\text{e yr}^{-1}$ )**

Knödseder et al. (2022), Nature Astronomy, 6, 503

- **Someone may conclude: Let's stop or slow down research (but can be unethical in itself)**
- **Minna's Conclusions:**
  - Travel and office are the same as in any other research area
  - Computing can be done in carbon-negative computing centres (such as in Kajaani)
  - A lot depends on how society's electricity is produced



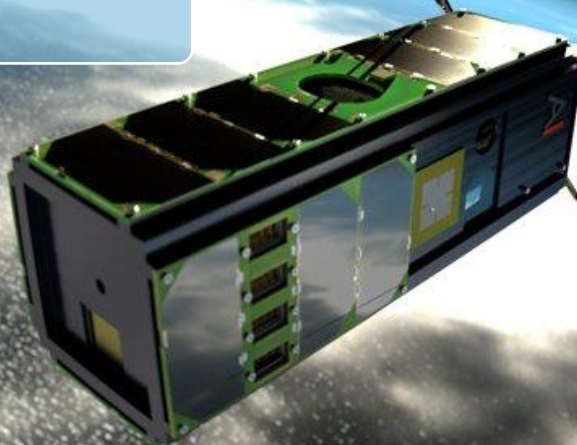
## Challenges

- Rapid evolution of space utilisation
  - Especially commercial
- Complex connections to modern society that are not understood
- Binding regulation through national space laws
  - Internationally non-binding agreements mainly from 1960s
- Some ethical principles exist



# Finnish Centre of Excellence in Research of Sustainable Space

- Investigates the conditions in space
- Develops durable satellites
- Develops cost-efficient de-orbiting devices
- Objective is a significant improvement in orbit safety



A?



# MOOC course: Sustainable space

<https://sustainable-space.mooc.fi>

## Sustainable Space

This University of Helsinki MOOC offers a thorough introduction to topics concerning sustainable use of space and explores how space activities solve sustainability challenges on Earth

START COURSE

GIVE FEEDBACK

- Open to everyone
- No previous knowledge required
- Includes ethical questions and space law