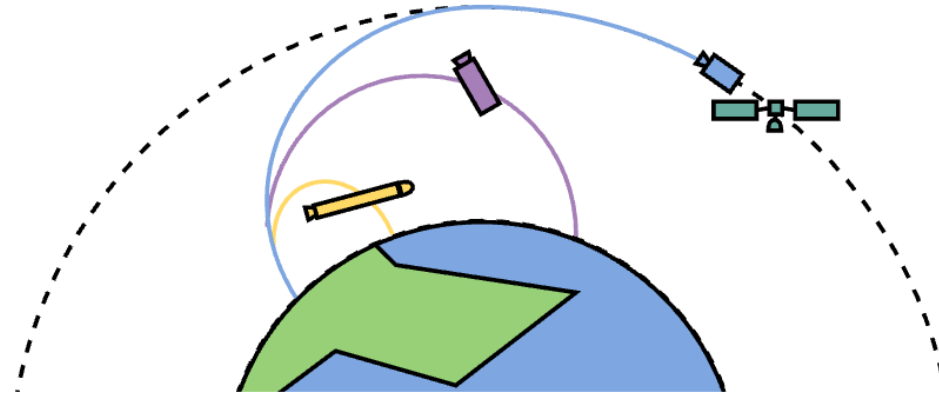


Rocket body re-entry trends



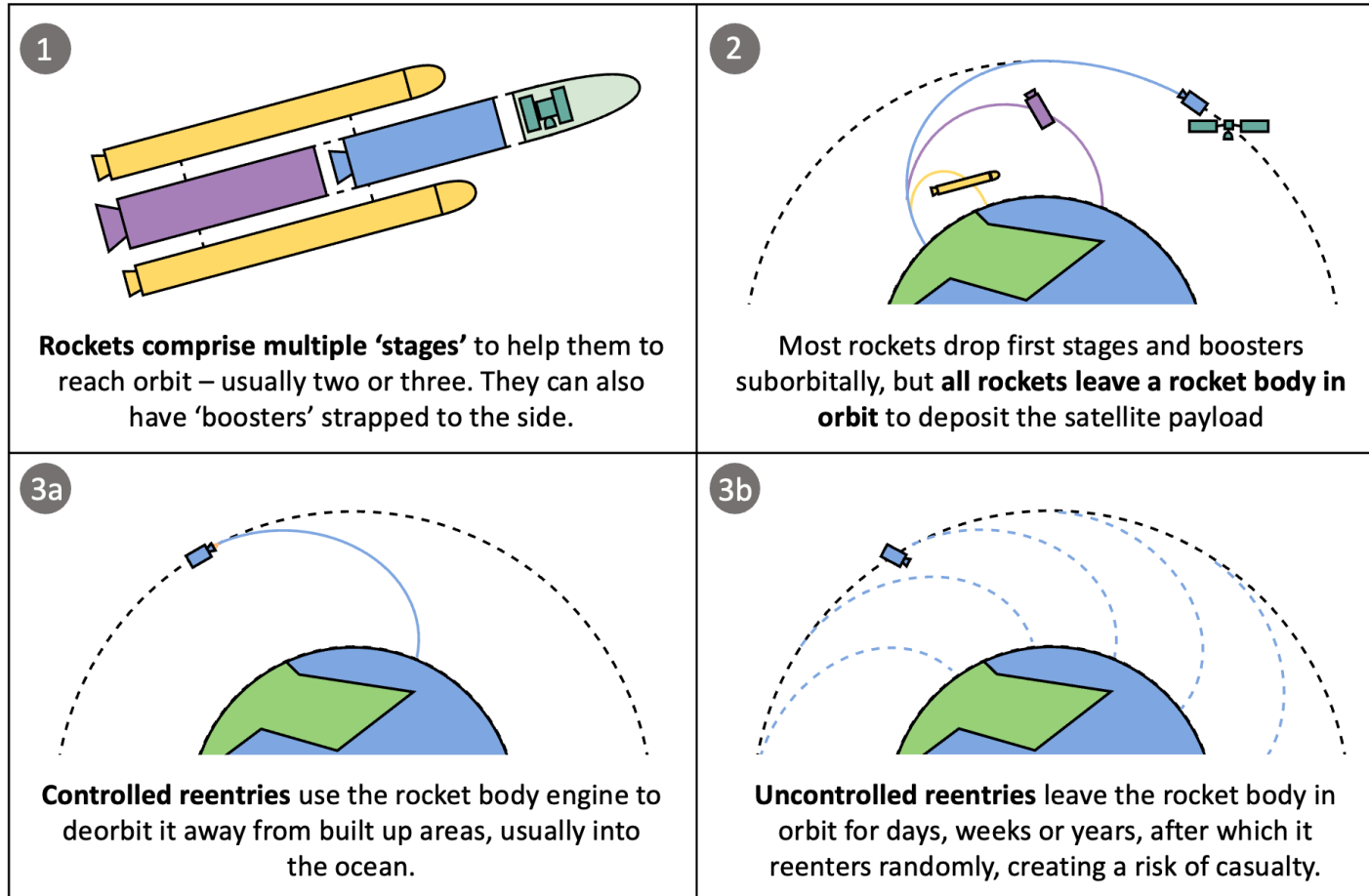
Ewan Wright, Aaron Boley, Michael Byers
University of British Columbia, Canada
Outer Space Institute



THE UNIVERSITY
OF BRITISH COLUMBIA



Uncontrolled vs controlled reentries



Reentries in 2022 alone



April 2, LM-3B, India



May 12, LM-3B, India



Mar 16, SpaceX Falcon 9, Brazil



July 9, SpaceX Dragon Trunk, Australia

Civil News

Long March 5B rocket reenters over Pacific Ocean after forcing airspace closures in Europe

Andrew Jones November 4, 2022



Nov 4, LM-5B, Pacific



July 30, LM-5B, Indonesia

Technologies vs behaviours

Which rockets can do controlled reentries?

Who chooses not to use them?

Why?



Data

1455 Earth orbital rocket bodies from 1198 launches

'Targeted' = No thruster but suborbital (predetermined landing area)

'Controlled' = thruster used for controlled reentry

'in orbit' = currently in orbit (uncontrolled)

'Uncontrolled' = reentered uncontrolled

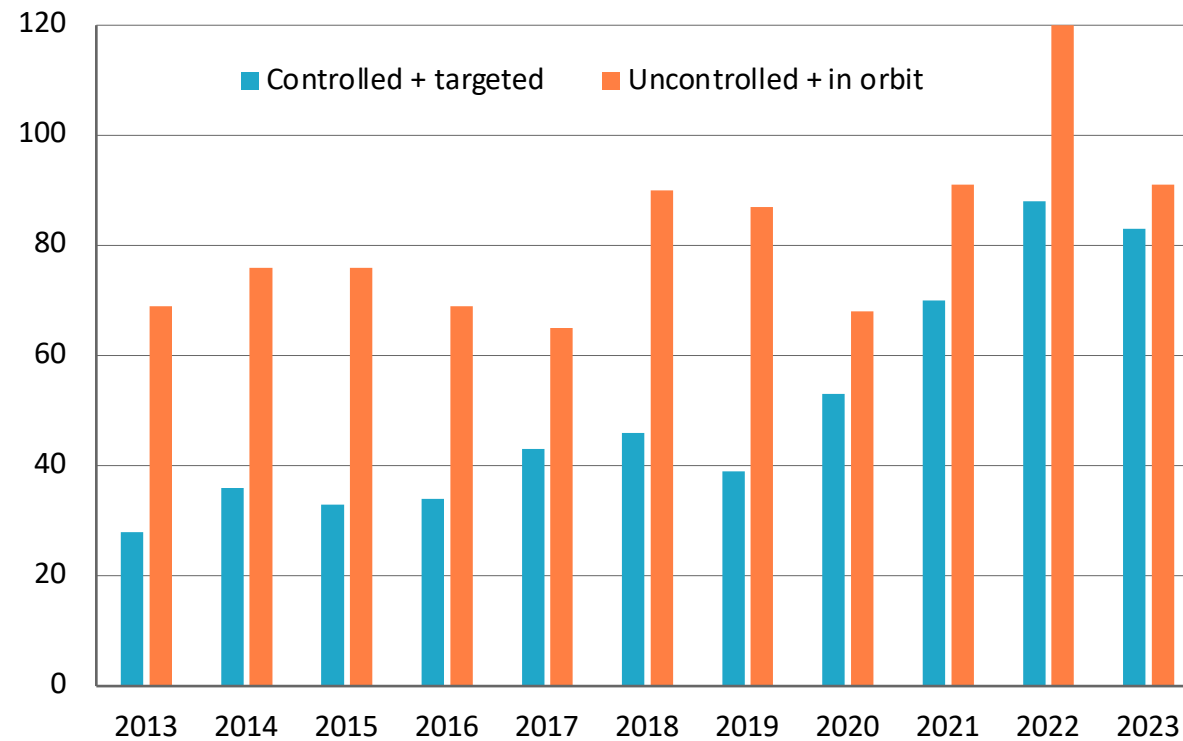
General Catalogue of Artificial Space Objects (GCAT)

Maintained by Jonathan McDowell

2nd October 2023

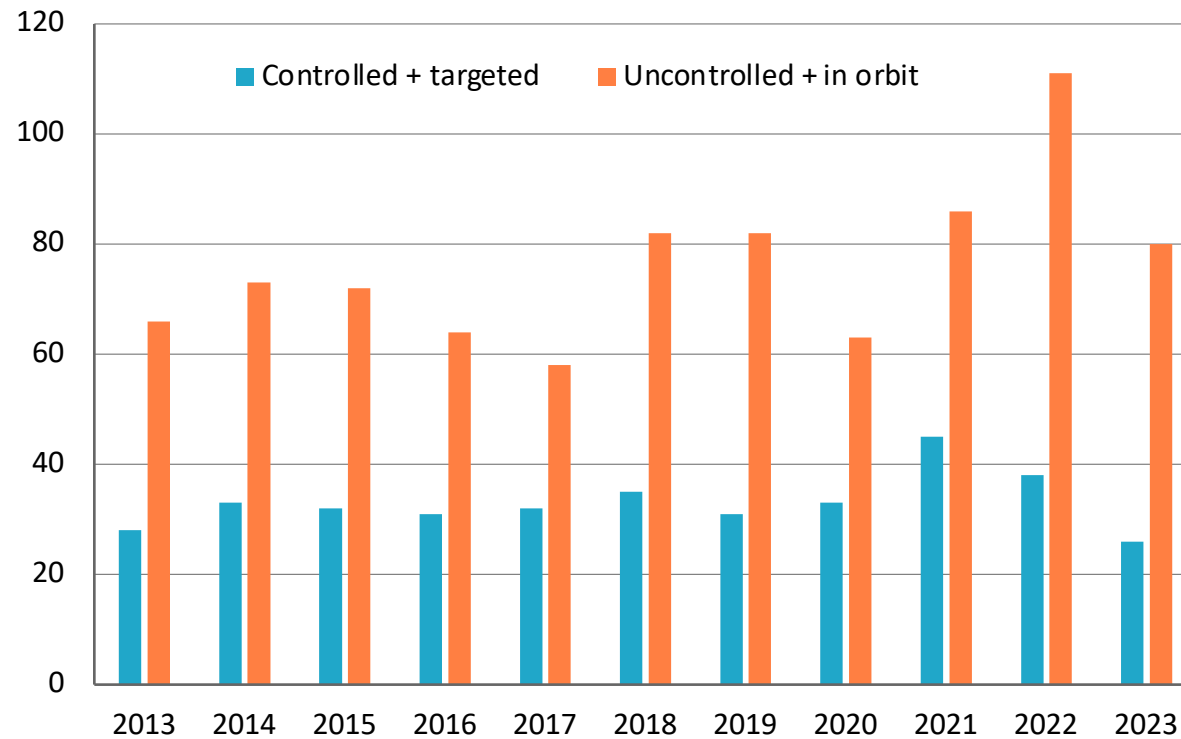


Controlled reentries are increasing, but so are uncontrolled reentries



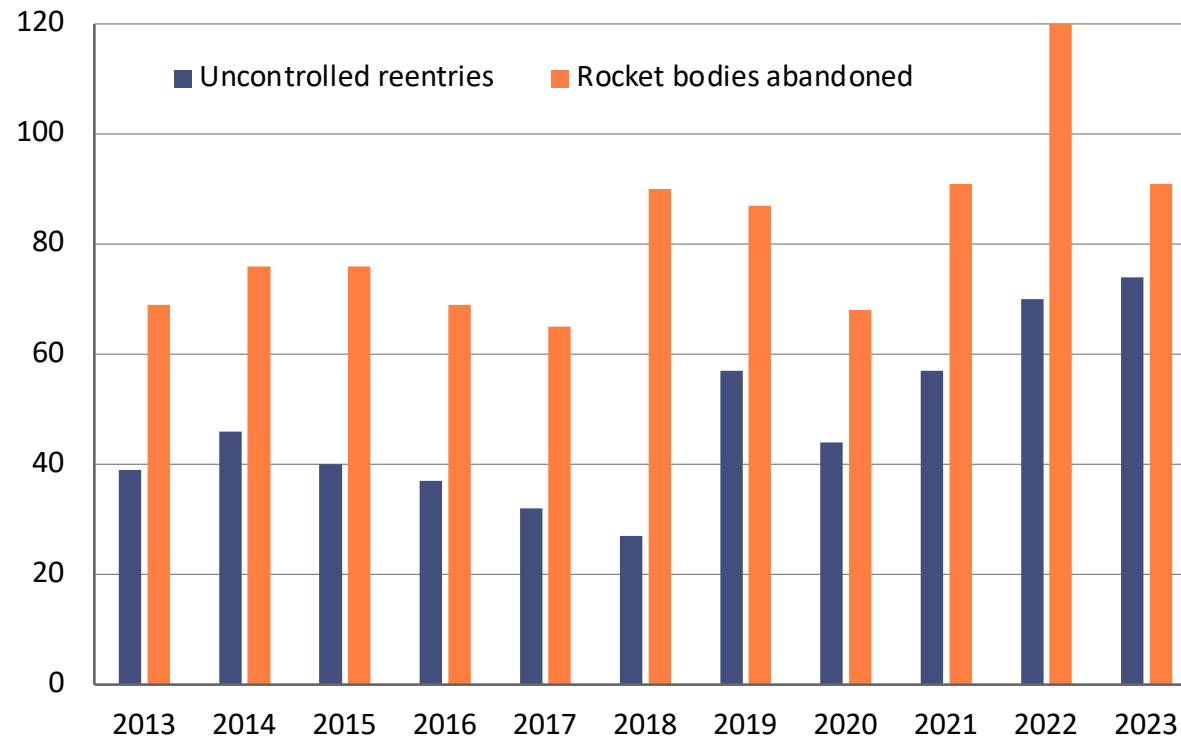
Reentry type for rocket bodies launched each year

The increase in controlled reentries is driven by SpaceX launches



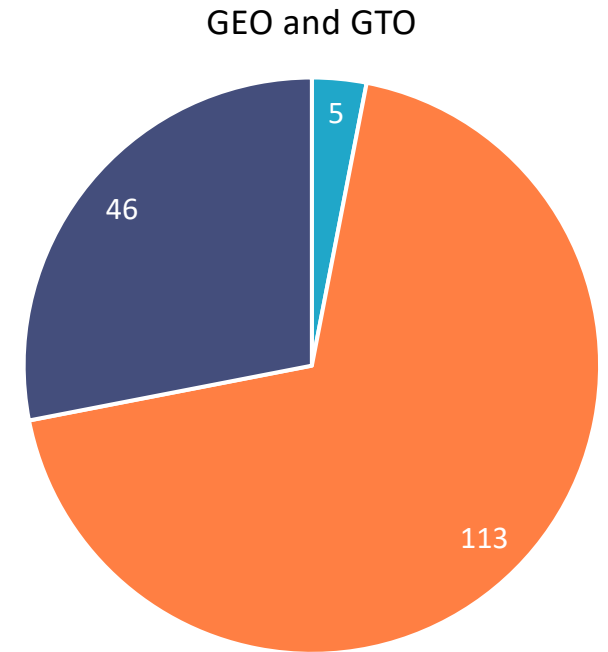
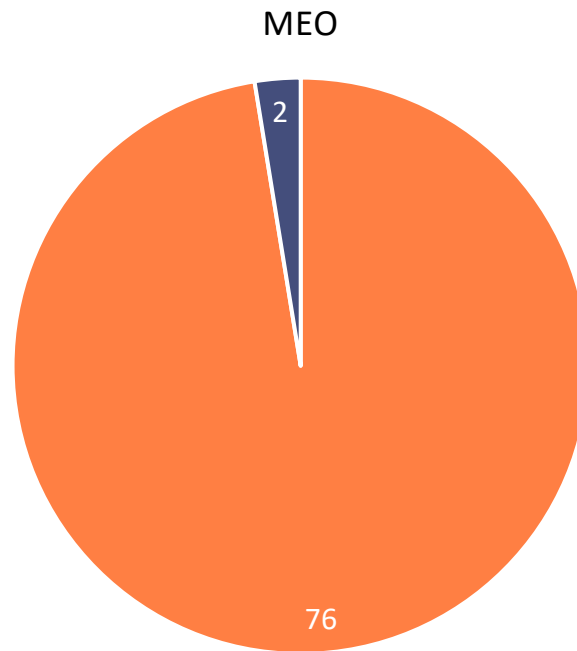
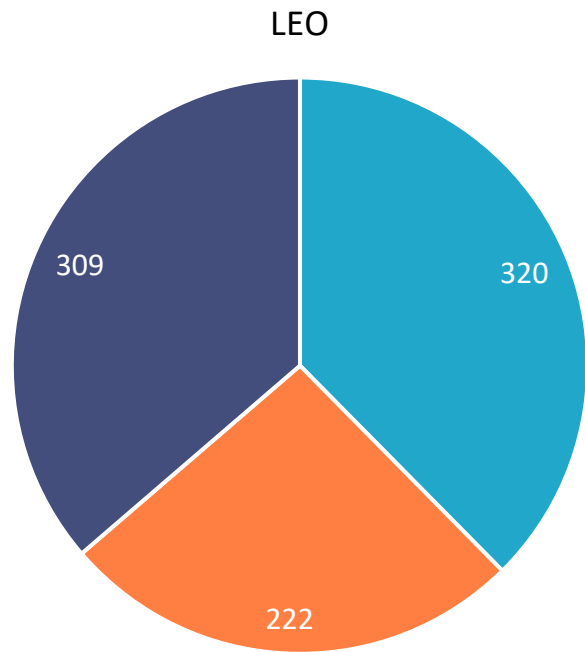
***Reentry type for rocket bodies launched each year
excluding SpaceX launches***

Net ~36 rocket bodies added to space debris population each year



Uncontrolled reentries each year vs the number of launches which left a rocket body in orbit

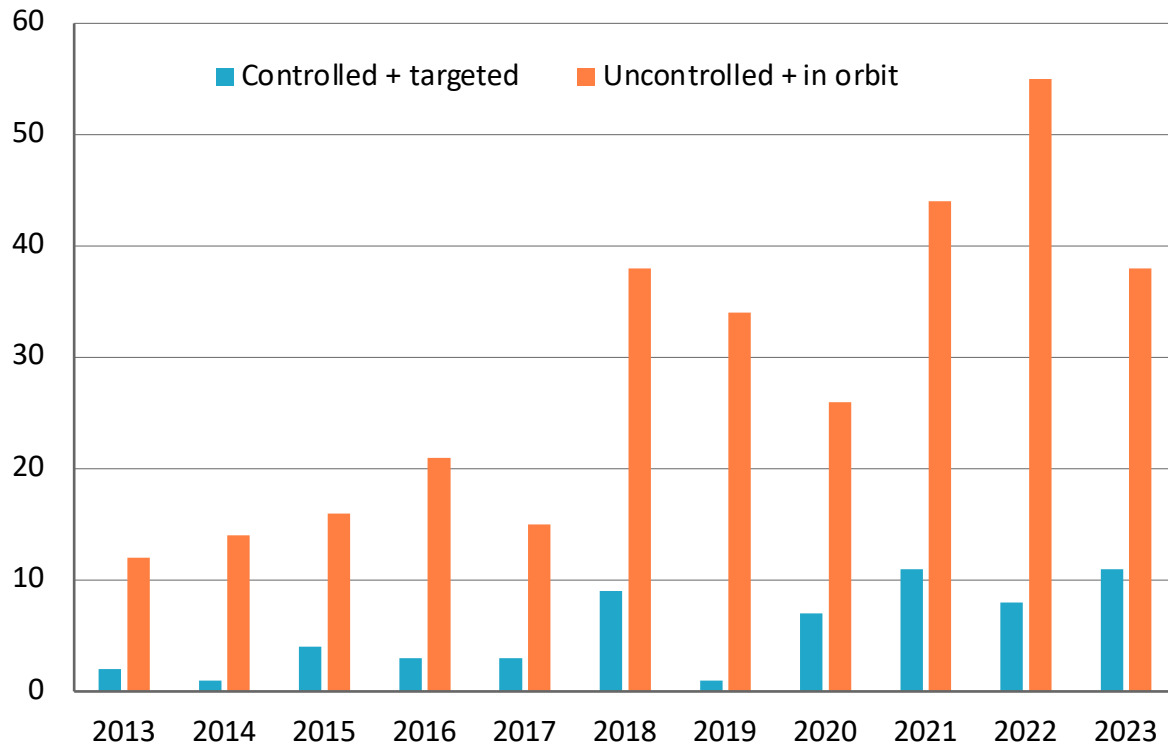
GTO controlled reentries are possible but not used



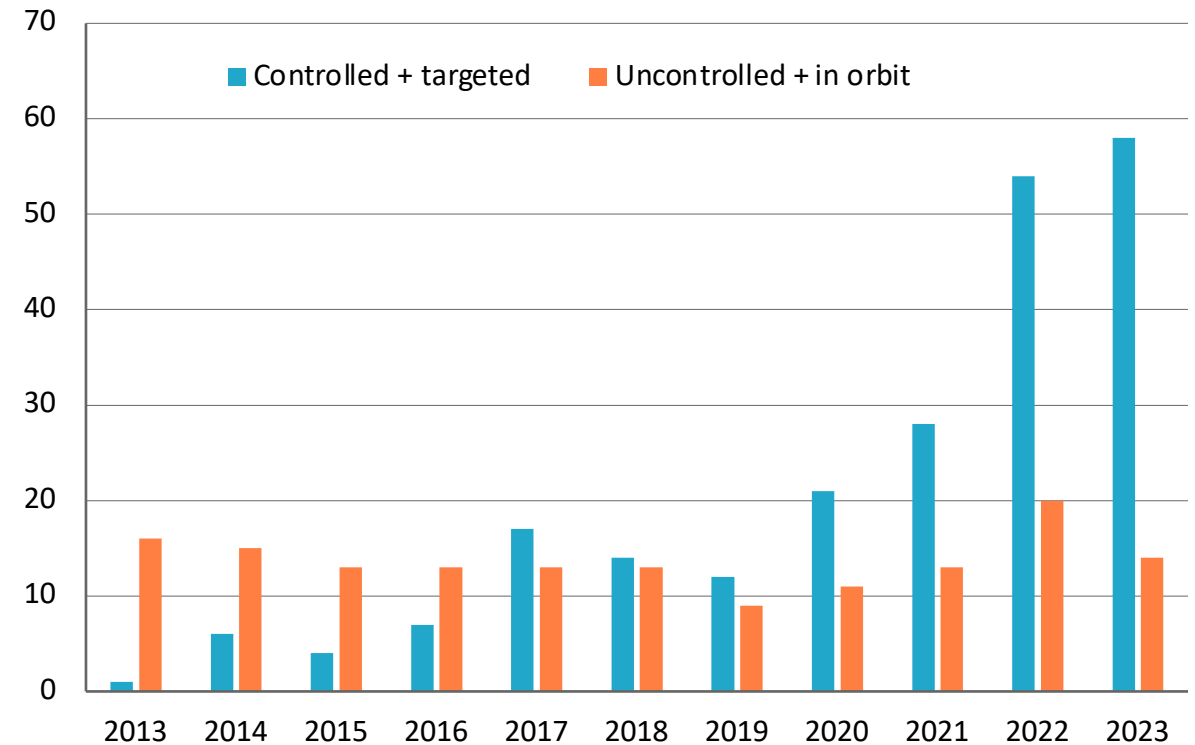
■ Controlled ■ In orbit ■ Uncontrolled

Launches 2013 - Oct2023

China can do controlled reentries, but many launches do not



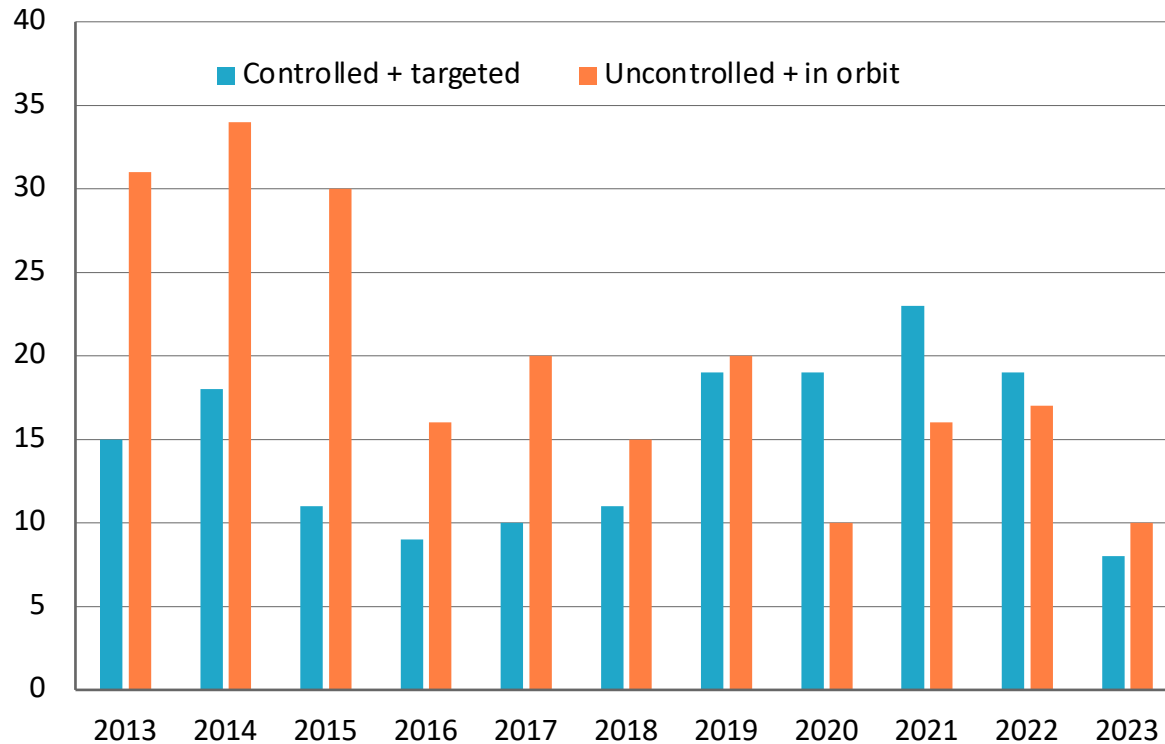
China



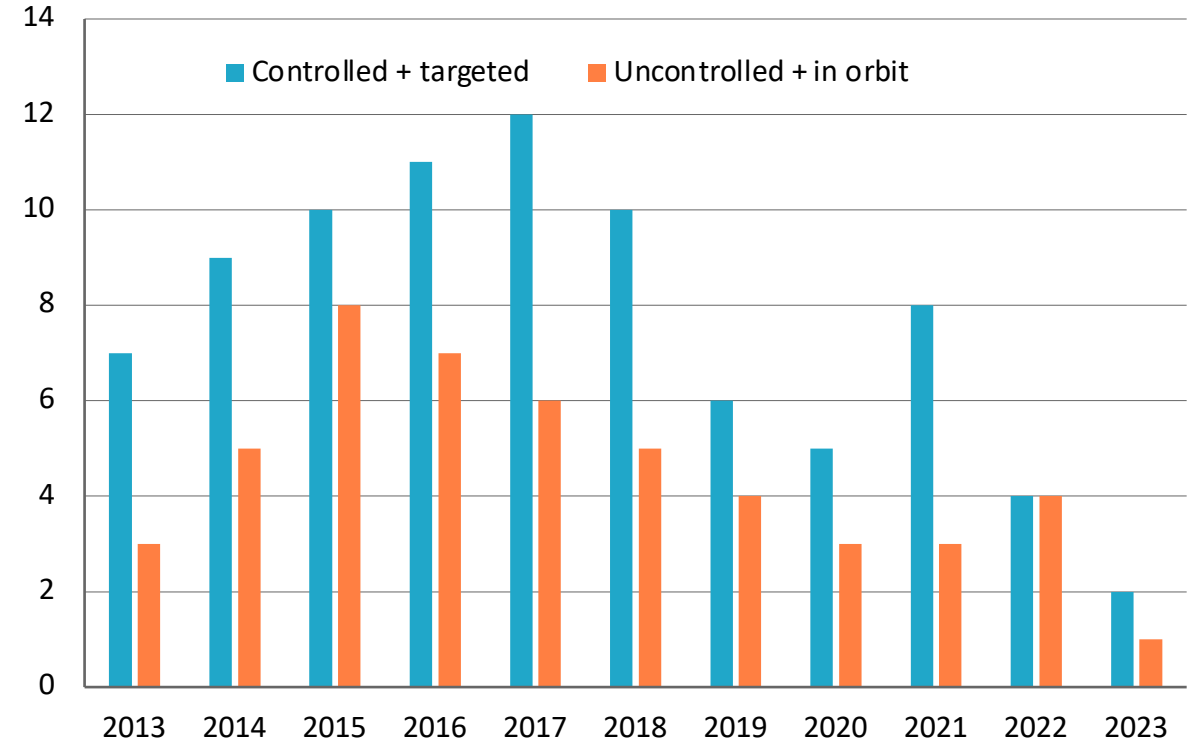
United States

United States is dominated by SpaceX launches

Russia does many targeted reentries



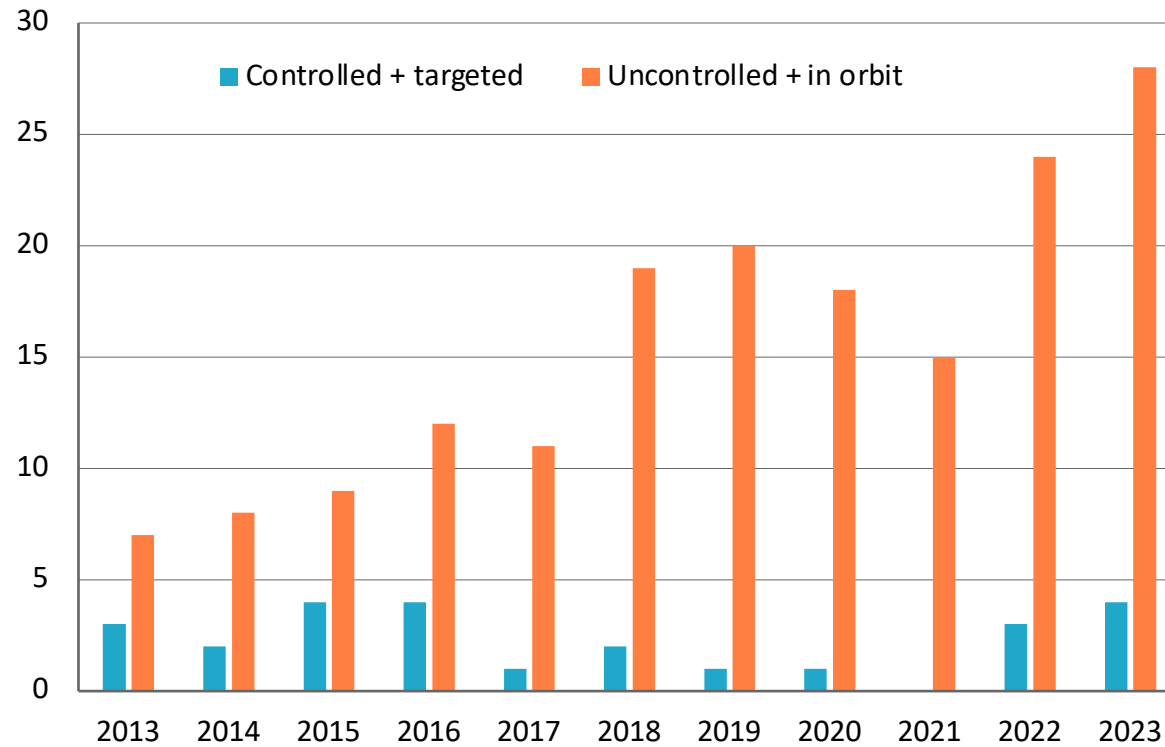
Russia



Europe

Europe does controlled and uncontrolled reentries regularly

Other states rarely use controlled reentries



India, Japan, Israel, Iran, North Korea

Rocket capabilities

China

Rocket	Controlled
LM-2	✓
LM-3	X
LM-4	X
LM-5	X
LM-6	✓
LM-11	✓

India

Rocket	Controlled
All	X

Russia

Rocket	Controlled
Soyuz – Fregat/Volga	✓
All others	X

Japan

Rocket	Controlled
H-2	✓
All others	X

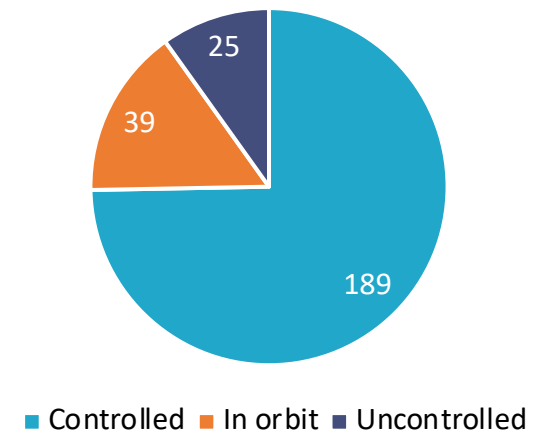
Europe

Rocket	Controlled
Ariane 5	✓
Vega	✓

United States

Rocket	Controlled
Atlas V	✓
Delta	✓
Falcon 9	✓
Pegasus	X
Firefly	✓
All others	X

Falcon 9



For launches 2013-Oct2023

New rules begin to address the issue

US FAA proposed rules

Controlled, ADR, or uncontrolled if risk less than 1 in 10,000 (small rocket bodies)

- conduct a controlled reentry;
- move the upper stage to a less congested storage or graveyard orbit;
- send the upper stage on an Earth-escape orbit;
- retrieve the upper stage (called active debris removal) within five years; or
- perform an uncontrolled atmospheric disposal.

Proposed French technical regulation

Controlled required

a) The launcher shall be designed, produced and implemented so that, after the end of the launch phase, its components placed in orbits passing through protected region A are de-orbited by controlled atmospheric re-entry.



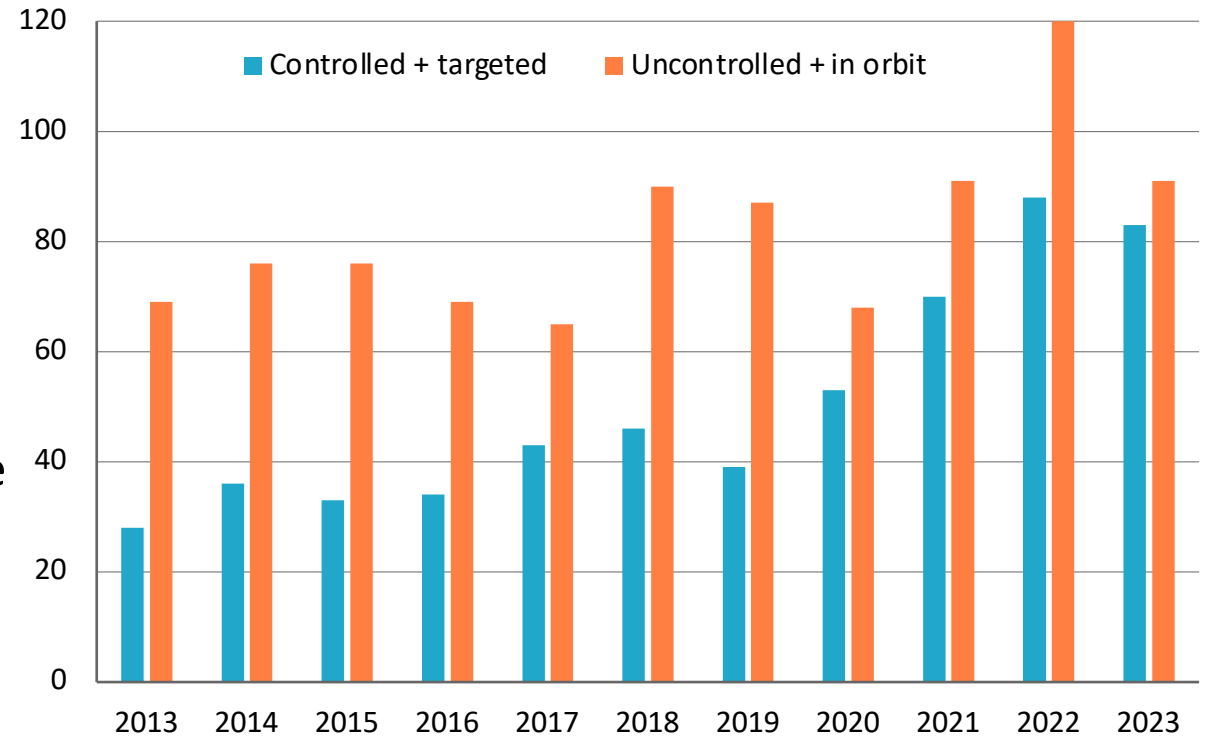
Summary

SpaceX is increasing the total number of controlled reentries

But uncontrolled reentries + abandonment are also increasing

Some rockets can do controlled reentries but choose not to

New regulations are beginning to address this issue



Extra slides



Data

General Catalogue of Artificial Space Objects (GCAT)

Maintained by Jonathan McDowell

2nd October 2023

Satcat + auxcat

R1 + R2 + R3 + R4 (rocket stages) only

Not including payload adapters or external tanks/trunks (arguably rocket bodies)

Sometimes multiple rocket bodies counted per launch

Ignoring deep space launches (37)

1455 Earth orbital rocket bodies from 1198 launches

‘Targeted’ = No thruster but suborbital (predetermined landing area)

‘Controlled’ = thruster used for controlled reentry

‘in orbit’ = currently in orbit (uncontrolled)

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