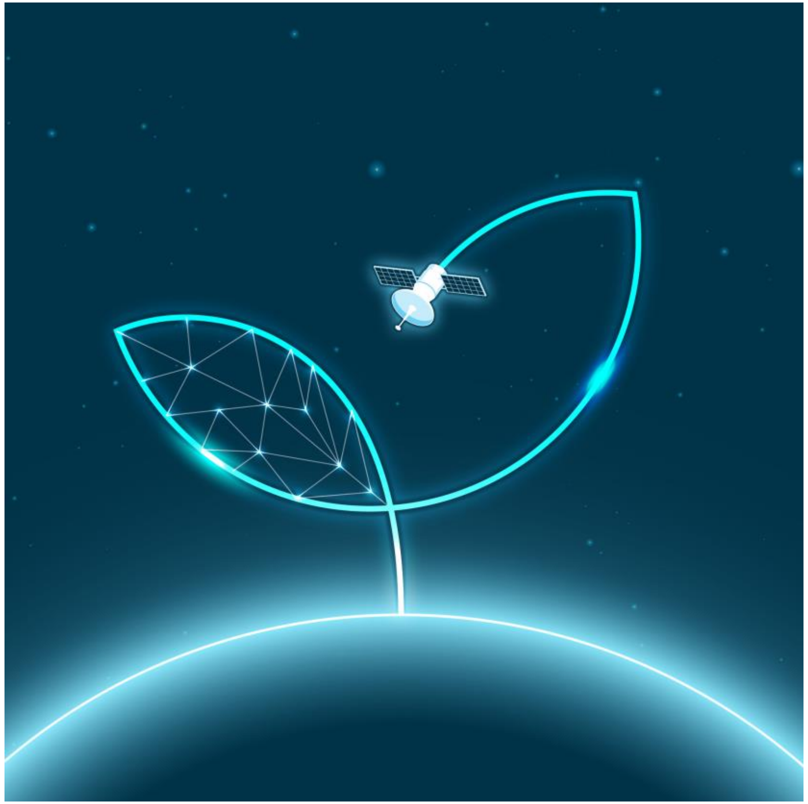
Green Space and Zero Debris - EEE evaluations

TESAT EEE Parts Agency

AGENDA

1. Why and how Zero Debris?
2. ESA Zero Debris Approach
3. Consequences to EEE parts
4. Plasma Wind Tunnel / TGA experiments
5. First Life-cycle impact assessment (LCIA) results
6. Outlook

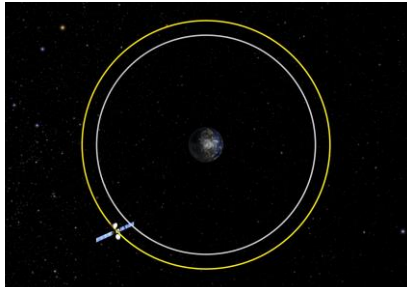


ESA [11]

1. Why and how Zero Debris?

- To mitigate collisions and fragmentation events the UN, ESA, NASA, and other organizations created guidelines on the use of orbital regions
- 3 options for end-of-life disposal in agreement with regulations

1. **Graveyard orbit**



ESA [1]

2. **Lunar impact**

NASA [2]

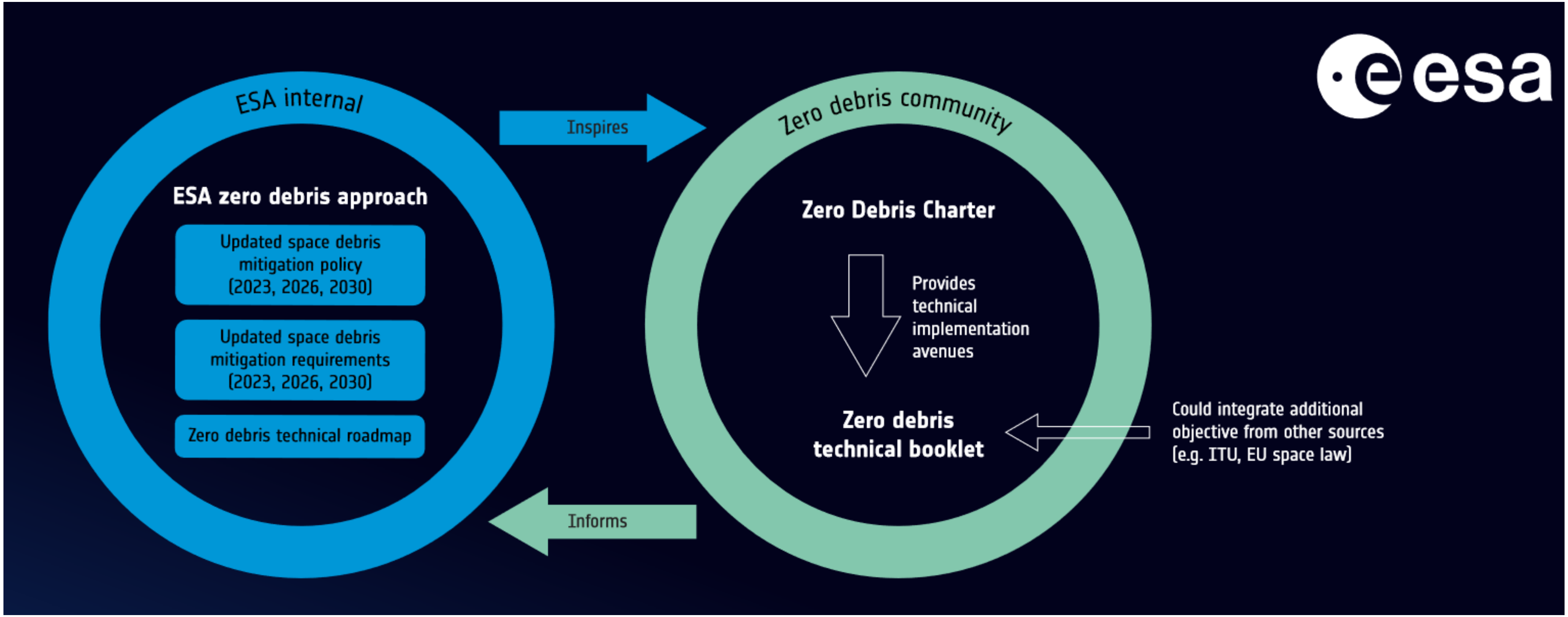
3. **Atmospheric re-entries**

Aerospace [3]

- Most constellations are located in low earth orbit (LEO, 0-2000 km) [4]
  - **Logical disposal via atmospheric re-entries** due to proximity to earth and atmospheric drag
- 51 – 95% of the satellite‘s mass burns-up and evaporates into atmosphere ~16.000t/a. [5]
  - **Objects must be actively designed for demise** (D4D) to avoid physical impact of uncontrolled re-entries

2. ESA Zero Debris Approach

» In November 2023: ESA policy and technical requirements were updated for Zero Debris approach



ESA [13]

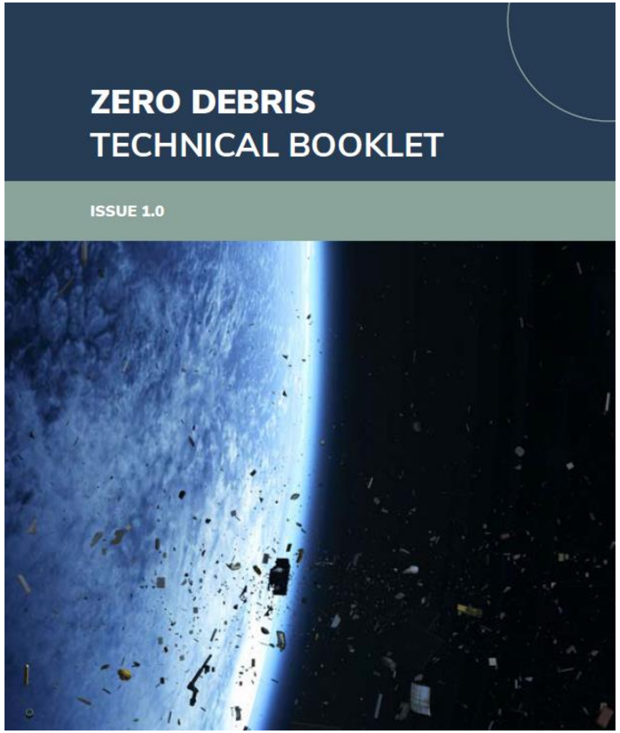
3. Consequences to EEE parts

- **ESA Zero Debris Technical Booklet: Published on Jan-15, 2025:**
  - Guidance and key enablers in respect to Zero Debris
  - Chapter 6.1.A and 6.1.B concerns EEE(E) parts:

  - A. Characterisation of materials used in spacecraft & their behaviour during re-entry for assessing their environmental impact

  - B. Characterisation of impacts of re-entry on the atmosphere for grasping the long-term consequences of re-entry events

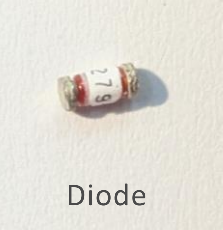
- **ESA LCA Data Questionnaire for Space Suppliers**
  - Life Cycle Assessment (LCA) for comprehensive approach
  - Tears down information and data request to supply chain
  - Levels down to EEE parts level

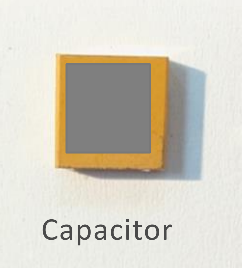


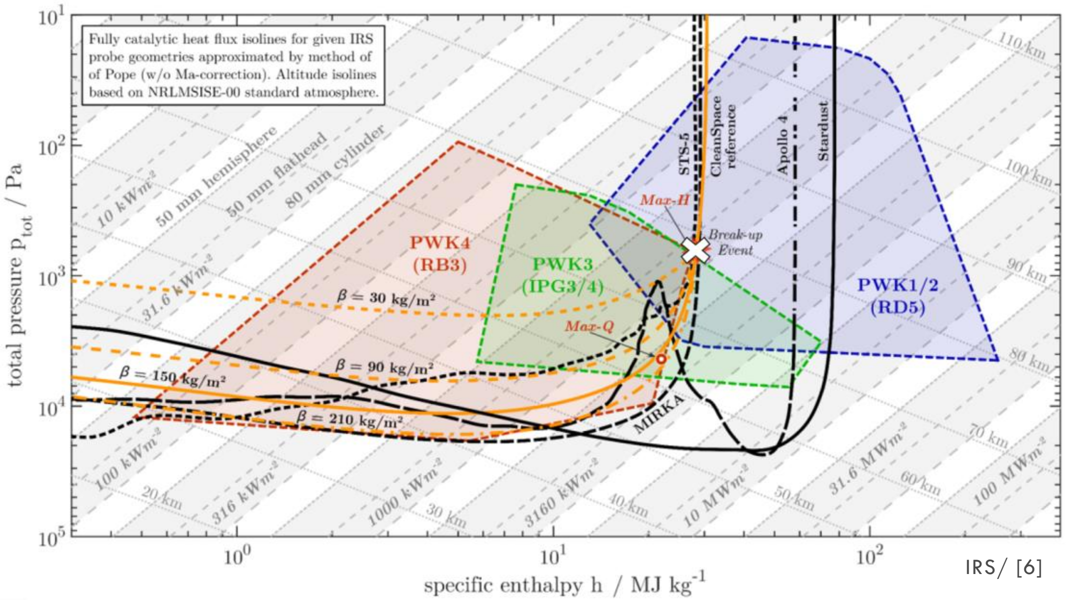
ESA/ [12]

4. Plasma Wind Tunnel / TGA experiments

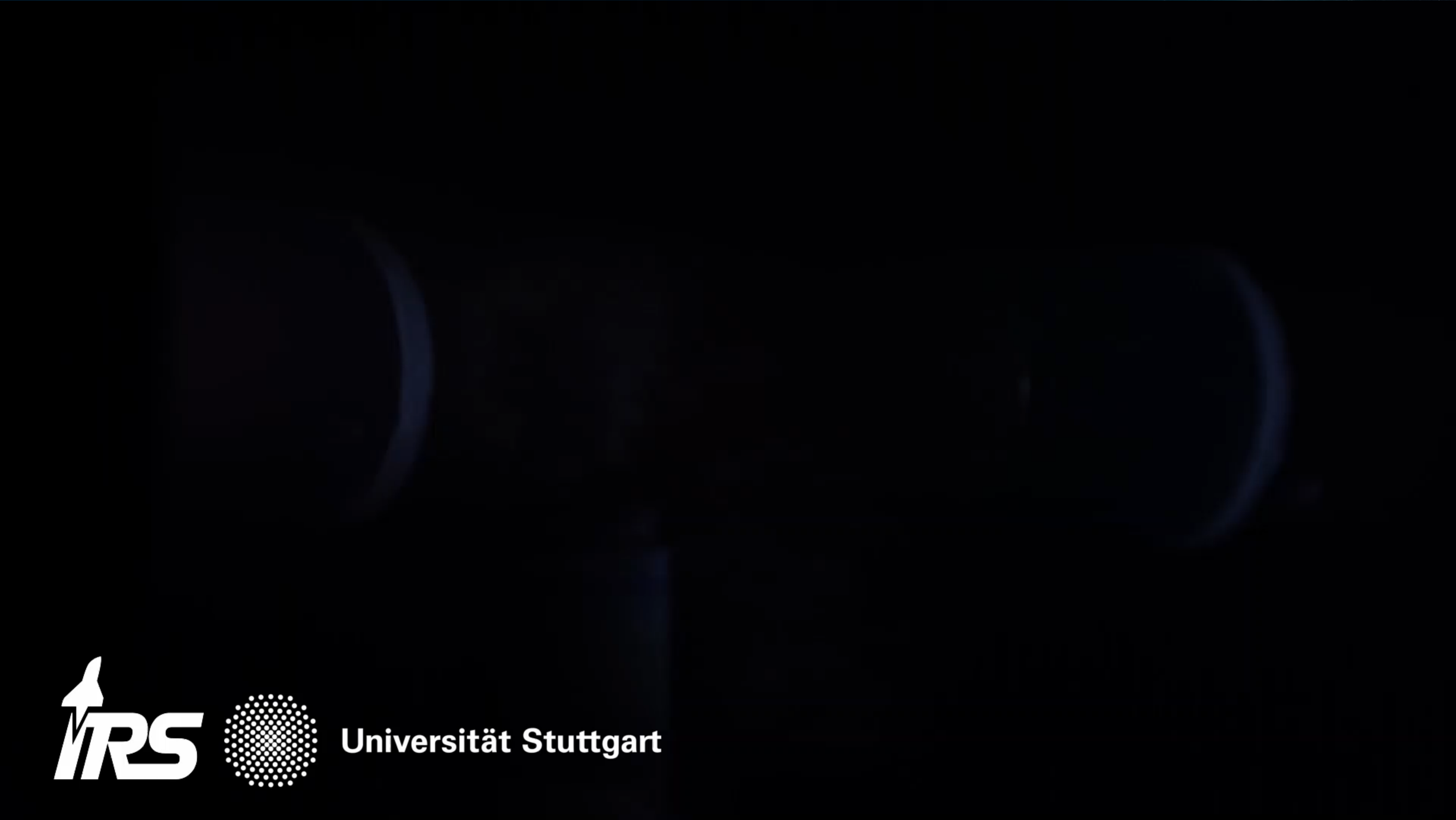
- Plasma wind tunnel (**PWT**) experiment for a typical LEO break-up event
  - Simulates heat flow & altitude specific enthalpy (plasma velocity)
  - Satellite break-up point chosen on joint ESA and IRS studies
  - Observation of plasma-induced ablation and thermal demise







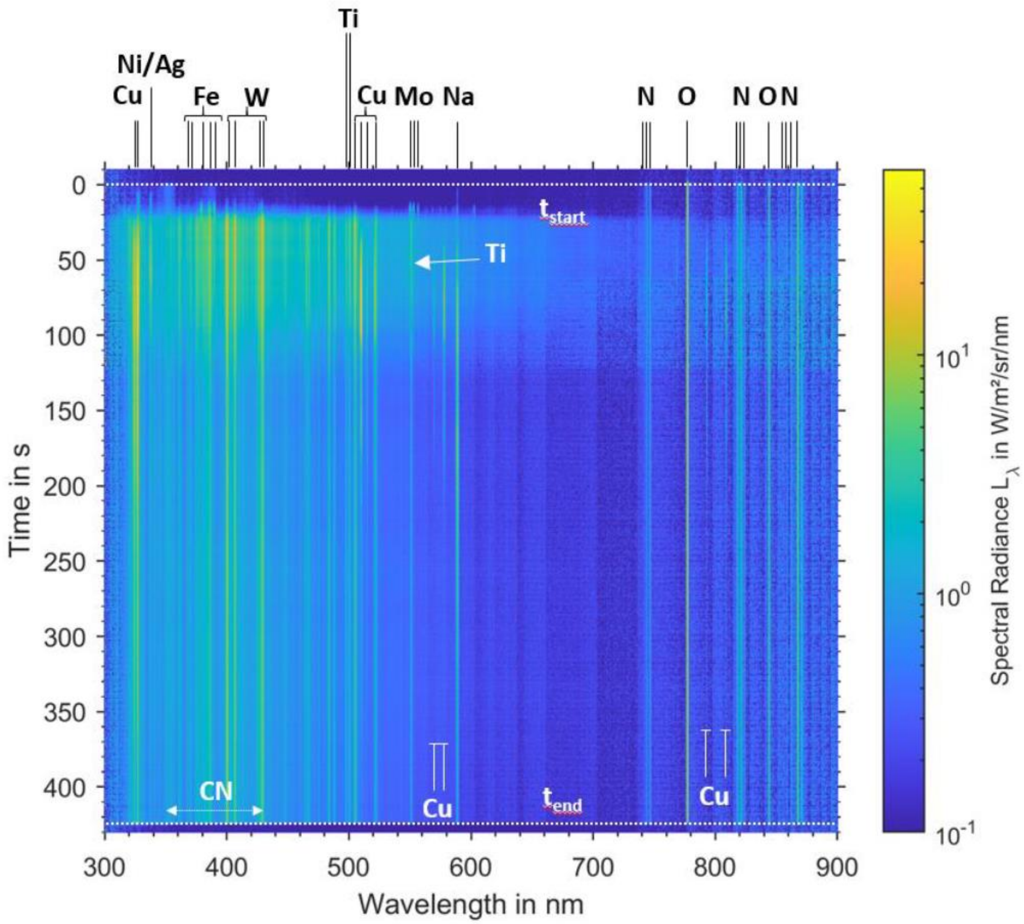
IRS/ [6]


IRS
Universität Stuttgart

4. Plasma Wind Tunnel / TGA experiments

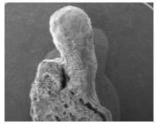
- In-situ optical emission spectroscopy (**OES**) during PWT
  - The physical emission of atoms and compounds into atmospheric plasma observed
  - Peak timestamp yields information of emission location (e.g., mesosphere vs. stratosphere)
  - Quantification not possible, as some species emit significantly more photons
  - Many common signals (Cu, Fe, O, N, AlO) but also rare ones (e.g., W, Ti, Mo)

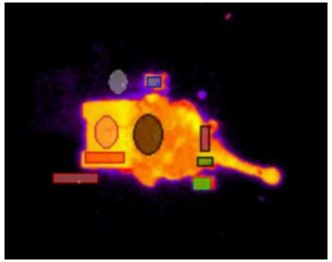
- OES was followed by Thermogravimetrical analysis (**TGA**) and scanning-electron microscopy coupled with energy-dispersive X-ray spectroscopy (**SEM-EDX**)



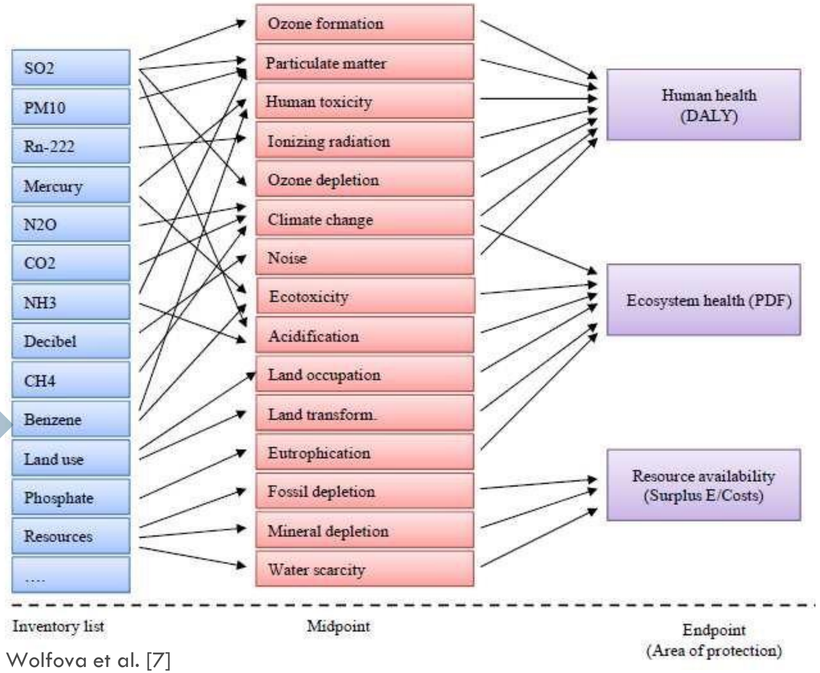
5. Life-cycle impact assessment (LCIA)

- EF LCIA method, version 3.1 (2022)
- Used by European Space Agency and IRS - Uni Stuttgart for the holistic impact of space missions
- 16 midpoint impact categories with multiple sub-categories
- Transparent and characterisation factors (CFs) publicly available
- Building of Excel tool for interface between EF method and
  own inventory analysis: Impact assessment (LCIA)
- 4 categories yielded results





Elementary flows for DJ2			
Most likely reaction product	Mass (g)	FLOW_name	Prefered flow class (Emission location in database)
NiO	0.61708	nickel (ii) oxide	Emissions to lower stratosphere and upper troposphere
Fe_3O_4	0.48734	iron(iii)oxide	Emissions to lower stratosphere and upper troposphere
Co_3O_4	0.15120	cobalt oxide	Emissions to lower stratosphere and upper troposphere
SiO_2	0.00876	silicon dioxide	Emissions to sea water
Au	0.00804	N/A	Emissions to lower stratosphere and upper troposphere

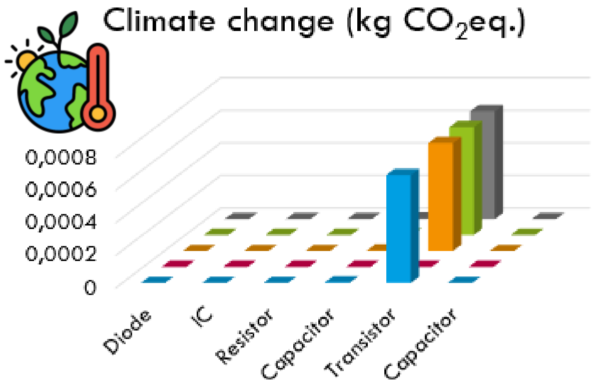


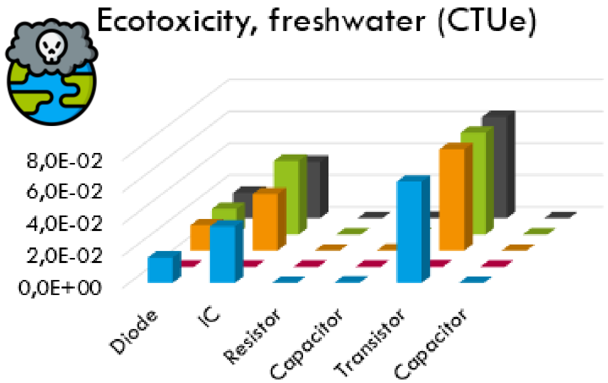
Wolfova et al. [7]

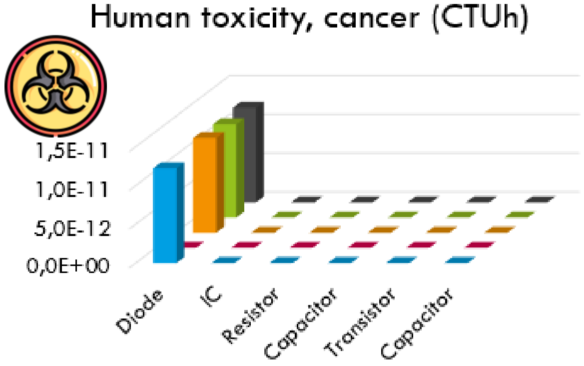
5. Life-cycle impact assessment (LCIA)

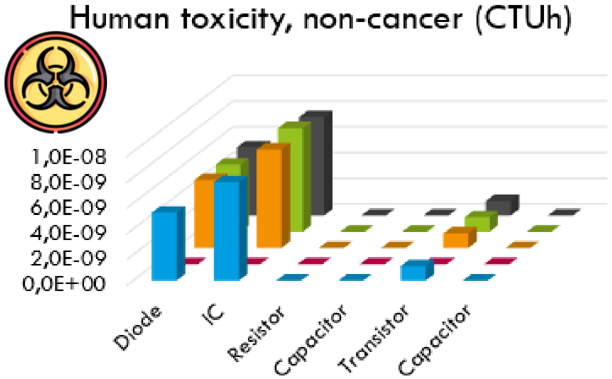
1. Scenario: Realistic demise
2. Scenario: No demise
3. Scenario: Full demise
4. Scenario: Emissions to air
5. Scenario: Emissions to soil

- Scenario 2 almost no impact in any category
- Diode, IC and transistor are due to metals more poisonously
- Pb let the diode being most dangerous to human toxicity.



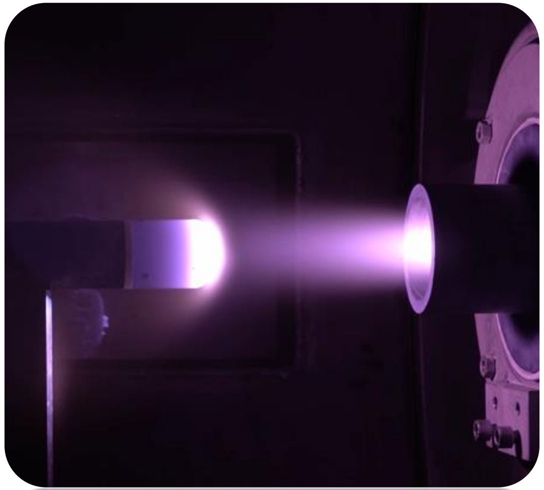






6. Outlook

- Re-entry prediction of 16,000 t/year [5] leads to extrapolated impact based on investigated parts:
  - Climate change: Up to 730 Mt CO_2 eq./year compared to 1.2 Mt CO_2-eq. in 2019 [9])
  - Toxicity equivalent of 1% of biggest toxicity sources in EU [8]



TESAT/IRS [10]

- TESAT Parts Agency will soon start to increase efforts in characterizing more and systematic parts families
- Identify materials that are re-entry friendly and enable supply chain

- Encourage responsible procurement and supply chain
  - Trigger to determine carbon footprint for supplied materials -> new information e.g. included in PAD
  - Recommend low impact EEE parts enable supply chain to promote sustainability

THANK YOU FOR YOUR ATTENTION

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Sources

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- [3] https://aerospace.org/article/what-does-reentry-look-like
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