Will CubeSats Introduce a Moore's law to Space Science Missions?

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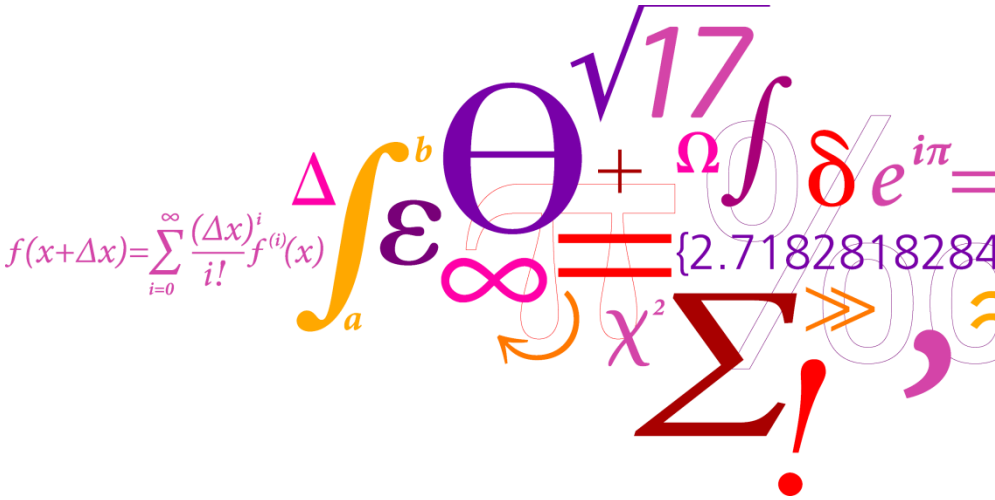
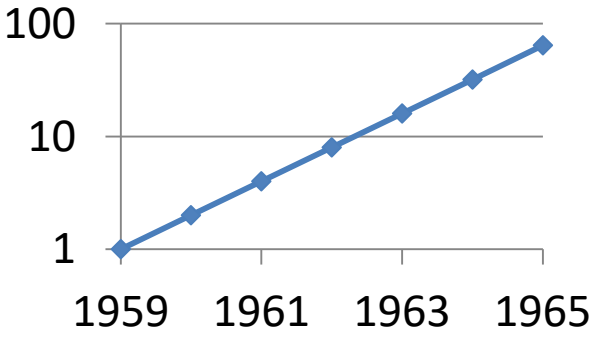


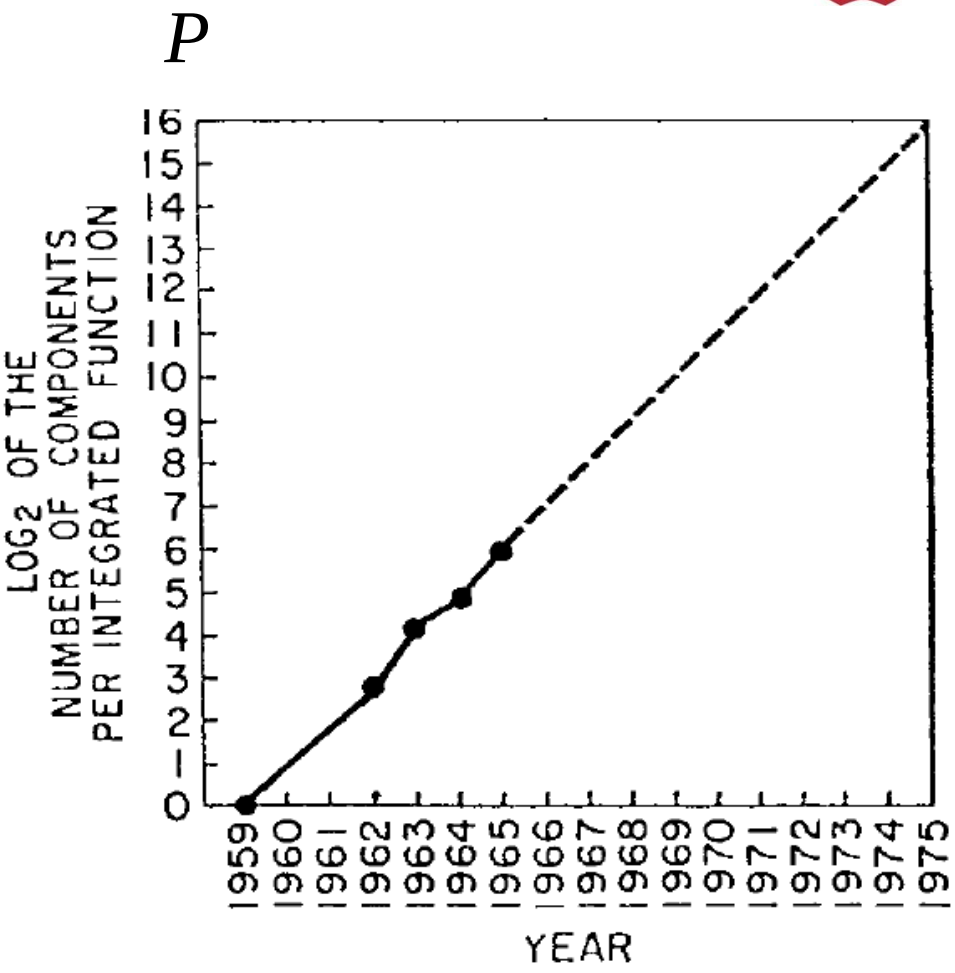
Moore's law

$$P = Log_2\left(n_{i.f.}\right)$$

$n_{i.f.}$: number of components per integrated function

$$P_t = P_0 2^{t/n}$$





G.E. Moore,
Electronics, April 19, 1965

Law for space missions

Moore's law:

$$P_t = P_0 2^{t/n}$$

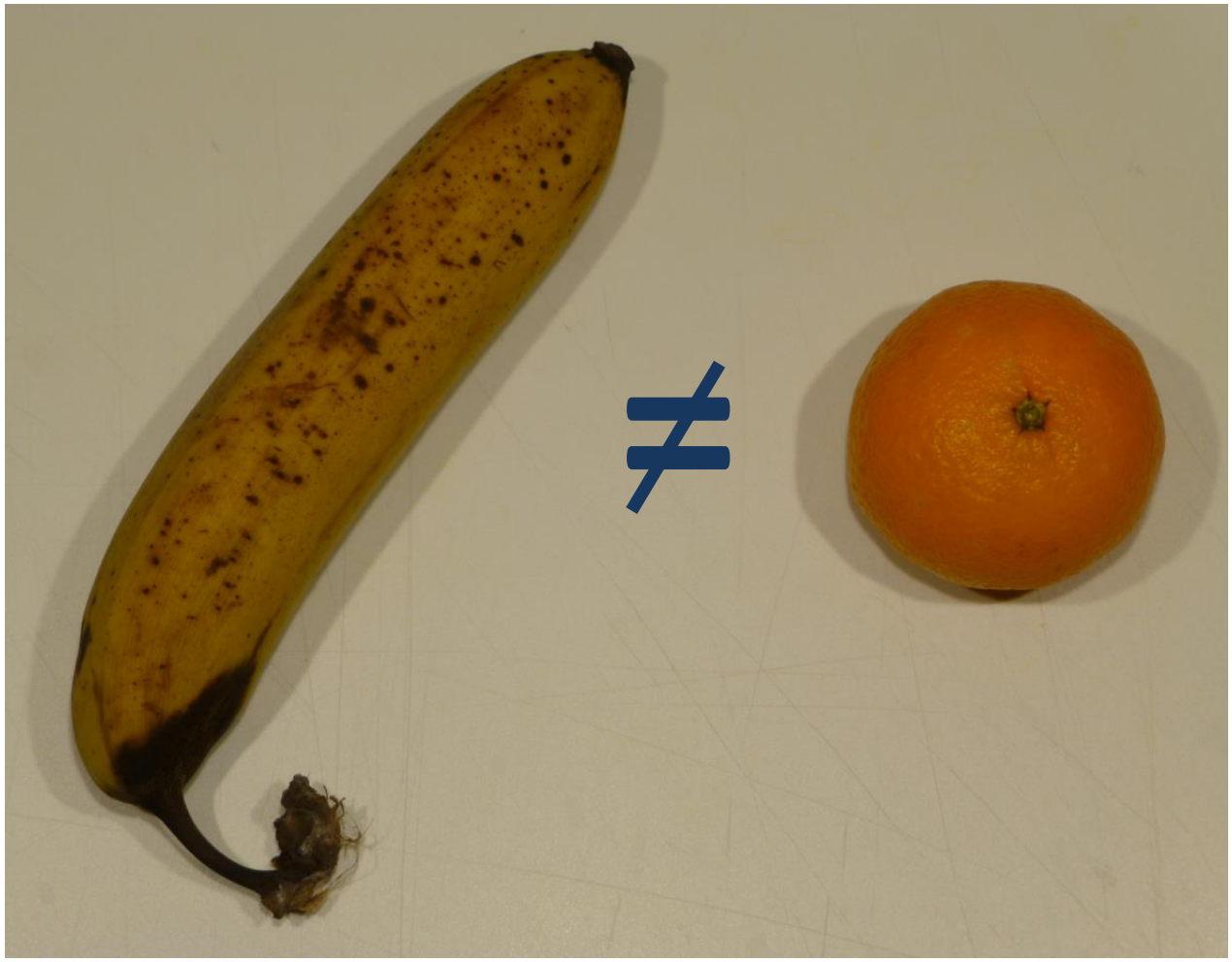
n: Time in months for number of components per area to double.

Space version of Moore's law:

$$P_t = \frac{P_0}{2^{t/n}}$$

n: Time in months for mass of a given spacecraft type to half.

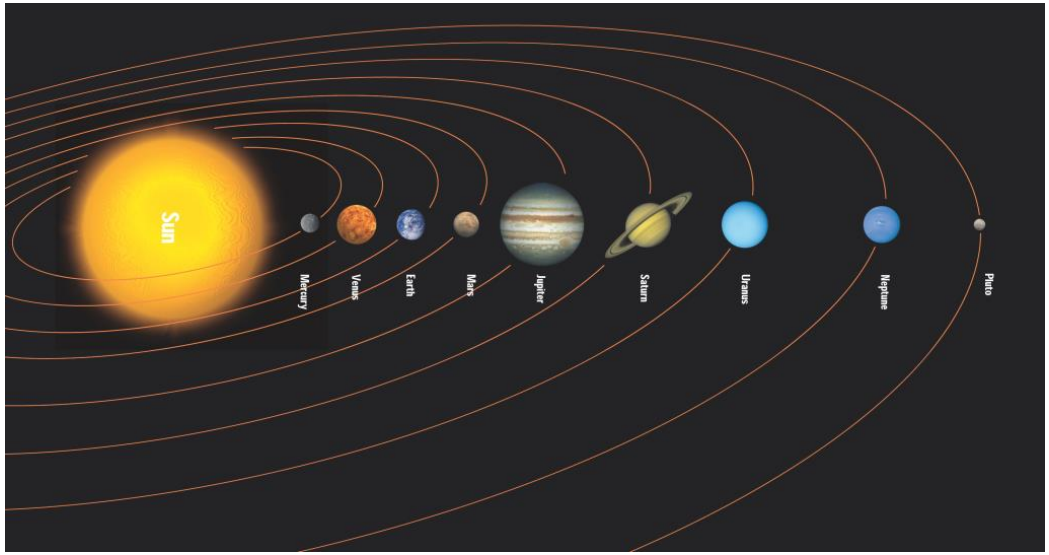
Avoid comparing bananas and clementine



Δ-*v* Map

$$\Delta v = v_e \ln\left(\frac{m_0}{m_f}\right)$$

Low Earth orbit LEO	9.1-12.5 km/s
Lunar soft landing LSO	15.2 km/s
Lunar escape velocity LEV	2.4 km/s
Lunar orbit (min.) LSO-LEV	12.8 km/s
Mars soft landing MSL	20 km/s
Mars escape velocity MEV	6.4 km/s
Mars orbit (min.) MSL-MEV	14.2 km/s



Δ-*v* Map

Money

$$\Delta v = v_e \ln \frac{m_0}{m_f}$$

P.I.

Technology

Dest./operation

Low Earth orbit LEO	9.1-12.5 km/s
Lunar soft landing LSO	15.2 km/s
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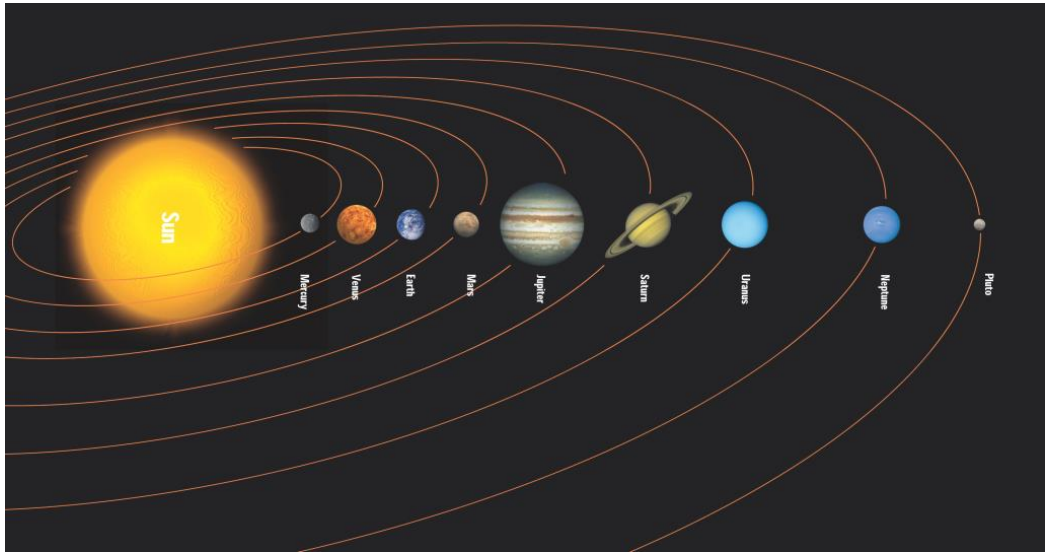


Mission classification

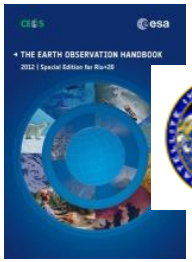
Earth orbiters	Deep space	
Low earth orbit, Earth observing visible	Lunar flyby	Mars flyby
Low earth orbit, Earth observing IR	Lunar orbit	Mars orbit
Low earth orbit, Earth observing SAR	Lunar penetrator	Mars lander
Low earth orbit, Earth observing magnetometer	Lunar lander	Comets flyby, orbit, land
Low earth orbit, Earth observing AIS, Asset tracking etc	L1	Asteroid belt flyby, orbit, land
Medium earth orbit, GNSS	Asteroid, NEO flyby, orbit, land	Jupiter flyby
Geostationary orbit, weather	Venus flyby	Jupiter orbit
Geostationary orbit, communications	Venus orbit	ETC...
ETC...	Venus lander	

Missions Tally and Data Sources

In total 115 missions have been used for the survey, divided as:

- LEO-EO: 32
- Lunar missions: 43 (Chang'E-2)
- Mars missions: 23 (Rosetta, Dawn)
- Comet / asteroid missions: 20 (Rosetta, Dawn, Chang'E-2)

-ESA Handbook of Earth Observations
-Satellite Imaging Coorporation
-WikiPedia
-NASA webpage
-Eoportal (ESA webpage)
-Gunters Spacepage
-and a few more...



SATELLITE IMAGING CORPORATION

NASA

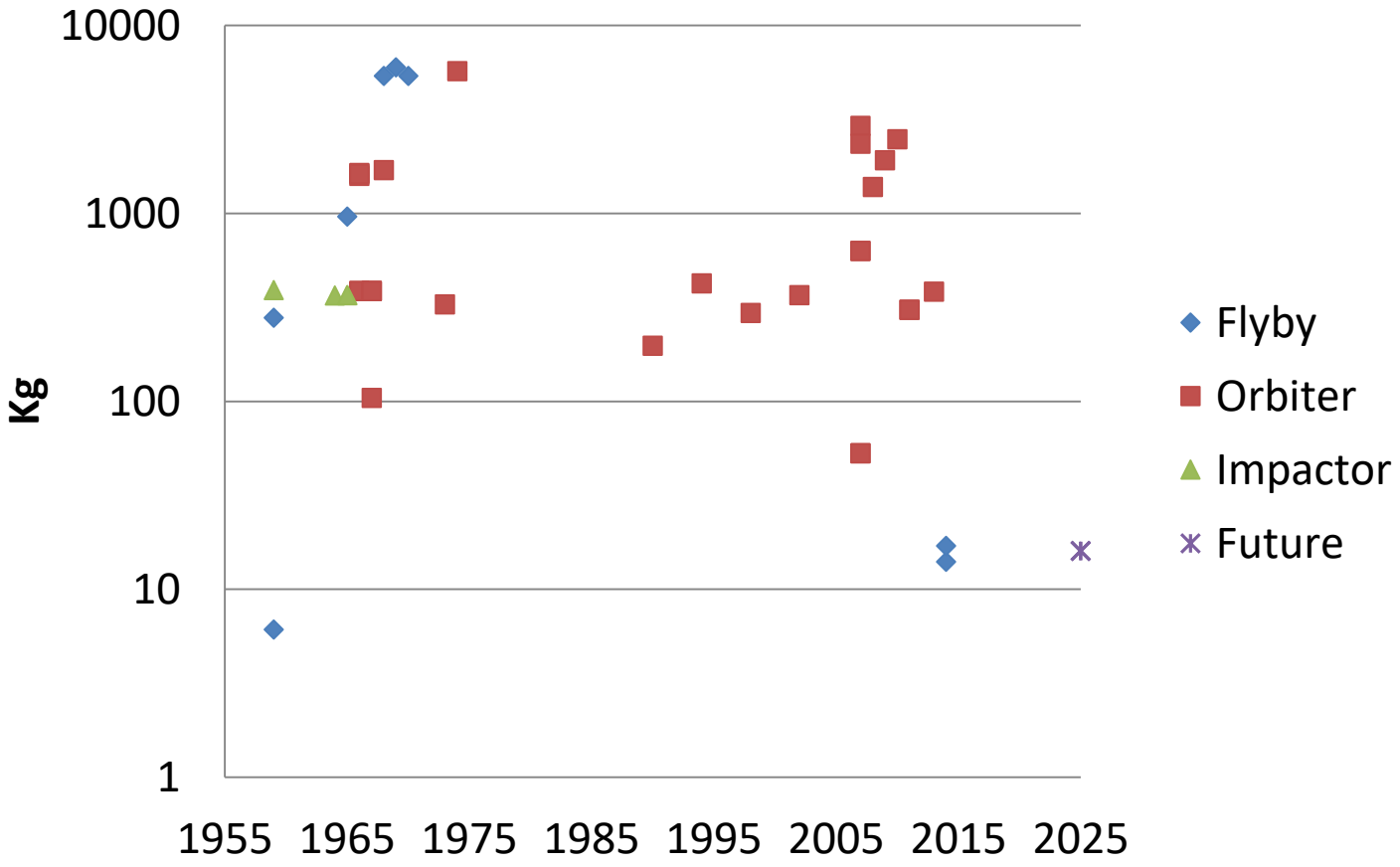
Sharing Earth Observation Resources

GUNTER'S SPACE PAGE

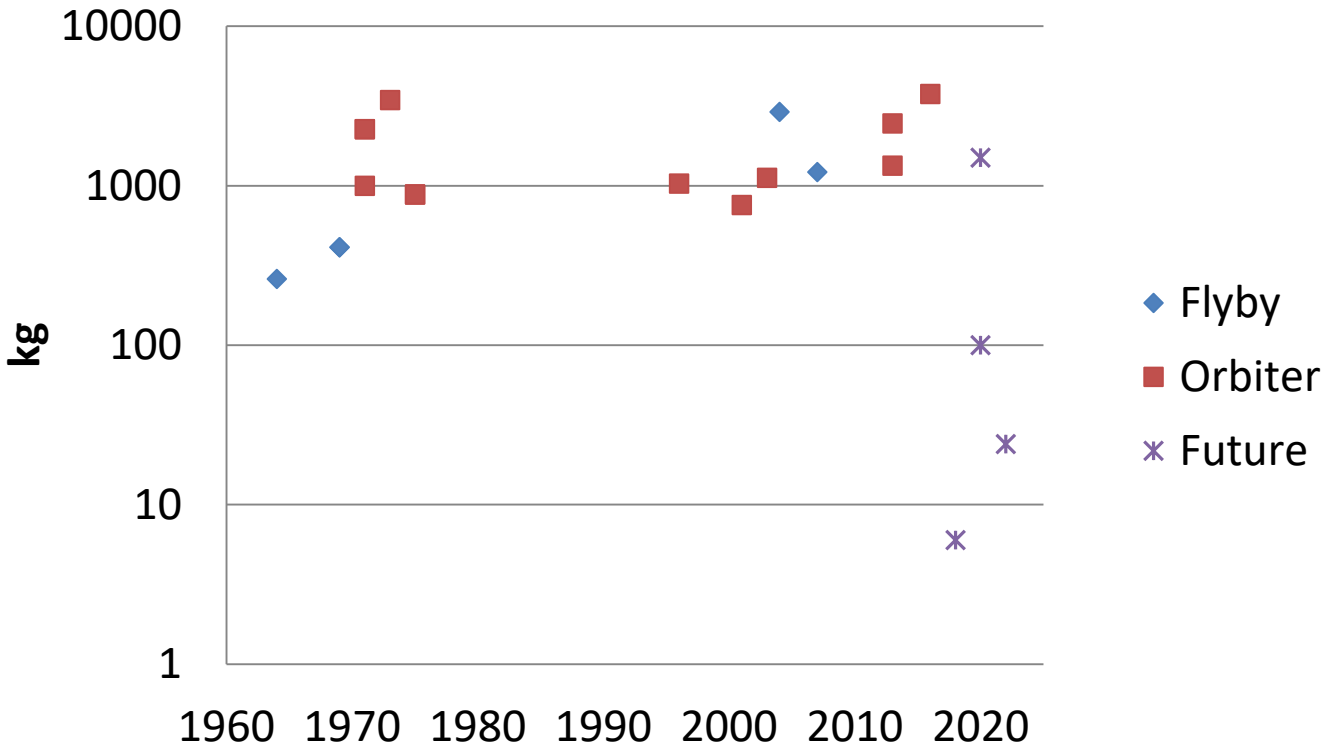
Sources of errors

- LEO-EO: Eliptical orbits – perigee altitude
- Multiple payloads
- Mass uncertainty – for Keyhole sat's lowest chosen

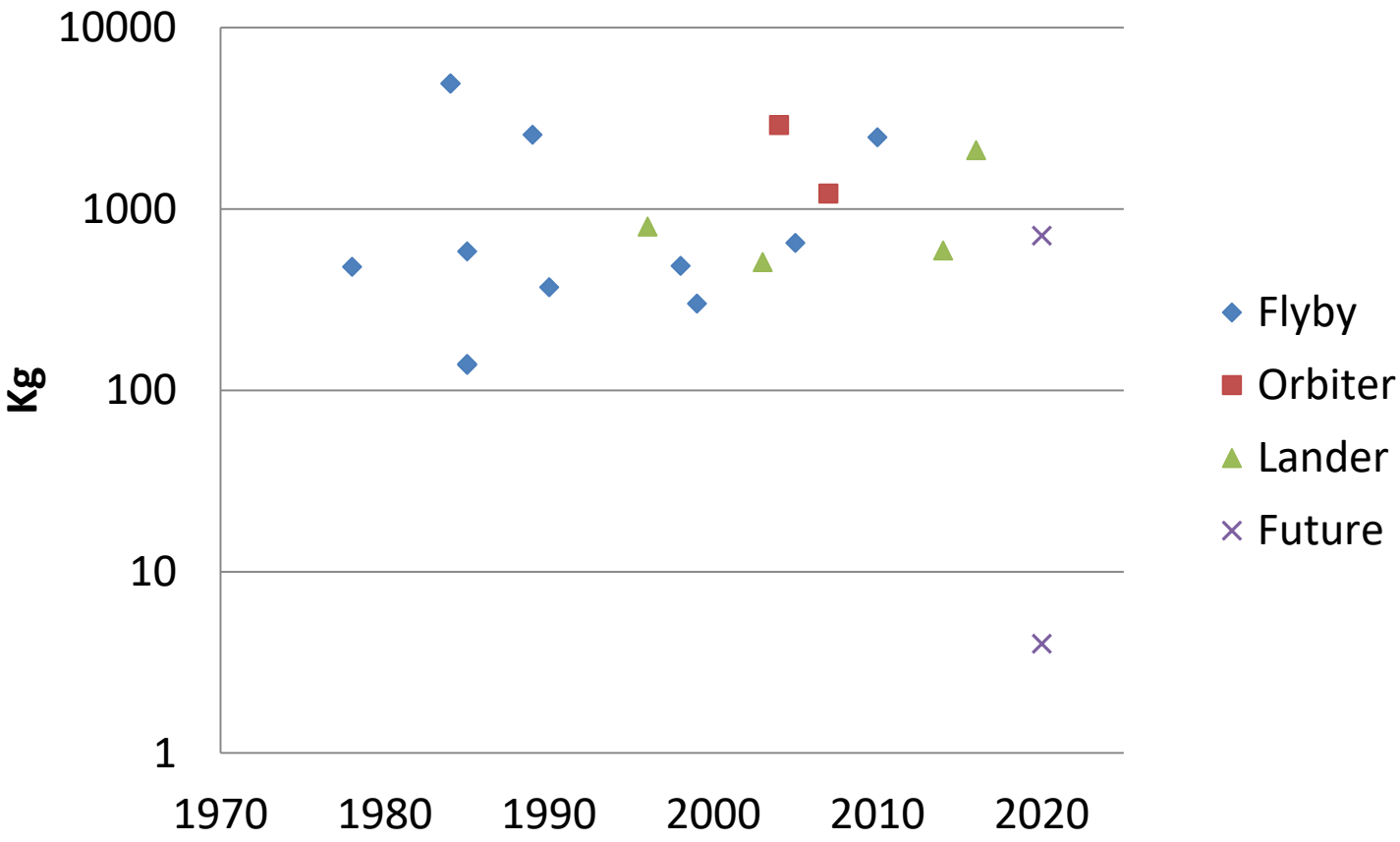
Results lunar missions



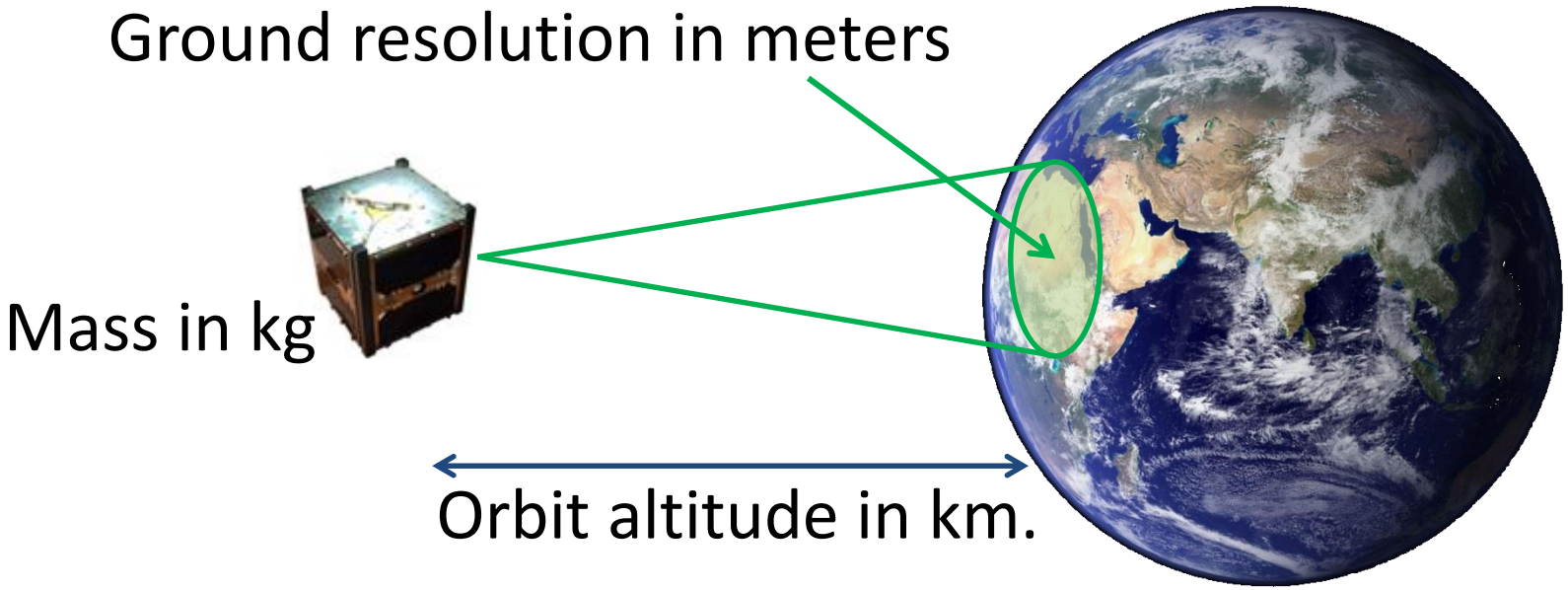
Results Mars missions



Results comets / asteroids



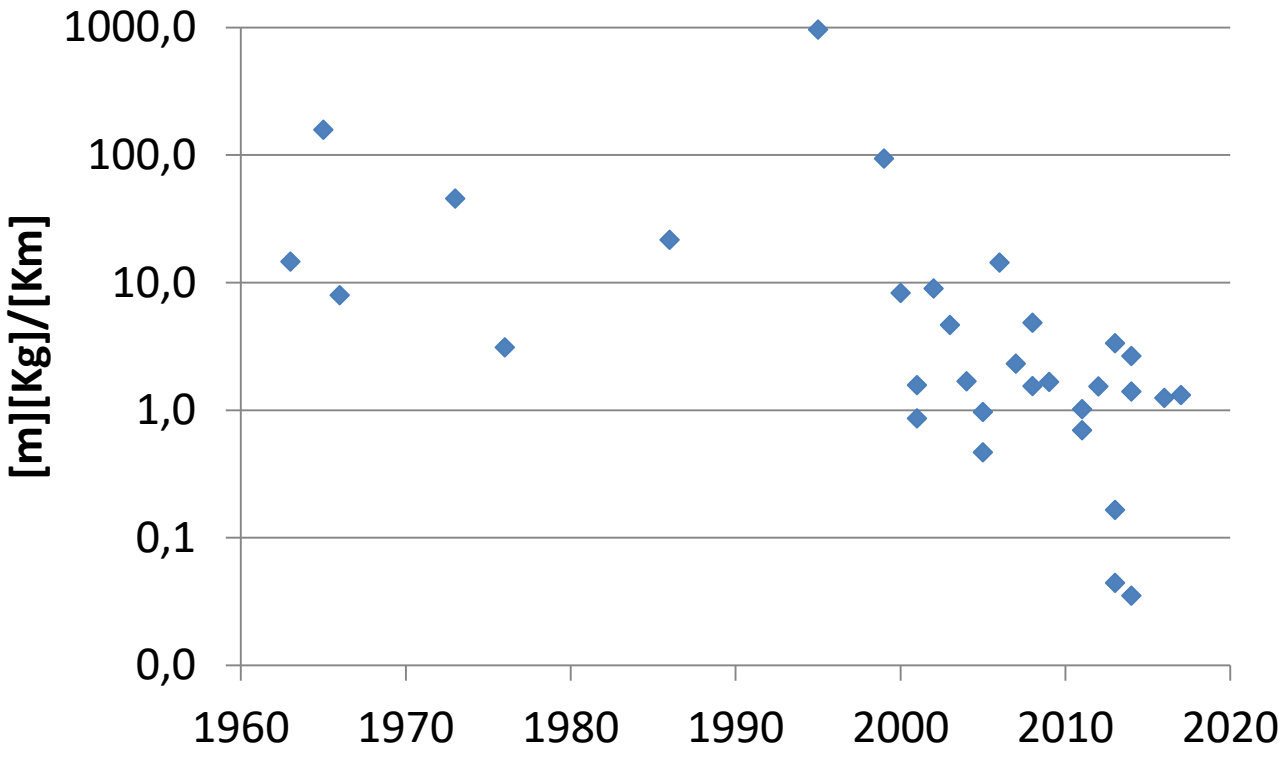
LEO-EO Figure of merit



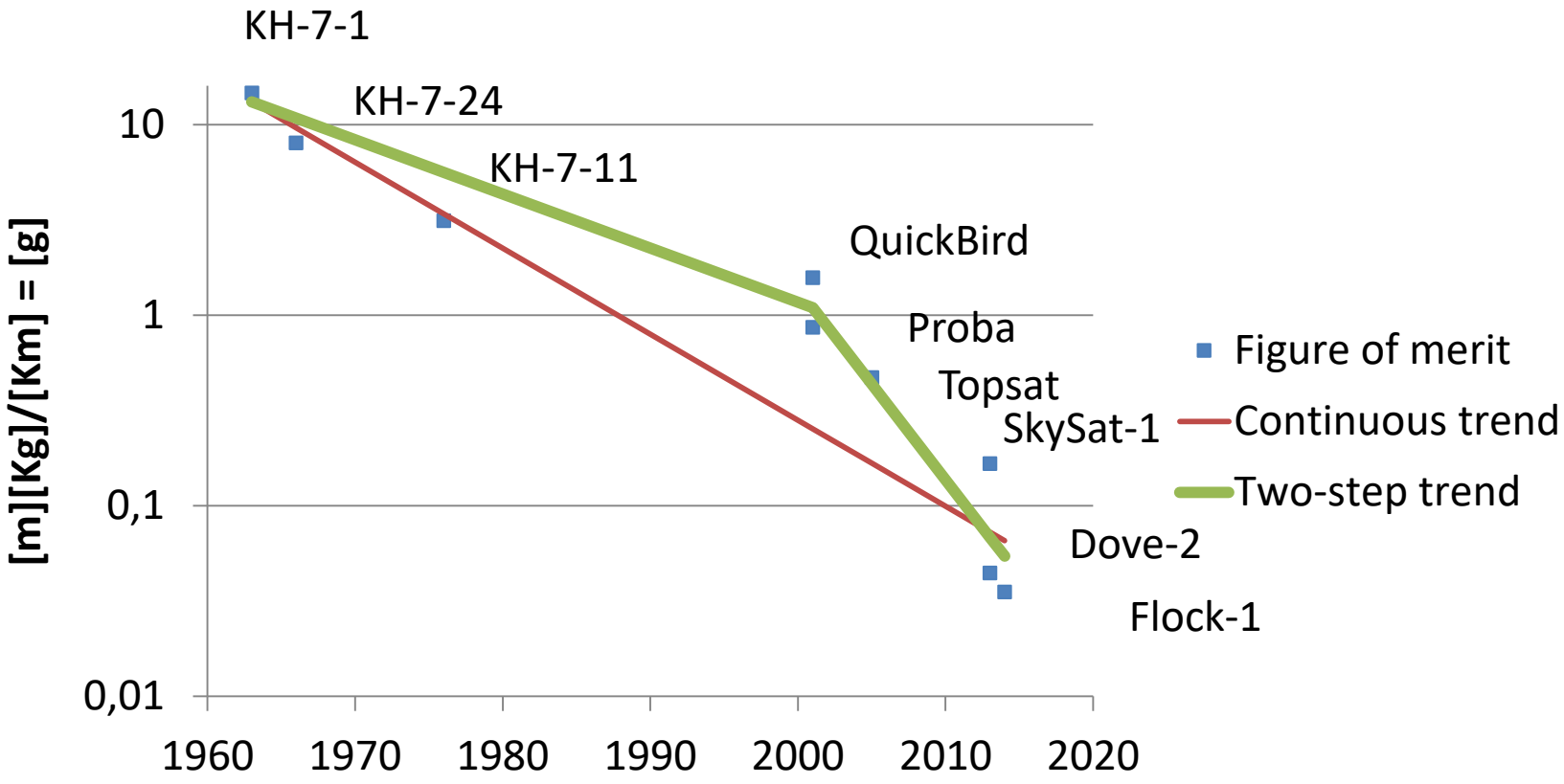
$$\frac{\text{Resolution} \times \text{Mass}}{\text{Altitude}}$$

$$\frac{[m][Kg]}{[Km]} = [g]$$

Results LEO-EO



Results cherry picking LEO-EO



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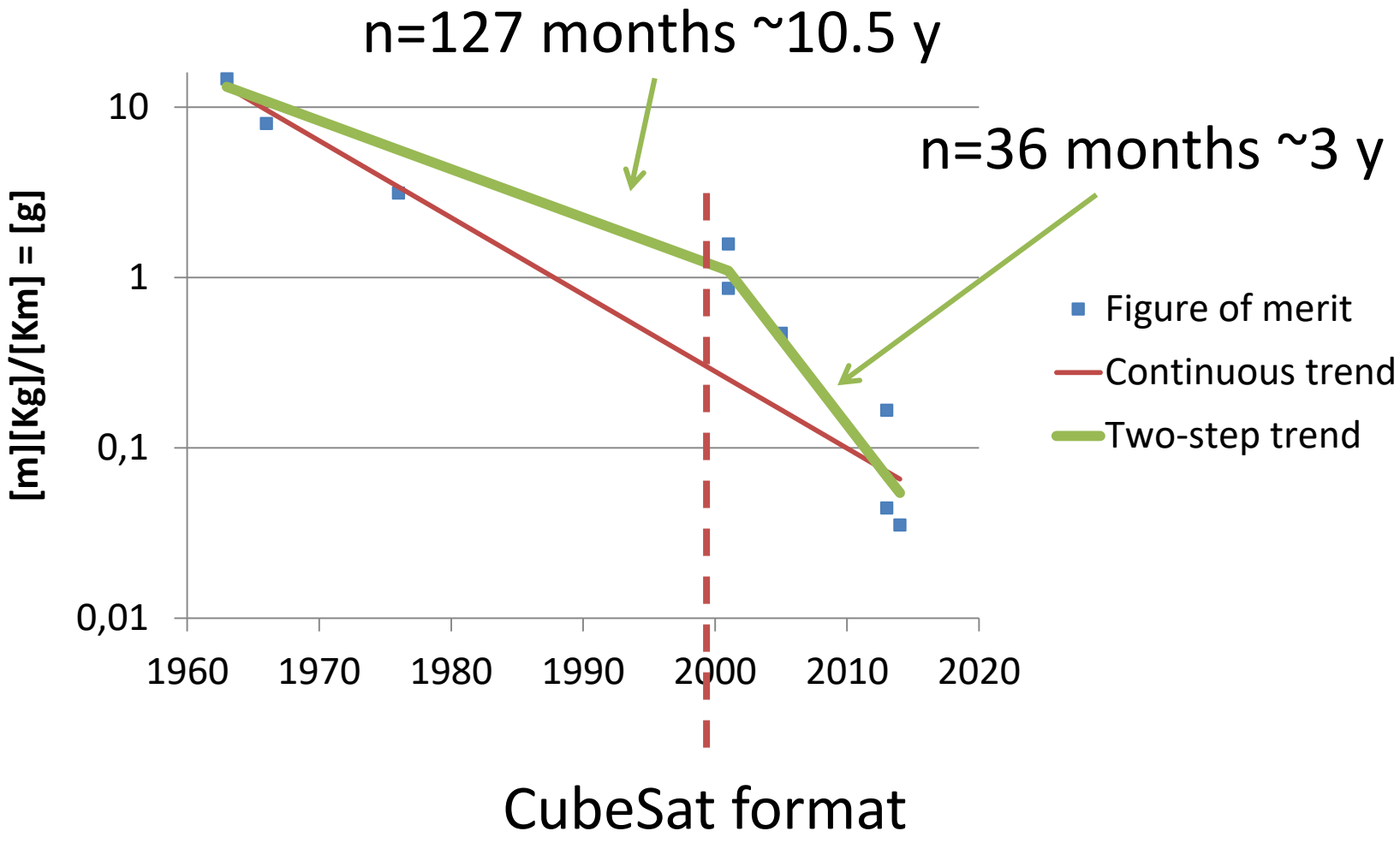


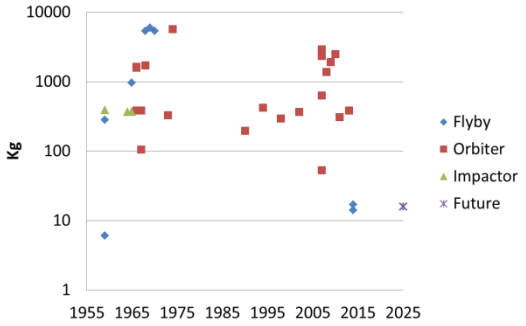
Isn’t it violating laws of physics?

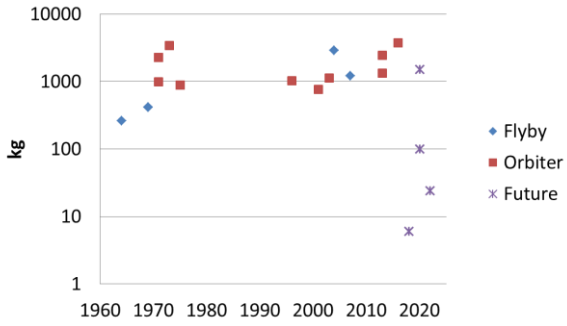
No, not aperture but ”capability” (i.e. mass related)

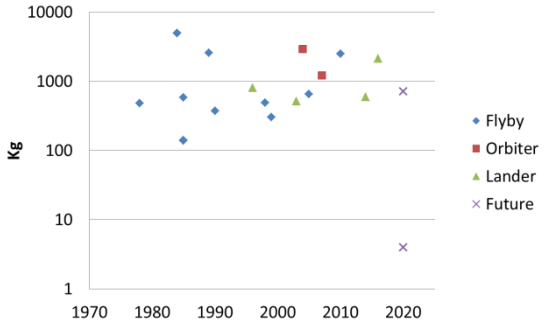
Will it continue?

Depends on tech development and drivers.

- Inflateable mirrors.
- Further mass reduction of systems and smarter materials (lighter mechanics) may still reduce mass.
- SLS EM-1 mission

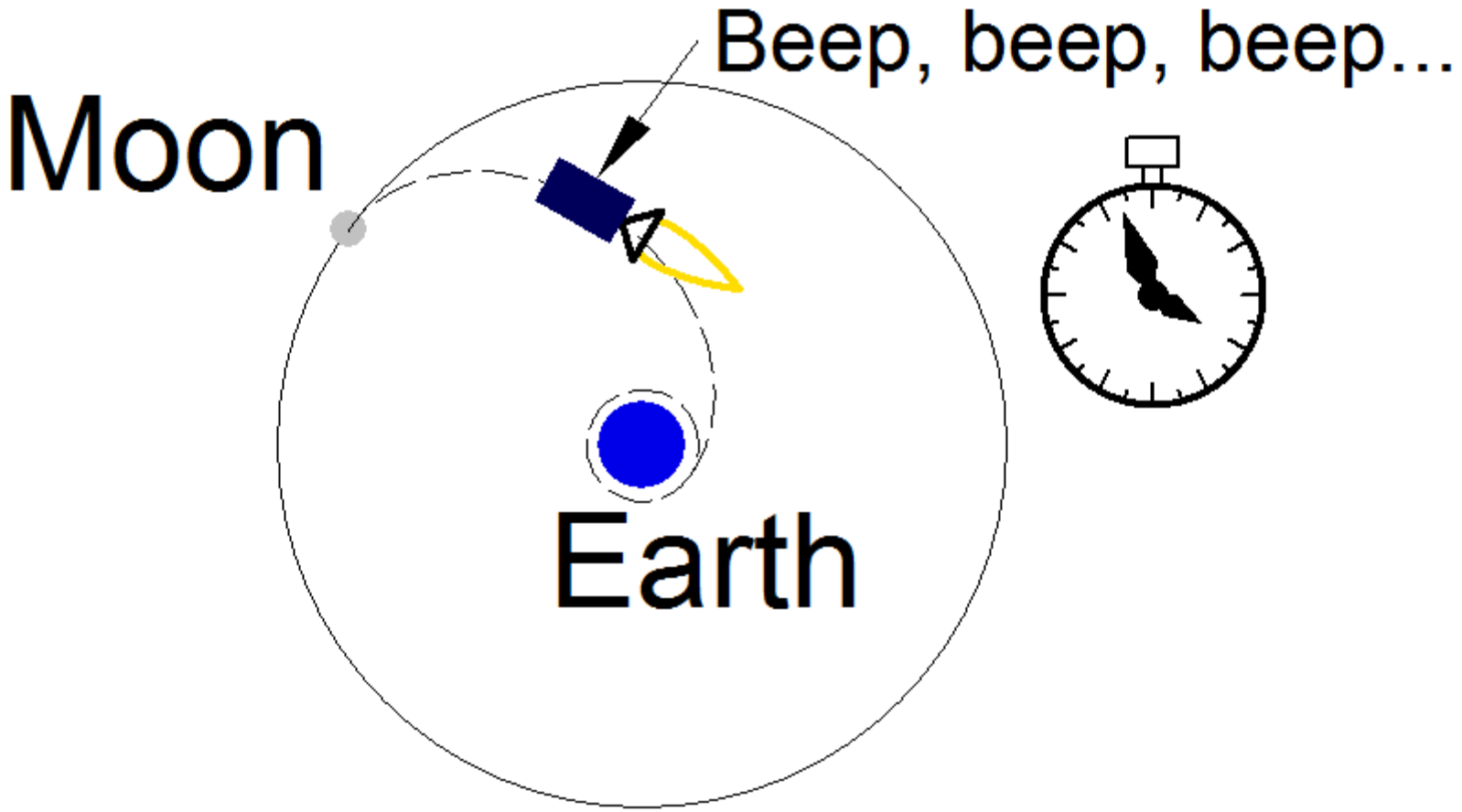






FIN !

Tech driver proposal



An international Student Satellite Space Race to drive propulsion development.