Using CubeSats for Science Missions seen from a physics point of view. What can we do and when?

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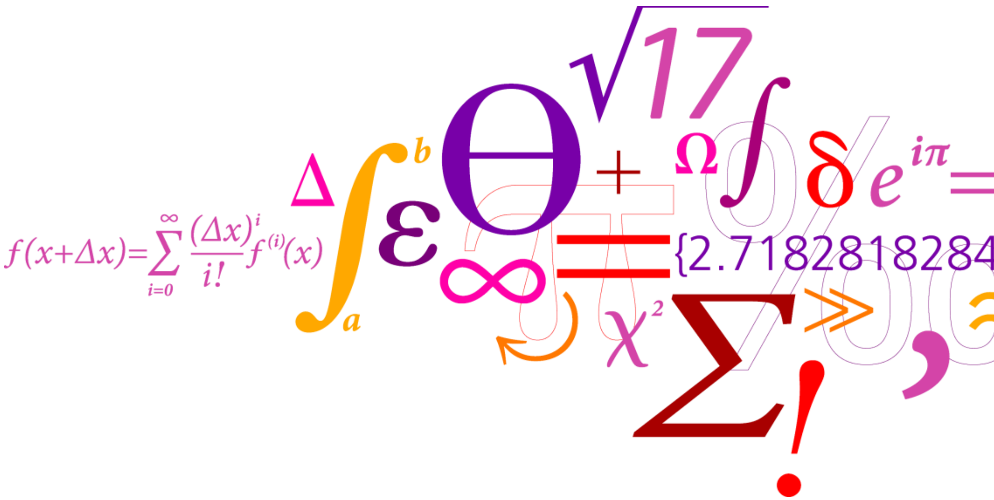


Outline

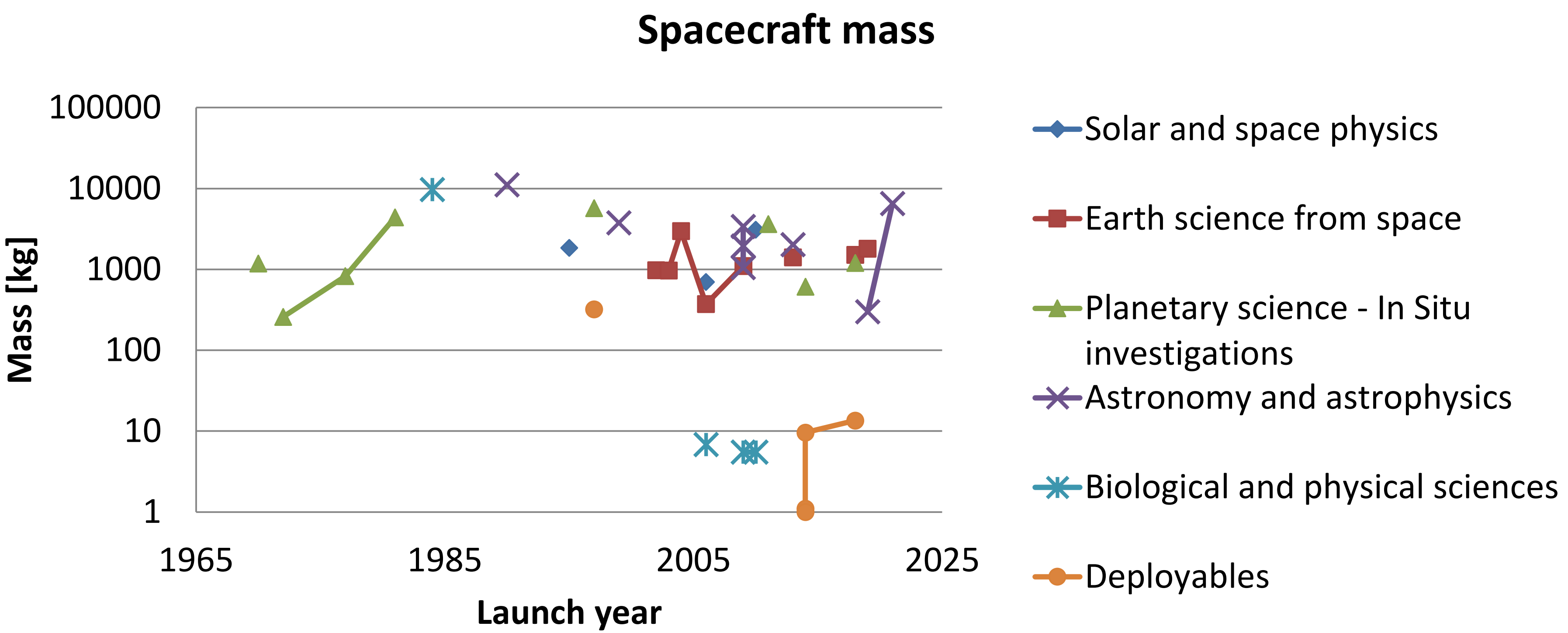
1. History (contemporary S/C's) of space science missions
2. Three S/C options science-wise for the CubeSats seen from an engineering / physics perspective:
   - Formations / swarms, extending baseline
   - Augmented spacecraft, expendable probes
   - Stand alone deep-space pico/nano S/C
3. When can we do it? example: The starshot initiative

The work presented here is based on the Cospar Road map and my presentation at IAA-Cu-17 in Rome:

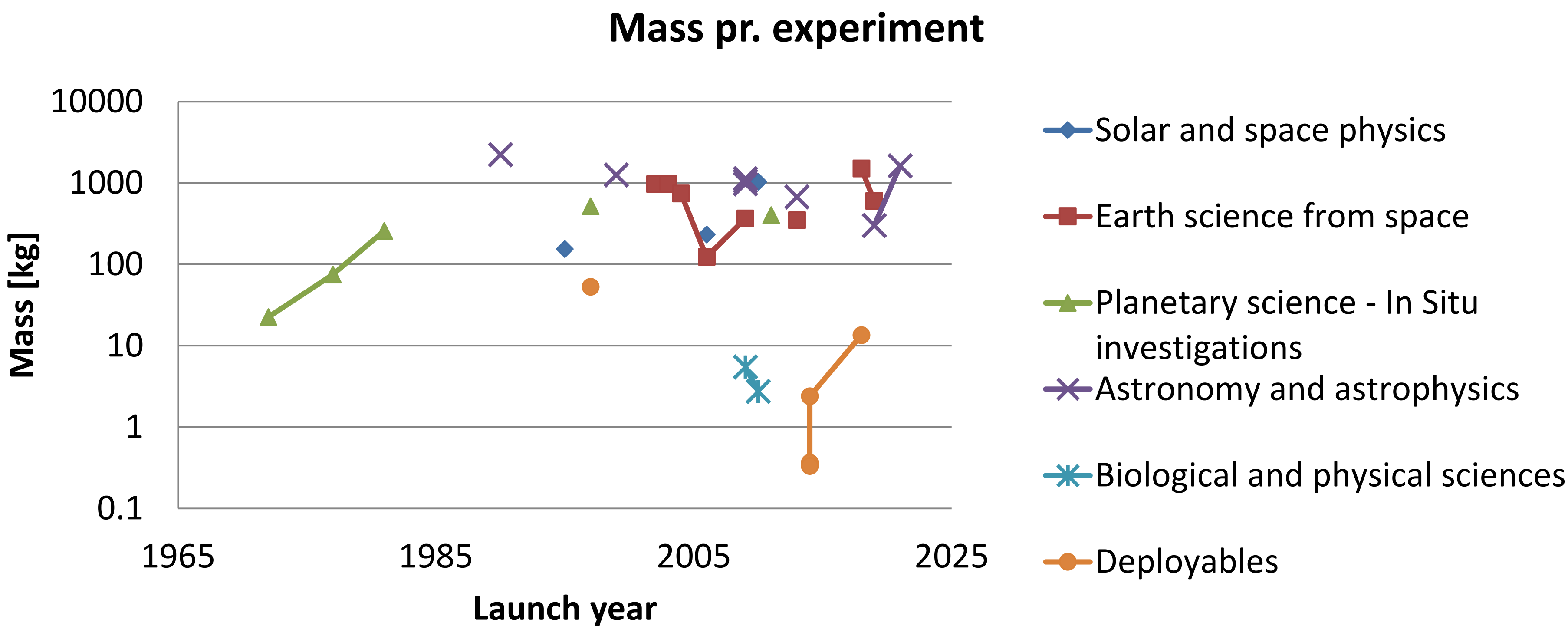
Small Satellites for Space Science
A COSPAR Roadmap Document

Will CubeSats introduce a Moore's law to space science missions,
René Fléron,
IAA-Cu-17,
Rome, Italy

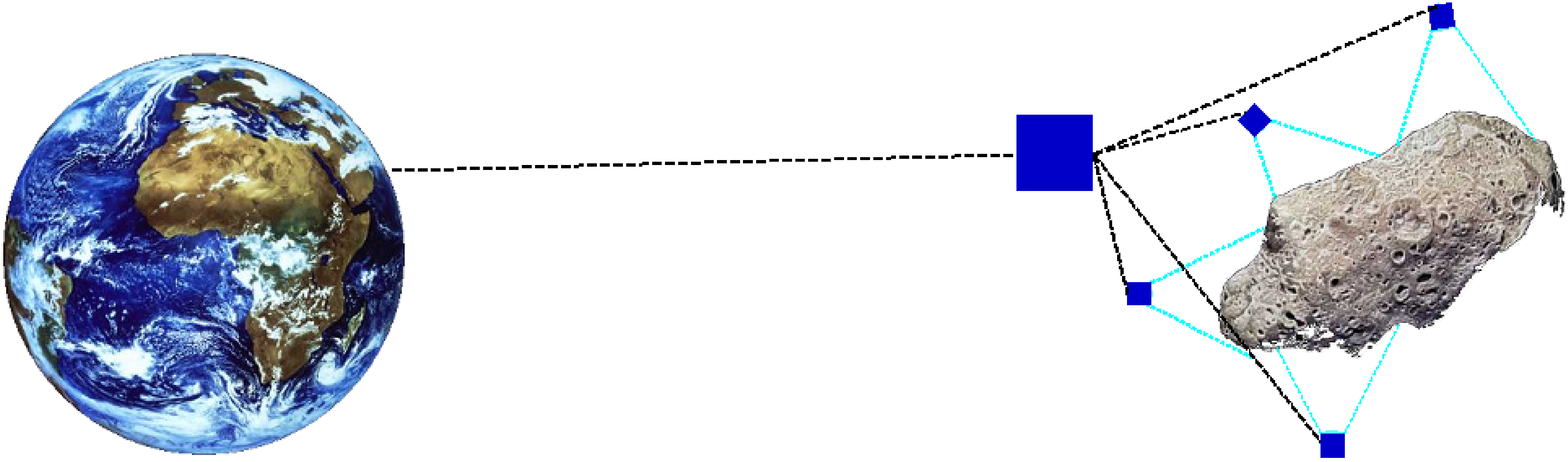
Contemporary Spacecrafts



Contemporary Spacecrafts



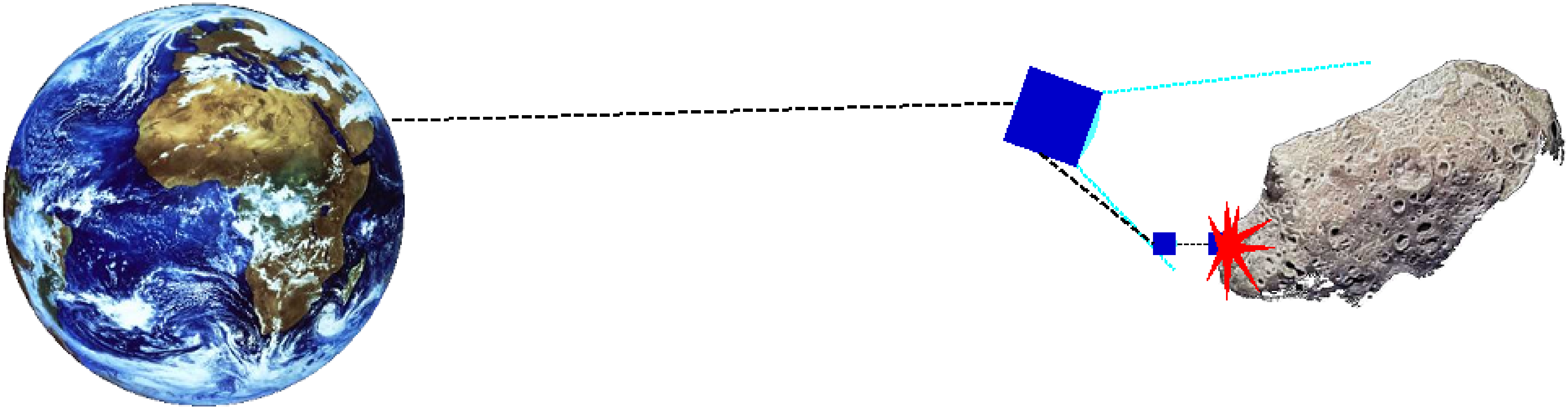
Multiple probes – longer baseline



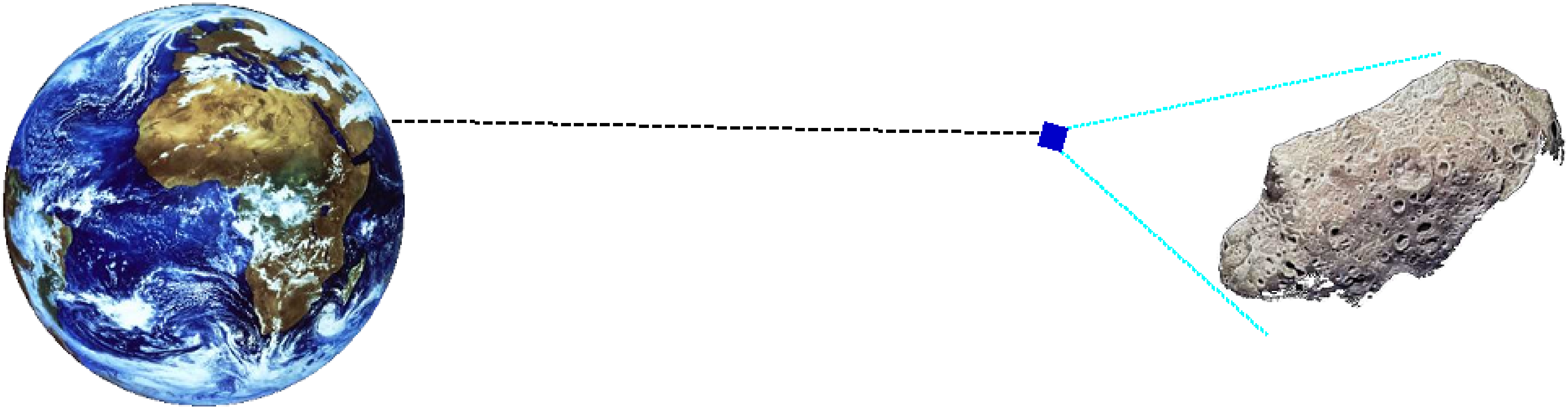
MarCo mission (Mars)
6U

Hera mission (Didymos)
3U

Expendable probes – mission augmentation



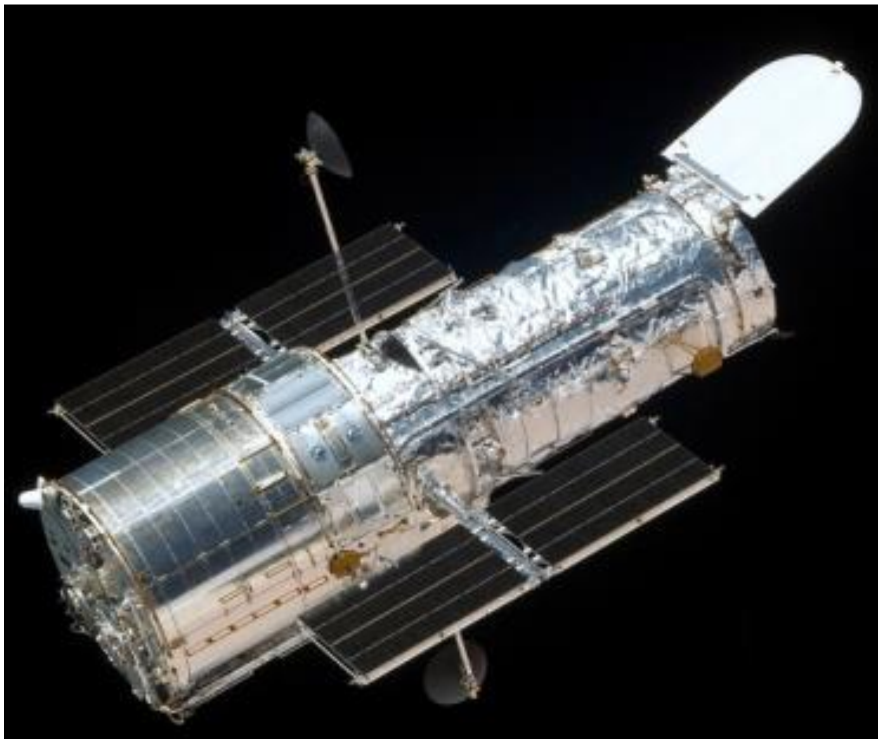
Pico / nano deep space S/C



SLS EM-2 (Moon and beyond)
6U and 12U

SkyFire, LunaH-Map, IceCube, CuSP, EQUULEUS, OMOTENASHI, ArgoMoon and more. (13 in total)

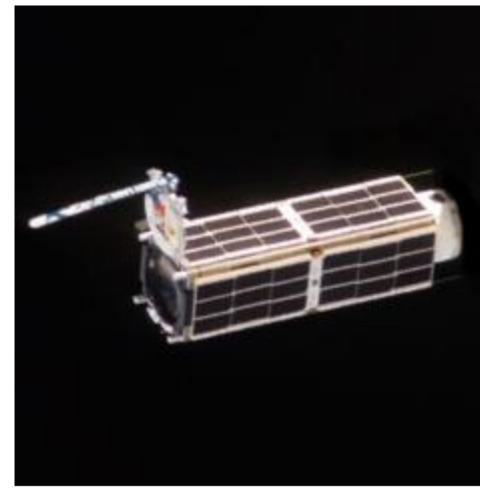
Aperture vs distance, example



Hubble Space Telescope

Mass: 11110 kg
Aperture: 2.4 m

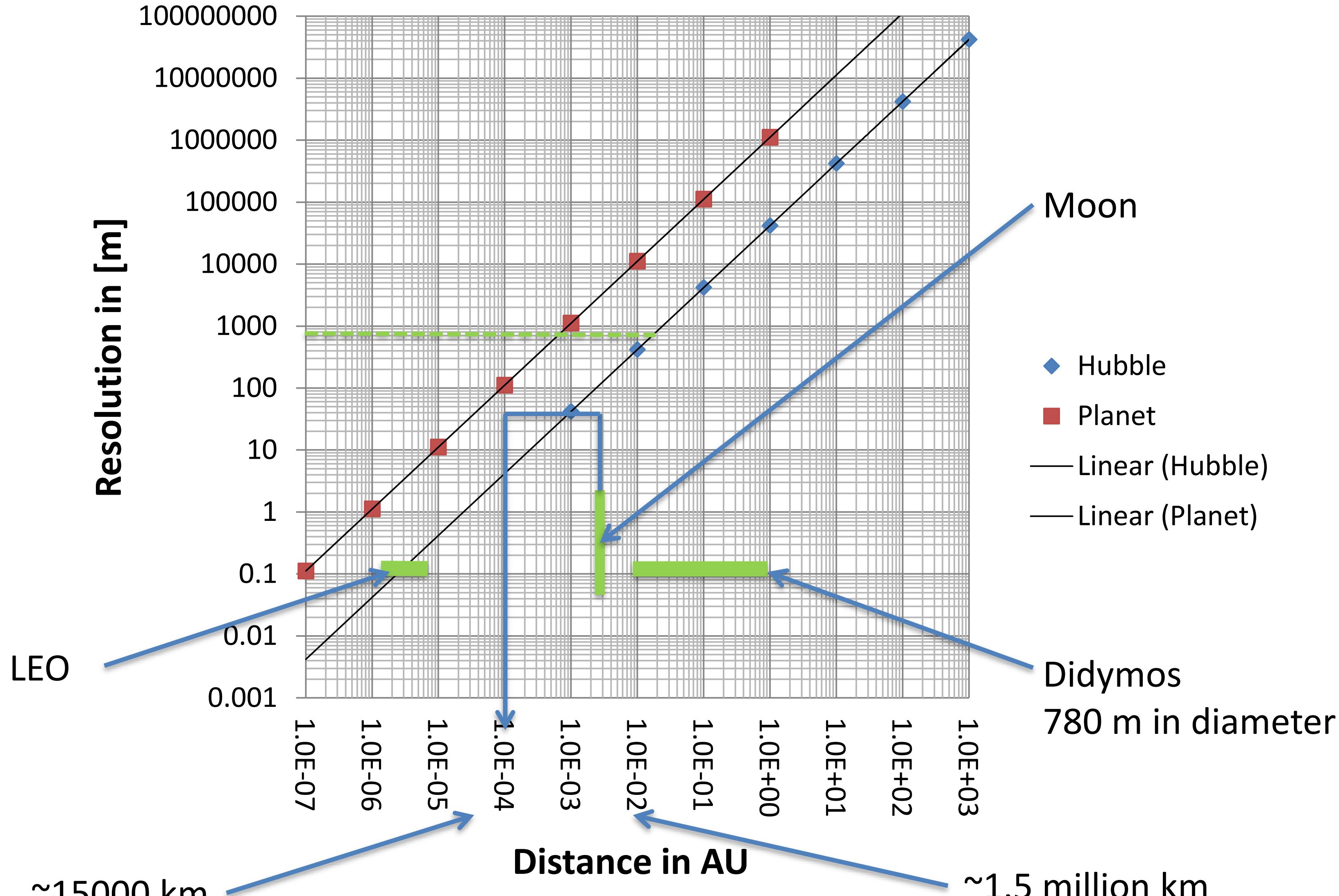
versus



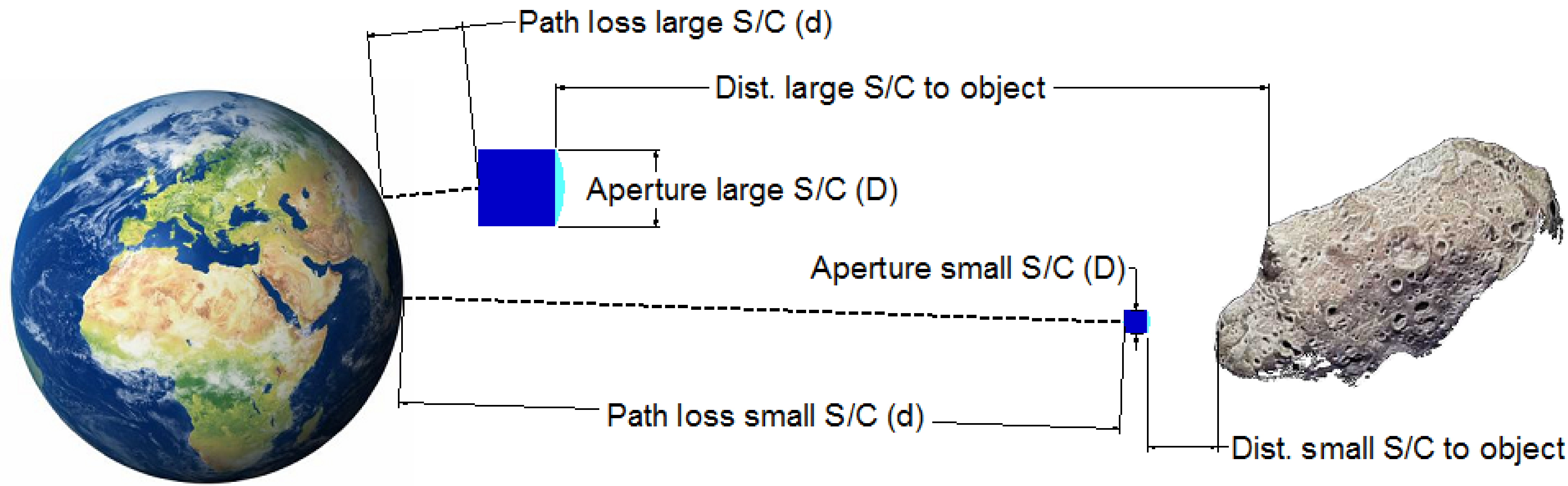
Dove 1 (Planet)

Mass: 5.8 kg
Aperture: 0.09 m

Aperture vs distance, example



Going closer – the aperture problem



$$P_{Rx} = P_{Tx} G_{Tx} G_{Rx} \left(\frac{\lambda}{4\pi d} \right)^2 \quad \text{versus} \quad \emptyset_{min} = \frac{1.22\lambda}{D}$$

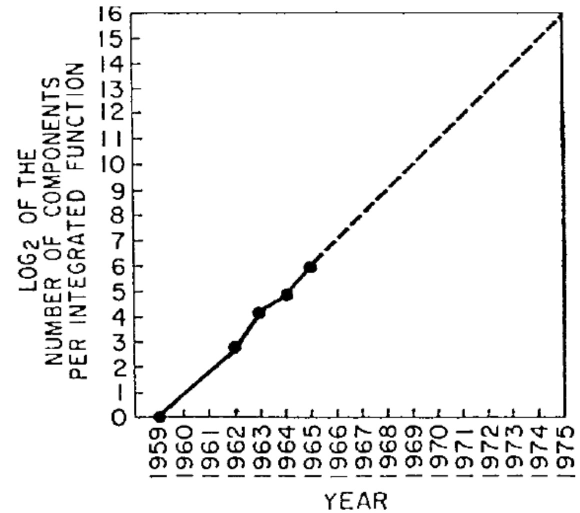
When can we do it?
Moore's law

Original Moore's law:

P

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

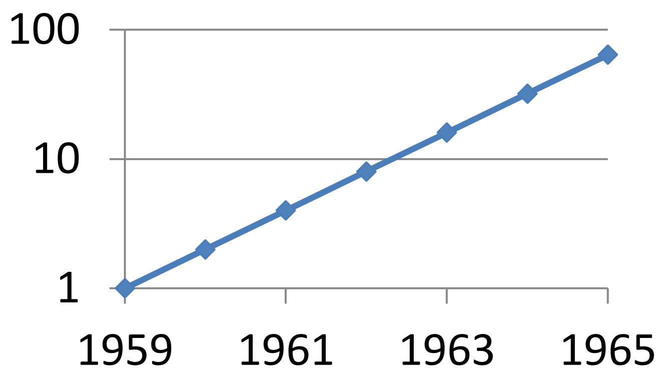
$n_{i.f.}$: number of components per integrated function



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

Modern Moore's law:

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



When can we do it?
Moore's law for space.

Moore's law:

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

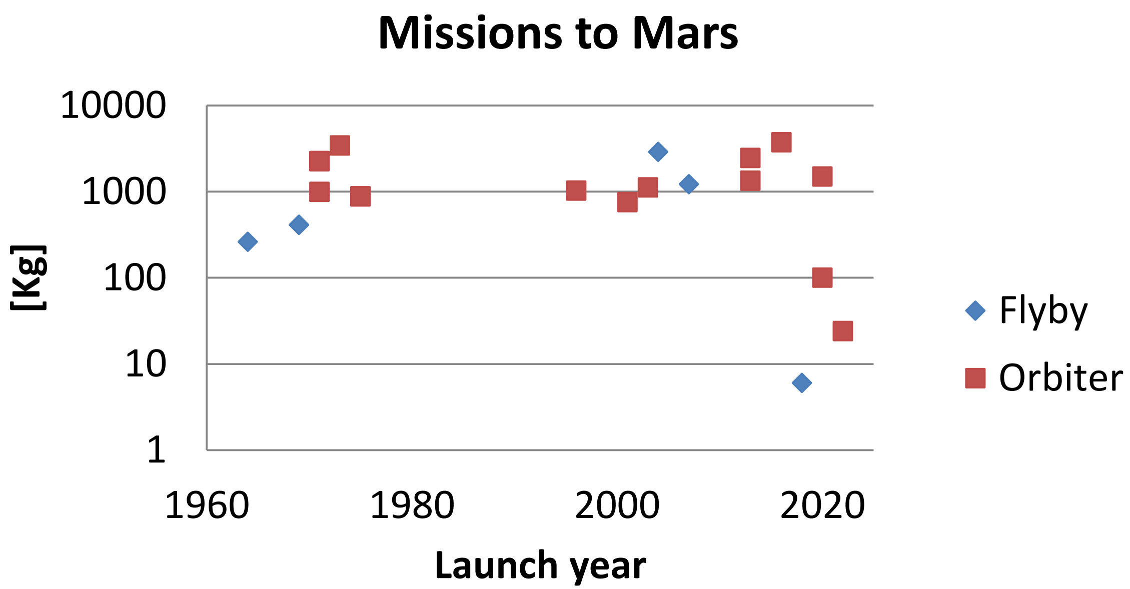
n: Time in months for number of components per area to **double**.

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.**

When can we do it?



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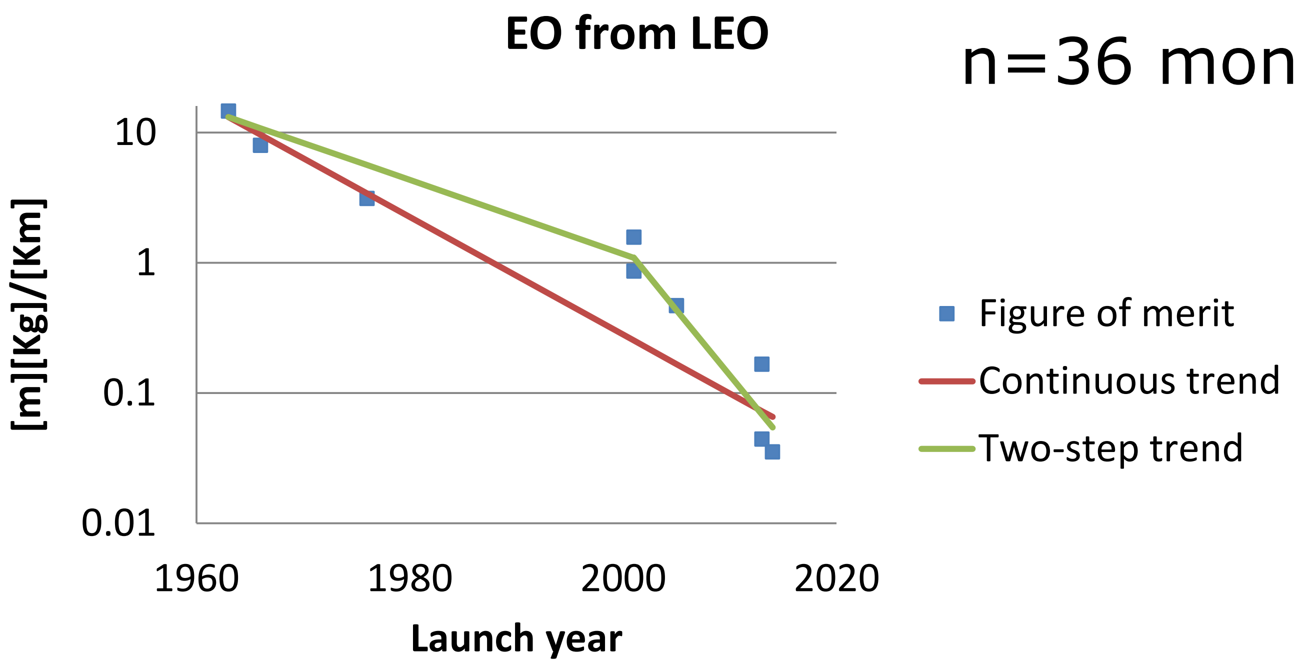
When can we do it?



n=36 months

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

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When can we do it?
Example: starshot initiative

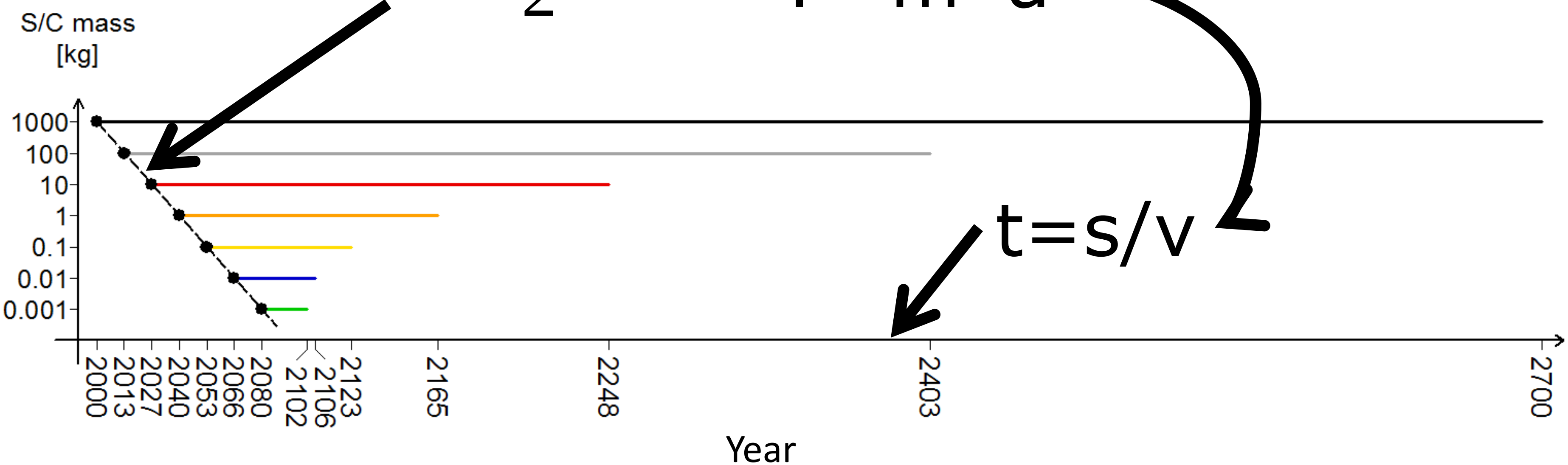
"Space Moore" vs Newton

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

F=m*a

n=36 months

t=s/v



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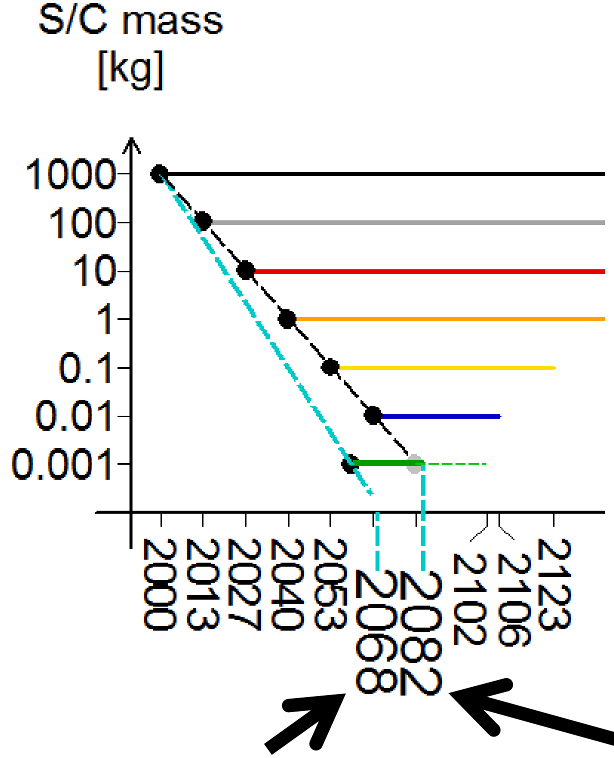
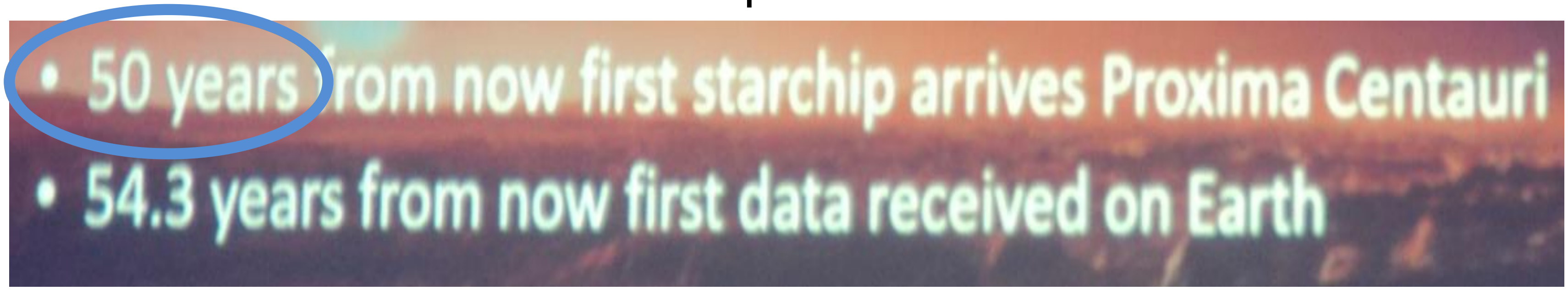
Assume same laser system all along.

When can we do it?
Example: starshot initiative



Pete Klupar.

n=36 months



Suggestions

Three posibilities with CubeSats and other small satellites exists:	Suited for LEO	Suited for cis-lunar	Suited for Deep Space (trans Lunar)
1. To fly as mission enhancing or enabling spacecraft in concert with a larger mother ship and possibly several other smaller satellites/CubeSats.	(v)	v	v
2. To fly in large constellations in order to increase base-lines beyond what a traditional monolithic large spacecraft is capable of.		v	(v)
3. To fly faster than traditional larger spacecrafts because the overall mass is lower – and therefore be able to go closer faster (in case of distant objects).			v

Suggestions

- Mission augmentation
- Swarm missions
- Fly faster and go closer