

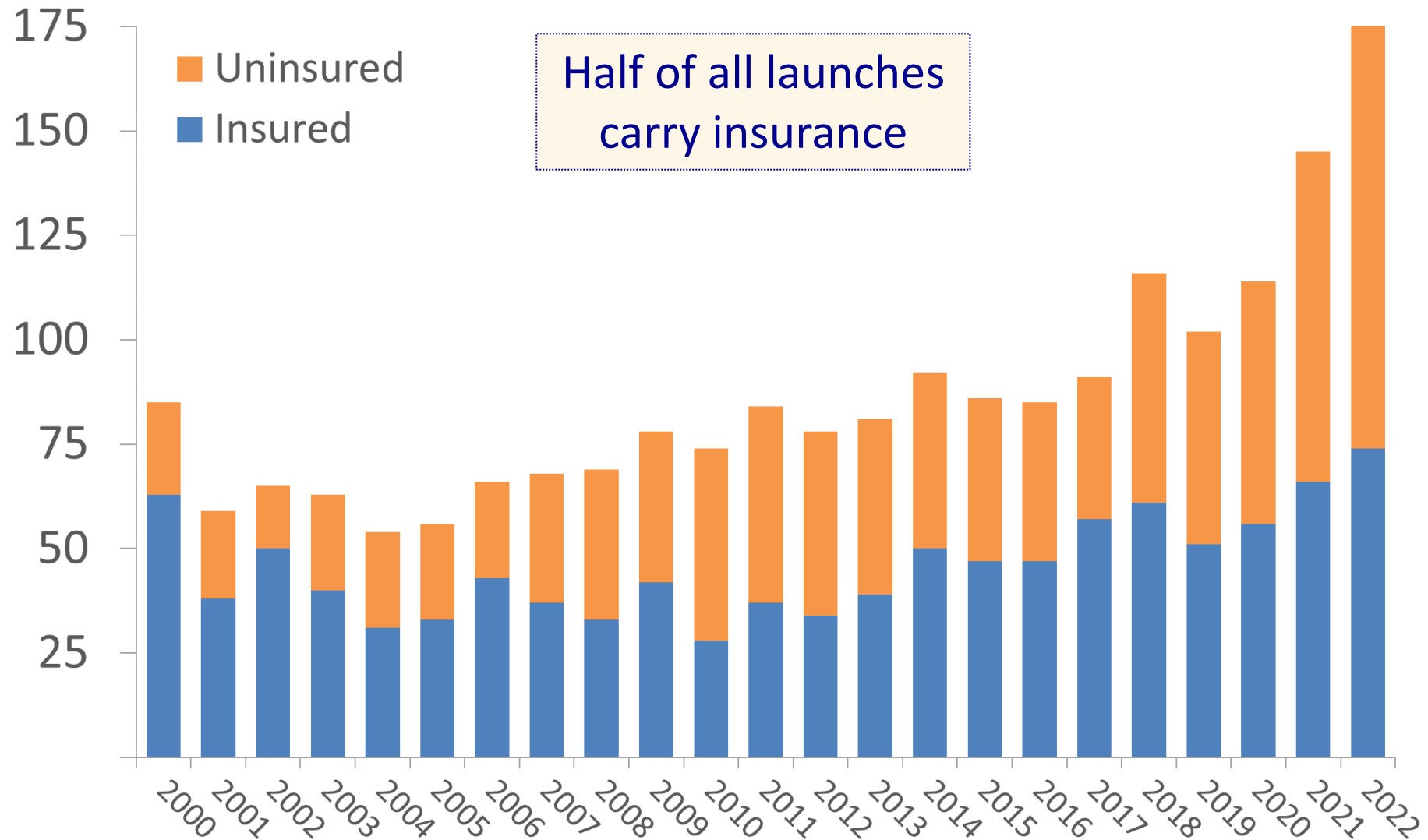


Space Insurance Market Update

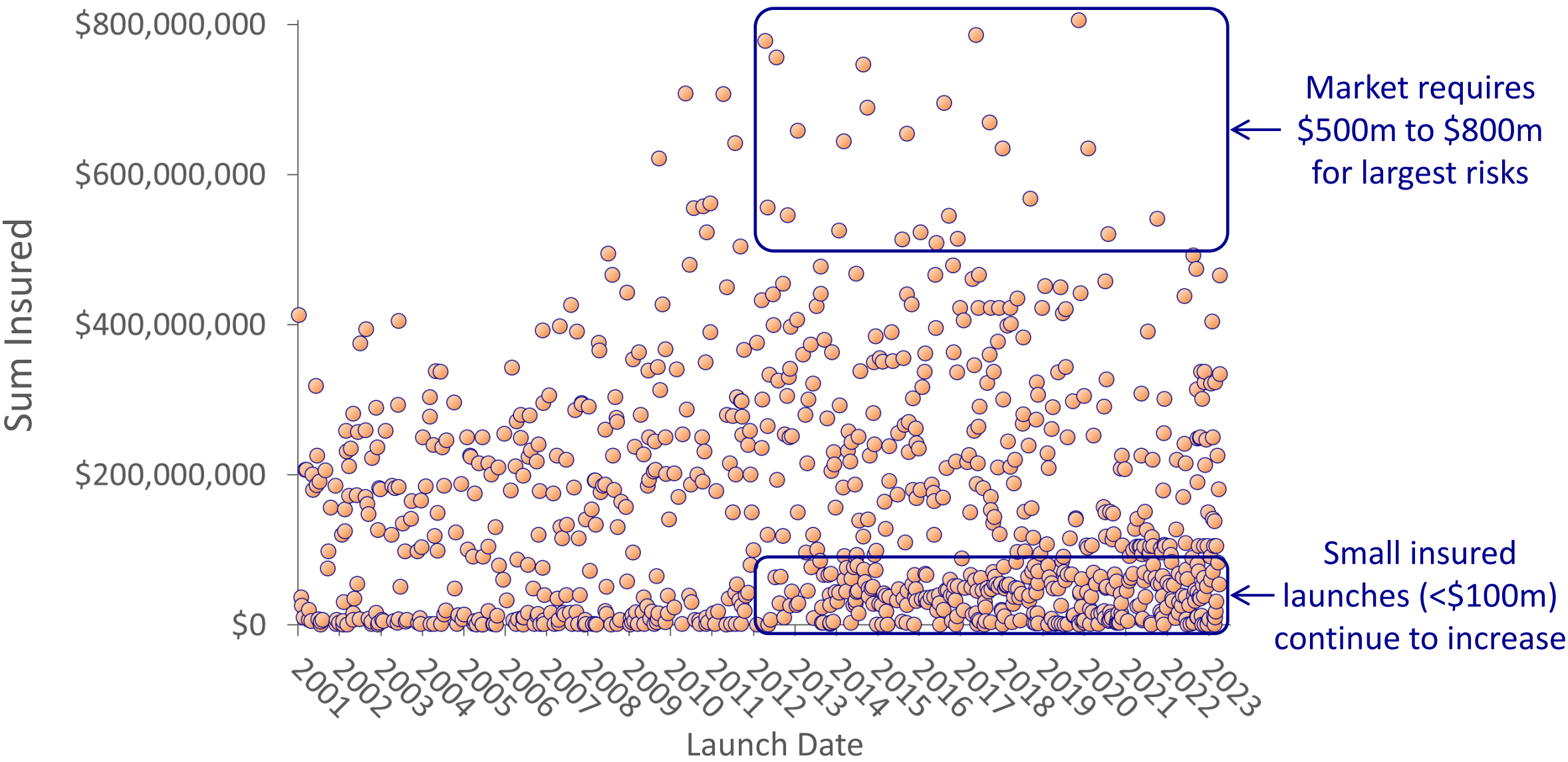
Chris Kunstadter, AXA XL

Launches to Orbit

Insured vs. uninsured

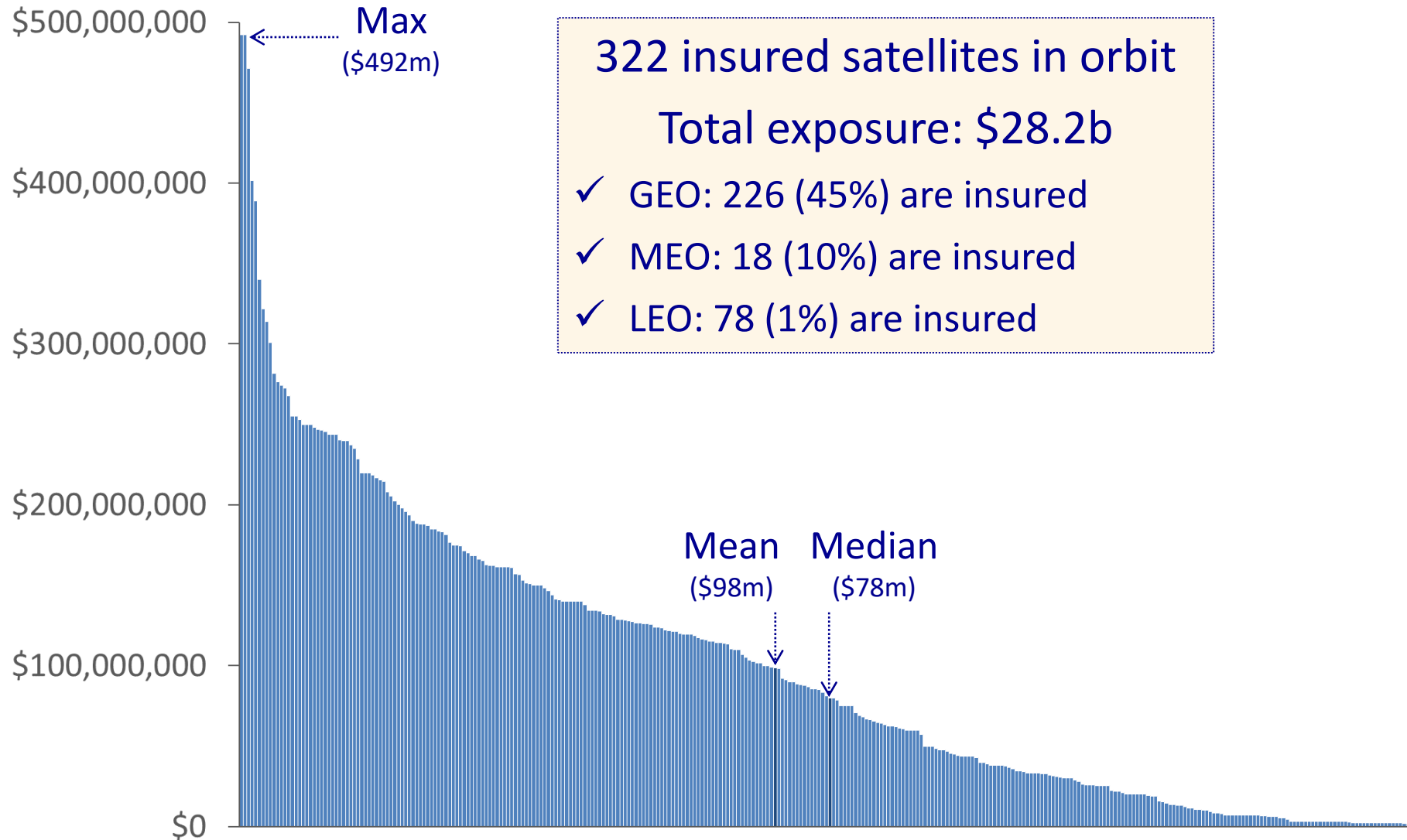


Insured Values During Launch



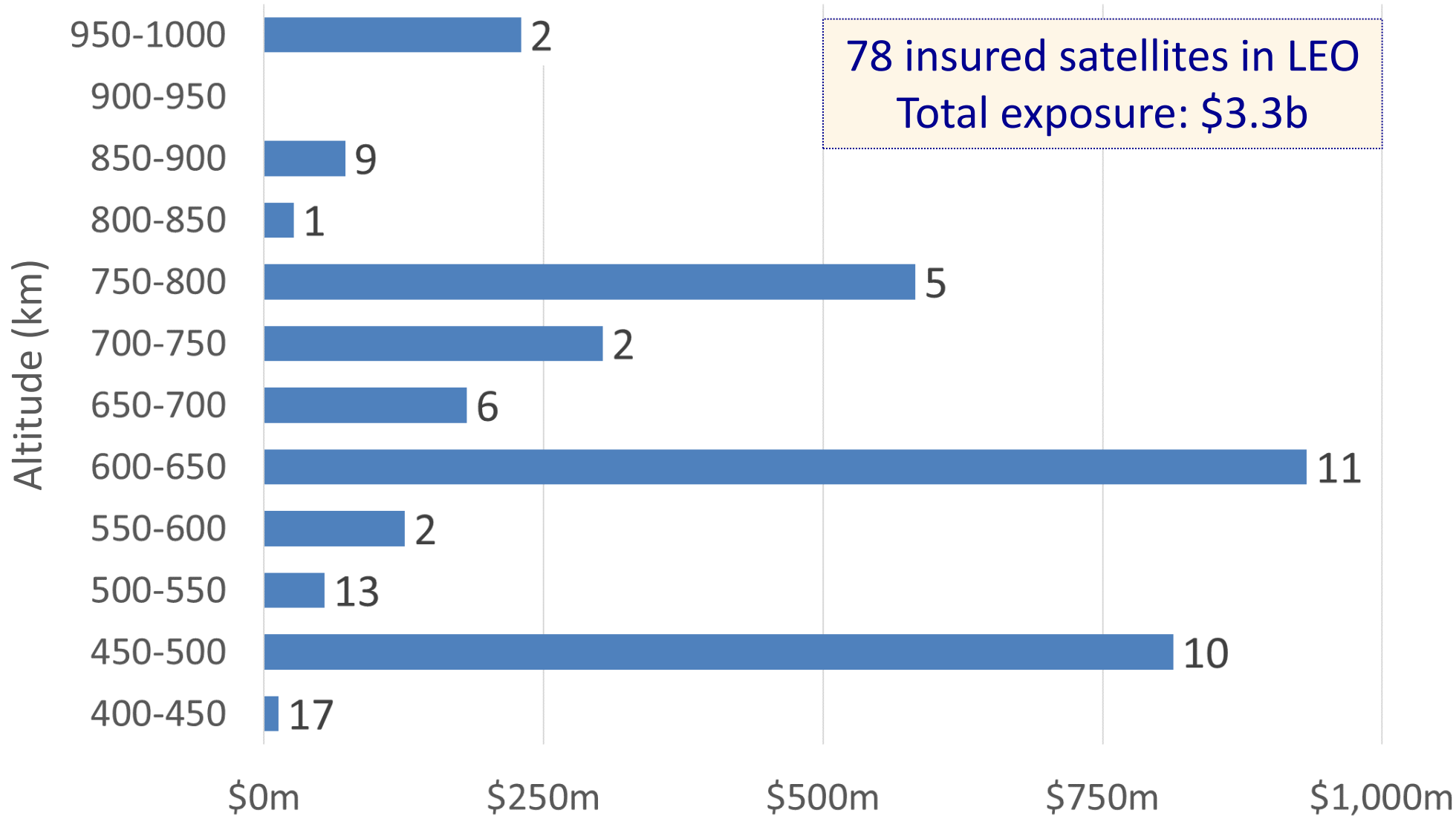
Exposures On Orbit

Satellites in orbit, by individual risk



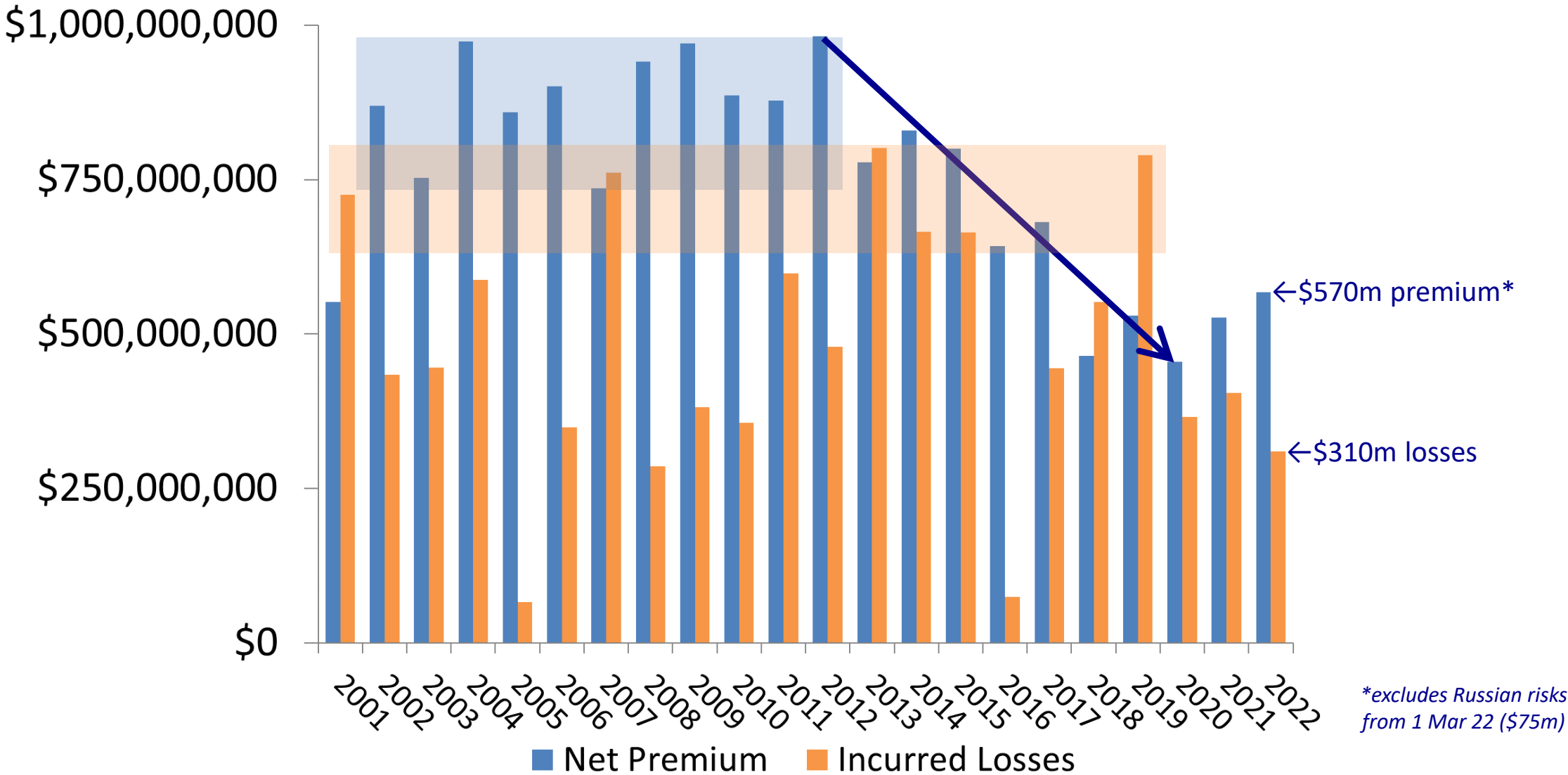
Exposures On Orbit

LEO satellites, by altitude



Annual Premium and Claims

Net premium on risks attaching, losses at date of loss





A Survey of Launch Vehicle Reliability

Chris Kunstadter, AXA XL

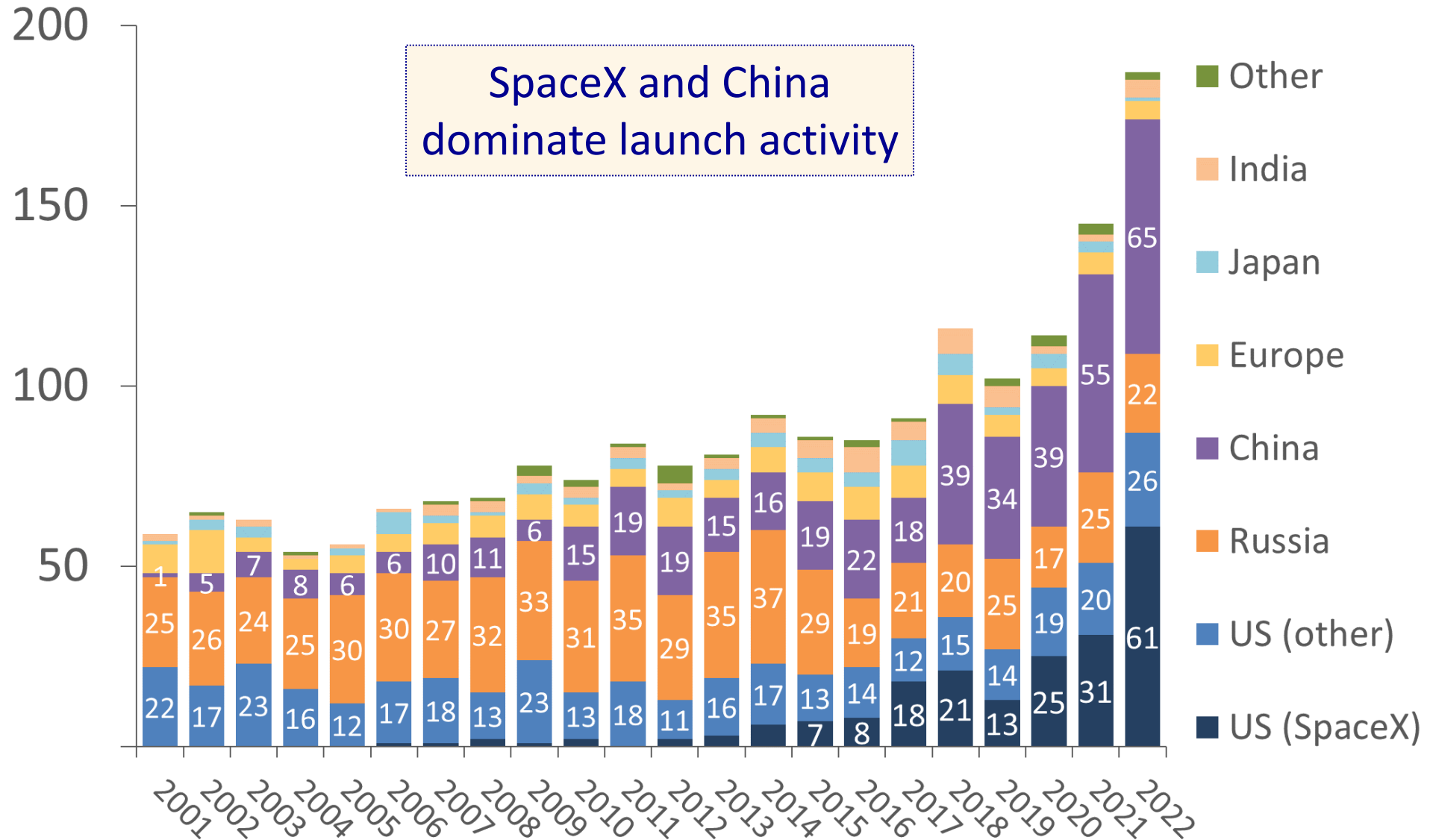
Launch Vehicles In Review – Definitions

Many ways to assess launch vehicle reliability – for this study we look at flight experience and categorize vehicles by size, mission types, age, number of flights, and country/region

- **Large:** Launch vehicle is capable of launching large satellites to geostationary orbit (GEO), including geostationary transfer orbit (GTO), as well as to deep space, and is (or is planned to be) routinely used for that purpose
- **Small:** All other launch vehicles
 - ✓ Soyuz, CZ-2C, and PSLV, among others, have launched a few satellites to GEO or GTO, but are not routinely used for those launches
- **Active:** Launch vehicle has flown and is planned to continue flying
 - ✓ 16 launch vehicles active since 2000 have flown fewer than 10 times and have subsequently been retired
- **Failure:** Launch resulted in an insurance claim, or would have if insured, due to performance of the launch vehicle

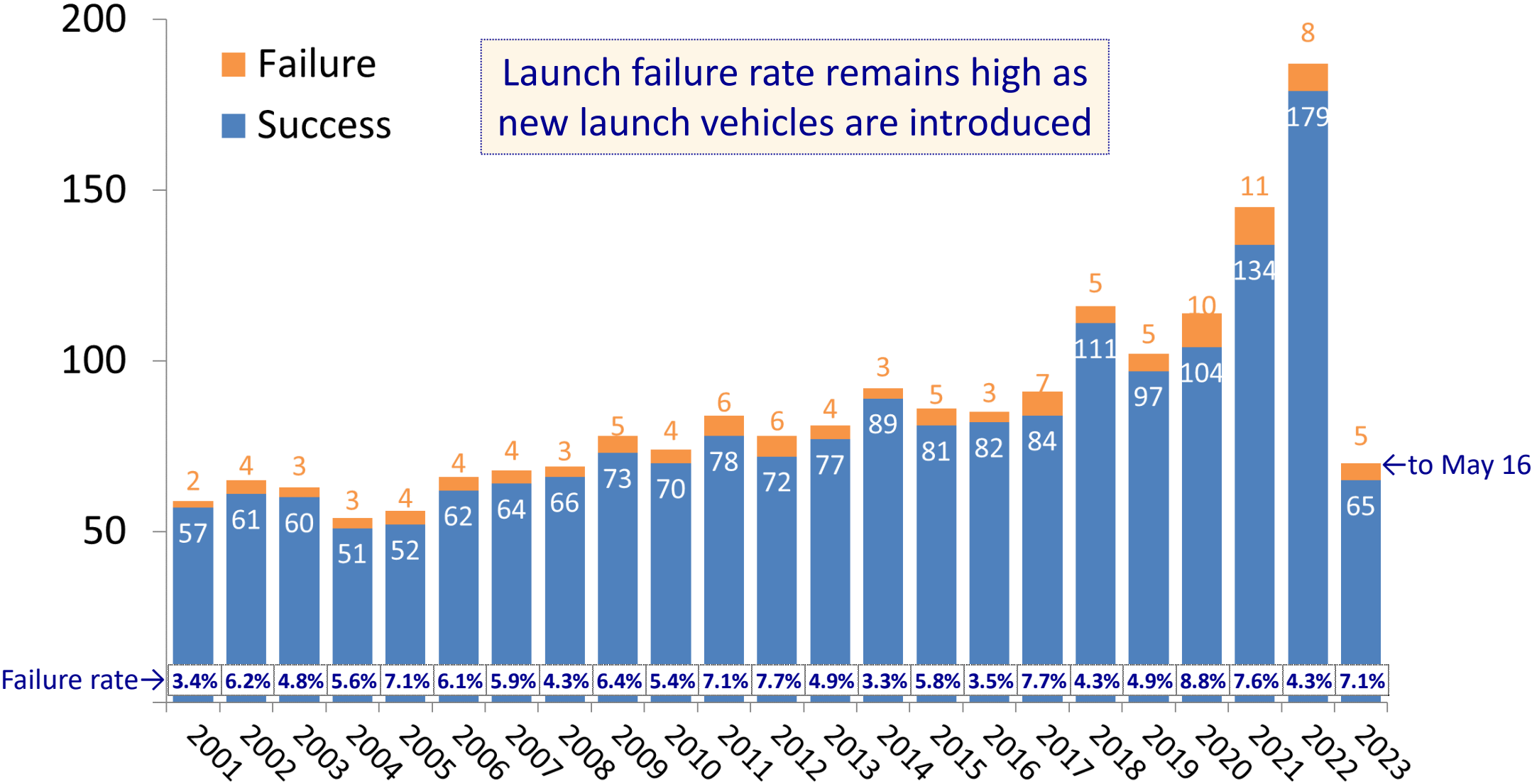
Launches to Orbit

By country/region



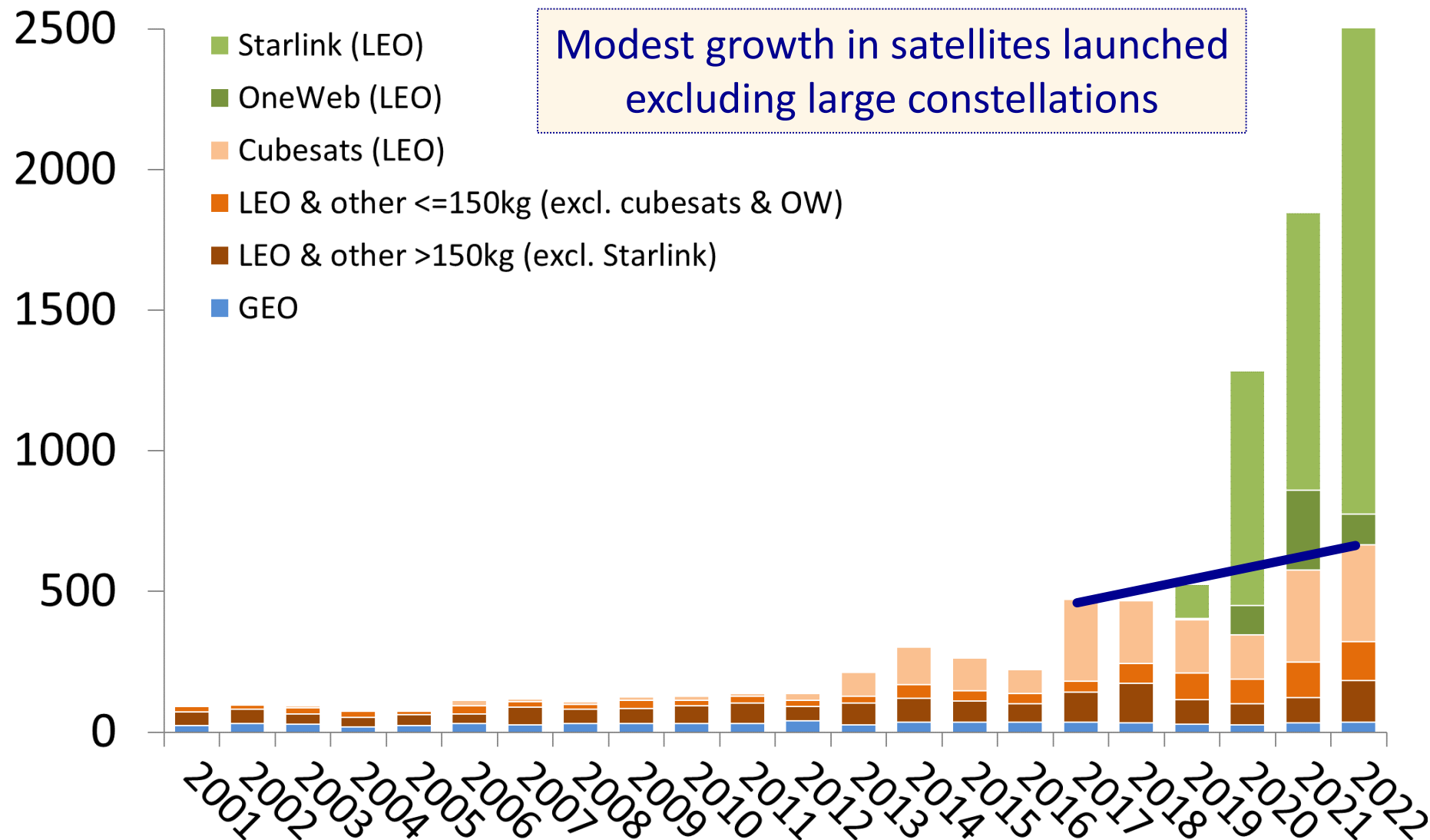
Launches to Orbit

Successes vs. failures

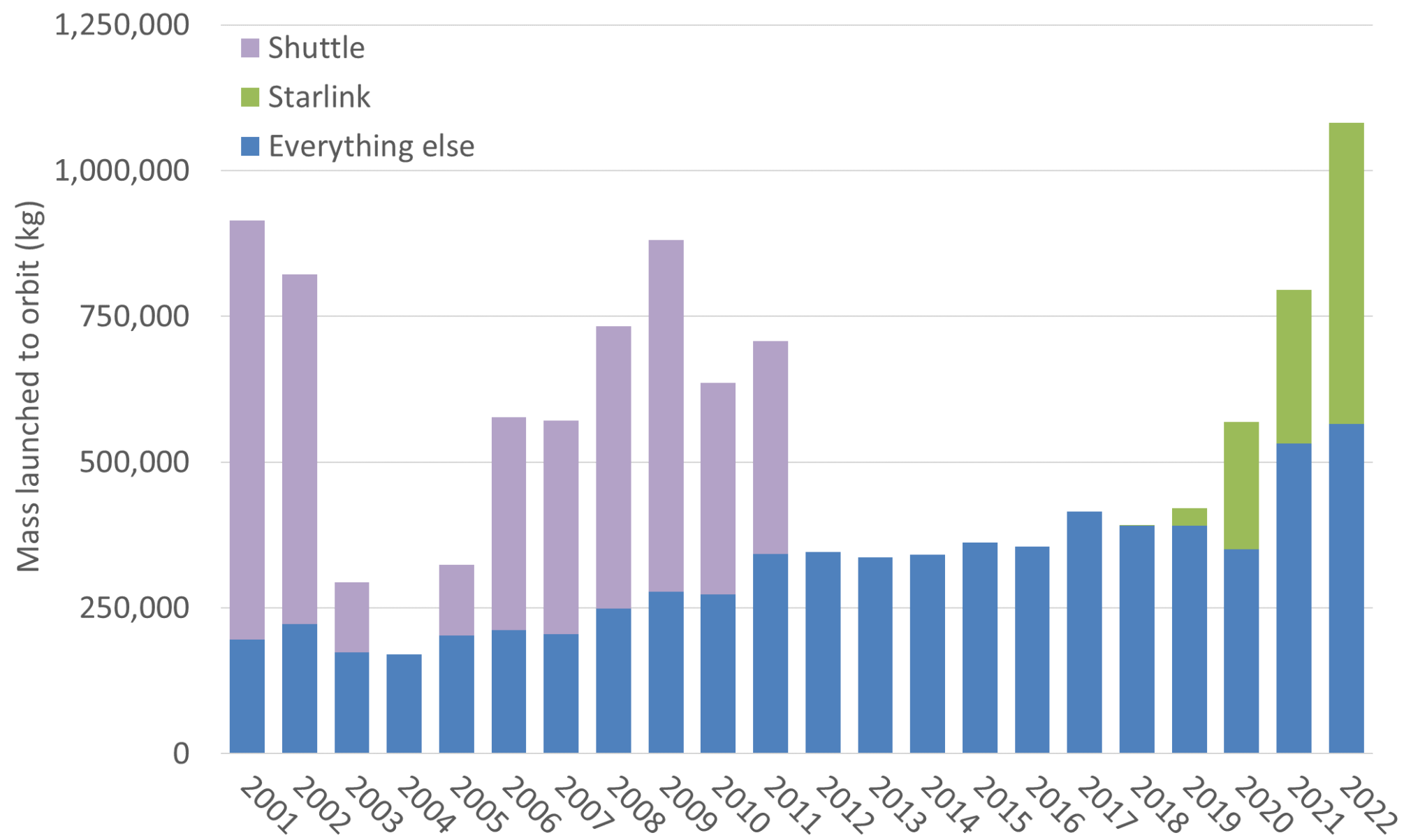


Satellites Launched

By orbit and size



Mass to Orbit



Active Launch Vehicles – Large



Launch Vehicle Family	Country / Region	Size	First Launch↓	Flights	Failures	Fail %	Consecutive successes since last failure	6th launch
LONG MARCH CZ-2E/2F	CN	Large	1990-07-16	26	2	8%	21	S
H-2/2A/2B	JP	Large	1994-02-03	61	3	5%	48	F
LONG MARCH CZ-3A/3B/3C	CN	Large	1994-02-08	134	4	3%	23	S
PROTON SINCE ILS	RU	Large	1996-04-08	191	18	9%	25	F
ARIANE 5	EU	Large	1996-06-04	116	5	4%	19	S
GSLV	IN	Large	2001-04-20	14	6	43%	0	F
ATLAS 5	US	Large	2002-08-21	97	1	1%	87	S
DELTA 4 HEAVY	US	Large	2004-12-21	14	1	7%	13	S
FALCON 9	US	Large	2010-06-04	223	2	1%	204	S
ANGARA	RU	Large	2014-12-23	5	1	20%	2	
LONG MARCH CZ-7/7A	CN	Large	2016-06-25	12	1	8%	9	S
LONG MARCH CZ-5/5B	CN	Large	2016-11-03	9	1	11%	7	S
LVM 3/GSLV 3	IN	Large	2017-06-05	4	0	0%	4	
FALCON HEAVY	US	Large	2018-02-06	6	0	0%	6	S
LONG MARCH CZ-8	CN	Large	2020-12-22	2	0	0%	2	
SLS	US	Large	2022-11-16	1	0	0%	1	
H3	JP	Large	2023-03-07	1	1	100%	0	
STARSHIP	US	Large	2023-04-20	1	1	100%	0	

Active Launch Vehicles – Small

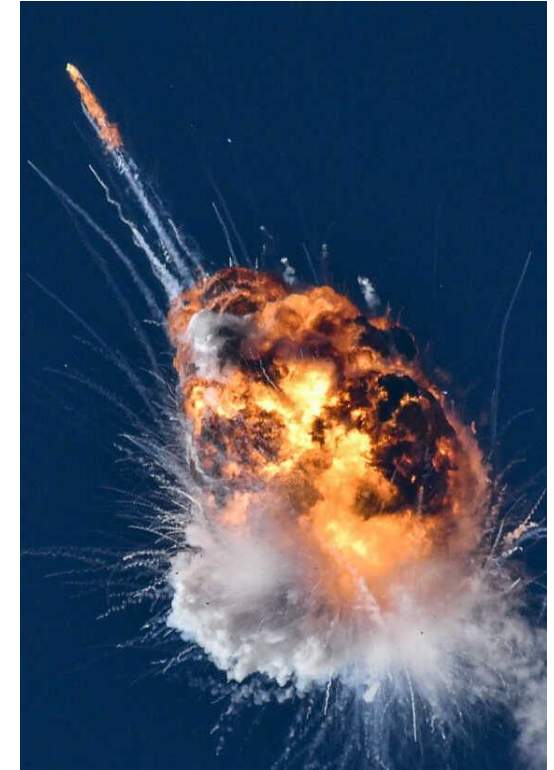
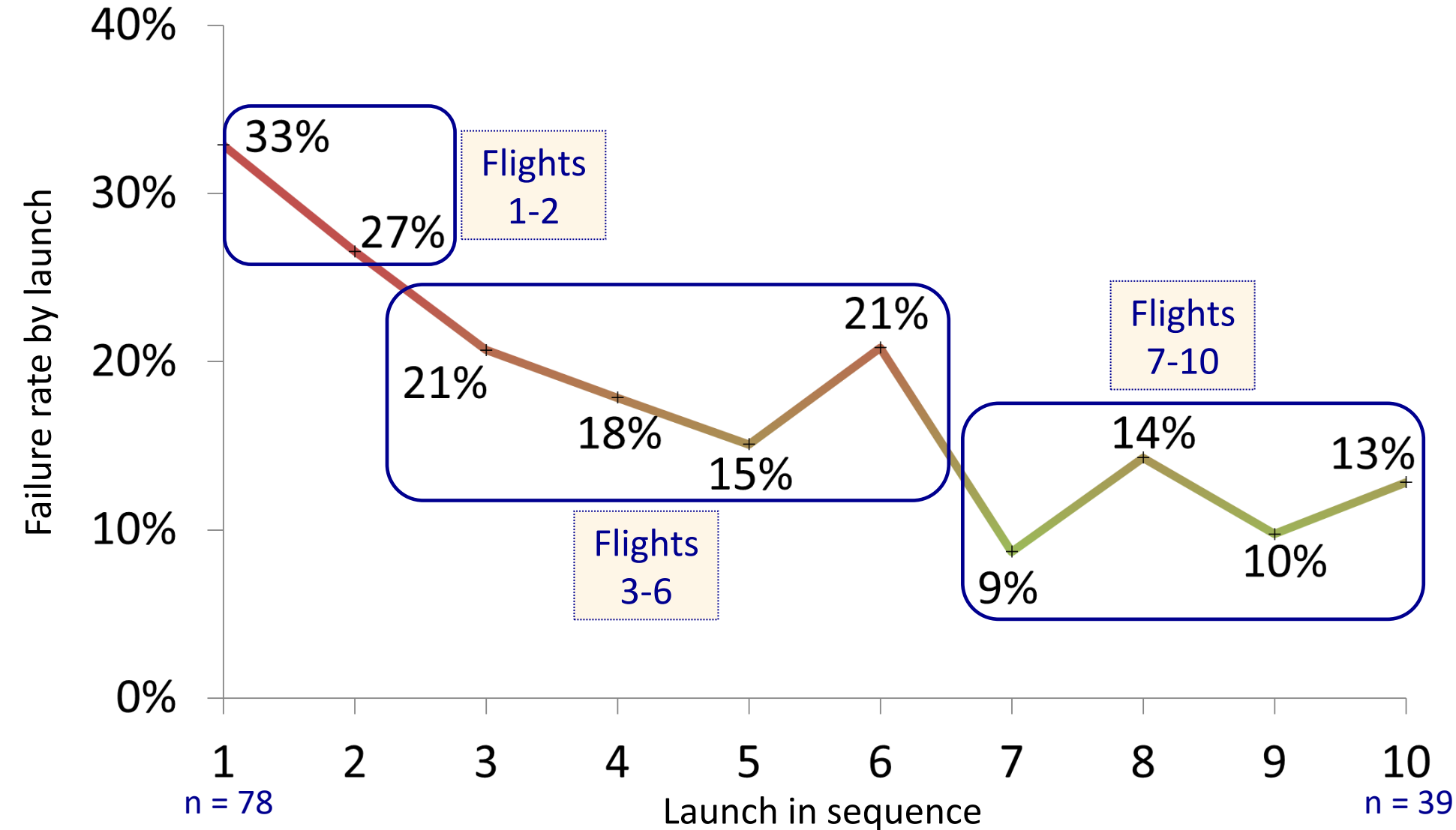


Launch Vehicle Family	Country / Region	Size	First Launch↓	Flights	Failures	Fail %	Consecutive successes since last failure	6th launch
LONG MARCH CZ-2C/2D	CN	Small	1982-09-09	150	3	2%	71	S
SHAVIT	IS	Small	1988-09-19	12	2	17%	6	F
PEGASUS	US	Small	1990-04-05	48	6	13%	17	F
PSLV	IN	Small	1993-09-20	57	3	5%	16	S
TAURUS/MINOTAUR	US	Small	1994-03-13	40	4	10%	0	F
LONG MARCH CZ-4B/4C	CN	Small	1999-05-10	97	3	3%	39	S
SOYUZ 2	RU	Small	2004-11-08	157	8	5%	73	S
KSLV	SK	Small	2009-08-25	5	3	60%	1	
VEGA/VEGA-C	EU	Small	2012-02-13	22	3	14%	0	S
ANTARES	US	Small	2013-04-21	17	1	6%	12	S
EPSILON	JP	Small	2013-09-14	6	1	17%	0	F
LONG MARCH CZ-6/6A	CN	Small	2015-09-19	12	0		12	S
LONG MARCH CZ-11/11H	CN	Small	2015-09-25	16	0		16	S
KUAIZHOU KZ-1A	CN	Small	2017-01-09	19	3	16%	5	S
ELECTRON	US	Small	2017-05-25	36	3	8%	16	S
SQX-1/HYPERBOLA-1	CN	Small	2019-07-25	5	3	60%	1	
JIELONG JL-1	CN	Small	2019-08-17	1	0		1	
LAUNCHERONE	US	Small	2020-05-25	6	2	33%	0	F
KUAIZHOU KZ-11	CN	Small	2020-07-10	2	1	50%	1	
GX-1/CERES-1	CN	Small	2020-11-07	5	0		5	
FIREFLY ALPHA	US	Small	2021-09-02	2	2	100%	0	
LIJIAN ZK-1	CN	Small	2022-07-27	1	0		1	
SSLV	IN	Small	2022-08-07	2	1	50%	1	
JIELONG JL-3	CN	Small	2022-12-09	1	0		1	
ZHUQUE ZQ-2	CN	Small	2022-12-14	1	1	100%	0	
ABL RS1	US	Small	2023-01-10	1	1	100%	0	
TIANLONG TL-2	CN	Small	2023-04-02	1	0		1	

Launch Vehicle Failure Rates



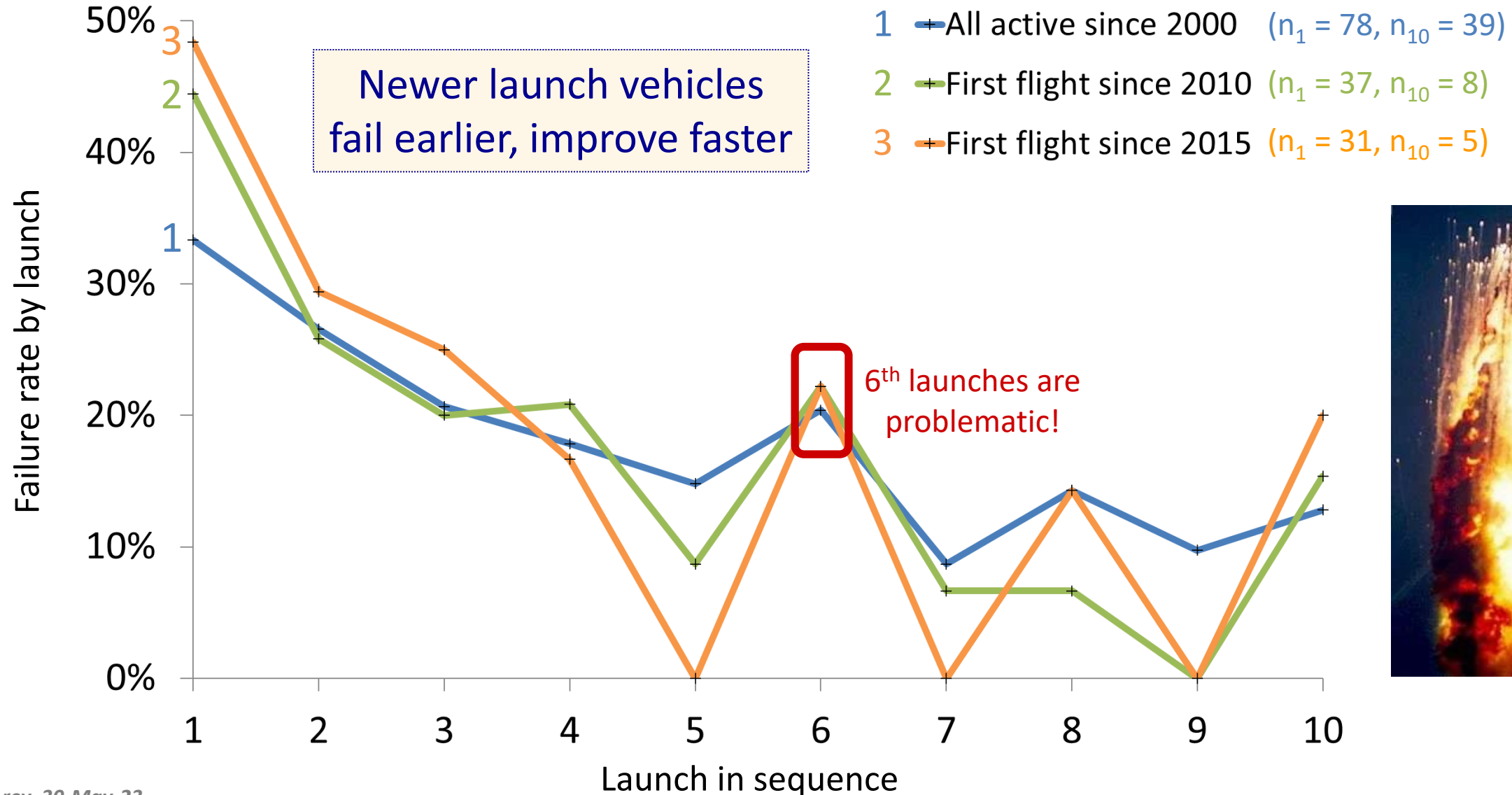
First 10 launches, all orbital launch vehicle families **active since 2000***



**excludes Iran
& N Korea*

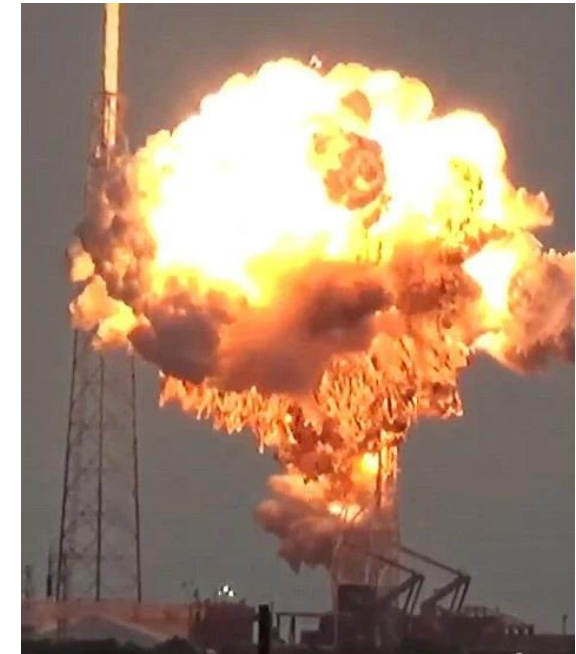
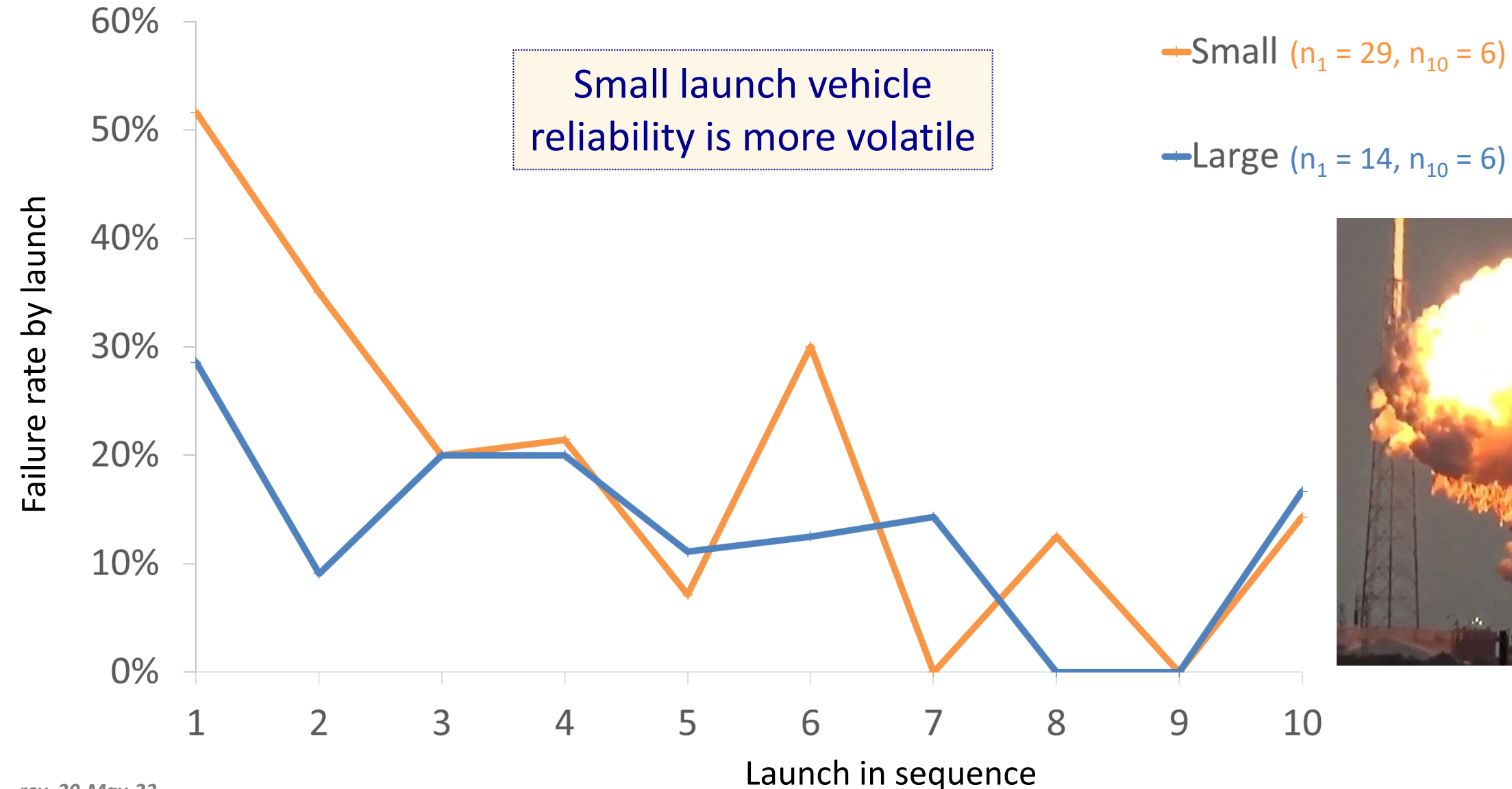
Launch Vehicle Failure Rate Comparison

First 10 launches, by **first flight date**



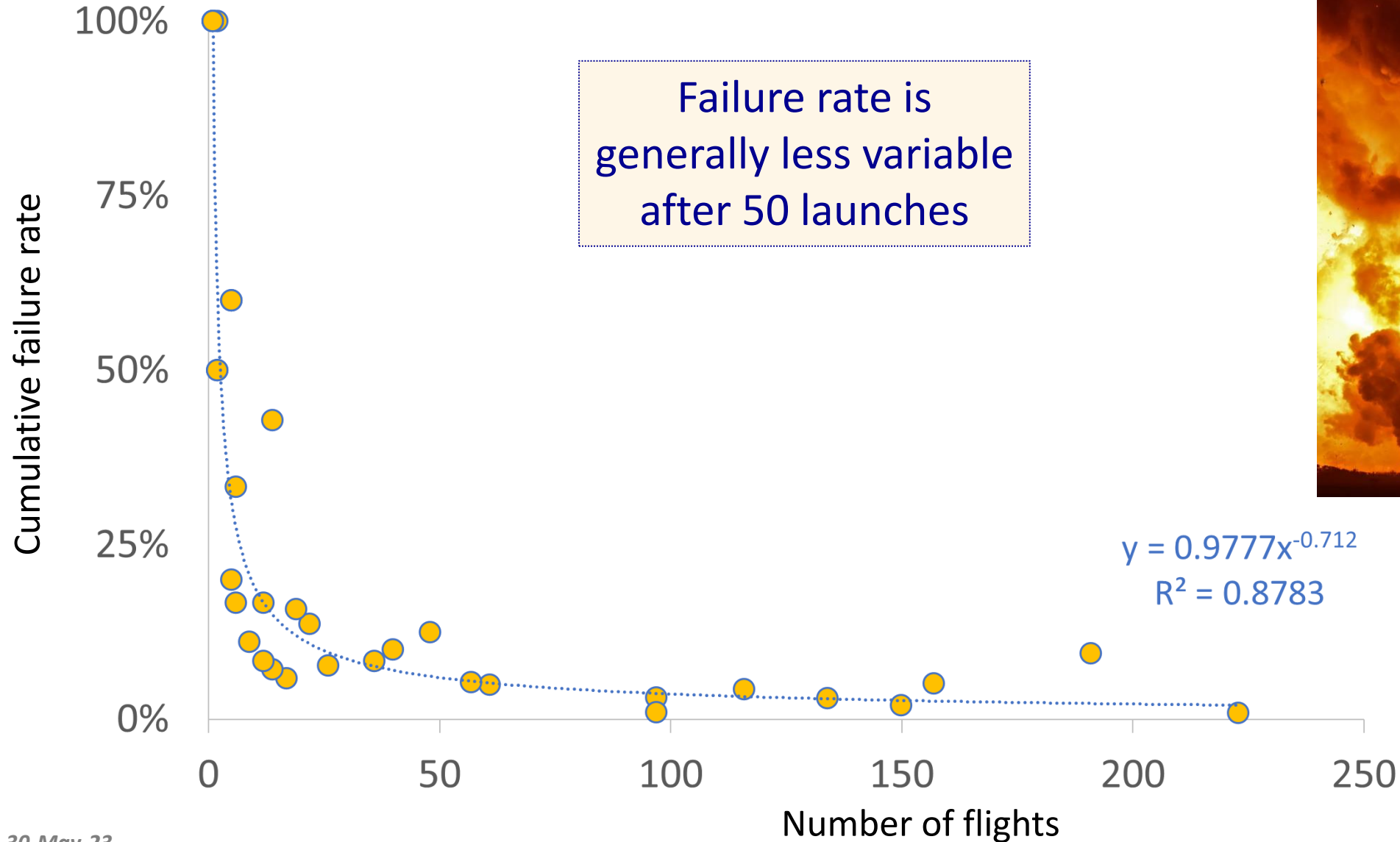
Launch Vehicle Failure Rate Comparison

Each launch, first 10 launches, by size, first flight since 2000



Launch Vehicle Failure Rate Comparison

Cumulative failure rate, all **currently active launch vehicles** (n = 45)



Why Do Launch Vehicles Fail?

→ **Virtually all launch failures are design- or process-related**

- ✓ External factors are almost never a root cause

→ **Root causes of launch failures are usually based in human factors**

- ✓ Design issues: unanticipated vehicle flight dynamics, insufficient testing of mission scenarios and phases, inadequate launch pad margins, schedule pressures, focus on first stage propulsion, and many more
- ✓ Process issues: moving from vehicle development to production, introduction of new technologies and processes with insufficient qualification, new people and teams with insufficient training and loss of experience, complacency and hubris, and many more

Launch Vehicles In Review – Takeaways

- **Generalizations about future launch vehicle performance are difficult due to differences in rocket engine technologies, vehicle size, payload capability, mission type, propellants, number of flights, etc.**
 - ✓ Nonetheless, newer launch vehicles fail earlier, improve faster
 - ✓ Small launch vehicles have more volatile reliability, perhaps due to mission type, cost, and criticality
- **Performance improves as the number of flights increases**
 - ✓ There are outliers, *e.g.*, Proton, due to significantly decreased launch cadence
 - ✓ Falcon 9 has set the standard for heavy-lift launch vehicles due to SpaceX's ability to maintain launch cadence and low prices
- **Several new launch vehicles are expected to fly in the next few years**
 - ✓ Large: Vulcan, Ariane 6
 - ✓ Small: Neutron, Terran-R, ISAR, RFA, and many others
- **Many other mature launch vehicles will be retired**
 - ✓ Atlas 5, Ariane 5, Proton, Delta 4 Heavy
- **Be attentive to first launches (~30-50% failure rate, typically design issues) and sixth launches (~20-30% failure rate, typically process issues)**
 - ✓ Complacency is bad in the launch business

Actually...pay attention to every launch!



Thank you!

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