Nanosatellites Through 2020 and Beyond

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CubeSat Developers Workshop 2021

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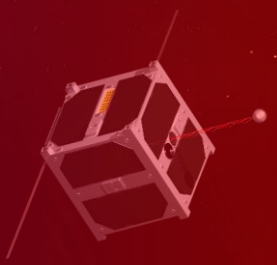
Nanosats Database



Agenda

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  - Why & Approach
  - Definitions
  - Challenges & Errors
- 2021 Graphs and Trends
  - Total
  - Launches
  - Orbits
  - Form Factors
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  - Map
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- Conclusion
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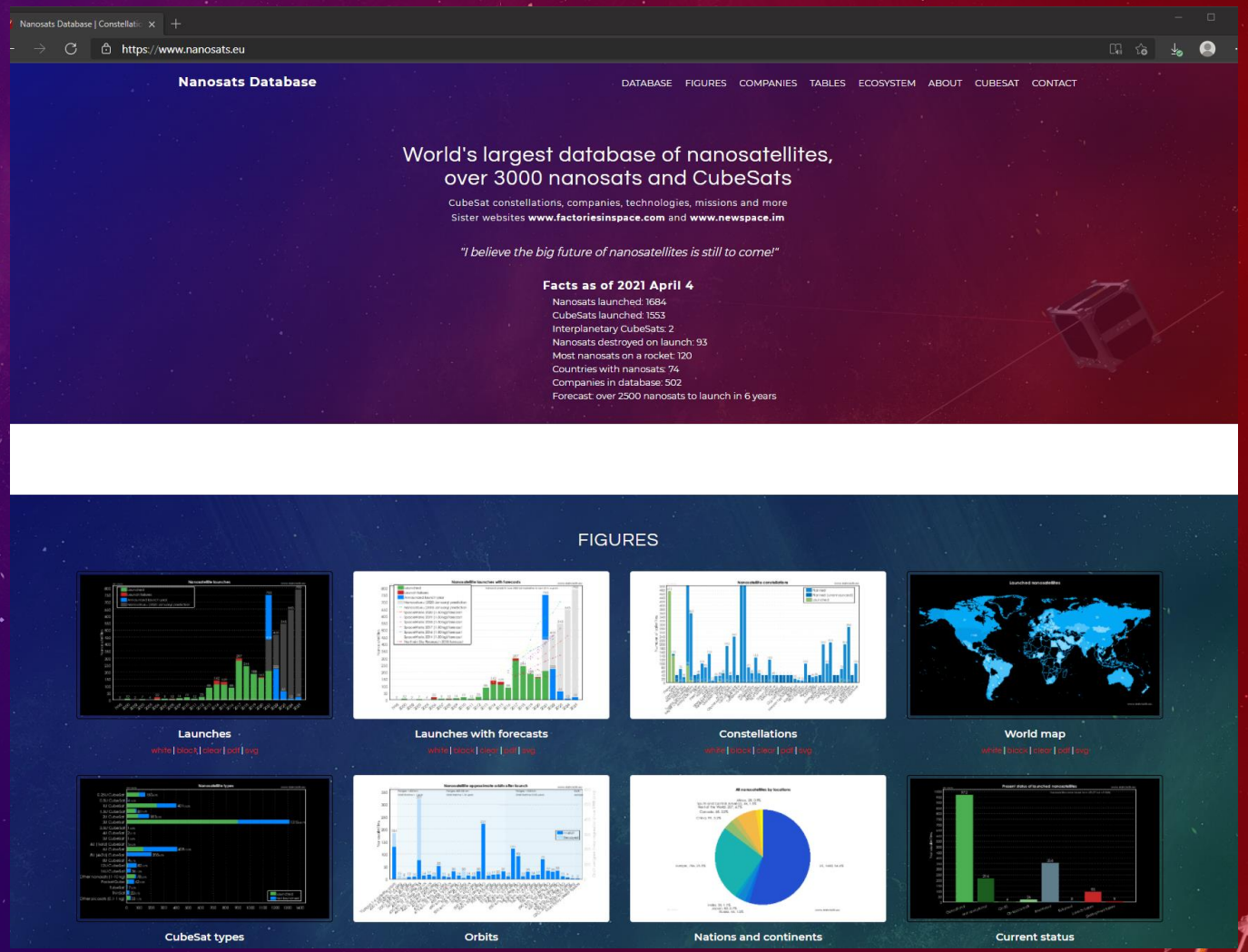
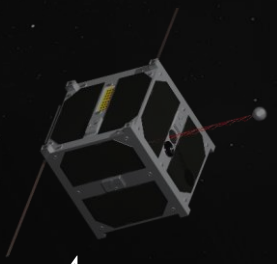
Nanosats Database

- Began in 2013 as an Excel file.
- Aim is to be the historical record.
  - Most information, all photos and attached publications.
  - Old satellite names and renders are great as they show changes over time.
  - Updating frequently (after every launch) has not been the goal.
  - Everything should have a linkable source.
  - Already many hidden columns.
- Planned and cancelled missions.
  - Gives a larger picture.
  - Notice new trends earlier.
  - Will also add more concepts.



"Just because a spacecraft is small, it doesn't make it easy. A highly constrained spacecraft can push the engineering, push the ingenuity of the team in a way that, in every way, is comparable to some of these big missions that we're doing."

- Dr. Thomas Zurbuchen,
NASA Associate Administrator



Why & Approach

- Continuing M. A. Swartwout's annual presentations, but including constellation spacecraft.
- Even bigger future of nanosatellites is ahead.
  - Only 2 Mars fly-by/interplanetary and 2 GTO CubeSats.
  - Novel deployable technologies, new constellations and exploration missions.
  - Will be able to visit many more moons and asteroids across the Solar System.
  - Being bound to fit into a box (CubeSat) empowers creativity and innovation.
- Purpose to increase awareness and inspire to aim higher
  - Too many similar missions and even satellite names, teams should set a goal to have more unique aspects.
  - Pushing the limits of technology can be more challenging and risky, but larger motivation and opening of new opportunities will likely make up for it.

“Nanosatellite” Broader Definition

Included in Nanosats Database

- All CubeSats from 0.25U to 27U (largest launched is 16U).
- Nanosatellites from 1 kg to 10 kg (shown in kilograms).
- Picosatellites from 100 g to 1 kg (shown in grams).
- PocketQubes, TubeSats and ThinSats have own categories.

Not (yet) included

- Femtosatellites (10 g to 100 g), chipsats and suborbital launches.
- CubeSats bolted to stages and not meant to be separate objects.
- Deep space inspection cameras, like flown on IKAROS & Tianwen-1.
- Data is since 1998 - at least 21 nanosats launched in the 1960s.
- Microsatellites in the 10-50 kg range, increasing quickly.

Challenges & Errors

- Most nanosatellites have some public information - easy to collect.
  - But even in 2021, photos of some CubeSats are impossible to find.
  - Detailed and timely mission status is only rarely shared, but some do it well.
- Few other sources for structured information with references.
  - Source for an upcoming CubeSat could be a screenshot of a presentation.
  - Some CubeSat names are not unique making search challenging.
- Proactive sharing of information or offers for help are rare.
- Error of the cumulative satellite count is perhaps ±5 spacecraft.
  - Some unknown objects from military (X-37B?) and China.
  - No information about the form factors of many spacecraft, could fit criteria.

2021 Q1 Status

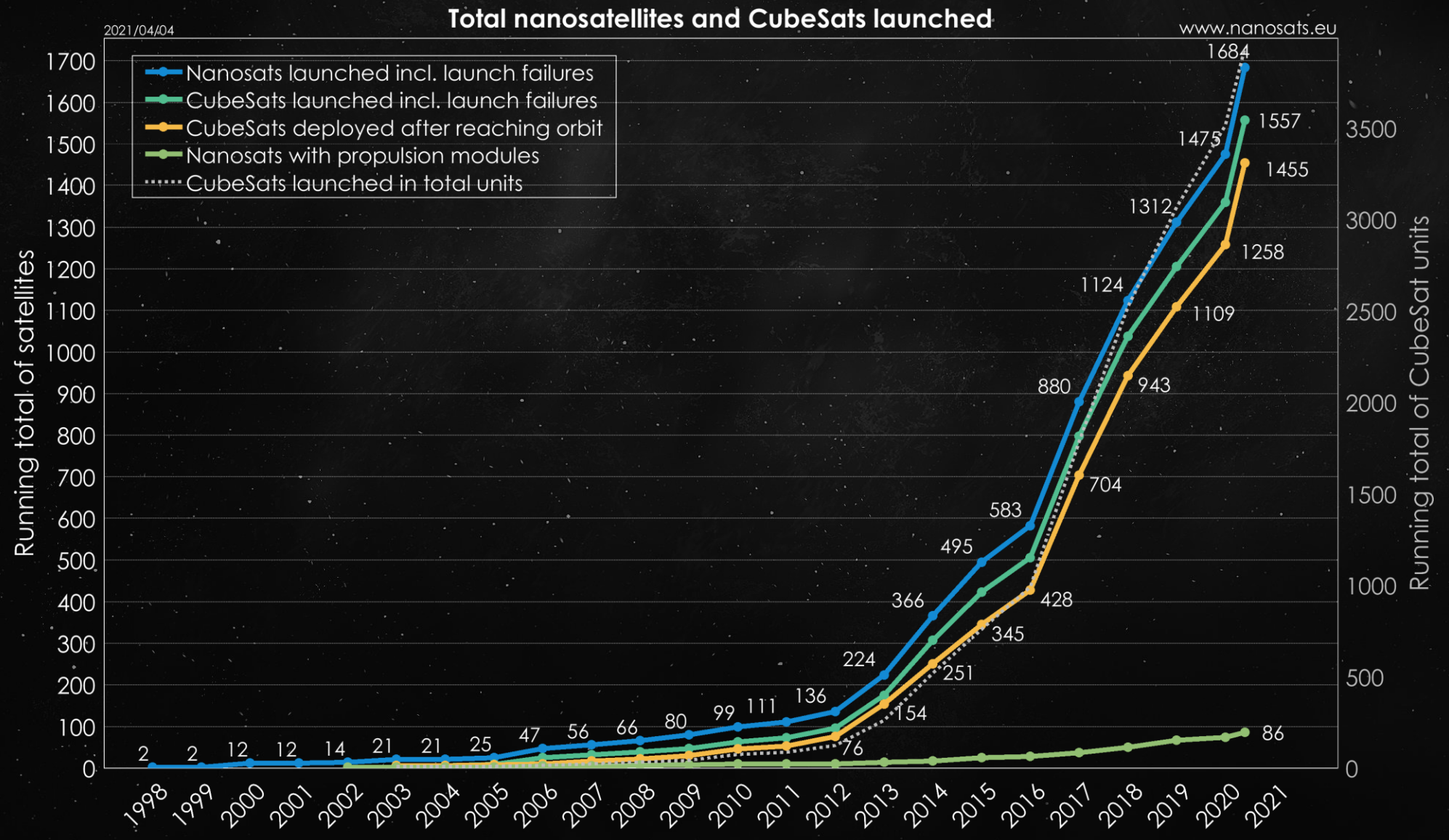
Nanosatellite statistics, trends & discussions

1000 CubeSats have been launched! 🚀 It only took ~~15~~ 16 years from 2003. Not all of them made it to orbit and handful are unknown, but certainly over 1000 have been on a rocket. Next thousand in 3 years?

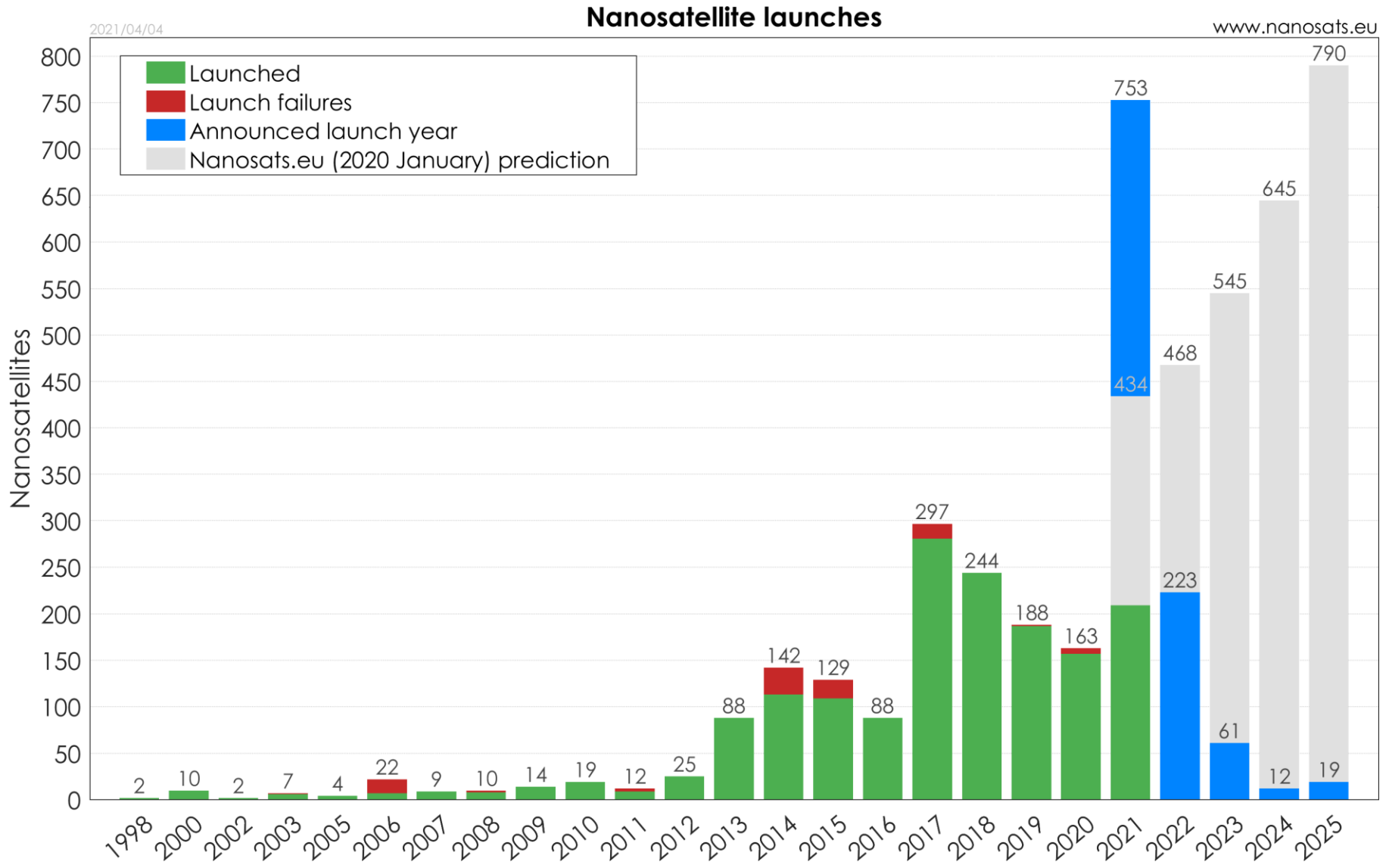
- Nanosats Database

Dec 30, 2018

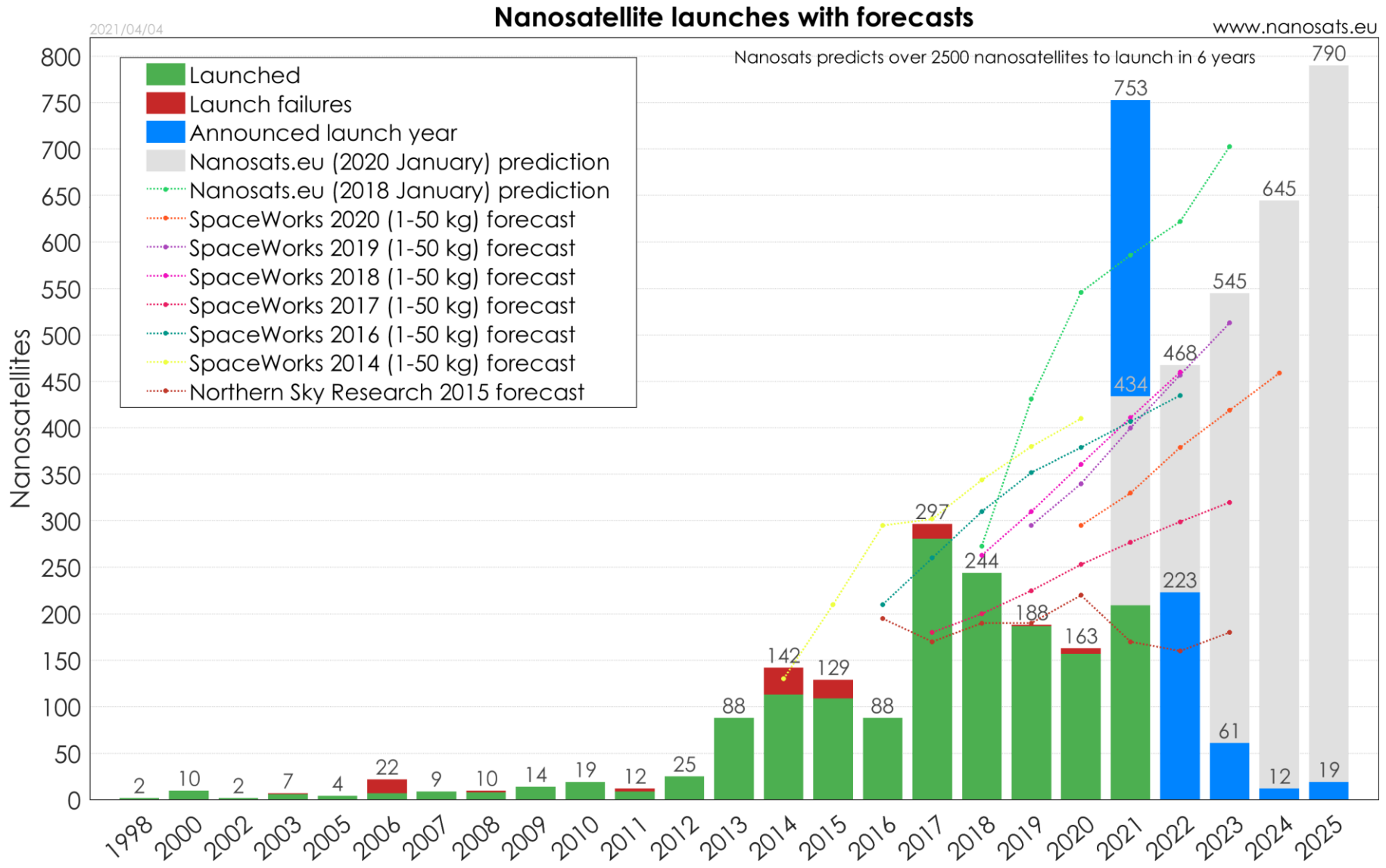
Total Nanosatellites



Launches by Years



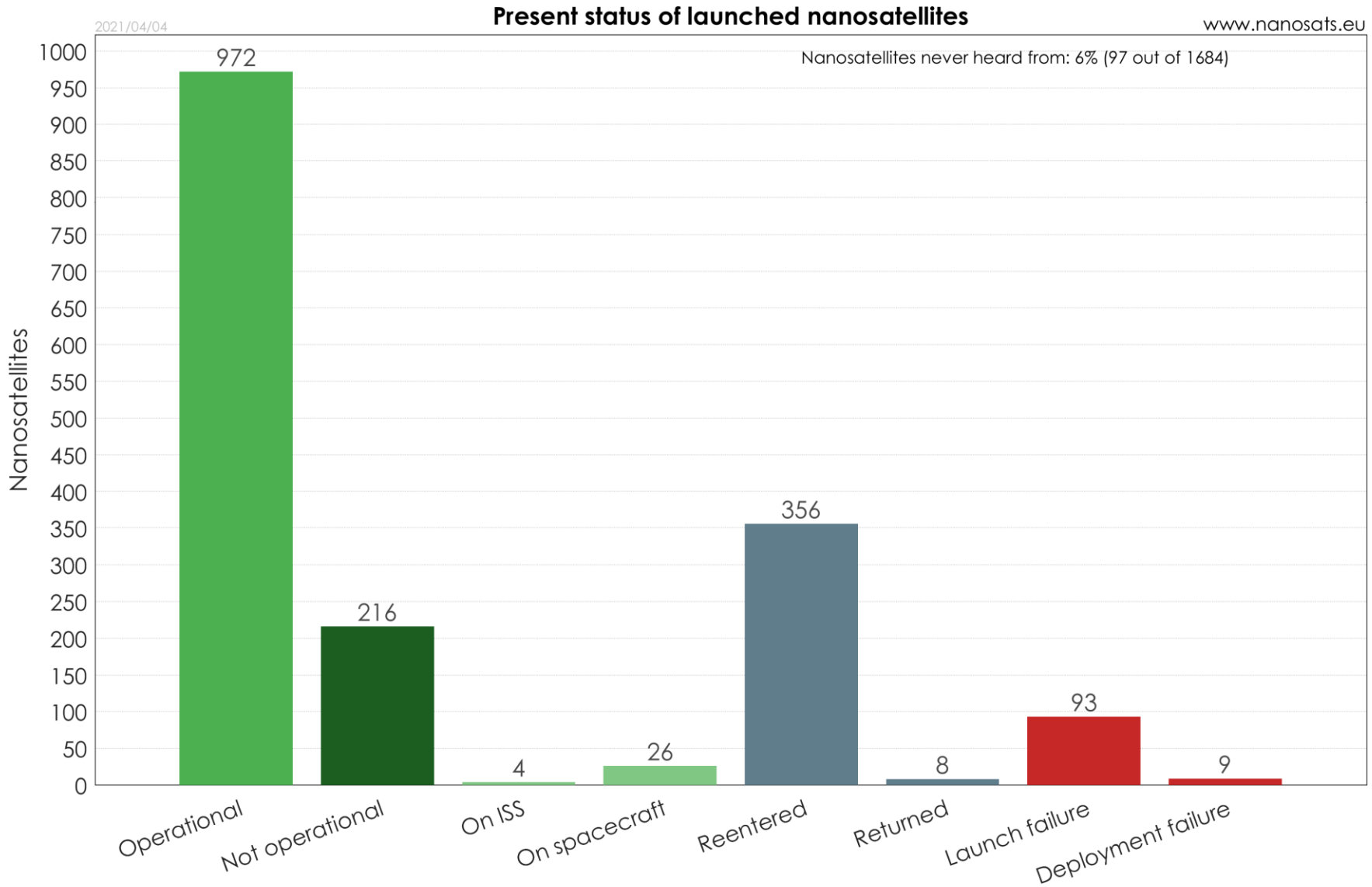
Launches by Years with Forecasts



Launches by Years - Discussion

- 3 years of decline in numbers after the record in 2017.
  - New rockets launches delayed by 2-3 years and Vega 1 year.
  - Constellations much slower to scale up from demonstrations.
- 2021 will be a new record in nanosatellite launches.
  - Unlikely to be 750 as shown, but perhaps 400-500.
- Most forecasts (including nanosats.eu's) have been too optimistic and not accounted for the up-and-down reality.

Status


Present status of launched nanosatellites
2021/04/04
www.nanosats.eu
Nanosatellites never heard from: 6% (97 out of 1684)
Nanosatellites
1000
950
900
850
800
750
700
650
600
550
500
450
400
350
300
250
200
150
100
50
0
972
216
4
26
356
8
93
9
Operational
Not operational
On ISS
On spacecraft
Reentered
Returned
Launch failure
Deployment failure

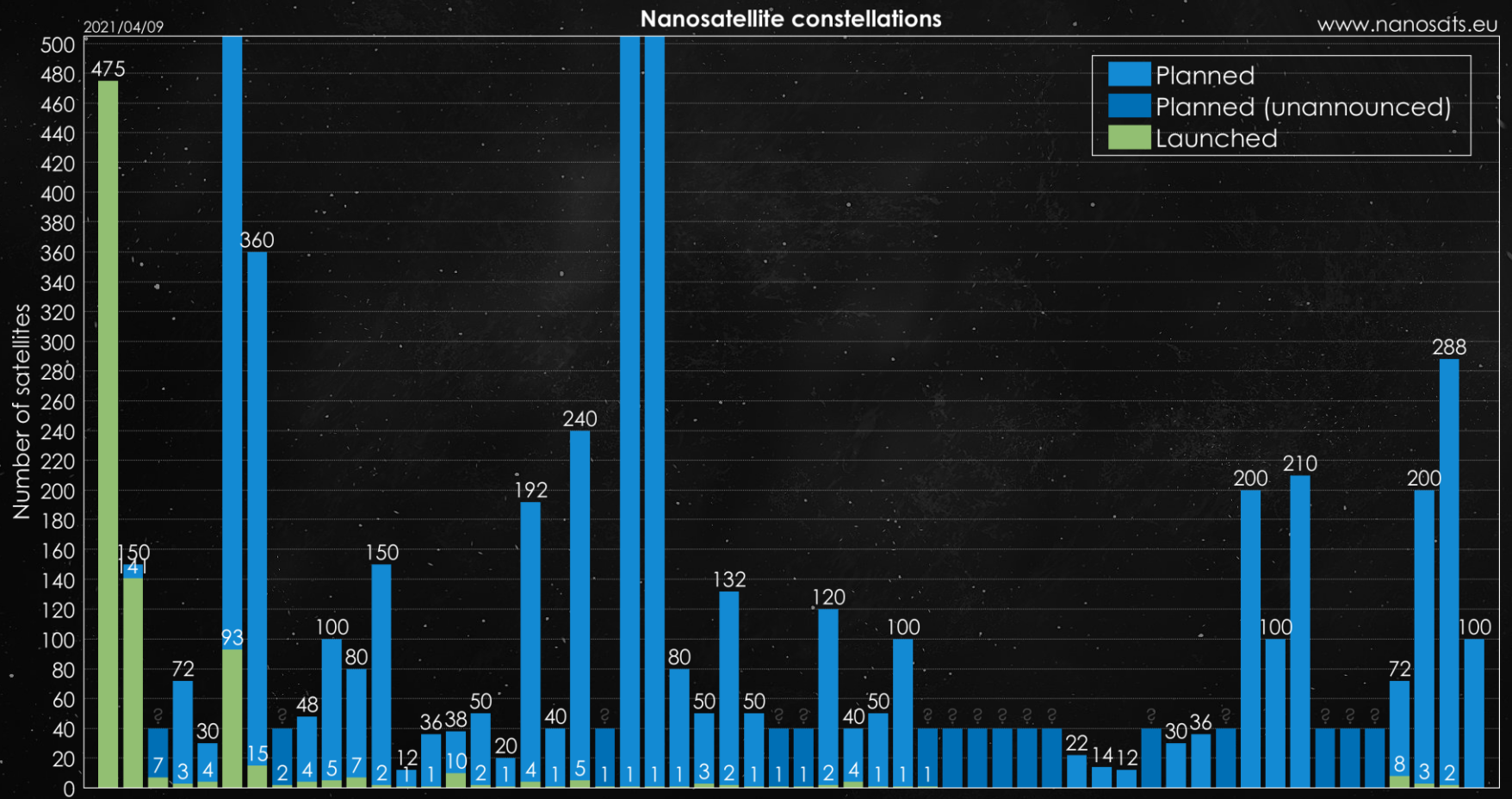
Status - Discussion

- Current status as of 2021 April 1.
- Mission status data is very challenging to collect.
- Operational is likely lower than the 972 shown on plot because constellation retirements or later statuses are not announced.
- Operational also includes semi-operational.
- Operational does not mean mission complete, but at least a beacon should be sent regularly with working telemetry.
- Correct “No Signal” is about 6%, 97 out of 1684.
- Partially failed complex missions could still achieve more than simplest missions, e.g. a single criteria can be misleading.

Facts as of 2021 April 4

- Nanosats launched: 1684
- CubeSats launched: 1553
- CubeSat 1U-sized units launched: 3941U
- CubeSats launched in mass: ~5900 kg (assuming 1.5 kg per U)
- Interplanetary CubeSats: 2
- Nanosats destroyed on launch: 93
- Most nanosats on a rocket: 120 on Transporter-1
- Countries with nanosatellites in space: 74
- Companies in the database: 502

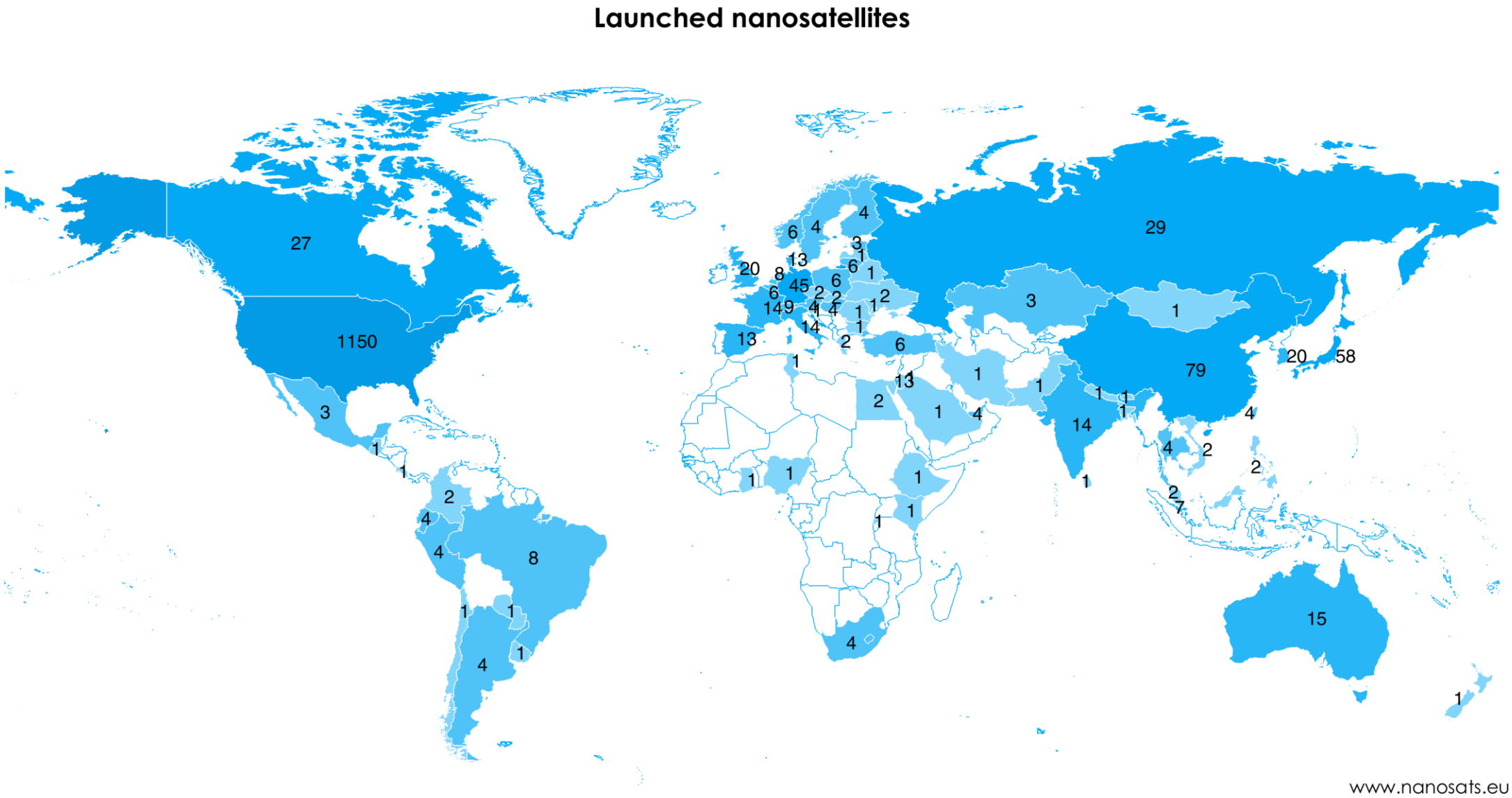
Constellations



Constellations - Discussion

- Planet and Spire (3U) are continuing to be the largest CubeSat constellations.
- Swarm has taken 3rd place. While 0.25U form factor makes it a bit easier as 12 fit into 3U, it is still an achievement.
- Kepler now at 4th place with 15 satellites.
  - 12 of them are 6U XL, largest constellation in that form factor.
- Many other companies are still at 0-2 demonstration missions and 2+ years behind with plans to scale up the constellations.

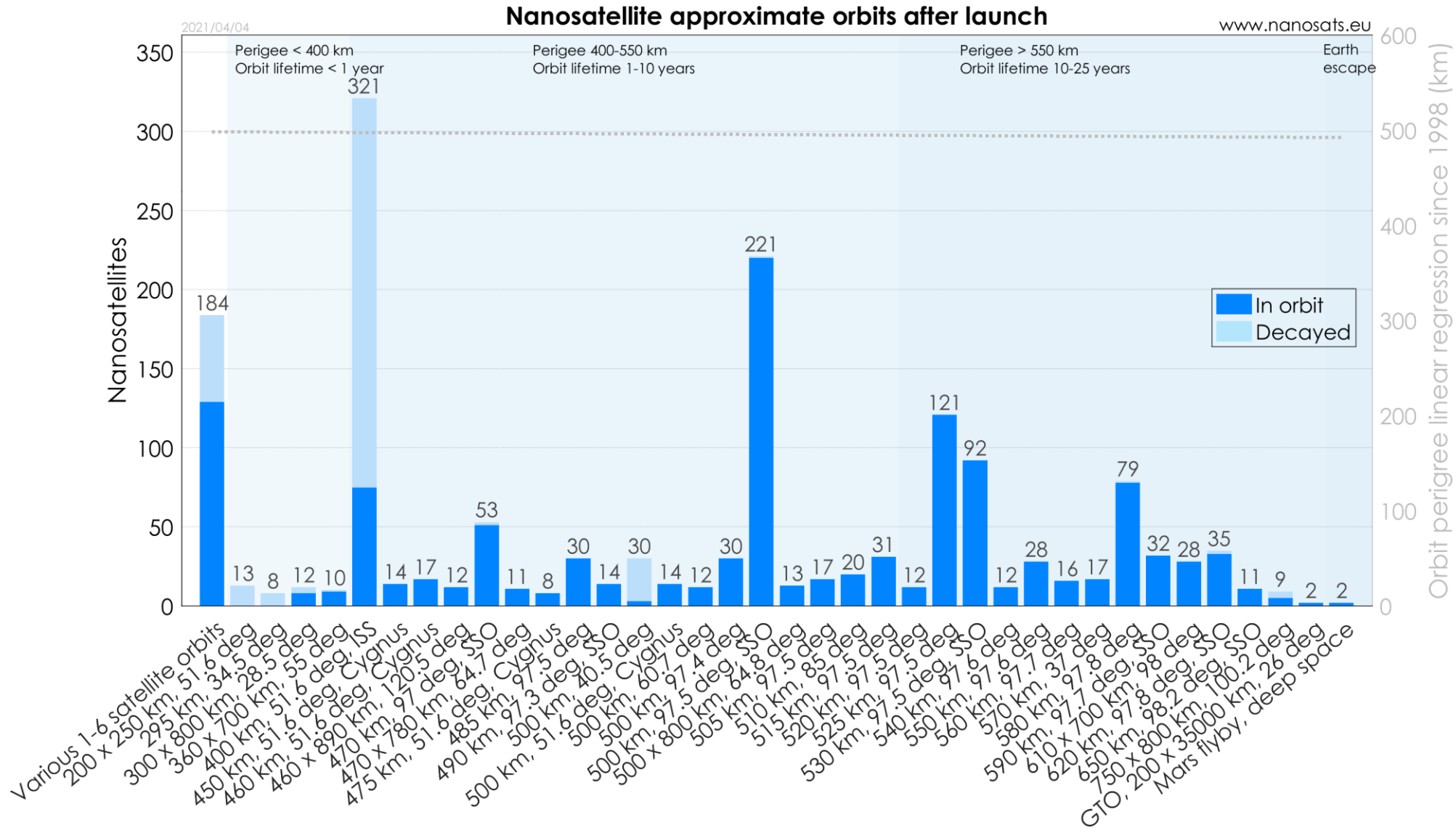
Map


Launched nanosatellites
27
1150
3
1
1
2
4
4
8
1
1
1
4
6
4
4
3
1
13
6
1
20
8
45
6
6
2
2
14
9
4
4
1
1
2
14
1
13
2
6
1
1
13
2
1
4
29
3
1
79
20
58
1
1
14
4
4
2
2
2
7
1
1
1
1
1
4
15
1
www.nanosats.eu

Map - Discussion

- This chart is by leading organisation headquarters location.
- US is far ahead in nanosatellite launches in any case.
  - Thanks to largest amount of constellation companies.
  - Thanks to NASA's ELaNa program and educational CubeSats.
- Great to see the map filling up. 74 countries have sent at least 1 nanosatellite to space.

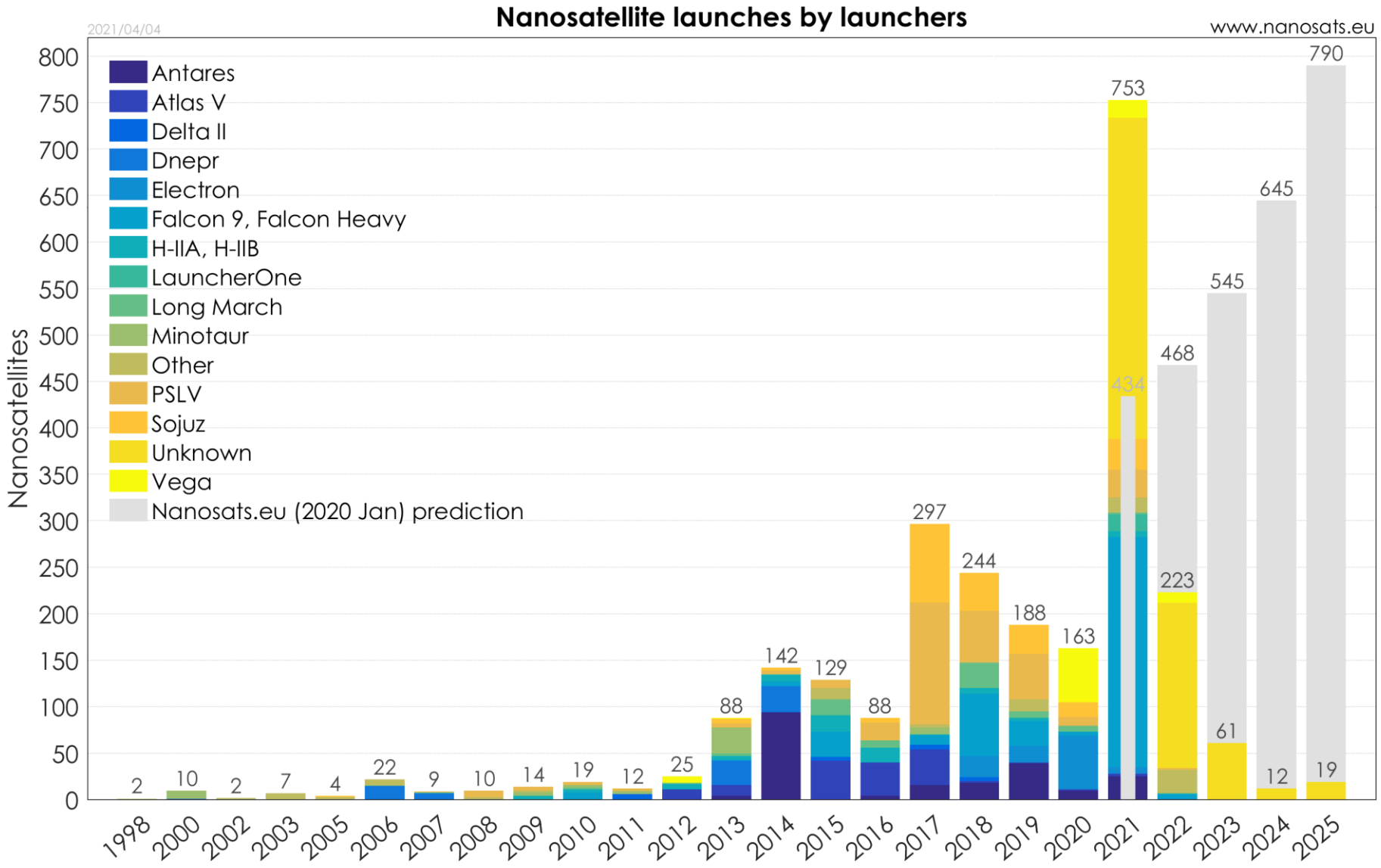
Orbits


Nanosatellite approximate orbits after launch
2021/04/04
www.nanosats.eu
Perigee < 400 km
Orbit lifetime < 1 year
Perigee 400-550 km
Orbit lifetime 1-10 years
Perigee > 550 km
Orbit lifetime 10-25 years
Earth escape
Nanosatellites
Orbit perigree linear regression since 1998 (km)
In orbit
Decayed
184
13
8
12
10
321
14
17
12
53
11
8
30
14
30
14
12
30
221
13
17
20
31
12
121
92
12
28
16
17
79
32
28
35
11
9
2
2
Various 1-6 satellite orbits
200 x 250 km, 51.6 deg
295 km, 34.5 deg
300 x 800 km, 28.5 deg
360 x 700 km, 55 deg, ISS
400 km, 51.6 deg, Cygnus
450 km, 51.6 deg, Cygnus
460 km, 51.6 deg, Cygnus
460 x 890 km, 120.5 deg, SSO
470 km, 97 deg, SSO
470 x 780 km, 64.7 deg
475 km, 51.6 deg, Cygnus
485 km, 97.5 deg, SSO
490 km, 97.3 deg, SSO
500 km, 40.5 deg
500 km, 51.6 deg, Cygnus
500 km, 60.7 deg
500 km, 97.4 deg
500 km, 97.5 deg, SSO
500 x 800 km, 64.8 deg
505 km, 97.5 deg
510 km, 85 deg
515 km, 97.5 deg
520 km, 97.5 deg
525 km, 97.5 deg, SSO
530 km, 97.6 deg
540 km, 97.6 deg, SSO
550 km, 97.6 deg
560 km, 97.7 deg
570 km, 37 deg
580 km, 97.8 deg
590 km, 97.7 deg, SSO
610 x 700 km, 98 deg, SSO
620 km, 97.8 deg, SSO
650 km, 98.2 deg, SSO
750 x 800 km, 100.2 deg
GTO, 200 x 35000 km, 26 deg
Mars flyby, deep space

Orbits - Discussion

- Trend into lower altitude orbits with 1-10 year lifetimes is continuing.
- Limited number of CubeSats at larger than 600 km altitudes, where orbital lifetime reaches ~25 years.
- These orbits used to be more common in the early days due to SSO rideshare missions and primary payloads.
- Note the 2 GTO and 2 deep space CubeSats.

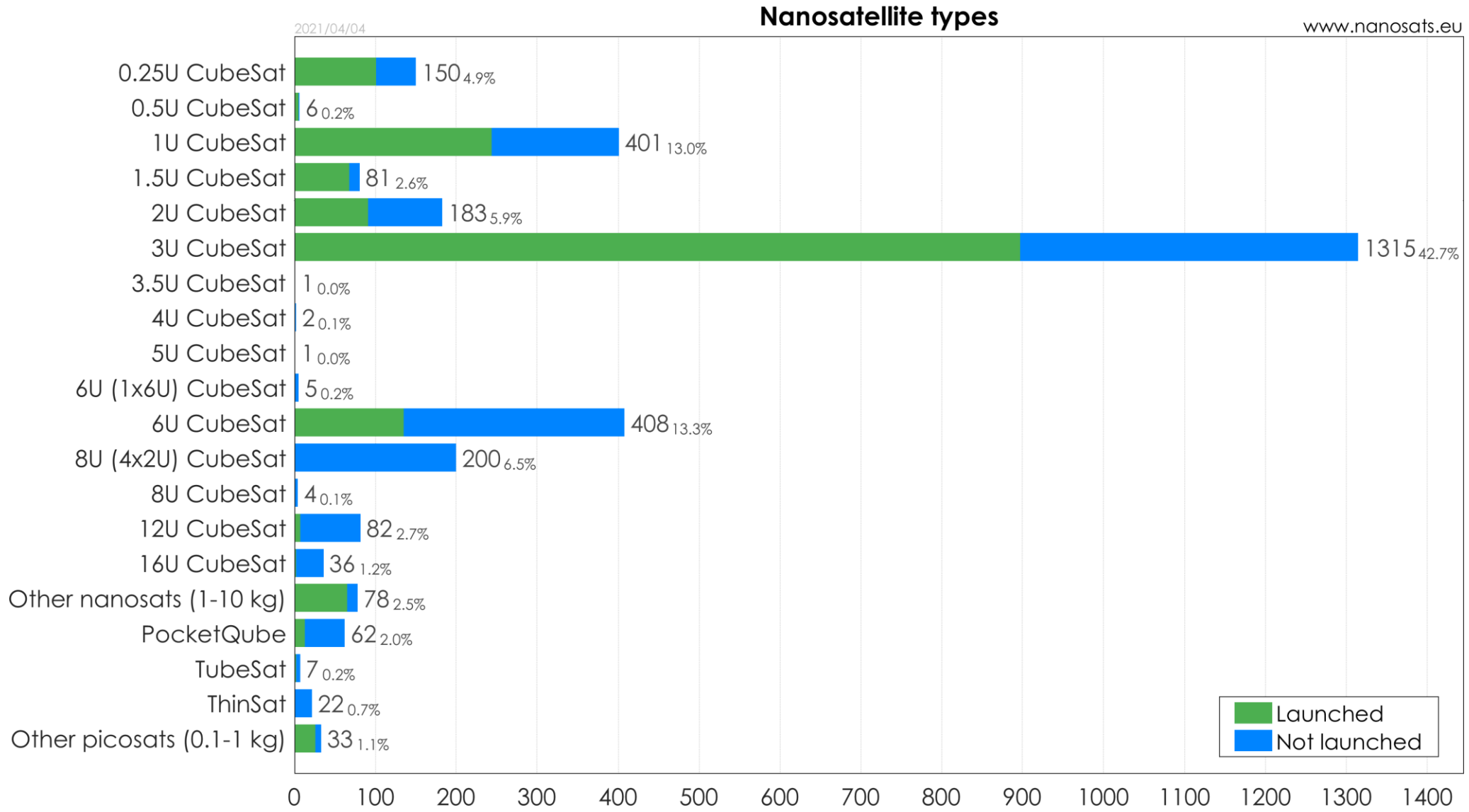
Launches by Launchers



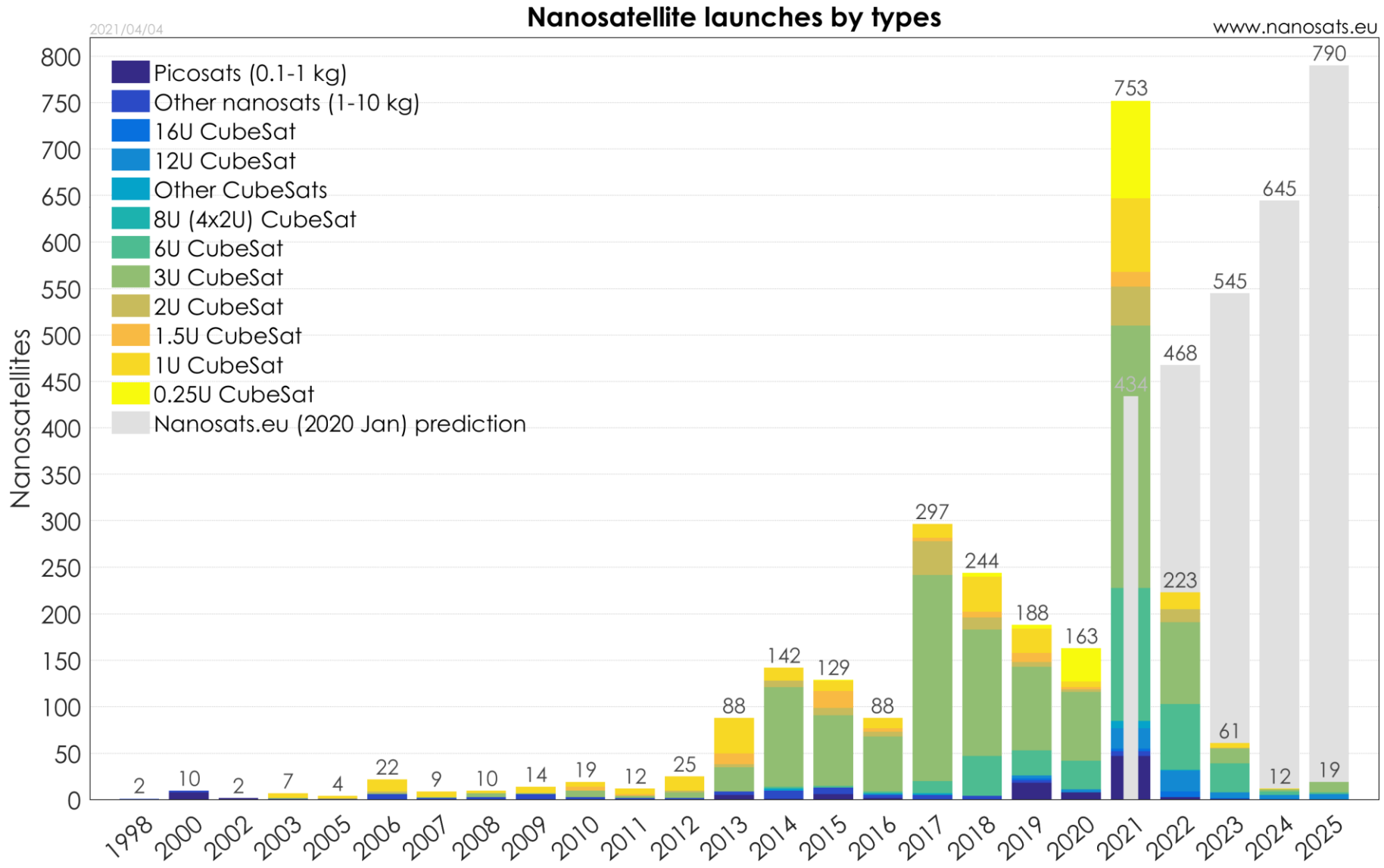
Launchers - Discussion

- Dnepr, Delta-II and Minotaur used to be the most common CubeSat rideshare launchers.
- Changed into Antares, PSLV and Sojuz.
- Now adding Falcon 9, Vega, Rocket Lab and most other small launchers.
- Space tugs (D-Orbit and Momentus) have also entered the market.

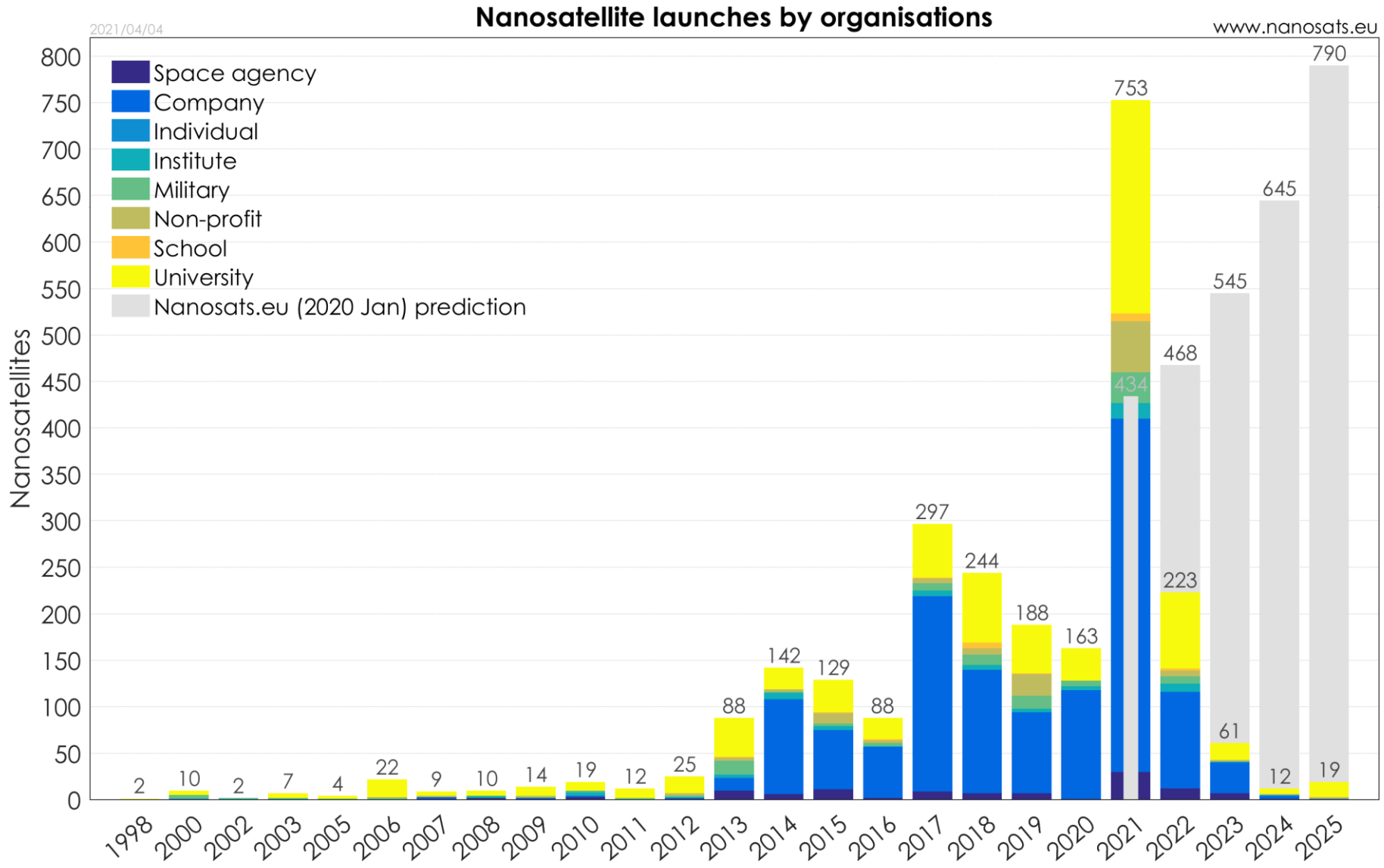
Form Factors



Launches by Form Factors



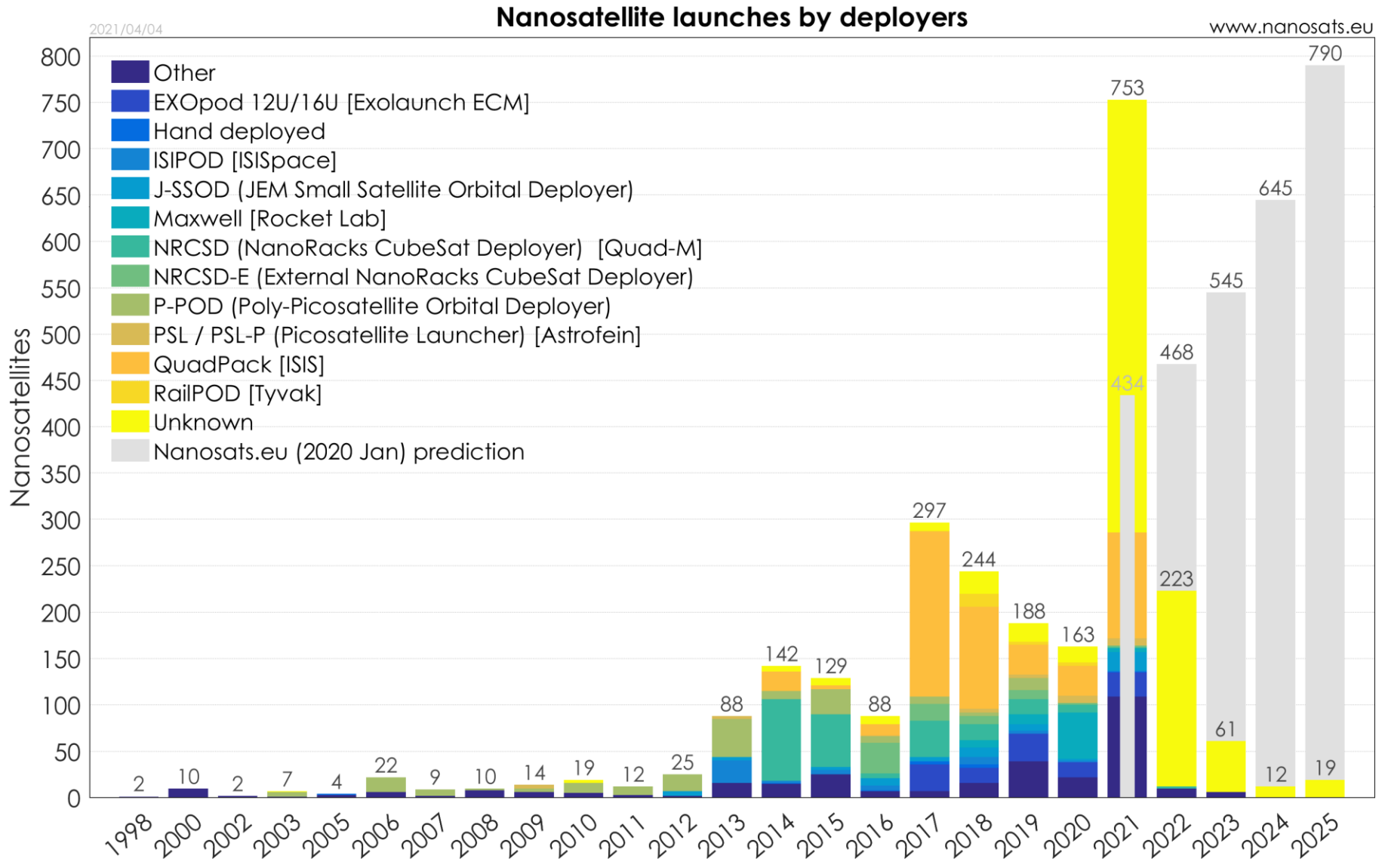
Launches by Organisations



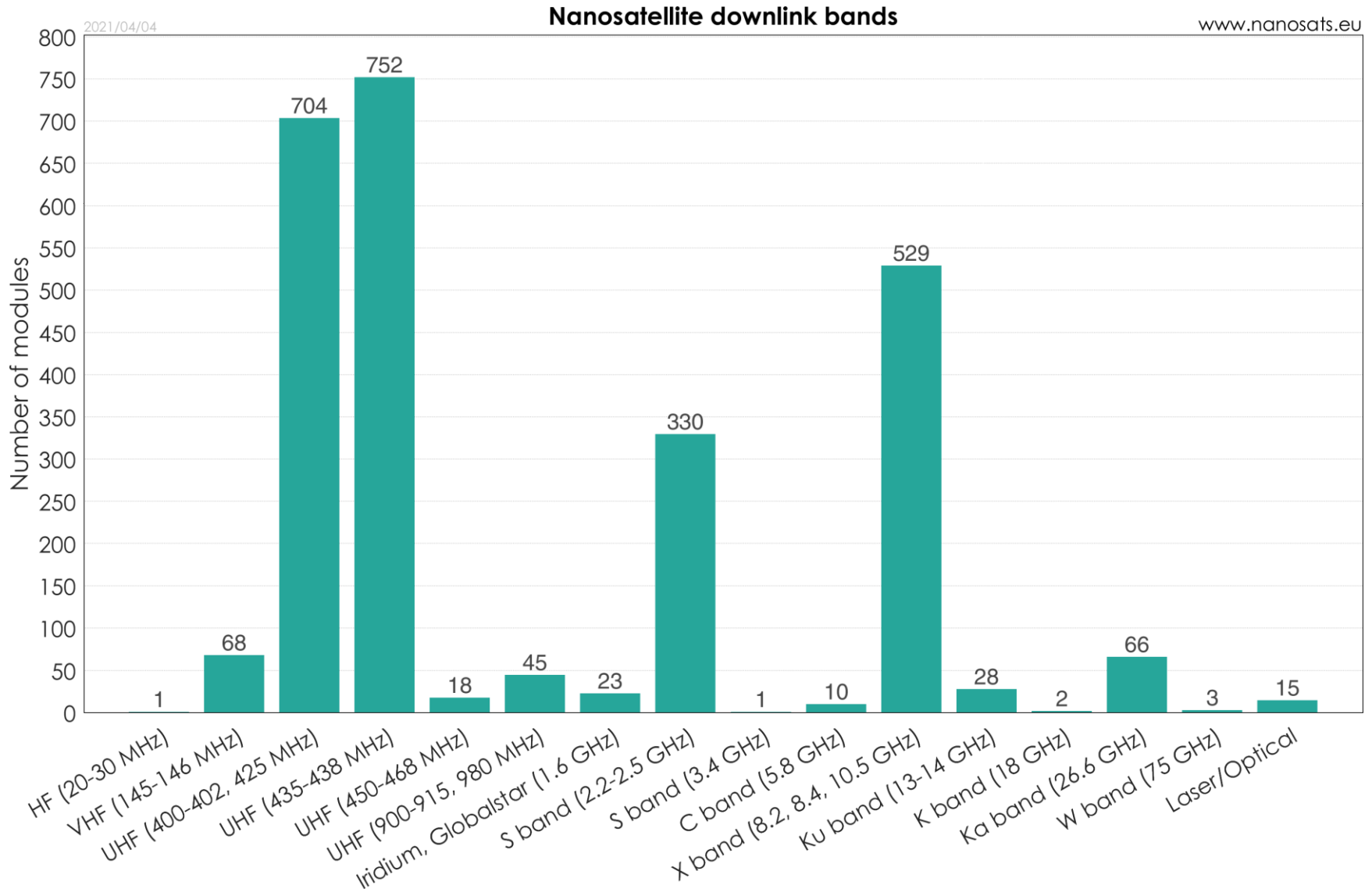
Organisations - Discussion

- Academia CubeSats are increasing, but have stayed relatively stable and predictable. Similar with governmental and non-profit spacecraft. Some fluctuations can be attributed to launch delays.
- Commercial satellites are now the most popular segment and also vary the most. That itself is very dependant on constellations coming to fruition.

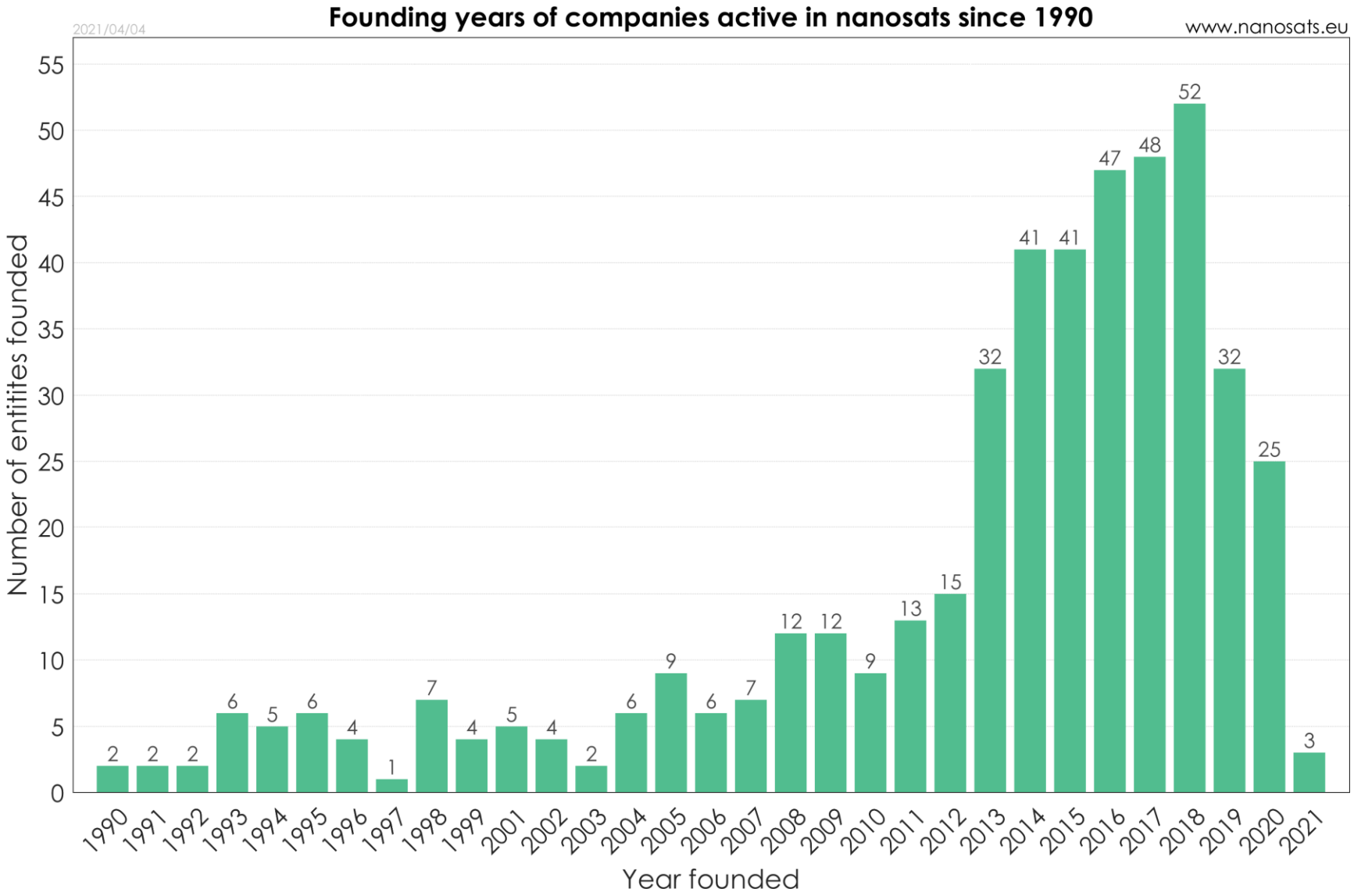
Launches by Deployers



Downlink Bands



Companies Founded



Companies Founded - Discussion

- The peak in 2016-2018 could be a partial sign of hype?
- Decrease could be a sign of more actors waiting to see what happens and nanosatellite ecosystem entering a more productive mature phase?

Conclusions

- Nanosats launched: 1684 and CubeSats launched: 1553.
- Total mass of launched CubeSats is only about ~5900 kg (3941U x 1.5 kg).
- 2021 will likely set a new record of launches after 2017.
- Second thousand in 4 years (2019-2022) vs 16 years for the first 1000 (2003–2018)?

- Sizes are both getting larger and smaller (PocketQubes, ThinSats, <1U CubeSats, microsatellites).
  - Primarily educational missions could move into smaller form factors.
  - Decreasing launch costs (SpaceX rideshare and Starship) might favour larger satellites to save development cost on miniaturization.
- Interplanetary, MEO, GTO and deep space CubeSats are still in the early days.
- Long-term sustainability of most CubeSat constellations remains to be proven, making market and launch forecasting challenging.

Sources & Acknowledgements

- Launch schedules and manifests such as Gunter's Space Page.
- Jonathan McDowell's Space Reports and Master Satellite List.
- Websites IARU, Space-Track, NASA Spaceflight, NewSpace Hub.
- Official websites, news articles and social media posts.
- Presentations and proceedings from related conferences.
- Radio amateurs such as DK3WN, JA0CAW and SatNOGS.
- Other databases such as M. A. Swartwout for some cross-checking.
- Databases SPOON (parts on orbit) and PMPedia (radiation tested).
- Occasional emails and self-additions. Thank you!

Nanosats Database

www.nanosats.eu

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