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Global trends in satellite deployments

sustainable or not?

Awareness on space impact is rising

Ecocide in

An Orbital House of Cards: Frequent Megaconstellation Close Conjunctions

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- Satellite reentry material accumulates at high latitudes between 10 and 30 km
- Small perturbations to heating rates results in as much as 1.5 K temperature

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2.8 Days t
Orbit Coul

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A new study suggests that modern satellite networks may be far more fragile than they appear, with the risk of orbital collisions rising sharply if control systems are disrupted. Credit: Shutterstock

The Atmospheric Impacts of Re-entry and Launch (AIRL): High-Priority Actions and Recommendations

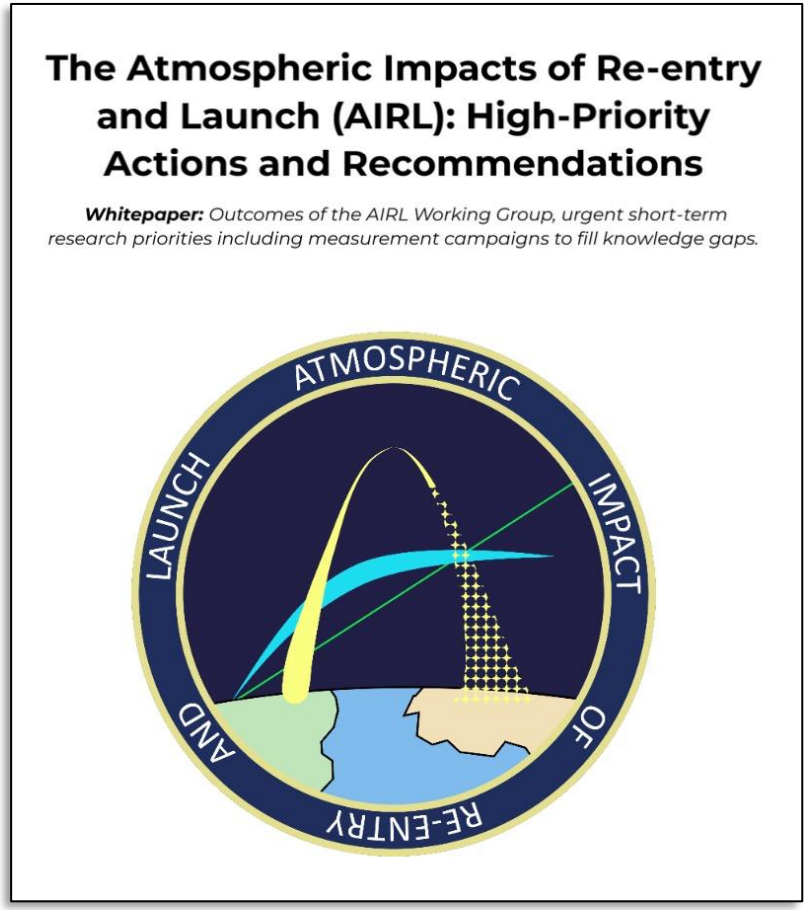
Whitepaper: *Outcomes of the AIRL Working Group, urgent short-term research priorities including measurement campaigns to fill knowledge gaps.*

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2026: AIRL white paper

https://www.essc.esf.org/wp-content/uploads/2026/07/Whitepaper-Atmospheric-Impacts-of-Re-entry-and-Launch_pu-1.pdf

- "Rocket launches and the ablation of re-entering spacecraft release a variety of gases and particles directly into the middle and upper atmosphere"
- "These emissions include metallic and carbon-rich particles and gases that are chemically and radiatively active. **As the frequency of launches and re-entries increases, so do the amounts of these emissions.**"
- "the **anthropogenic inputs** of Li, Al, Pb and Cu to the middle and upper atmosphere from space activities already **exceeded the natural inputs**, essentially of meteoritic origin"
- "**metallic ablation** particles, together with ***rocket*** **exhaust** and other space-related emissions, **have the potential to alter the chemistry and radiative balance of the stratosphere**, the region that contains the **ozone layer**"
- "The pace at which the space sector is expanding far outstrips our ability to evaluate its environmental footprint."



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A rough visualisation of global space activity

Total useful mass launched to orbit 1957-2026 (Q3)

For each kg of Payload thare are 0,7 to 1,2 kg of upper stage left in LEO

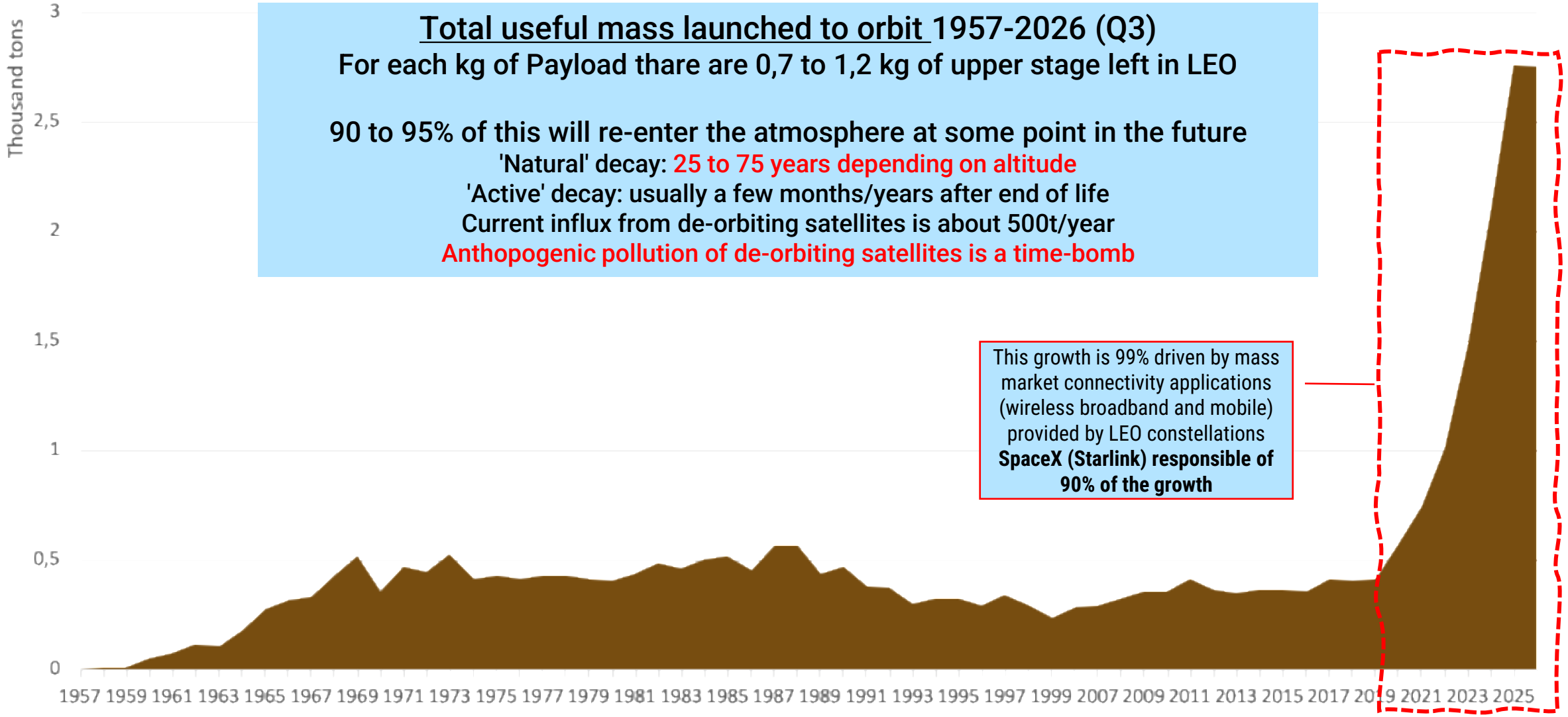
90 to 95% of this will re-enter the atmosphere at some point in the future

'Natural' decay: 25 to 75 years depending on altitude

'Active' decay: usually a few months/years after end of life

Current influx from de-orbiting satellites is about 500t/year

Anthopogenic pollution of de-orbiting satellites is a time-bomb



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Elements of appreciation

Space launch impact

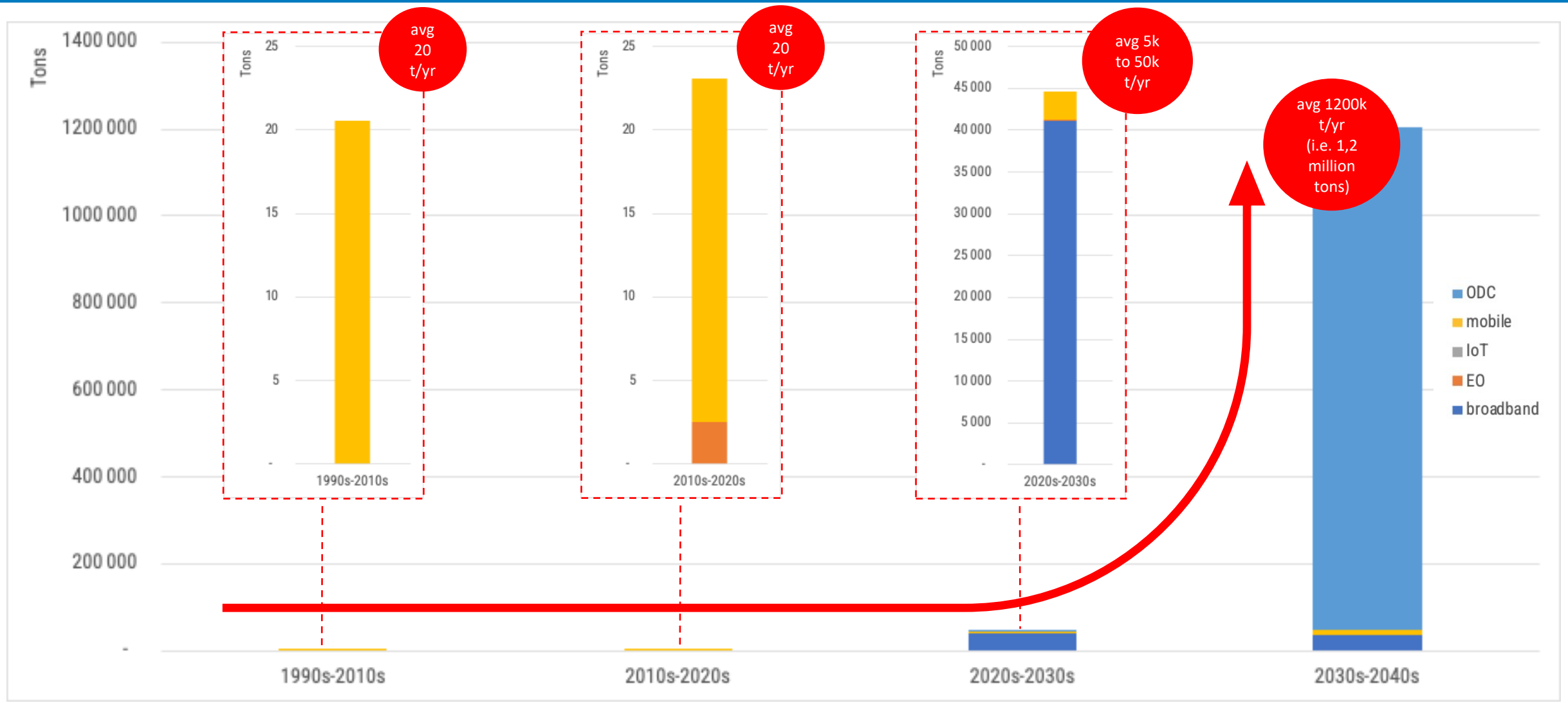
- Aerodecarbo (2025) quotes 3 different assessments
- Shift Project (2023)
- Launch activity global impact on atmosphere 0,1 to 0,6% of total anthropogenic impact.
- 500 t launched in 2022
- *Ecospheric life cycle impacts of annual global space activities. Science of the Total Environment* (2022)
- 0,01% of global impact
- 440 t launched in 2018 (study baseline)
- *Radiative forcing caused by rocket engine emissions. Earth's Future* (2014)
- 16 mW/m2 or about 0,6% of global anthropogenic impact
- 345 t launched in 2013
- Launch impact was negligible until cadence accelerated fast in 2019
- Launched mass doubles every 2 years since 2019
- The exponential growth is driven by mass market connectivity solutions (Starlink) and data center infrastructure (Starmind)

Data & connectivity impact

- Global data traffic has grown 22% every year in the past decade:
- most of the traffic is for video, most of the traffic is through wireless/mobile.
- Ofcom (UK) "Carbon emissions of streaming and digital terrestrial television"
- Video Streaming delivery has 5x the impact of Video Broadcast delivery
- ARCEP (FR)
- Wifi has 2x the impact of ethernet
- Mobile (5G) data delivery has 2,5x the impact of fixed data delivery
- Growing data consumption through wireless networks has exponential environmental impacts
- GM University/ Oxford University:
- "(Starlink broadband has) more than 31-91 times higher (impact) than equivalent terrestrial mobile broadband."
- Starlink Broadband is the most impactful connectivity solution by far

Mass trends in LEO constellation deployments

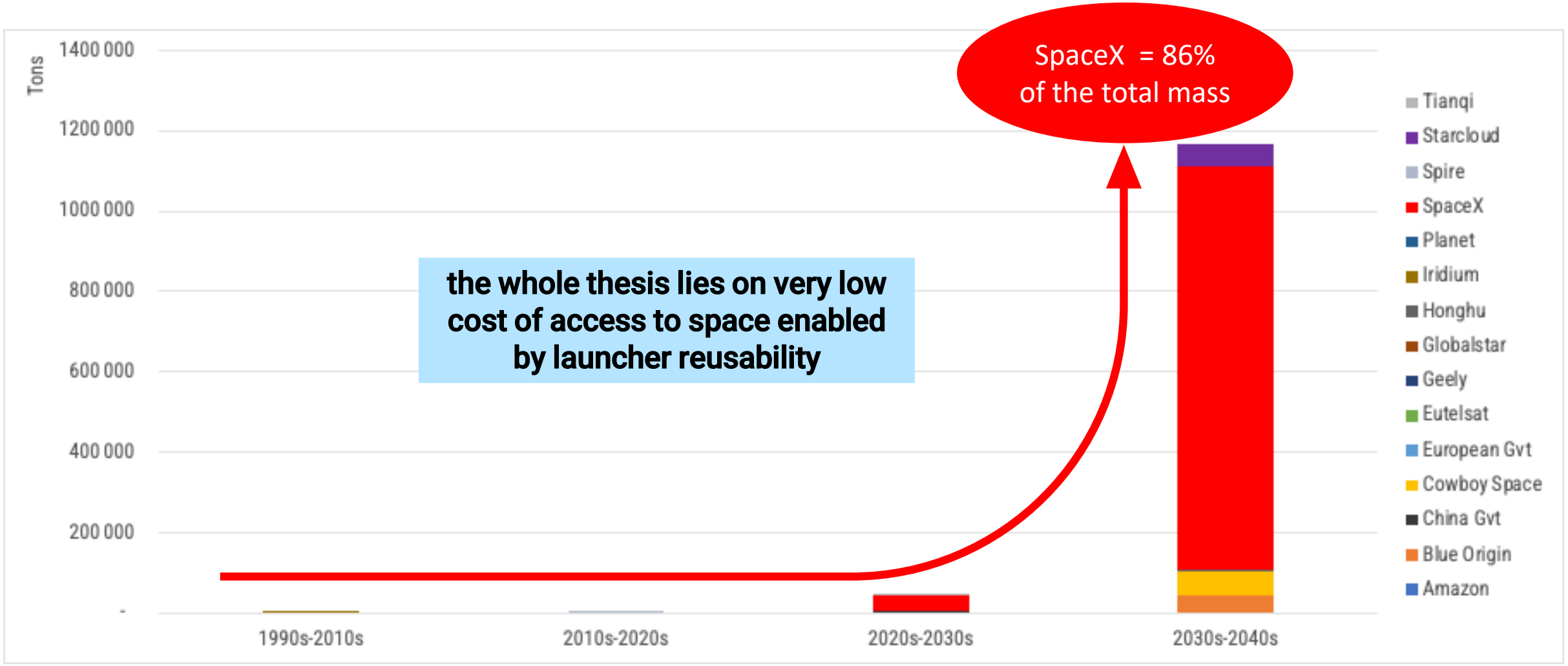
Average mass deployed per year by period and applications 1990-2040



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Mass trends in LEO constellation deployments

Average mass deployed per year by period and promoter 1990-2040



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Typical launcher propellant formulations

The 'cleanest'

- **Oxygen and Hydrogen**
- Pros:
  - high specific impulse (>350)
  - no toxicity
- Cons:
  - high storage and production costs
  - high volatilty
  - cryogenic
  - currently not considered for reusable systems
- Used on:
  - SLS
  - Ariane- 6
  - H-3
  - Vulcan
  - CZ-5
- **LOX/LH2 has the best overall performance and lowest environemntal footprint at launch**
- **Mostly used for MEO, GEO and HEO launch**

The 'ugliest'

- **Dinitrogen teroxide and Hydrazine**
- Pros:
  - storable at room temperature
  - no need for ignition
- Cons:
  - high toxicity
  - highly corrosive
  - low specific impulse (<300)
  - currently not considered for reusable systems
- Used on:
  - CZ-2 to 5
  - PSLV/GSLV

The 'solid'

- **Ammonium perchlorate and Aluminium**
- Pros:
  - storable at room temperature
  - synergy with defence
- Cons:
  - hard to throttle
  - source materials instability
  - metal dispersion
  - low specific impulse (<300)
  - currently not considered for reusable systems
- Used on:
  - SLS
  - Ariane- 6
  - H-3
  - Vulcan
  - Vega
  - Ceres-1
- **Solid boosters are afrequent add-on for high energy launch requirements**
- **Mostly used for MEO, GEO and HEO launch**

The 'legacy'

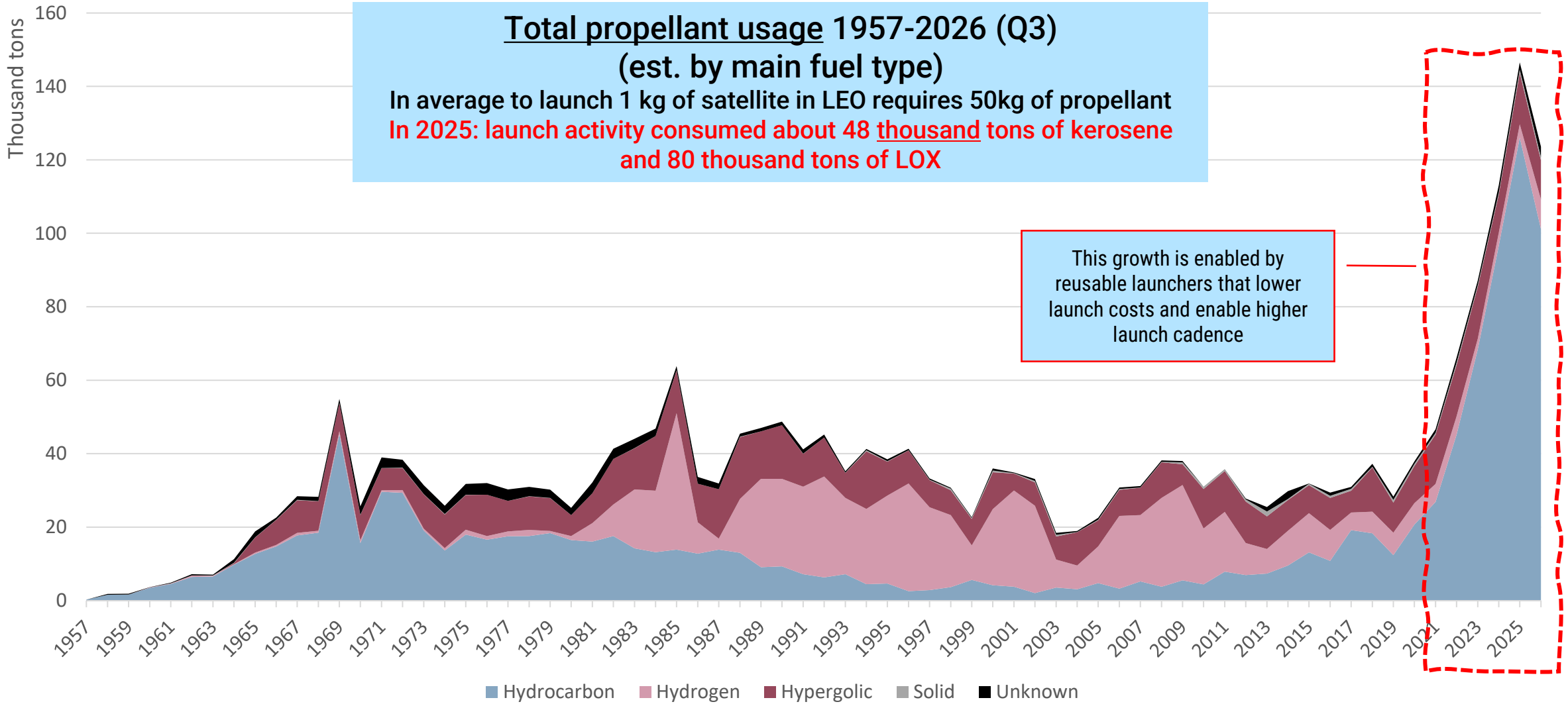
- **Oxygen and Kerosene**
- Pros:
  - storable at room temperature
  - availability and price
  - low cost
  - easiness of operations
  - most used for reusable systems today
- Cons:
  - soot
  - low/medium specific impulse (<340)
- Used on:
  - Soyuz (>7000t)
  - Falcon (>8500t)
  - CZ-6 to 8
- **50% of total mass launched since 1957 relied on kerosene mixtures.**
- **and 73% of mass launched since 2020**

The 'future'

- **Oxygen and Methane**
- Pros:
  - no soot
  - availability and price
  - baselined for all reusable systems announced
- Cons:
  - high storage/transport costs
  - volatility
  - potent greenhouse gas
  - medium specific impulse (350)
- Baselined for:
  - Starship
  - New Glenn
  - Neutron
  - Terran-R
  - Nova
  - Zhuque-3
- **Methane formulations are anticipated to dominate the reusable market**

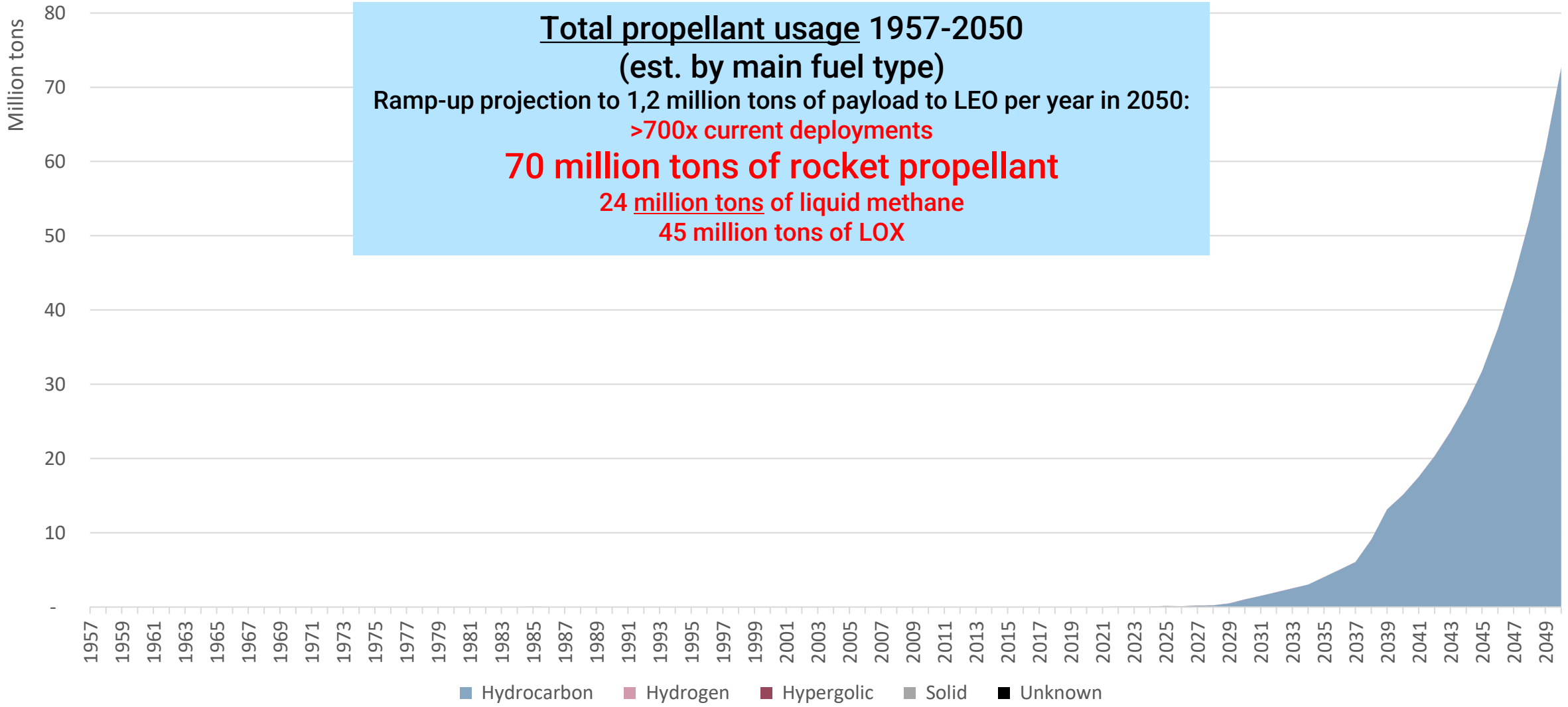
Liquid oxygen (LOX) is the most common cryogenic liquid oxidizer propellant: between 60 and 70% of total propellant mass
LOX production is driven by energetic costs and impact – LOX storage and transport is also driven by energetic costs

A rough visualisation of global space activity



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A rough projection of global launch activity



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Sustainable, or not?



