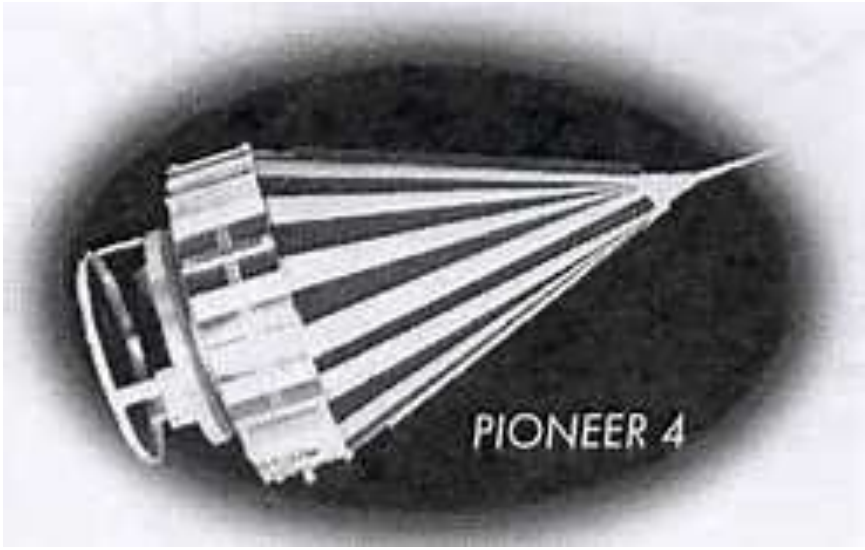
Exploration mission concepts based on miniaturized technologies, Perspectives drawn from the LCPM 13 conference.

Pierre Bousquet

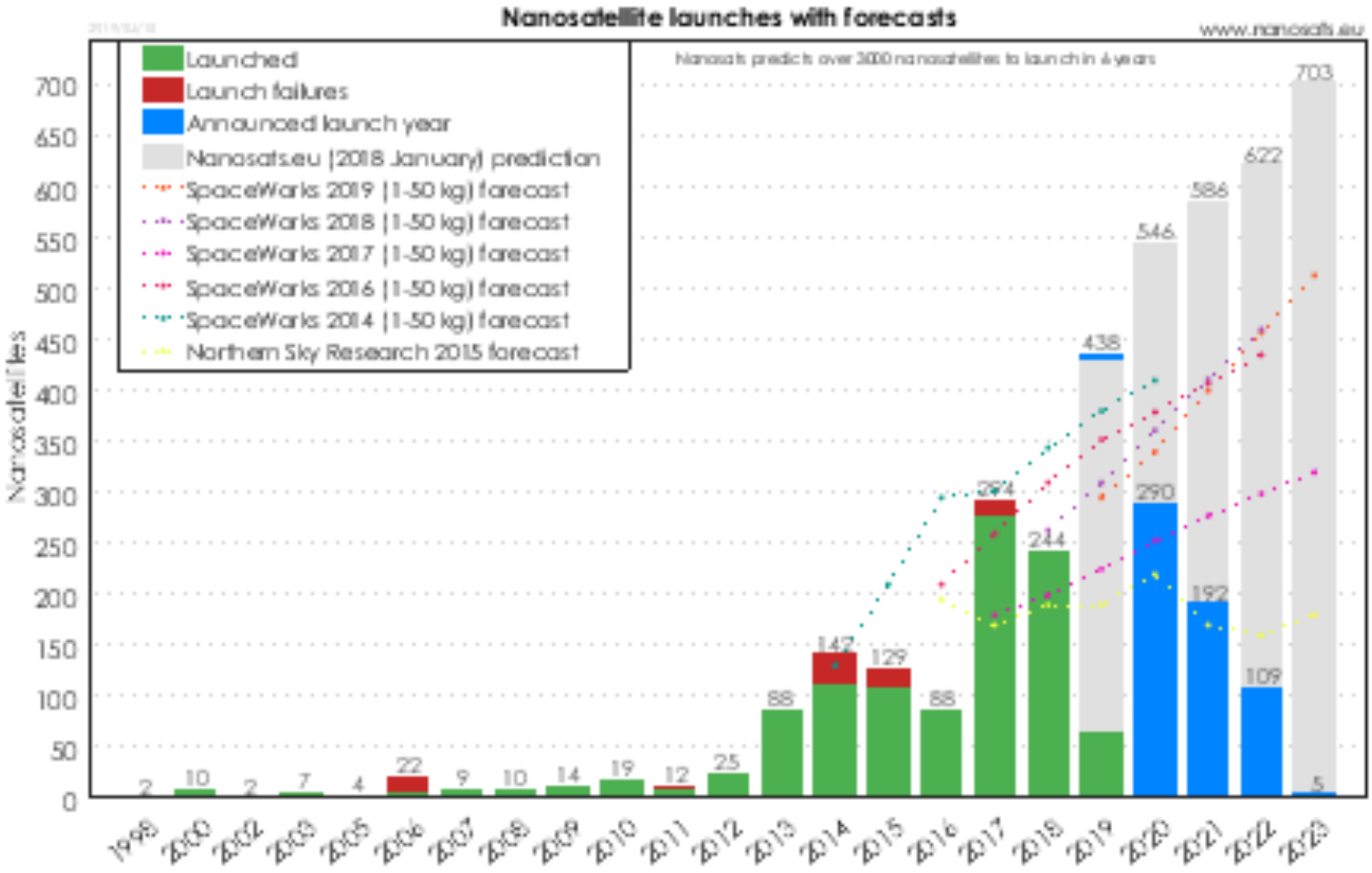
H2061 – step 3
session 4

Small probes to Deep Space ?

In 1959, 6.1 kg Pionner 4 studied the Lunar radiation environment.



In 1997, 11.5 kg Sojourner covered 100 m on Mars


Nanosatellite launches with forecasts
www.nanosats.eu
Launched
Launch failures
Announced launch year
Nanosats.eu (2018 January) prediction
SpaceWorks 2019 (1-50 kg) forecast
SpaceWorks 2018 (1-50 kg) forecast
SpaceWorks 2017 (1-50 kg) forecast
SpaceWorks 2016 (1-50 kg) forecast
SpaceWorks 2014 (1-50 kg) forecast
Northern Sky Research 2015 forecast
Nanosats predicts over 3000 nanosatellites to launch in 4 years
Nanosatellites
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
2
10
2
7
4
22
9
10
14
19
12
25
88
142
129
88
294
244
438
290
182
109
5
546
586
622
703
1998
2000
2002
2003
2005
2006
2007
2008
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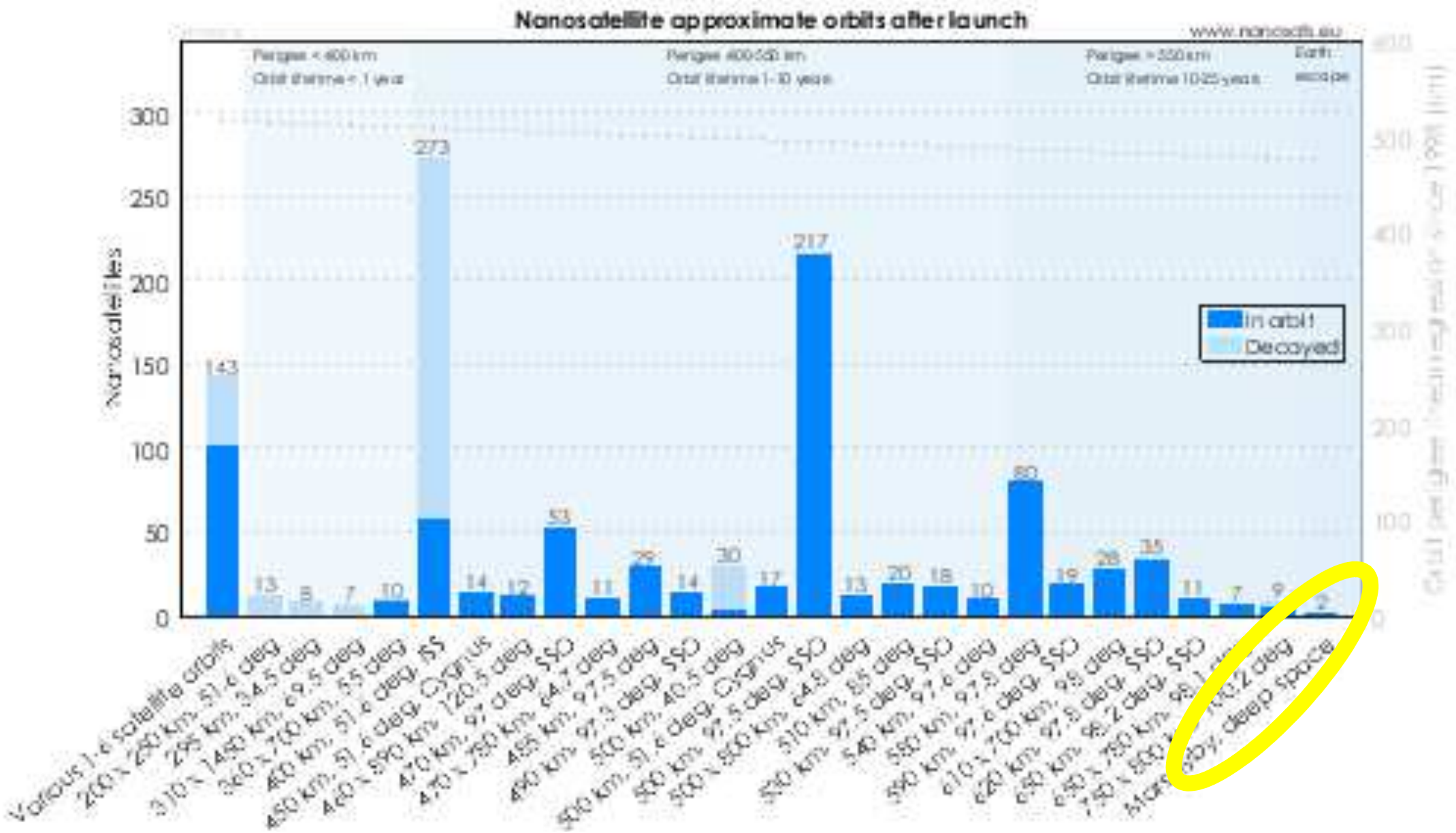
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023

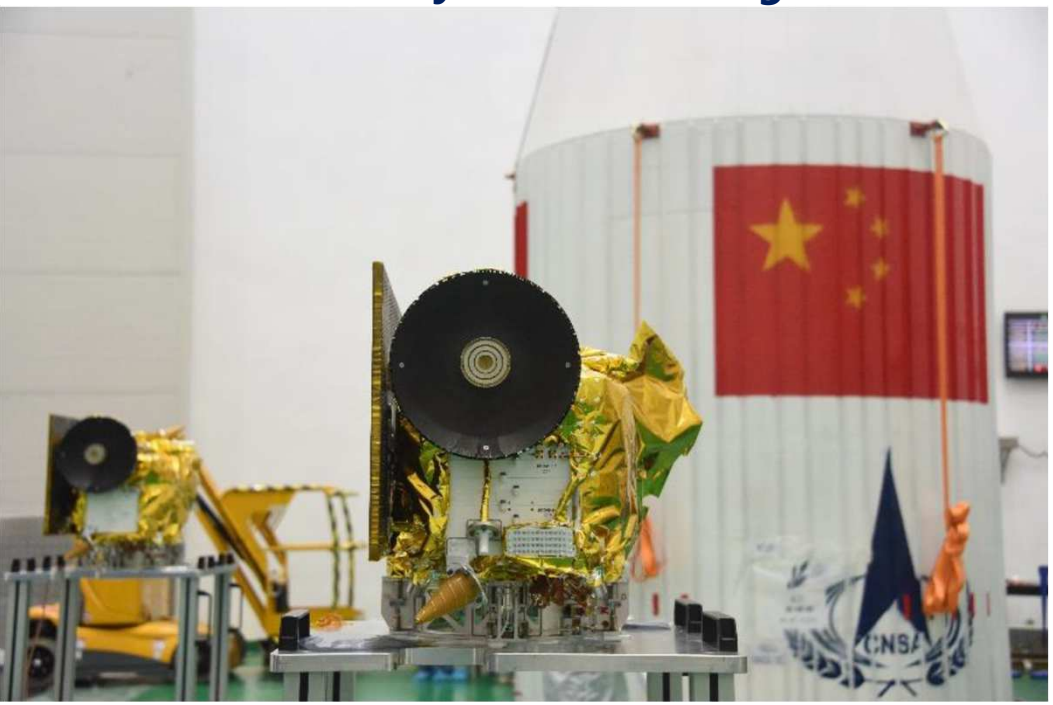

Nanosatellite approximate orbits after launch
www.nanosats.eu
Perigee < 400 km
Orbit lifetime < 1 year
Perigee 400-530 km
Orbit lifetime 1 - 10 years
Perigee > 530 km
Orbit lifetime 10-25 years
Earth escape
Nanosatellites
In orbit
Decayed
0
50
100
150
200
250
300
143
13
8
7
10
273
14
12
53
11
26
14
30
17
217
13
20
18
10
80
19
28
35
11
7
9
2
Various 1-c satellite orbits
200 x 200 km, 51.6 deg
295 km, 34.5 deg
310 x 1450 km, 69.5 deg
360 x 700 km, 55 deg
400 km, 51.6 deg, 55
450 km, 51.6 deg, Cygnus
460 x 590 km, 120.5 deg
470 km, 97 deg, SSO
470 x 780 km, 64.7 deg
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, 97.5 deg, SSO
500 x 800 km, 64.9 deg
510 km, 65 deg, SSO
520 km, 97.5 deg, SSO
540 km, 97.6 deg
550 km, 97.9 deg, SSO
590 km, 97.6 deg, 99 deg
610 x 700 km, 99 deg, SSO
620 km, 97.5 deg, SSO
650 km, 98.2 deg, SSO
650 x 780 km, 98.1 deg
780 x 800 km, 100.2 deg
Mars, deep space

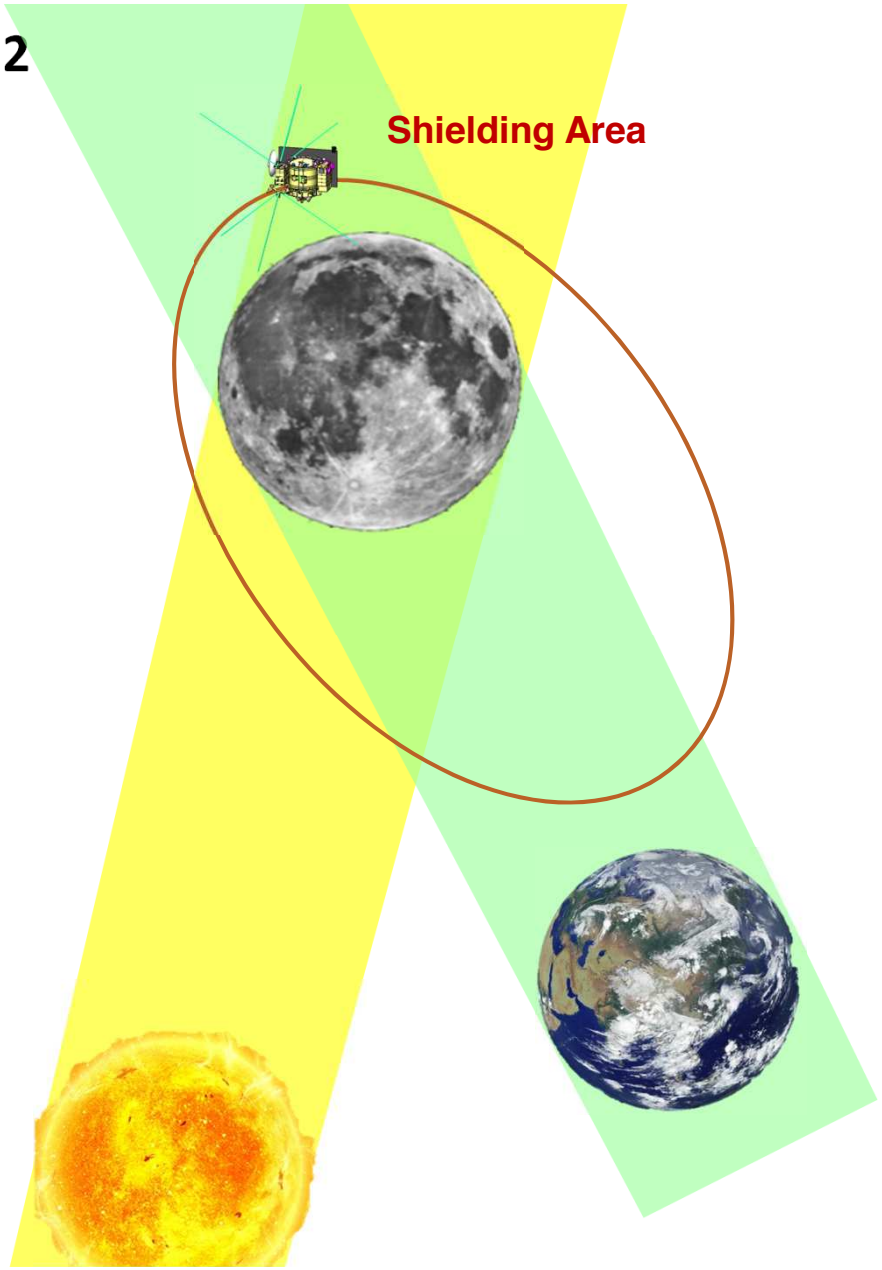
Small Deep Space probes have materialized since LCPM12

Mingchuan- Harbin Institute of Technology

Longjiang-1/2 Lunar Satellites

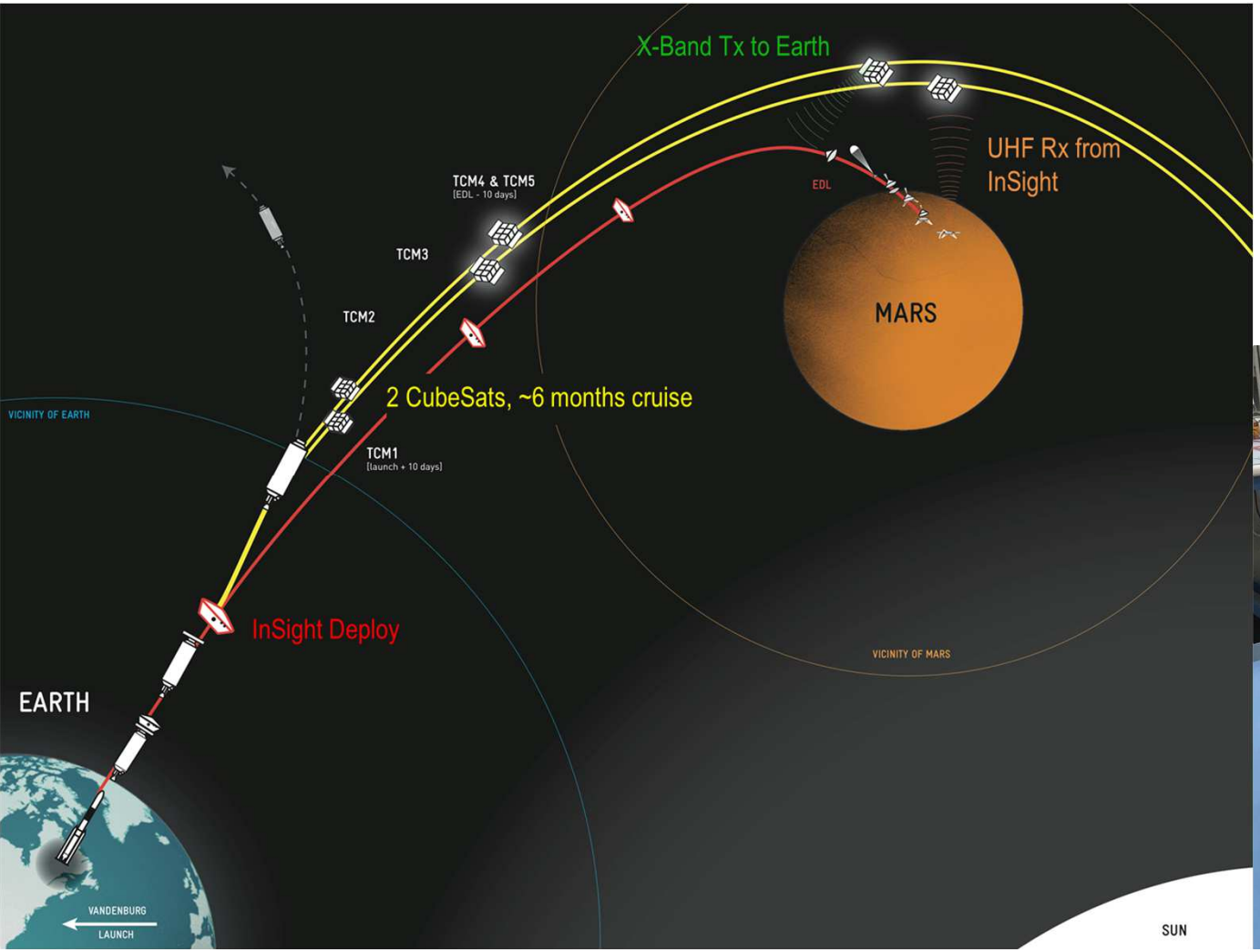
Radio Astronomy in 1-30 MHz
Interferometry with two 47 kg satellites



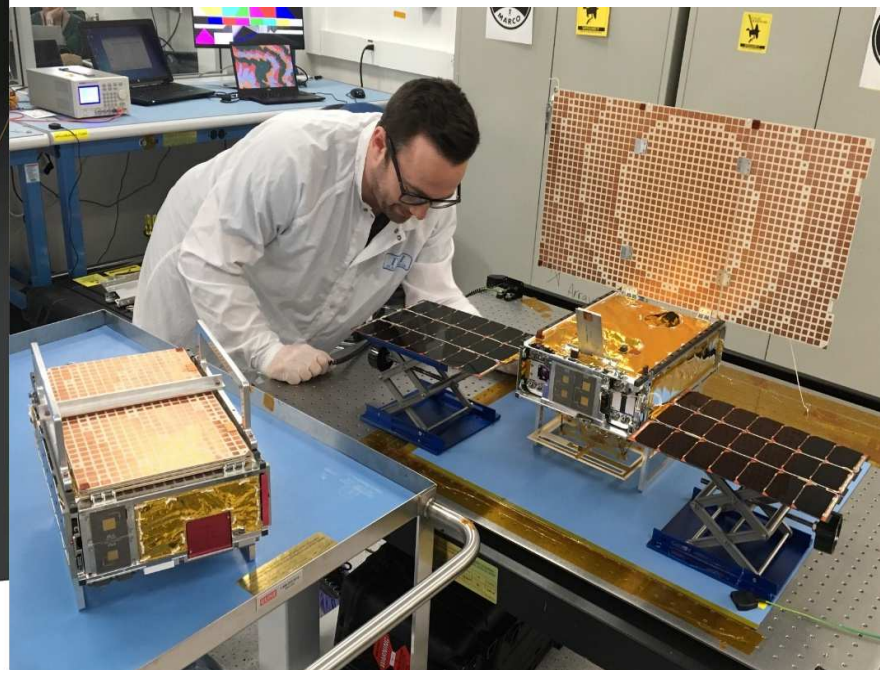


Small Deep Space probes have materialized since LCPM12

Sternberg - JPL

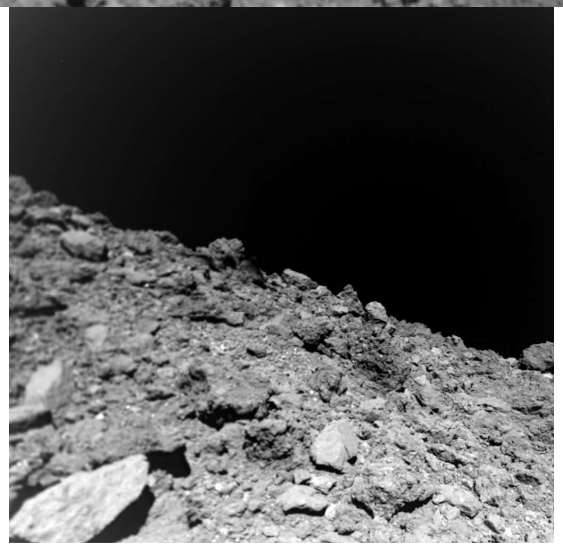


MarCO A & B



Small Deep Space probes have materialized since LCPM12

Lorda – CNES, Jaumann - DLR & Yano – JAXA



Hayabusa 2 - Mascot

Mercer

Agencies move to structure Deep Space Access opportunities

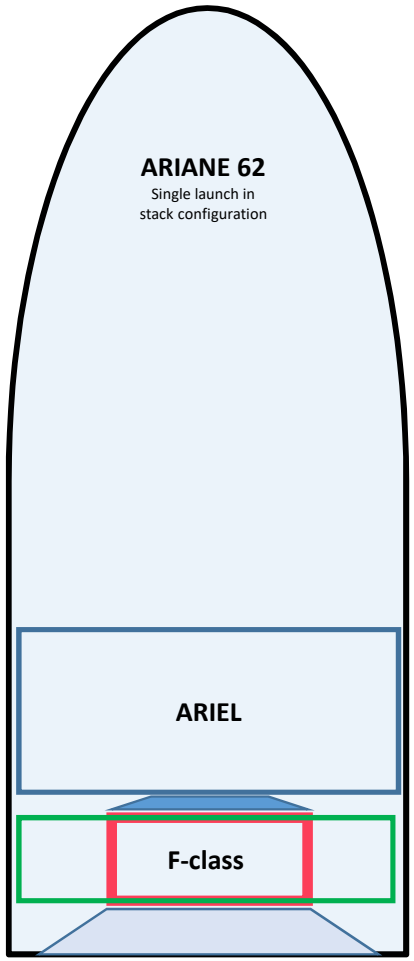
Primary Mission	SIMPLEx Proposal Cut-off Date	Launch Readiness Dates
LEO or GTO	On-going	On-going
Lucy	24 July 2018	October 2021
Psyche	24 July 2018	August 2022
IMAP	NET Oct 2019	Dec 2024
EM-x	TBA	TBD
New launch opportunities to be added as available		

June 19th 2019

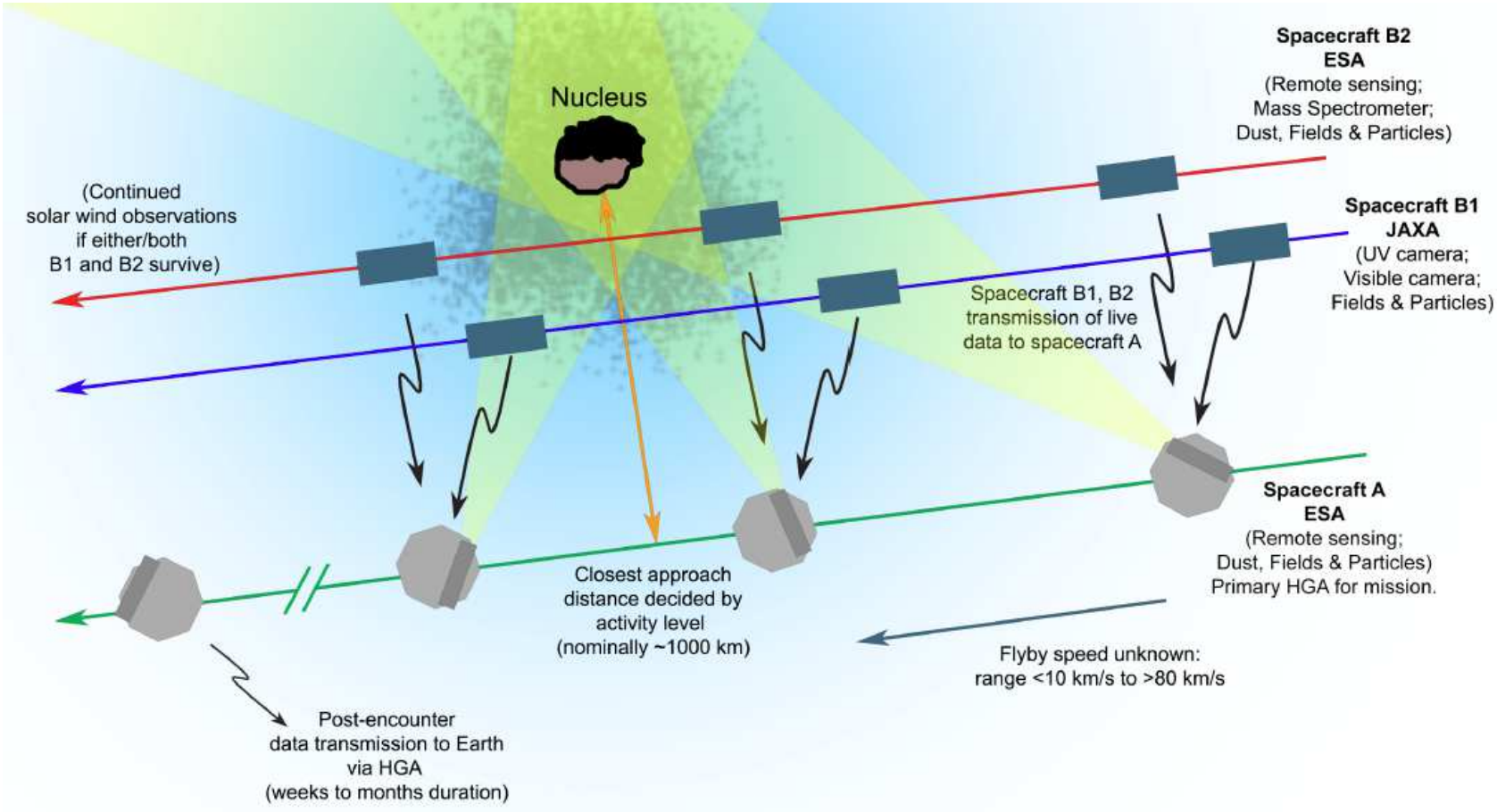
NASA has selected three finalists among a dozen concepts for future small satellites. The finalists include a 2022 robotic mission to study two asteroid systems, twin spacecraft to study the effects of energetic particles around Mars, and a lunar orbiter to study water on the Moon.

Agencies move to structure Deep Space Access opportunities

Bayon



Jones, UCL Mullard Space Science Laboratory - Comet Interceptor



Yano – JAXA

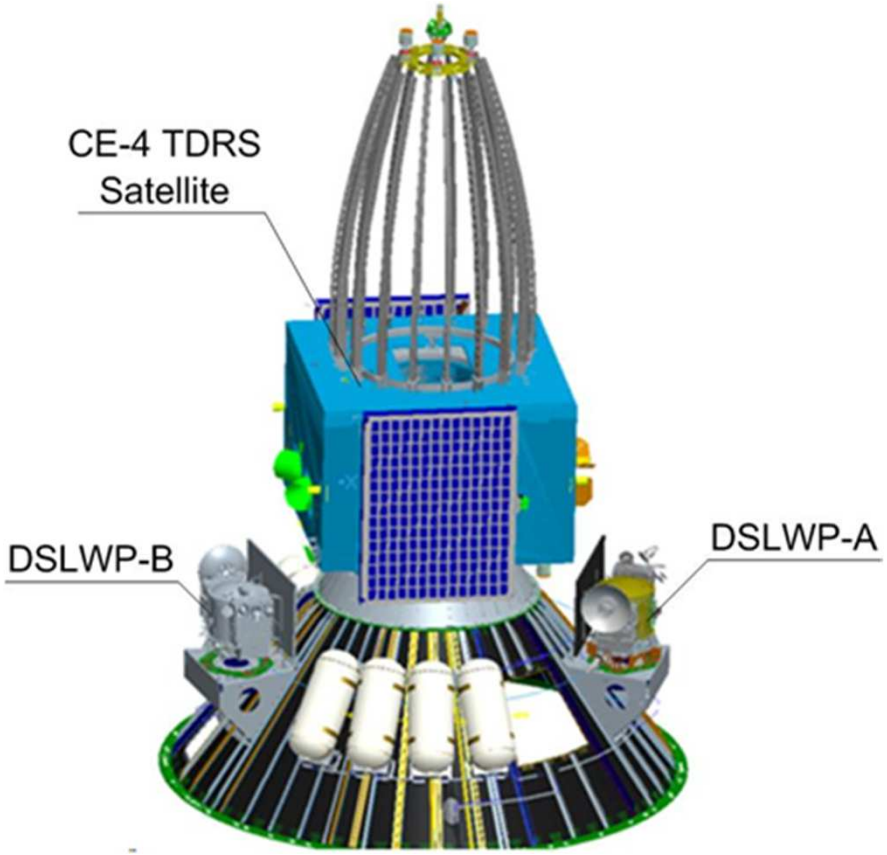
Frontiers of the Solar System Exploration as of 2019

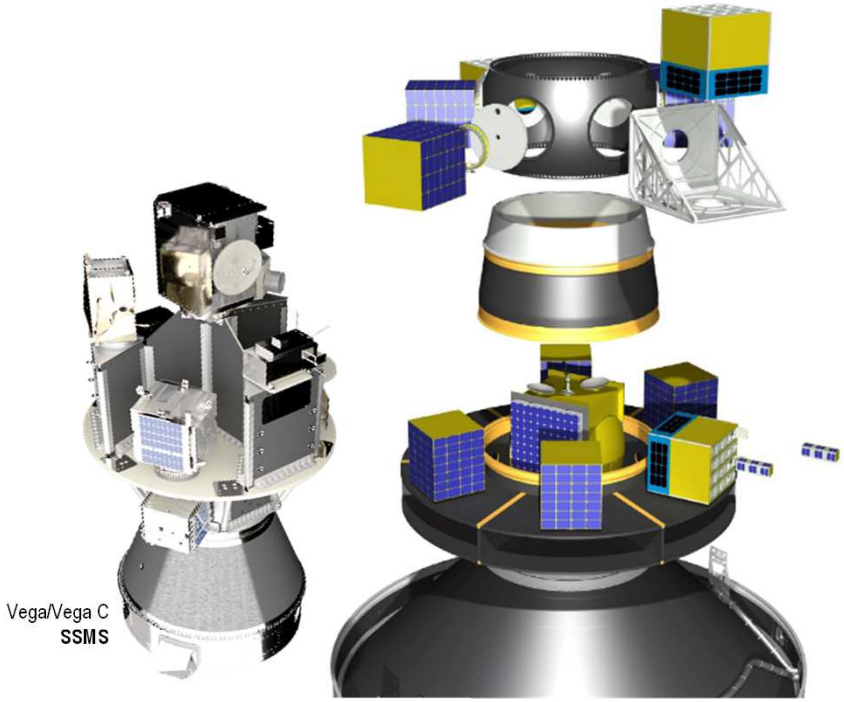
	Moon	Mercury	Venus	Mars	Comets	Asteroids	Jupiter	Saturn	Uranus	Neptune	Pluto & EKBO
Fly-by	● U, R	● U	● R, U	● U, R	● J, U, E, R	● U, E, C ■ J	● U ■ U (Trojans)	● U	● U	● U	● U
Orbiter	● U, R, J, C, I ■ K,J	● U ▲ E/J	● R, U, E, J	● U, R, E, I ■ C, J, A	● E	● J, U	● U ■ E/J /R	● U			
Lander/ Rover	● U, R, C ■ J		● R	● U ■ E,I, J, C	● E	● J/G, U	■ U, J/G (Europa, Trojan)	● E (Titan)			
Sample Return	● U, R ▲ C ■ J/ E/D			■ U/E, J(satellites)	● U ■ U/J	● J ▲ J(Sub-surface), U		■ U,J (Enceladus)			
Human	● U ■ C, I, R			■ U							

▲ Operation
● Accomplished
■ Development

U = USA; R = Russia/USSR; J = Japan; E = ESA; C = China; I = India; G = Germany; D = Canada, A = UAE; K = Korea

Launch providers optimize their low cost offer





Li Yi-de

上海航天技术研究院
中国航天 Shanghai Academy of Spaceflight Technology

Morisset

arianespace
arianeGROUP

So, towards 2061 ?

Miniaturisation is available now.

$\Rightarrow$ Focus on autonomy and performances

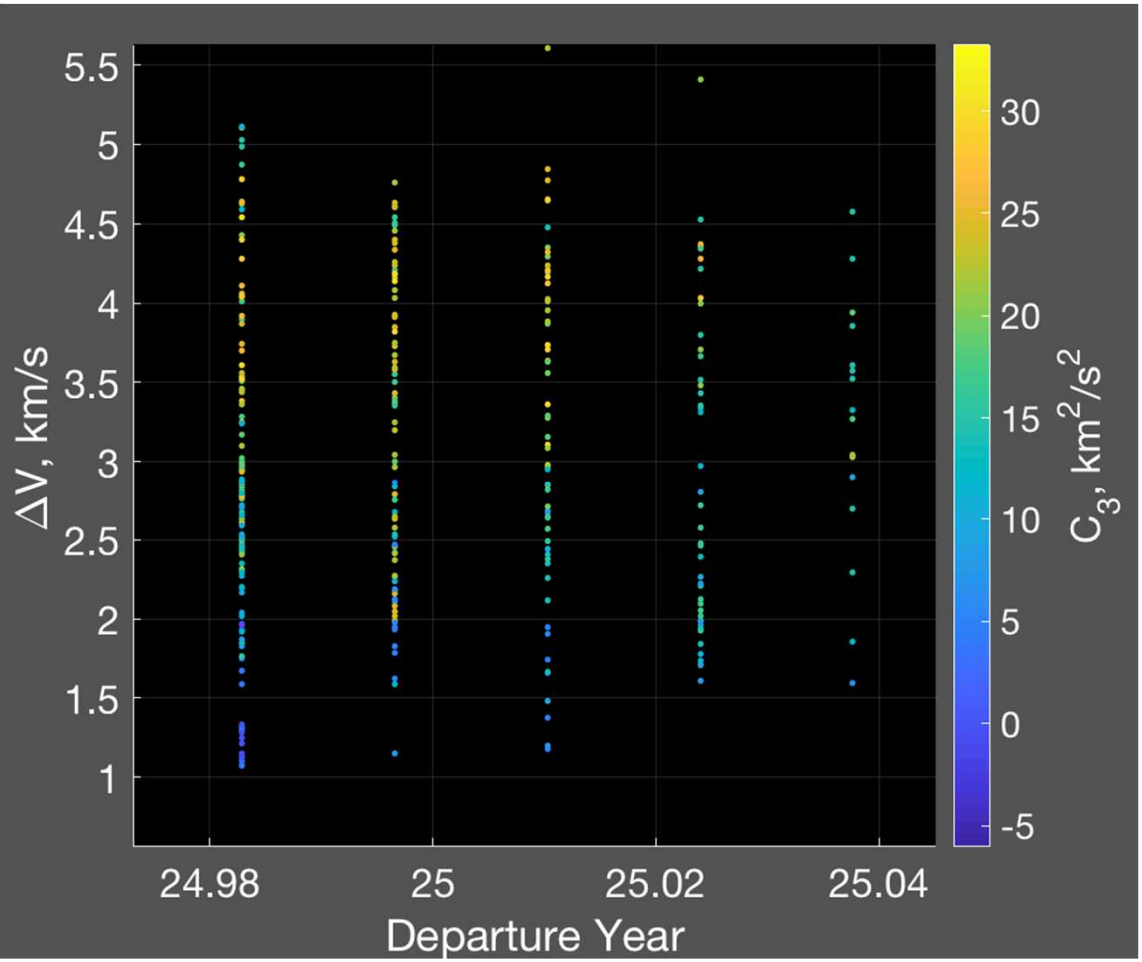
$\Rightarrow$ Revisit becomes affordable

$\Rightarrow$ Approach of many small bodies becomes affordable

Small probes can take risks and can be be multiplied to increase the chances of success.

Multi point and radioscience is greatly enhanced by small probes.

NEAs reconnaissance: Maximize the number of target destinations through multiple spacecraft launched together, each visiting many targets
Desire high target-to-spacecraft ratio. 250 kg - spacecraft uses electrical propulsion.



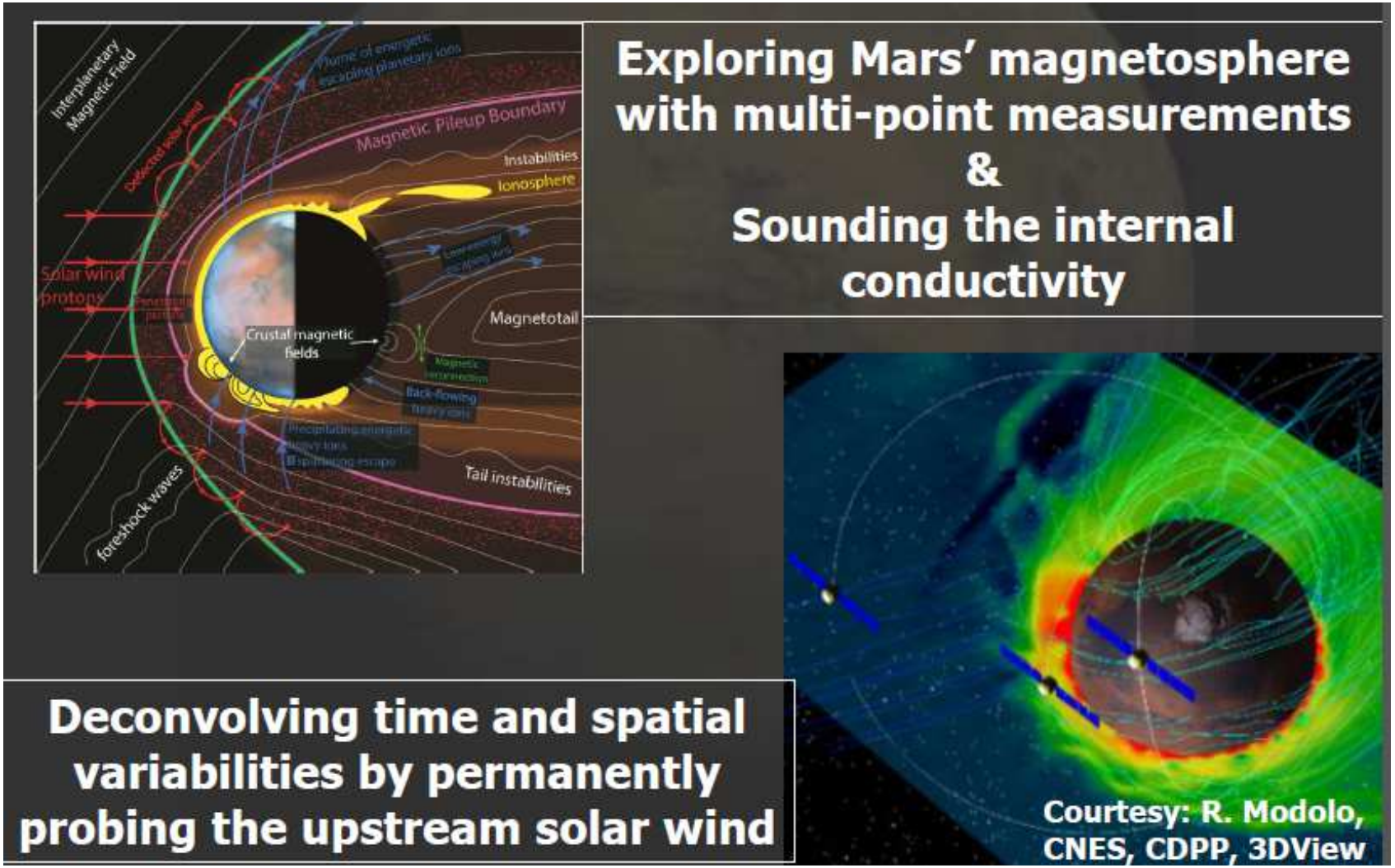
Muthulingam – JPL

57 unique NEAs can be visited by launching 25 spacecraft on the same day.

Many of these options share similar launch C3, so there is the option of launching on the same launch vehicle.

Multi point mission to investigate Mars' atmosphere and magnetosphere

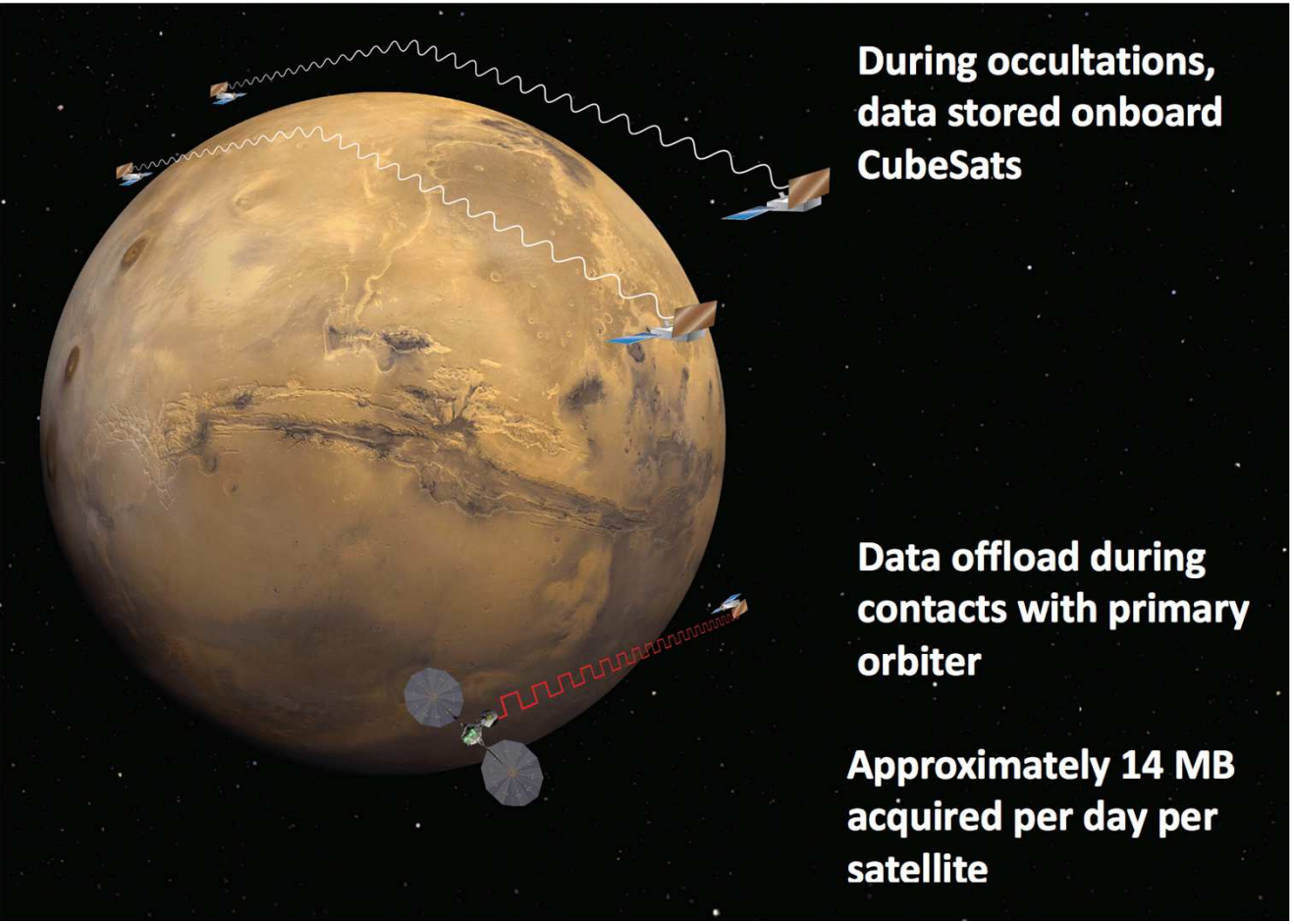
Leblanc – LATMOS



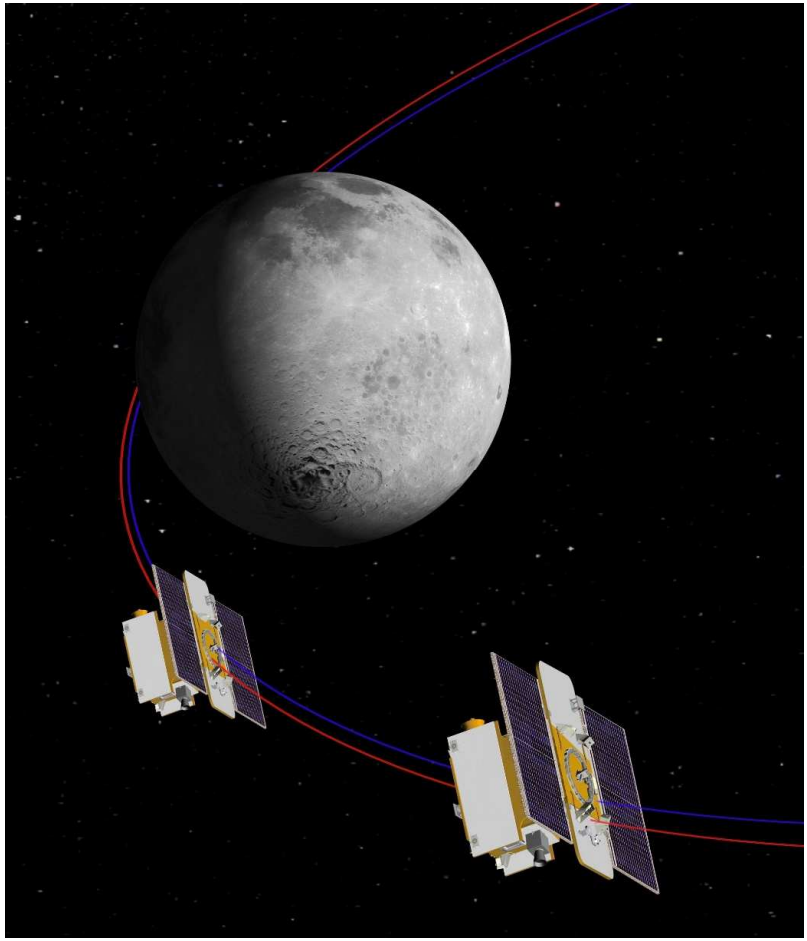
Spacecraft to spacecraft Radio science

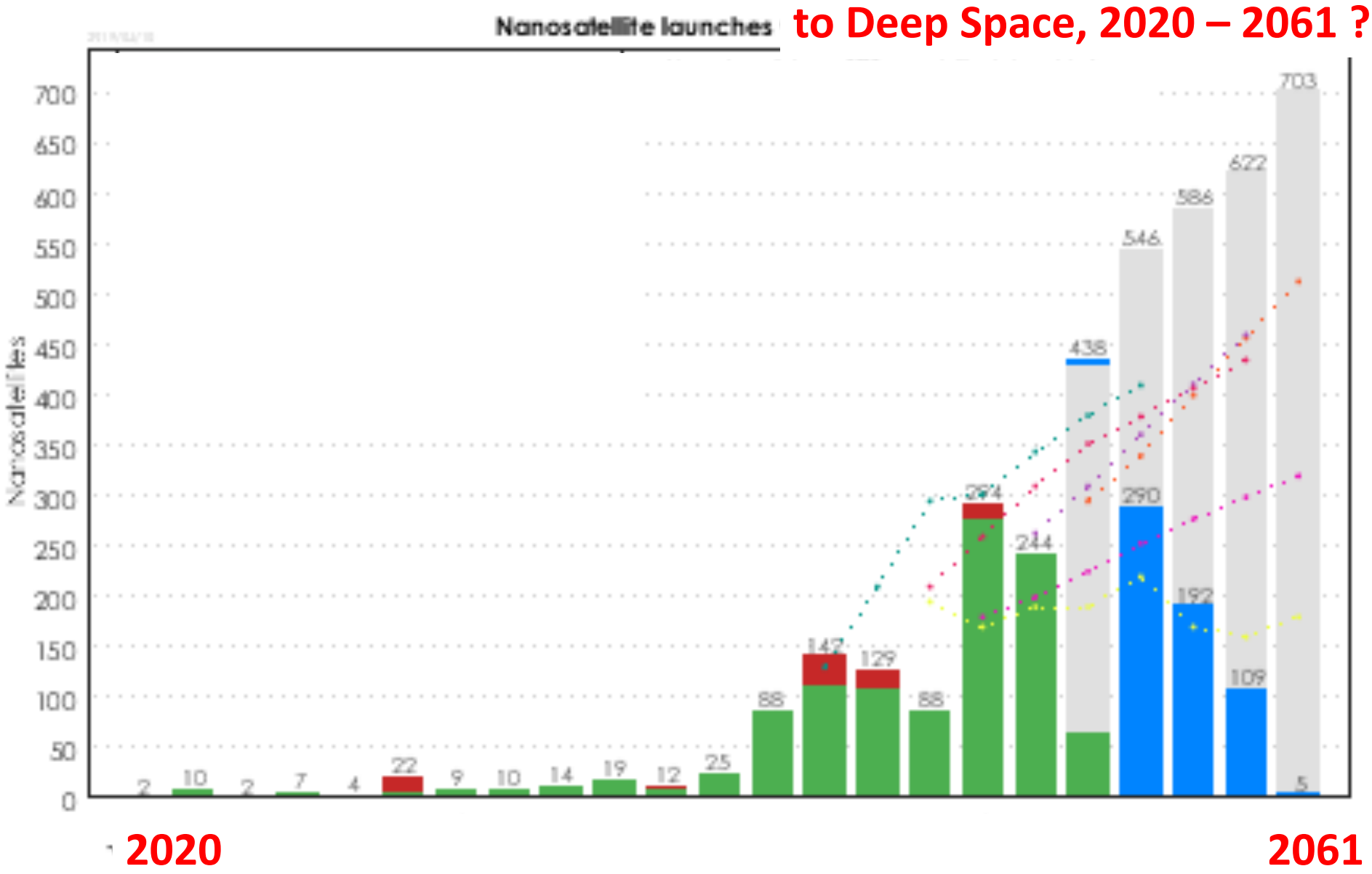
Asmar – JPL

Multiple opportunities with network in orbit



Short lifetime fly-by probes for key gravity field measurements




Nanosatellite launches
to Deep Space, 2020 – 2061 ?
Nanosatellites
700
650
600
550
500
450
400
350
300
250
200
150
100
50
0
2
10
2
7
4
22
9
10
14
19
12
25
88
142
129
88
294
244
438
546
586
622
703
290
182
109
5
2020
2061