SPENVIS at scientific projects of Space research institute (IKI)

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Space Research Institute, Moscow

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IKI is the leading organization of RAS and conducts investigations of outer space and Solar system. IKI develops and implements space experiments in astrophysics, plasma physics and planet sciences.

All projects are in different radiation environment and have specific features for radiation analysis

Radiation software used:

COSRAD

SPENVIS

OMERE

Space IKI experiments with SPENVIS analysis on missions:

1. Koronas Photon (2009 – 2009)
2. Radioastron (2011 – now)
3. Fobos Ground (2011 – 2011)
4. All-sky monitor on ISS (2014, 3 y)
5. Spectrum-X-Gamma (2014, 7y)
6. Resonance (2015, 5y)
7. Spectrum-UV (2016, 5y)
8. Luna Resource (2017, 1y)
9. Intergeliosond (2022, 6y)

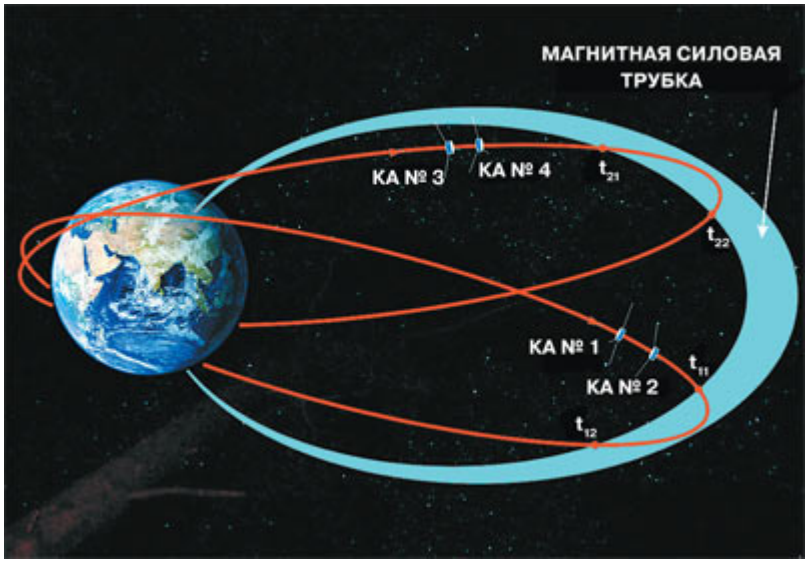
Plasma study

Orbit - 27 000 km - 500 km

Launch - 2015

Lifetime – 5 years

Magnetosphere study

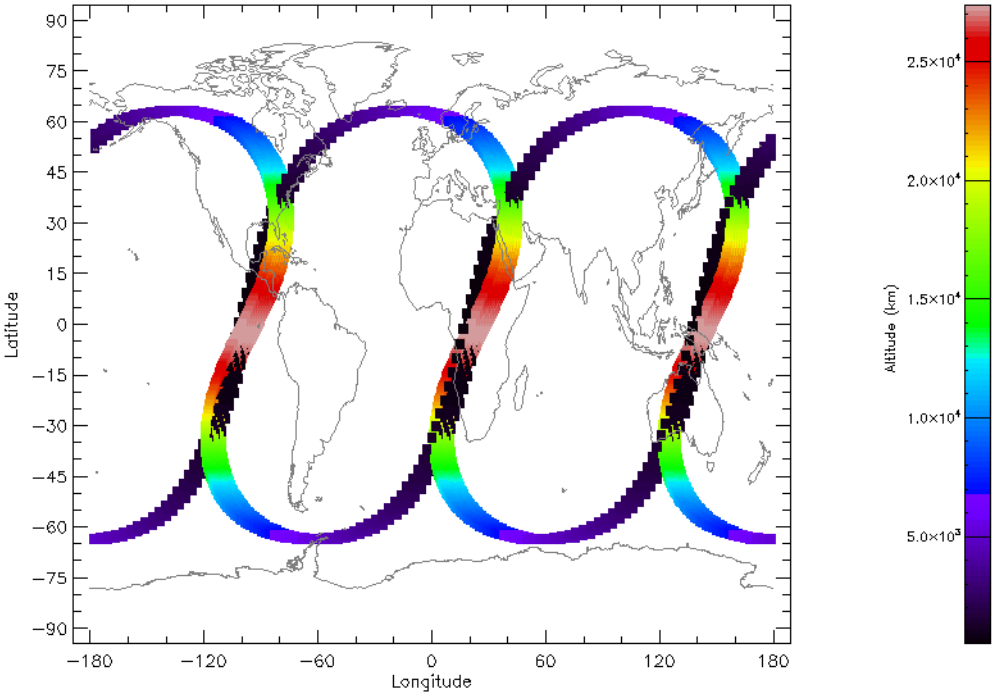


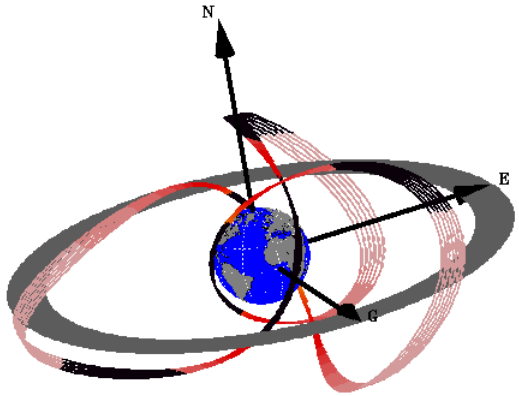
Small satellite

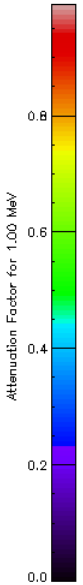
total mass of all experiments ~100 kg

Plasma

Radiation load is proportional to mission time







Most time in radiation belts with regions opened to Sun particles exposure

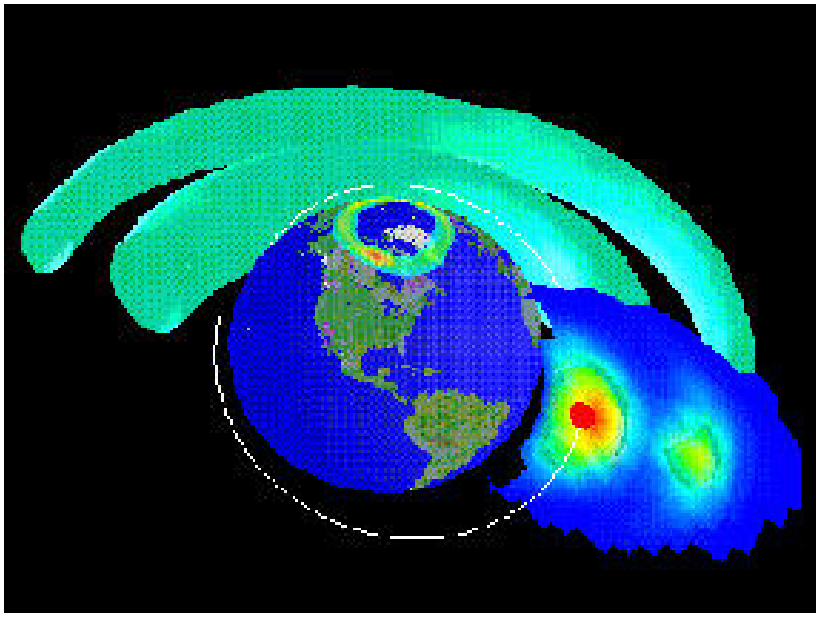
Magnetic shielding

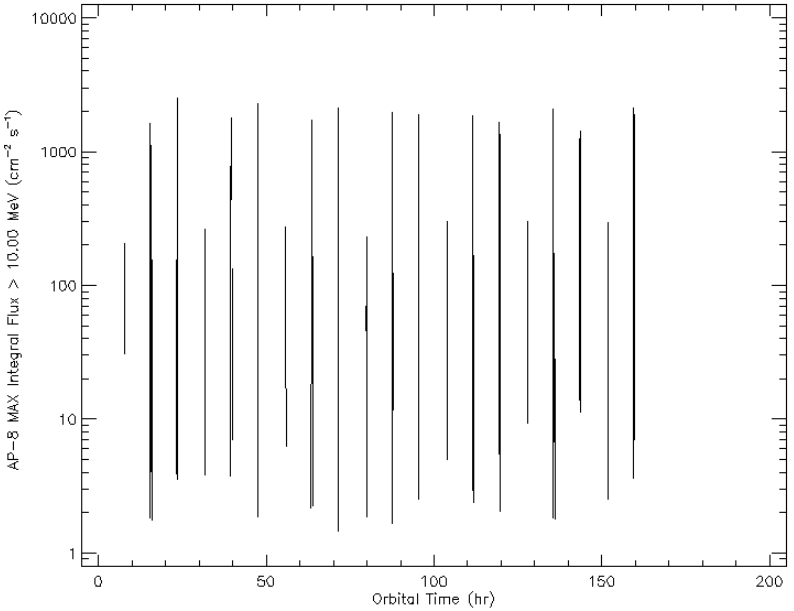
Plasma

Models :

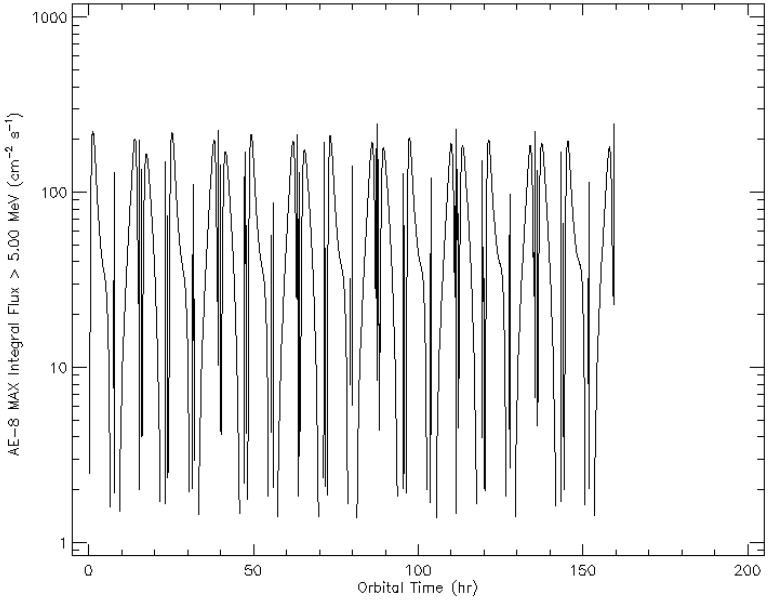
Radiation belts: AP8,AE8

Solar particles: ESP+ PSYCHIC





>10 MeV p+, > 5 MeV e-



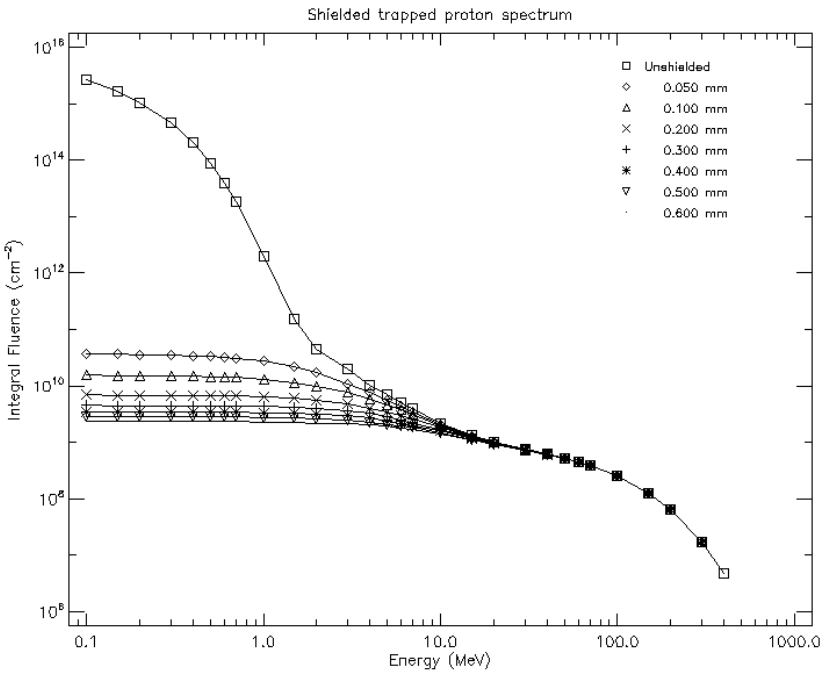
Plasma

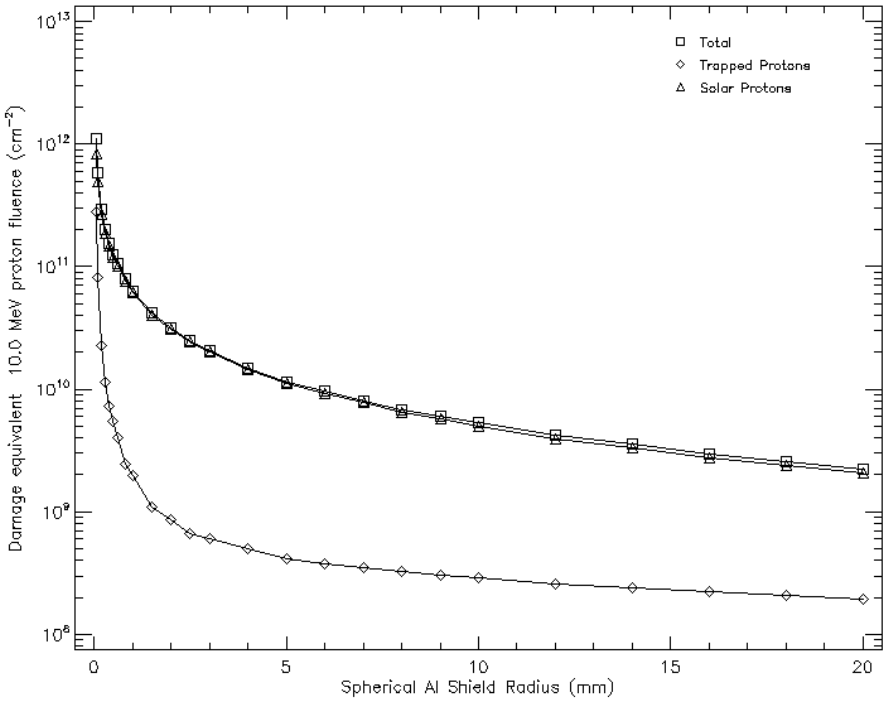
Orbit - 27 000 km - 500 km

Launch - 2015

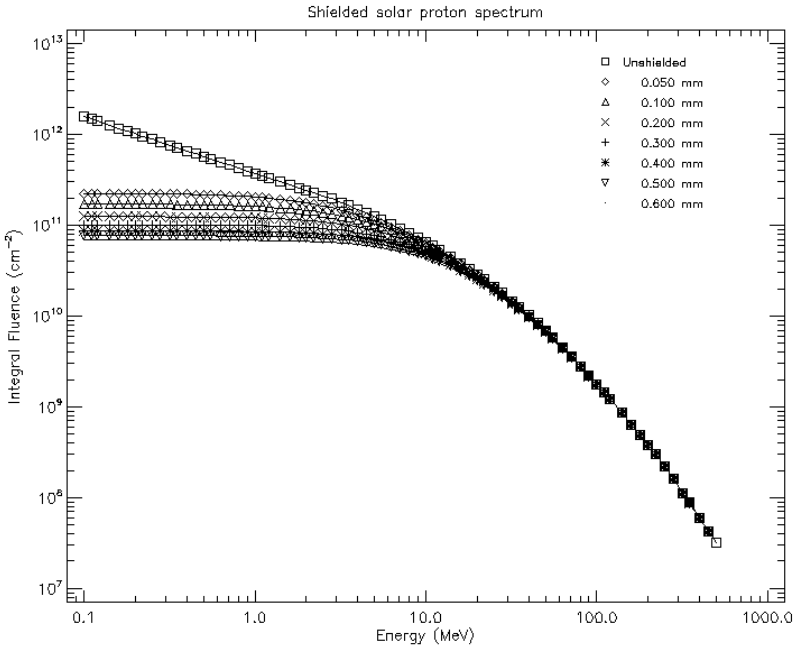
Lifetime – 5 years

Both Solar maximum and minimum





Trapped & Solar protons

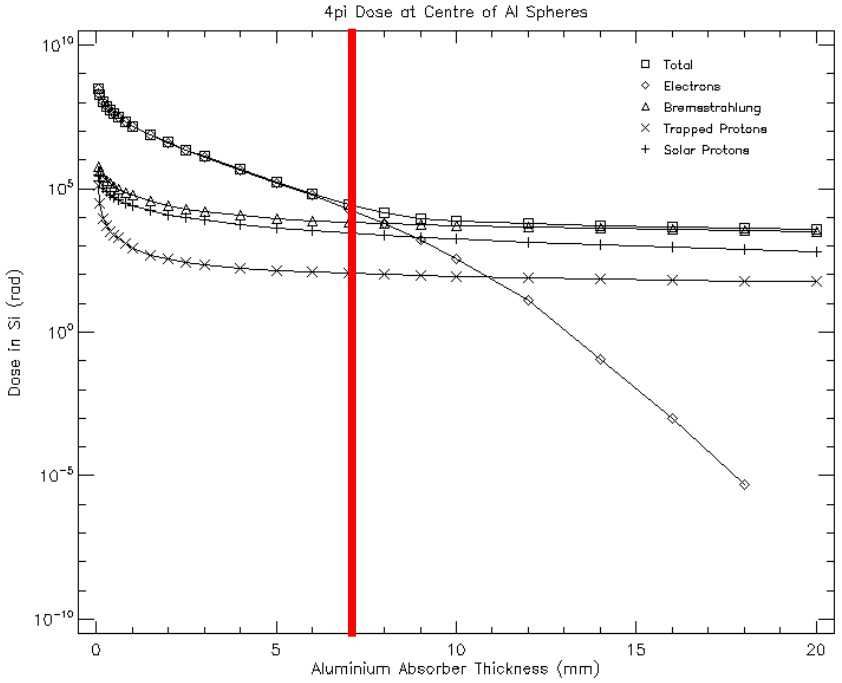


Total mission dose (rad)

Al (mm)	Al (g cm^{-2})	Total	Trapped protons	Solar protons	Tr. electrons+ Bremsstrahlung
0.050	0.014	2.953E+08	1.242E+05	2.994E+05	2.948E+08
0.100	0.027	1.840E+08	3.057E+04	1.804E+05	1.838E+08
1.000	0.270	1.488E+07	8.625E+02	2.497E+04	1.486E+07
2.000	0.540	4.073E+06	3.446E+02	1.222E+04	4.060E+06
3.000	0.810	1.316E+06	2.236E+02	7.809E+03	1.308E+06
4.000	1.080	4.666E+05	1.723E+02	5.556E+03	4.609E+05
5.000	1.350	1.742E+05	1.418E+02	4.199E+03	1.699E+05
6.000	1.620	6.854E+04	1.241E+02	3.392E+03	6.502E+04
7.000	1.890	2.899E+04	1.115E+02	2.784E+03	2.609E+04
8.000	2.160	1.437E+04	1.024E+02	2.338E+03	1.193E+04
9.000	2.430	9.239E+03	9.511E+01	2.015E+03	7.129E+03
10.000	2.700	7.303E+03	8.892E+01	1.737E+03	5.477E+03
20.000	5.400	3.966E+03	5.680E+01	6.511E+02	3.258E+03

Plasma

IC	Type	rad
DC-DC / 5V - 1.5W	Space	>100 k
DC-DC Buck Regulators	Space	>100 k
Voltage Reference	Space	>100 k
Adjustable Regulator	Space	>100 k
Charge Sens. Preampl.	Space	>100 k
Flash FPGAs	Space	>55 k
Differential Receiver	Space	>100 k
Differential Driver	Space	>100 k
Temperature Transducer	Space	>100 k
Oscillator 15MHz	Space	>100 k
NPN bipolar transistor	Space	>100 k
Diodes	Space	>150 k
Inductor (4.7 mkH)	Military	>1 M
Capacitors (0.1mkF-X7R)	Military	>1 M
Diodes	Space	>150 k
Capacitors (10n-200V)	Military	>1 M



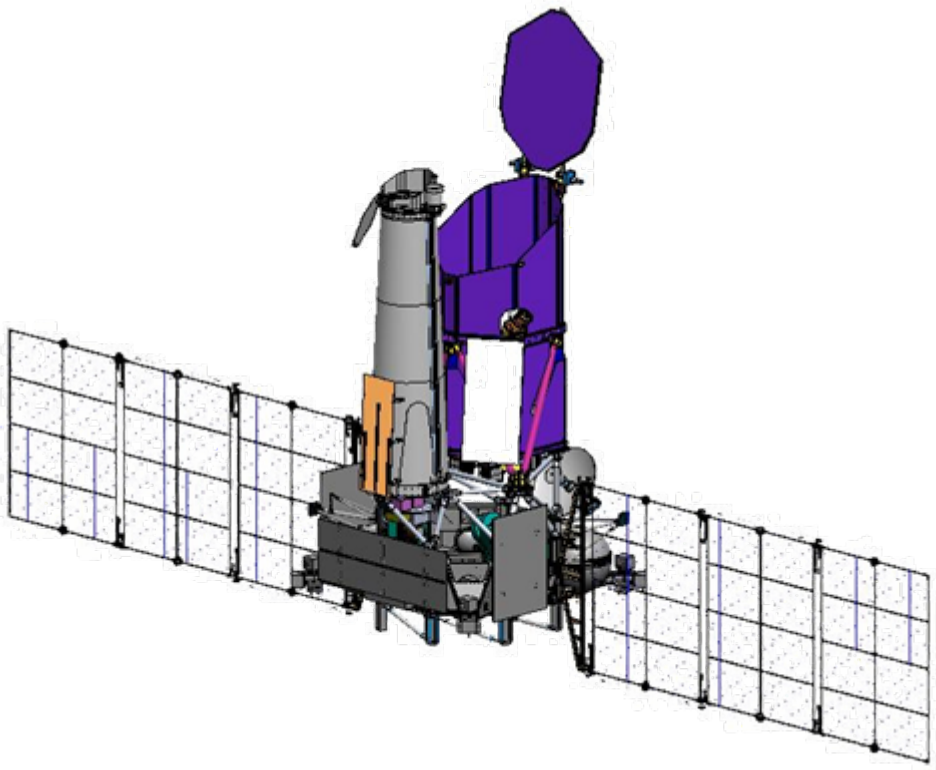
29 krad

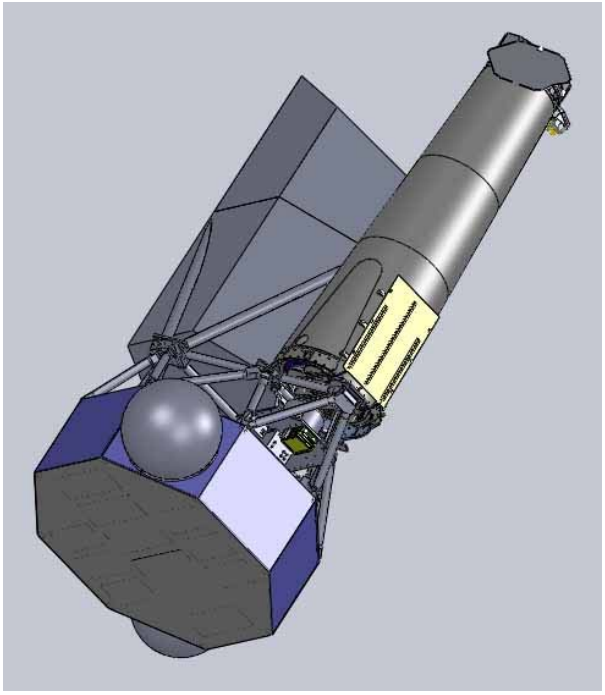
Astrophysical missions

Astrophysical missions	Orbit	Radiation environment	Specific requirements
Radioastron, 2011 – now	High elliptical, 350 000 km	Radiation belts + Solar maximum	High mass experiments
Spectrum –XG, 2014 - 2021	L2	Solar maximum + minimum	High mass experiments
Spectrum-UV, 2016-2021	~ HEO	Solar minimum + maximum + radiation belts	High mass experiments

Astrophysical missions

Large experiments with lot of extra shielding due to experiment design

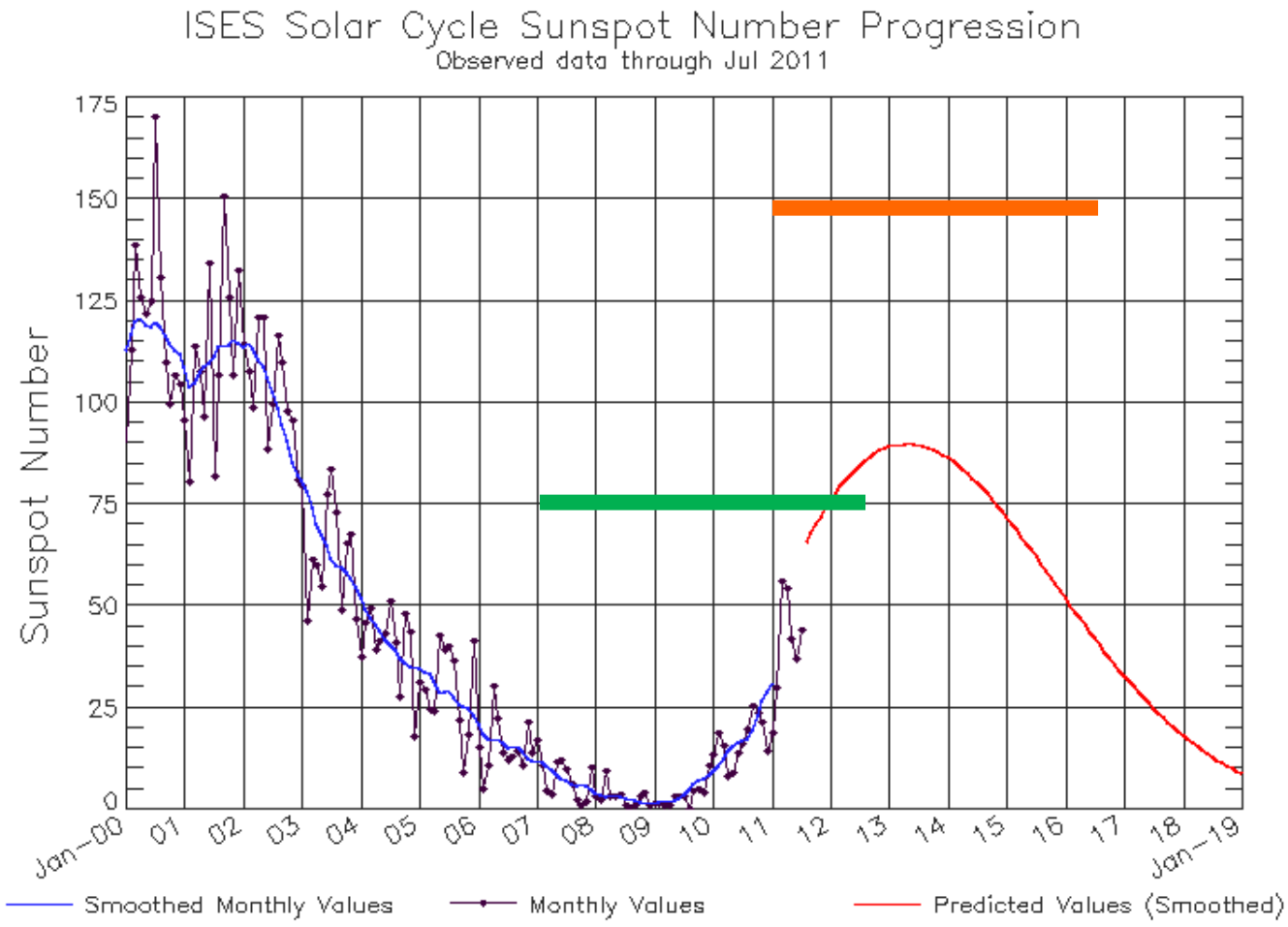




Solid sphere model predicts 2 -3 times harder radiation conditions in comparison with more elaborated model

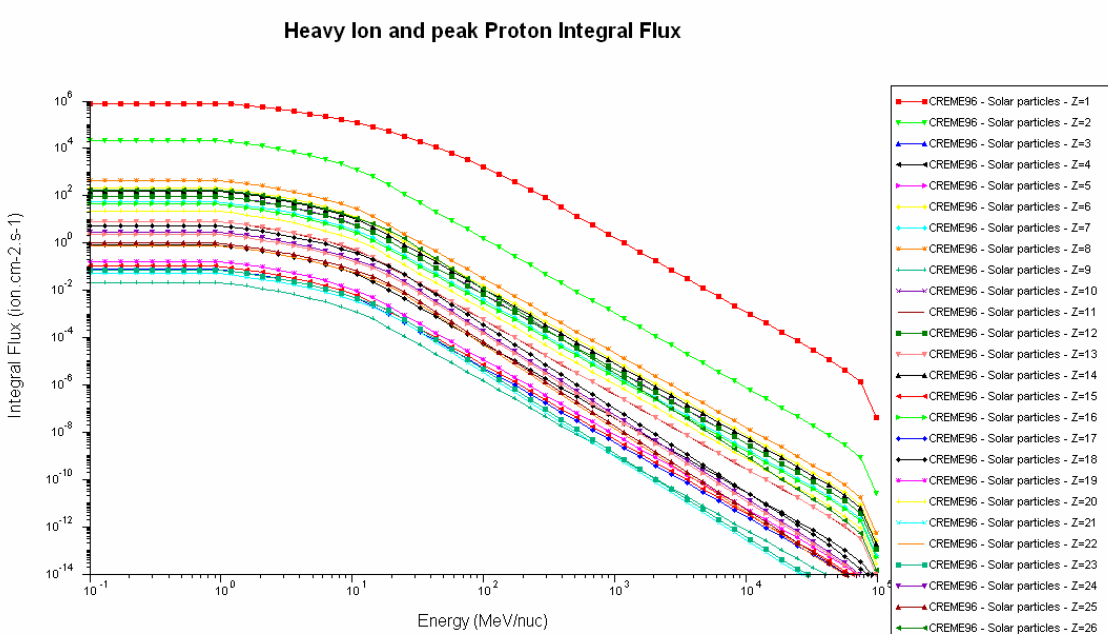
Astrophysical missions

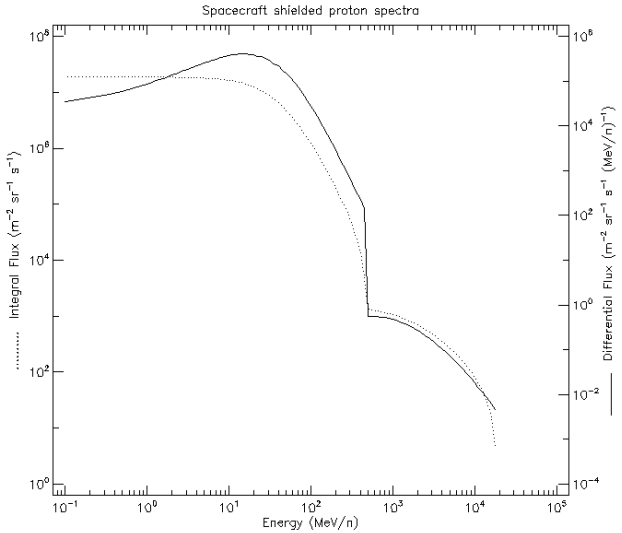
Hard to predict: long lifetime and NO fixed launch date

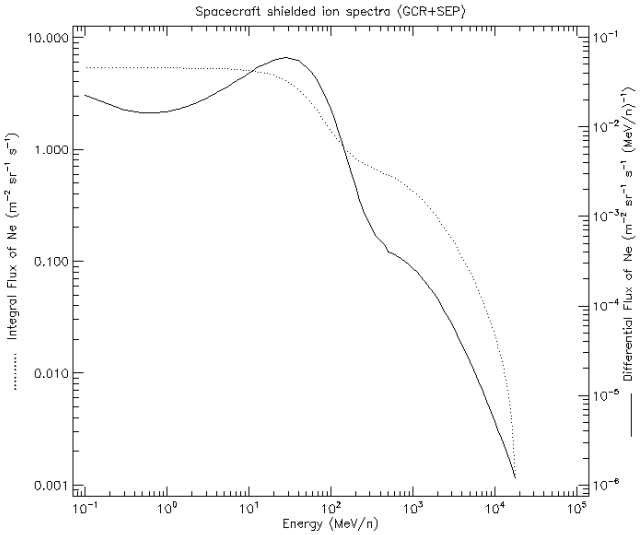


Astrophysical missions

Radiation damage can happen any time due to Single Event Effects







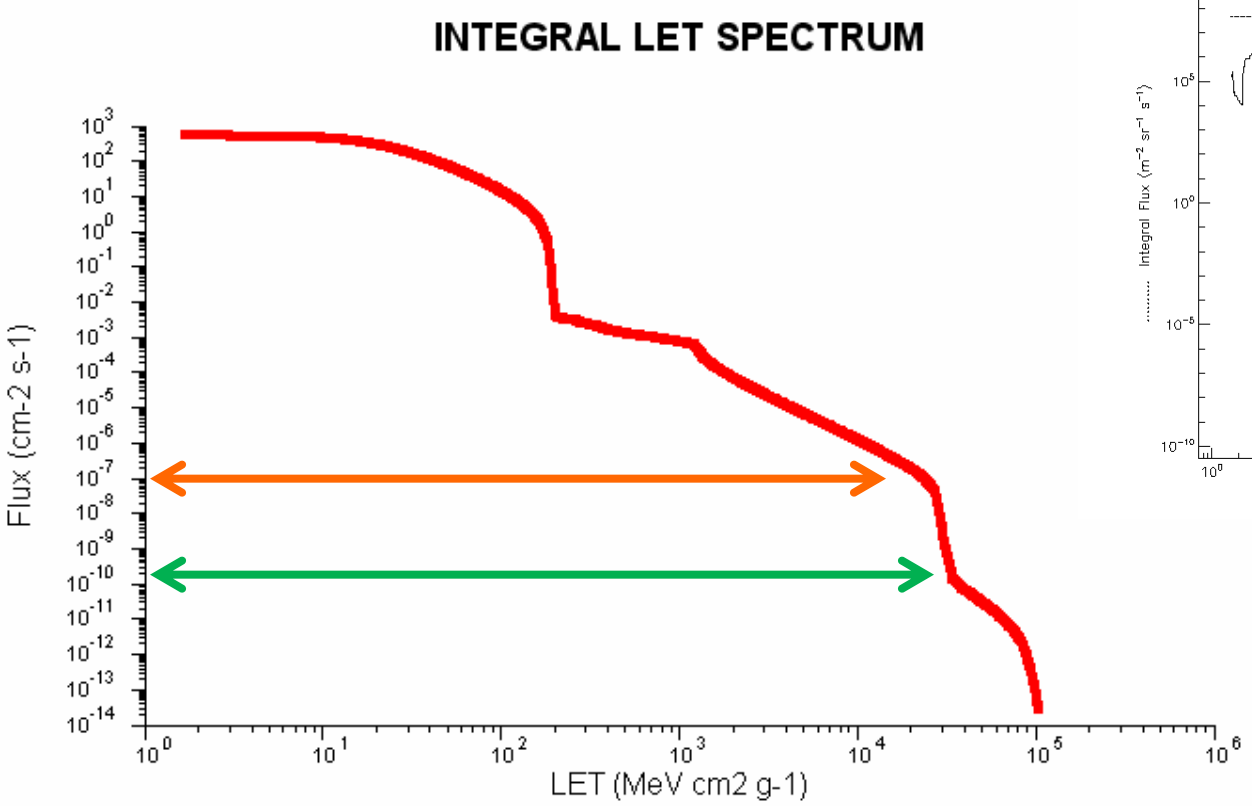
Worst 1 day

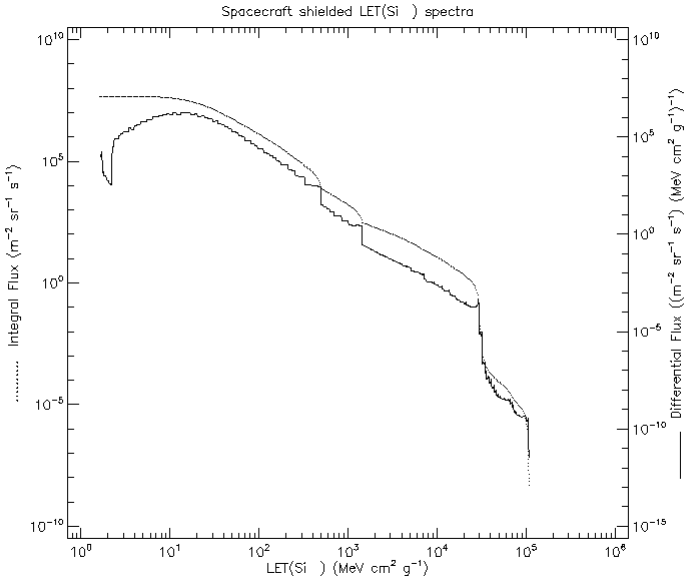
shielding with 5 mm Al

p & Ne

Astrophysical missions

Narrow LET range but dramatic change of flux in the area of interest

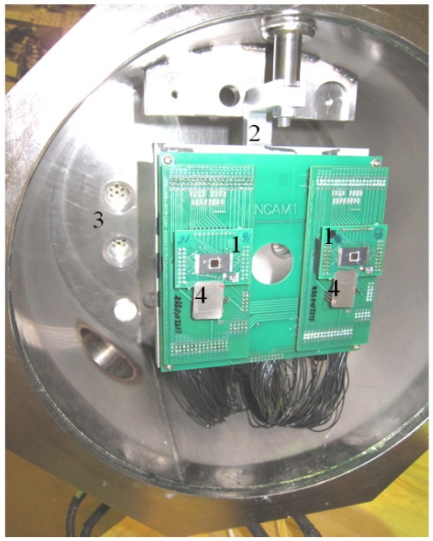


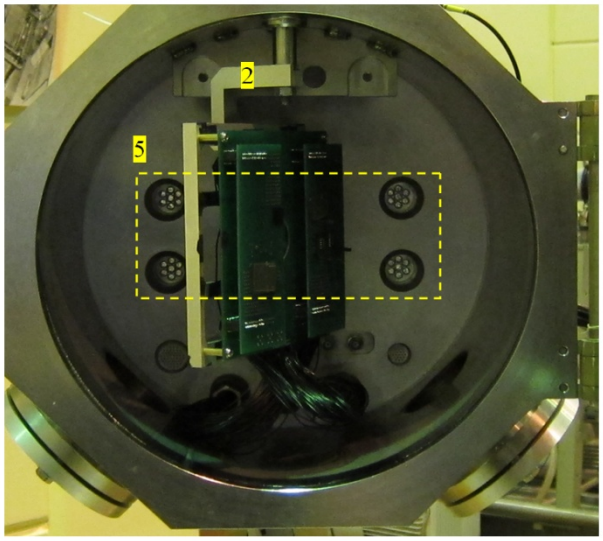


20 – 40 MeV cm^2/ mg

Astrophysical missions

Experimental measurements SE parameters of critical components





~ 200 IC were analyzed

~ 30 IC were tested

~ 10 IC were changed

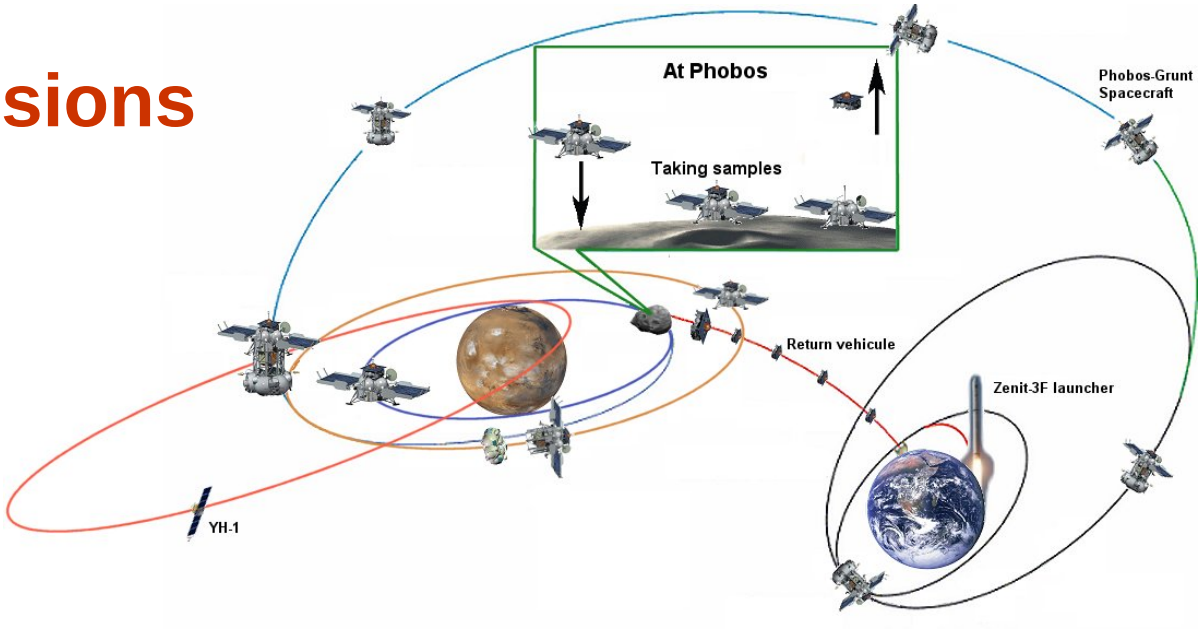
Critical IC were tested at ion beam accelerator with

Ion	Z	Energy, MeV	LET, MeV ·cm^2/mg	Length, micron
Kr	36	≈ 302	≈ 40	≈ 39
Xe	54	≈ 537	≈ 69	≈ 44
Ar	18	≈ 154	≈ 15	≈ 41
Ne	10	≈ 88	≈ 6	≈ 50

Planetary missions

Small experiments: thin walls and short operational time. As is design philosophy

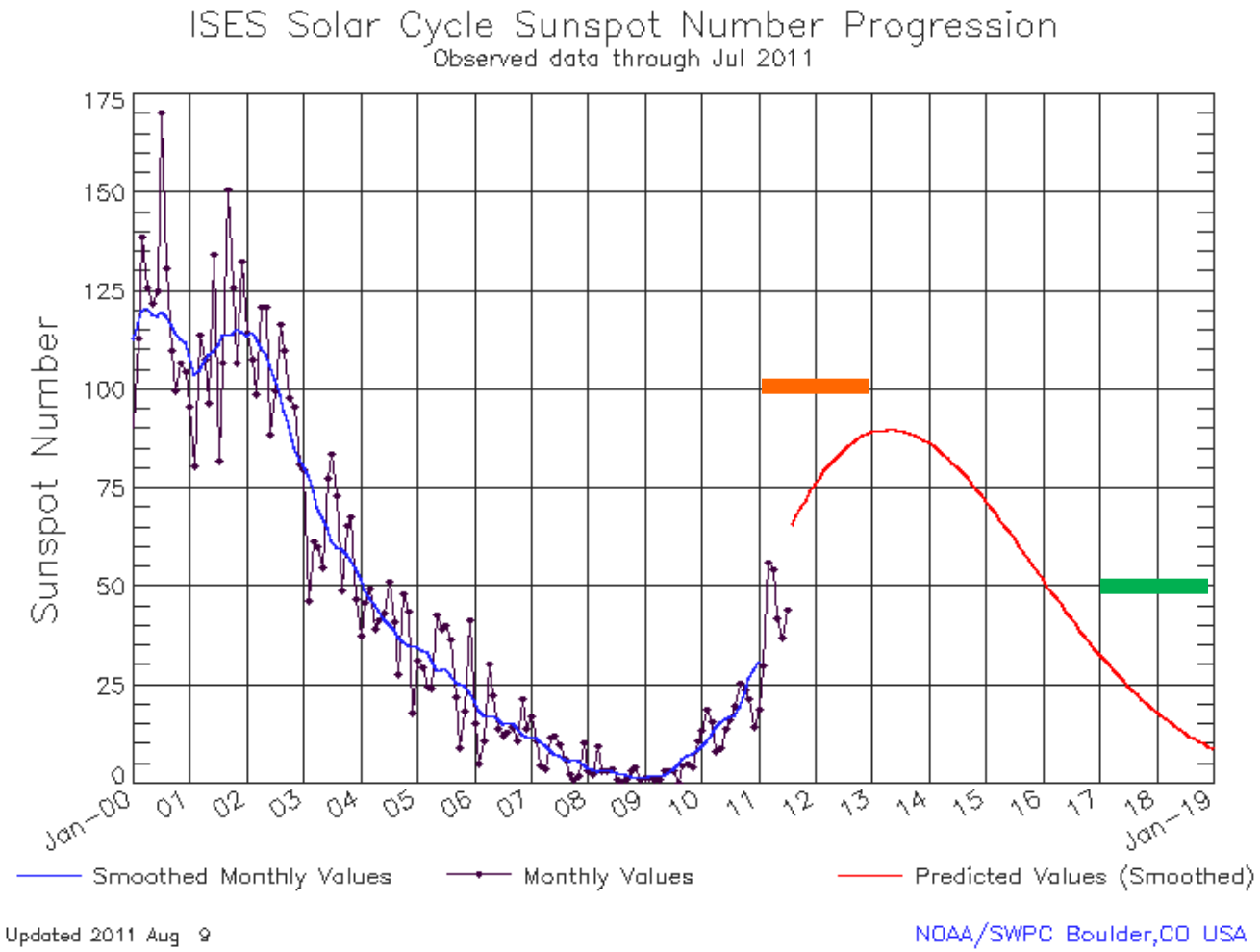
Planetary missions



Planetary missions	Orbit	Radiation environment	Specific requirements
Fobos-Ground, 2011 – 2011	to Mars	Solar maximum	Low mass experiments, fixed launch date
Luna – Resource, 2017 - 2017	to Moon	Solar minimum	Low mass experiments
ExoMars, 2018 – 2020	to Mars	Solar minimum	Low mass experiments, fixed launch date

Planetary missions

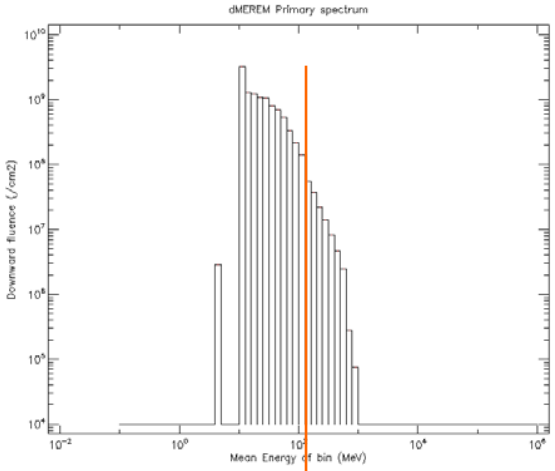
Easier to predict: relatively short and have fixed launch date



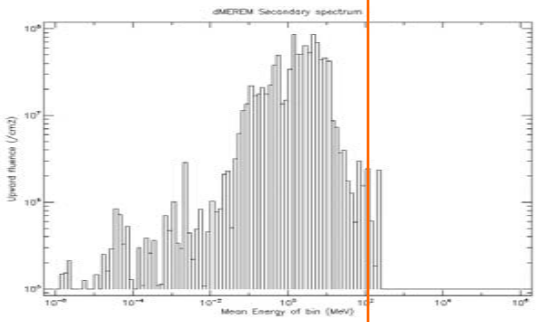
Planetary missions

Extra irradiation from activated soil – structural damage caused by secondary neutrons

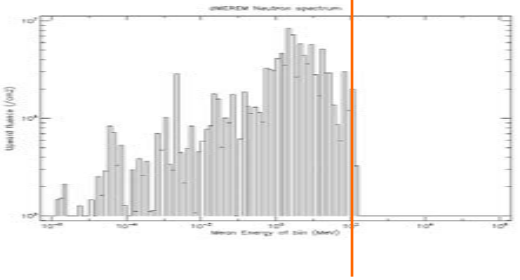
Soil composition	Olivine	Fobos composition ?
SiO_2	39.2	38.7
Fe_2O_3	18.8	23.2
Al_2O_3	0.0	2.0
MgO	42.1	24.4
MnO	0.0	0.3
CaO	0.0	1.8
Na_2O	0.0	0.9
K_2O	0.0	0.1
TiO_2	0.0	0.1
Cr_2O_3	0.0	0.5
FeS	0.0	6.3
CoO	0.0	0.1
NiO	0.0	1.2
P_2O_3	0.0	0.3



primary radiation



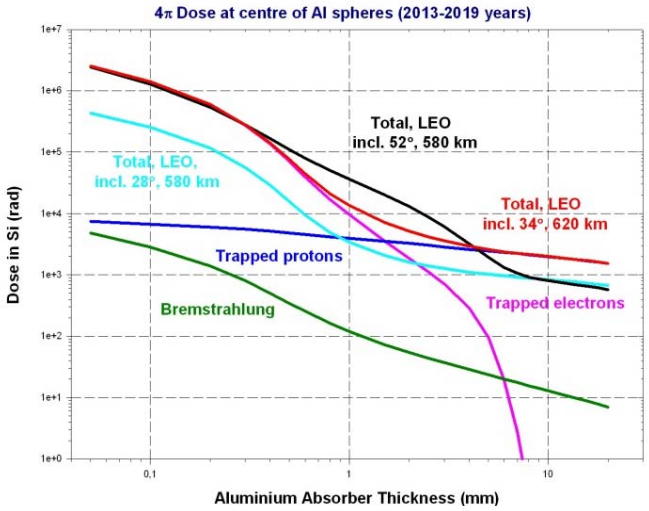
secondary radiation

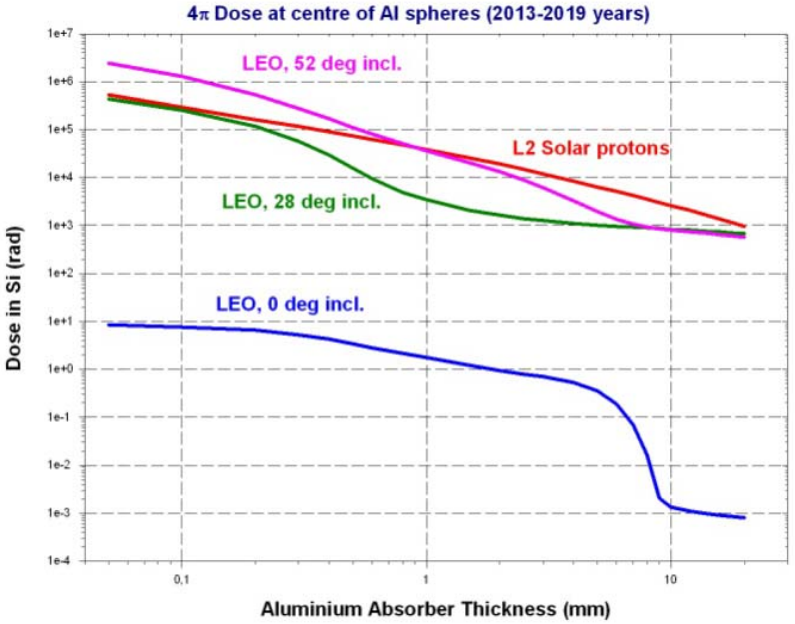


secondary neutrons

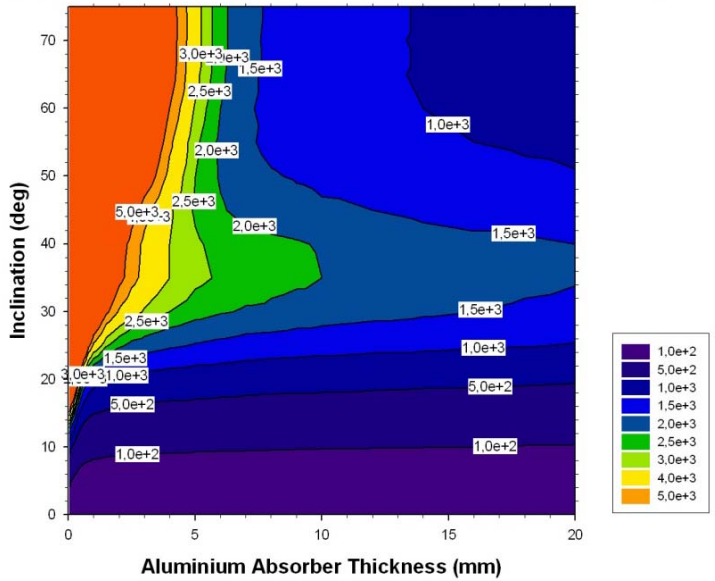
Orbit choice and change

Experiment requirements vs. technical constraints

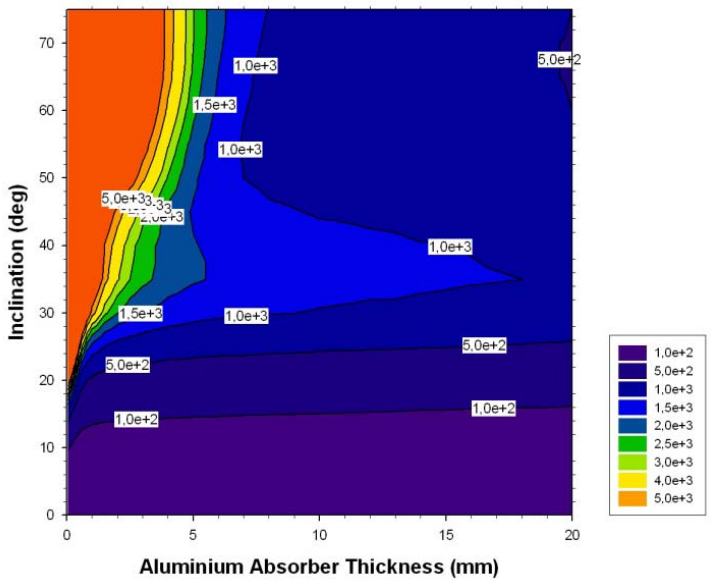




4π Dose (rad) at centre of Al spheres (2013-2019 years), 620 km

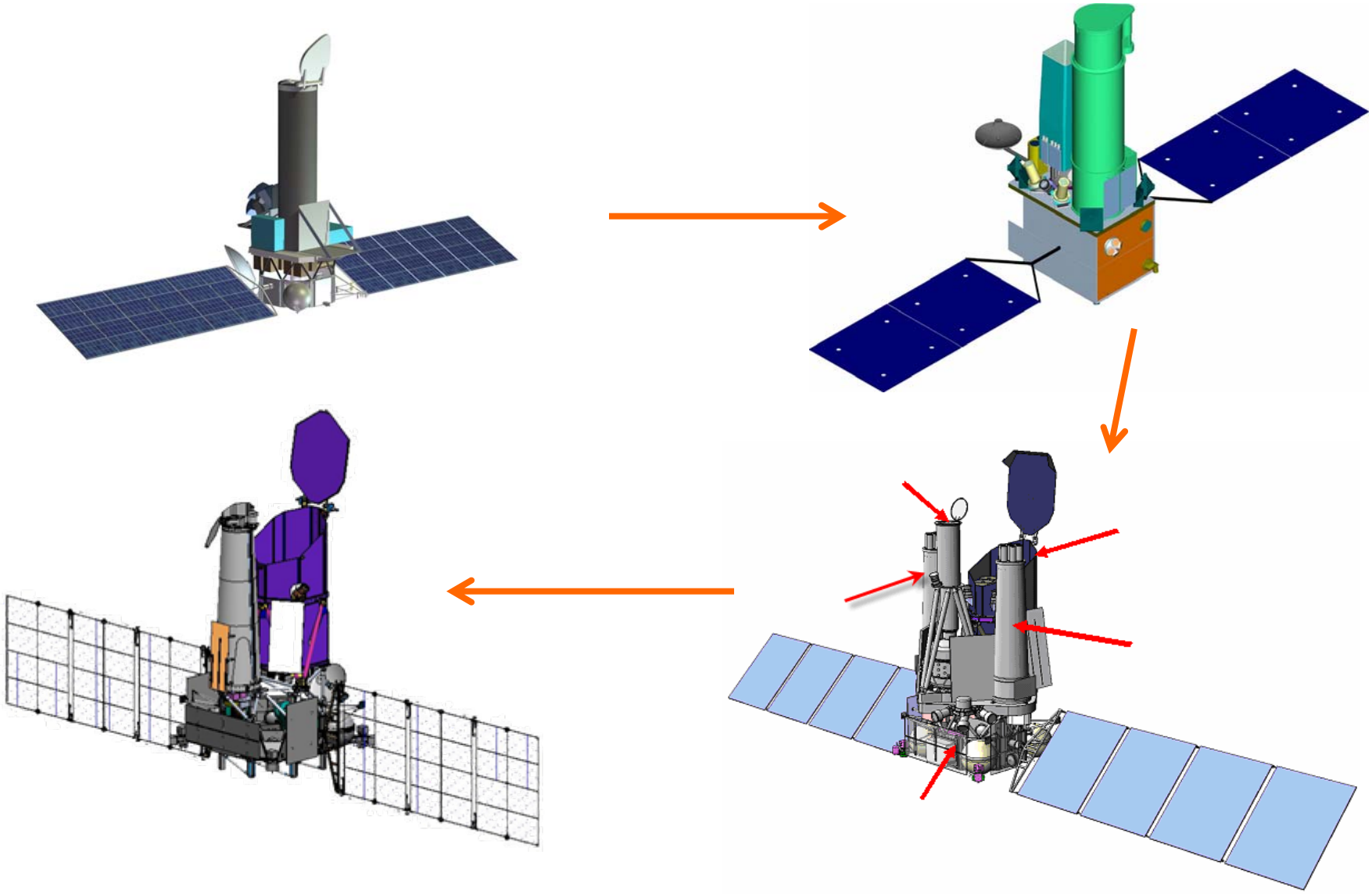


4π Dose (rad) at centre of Al spheres (2013-2019 years), 550 km

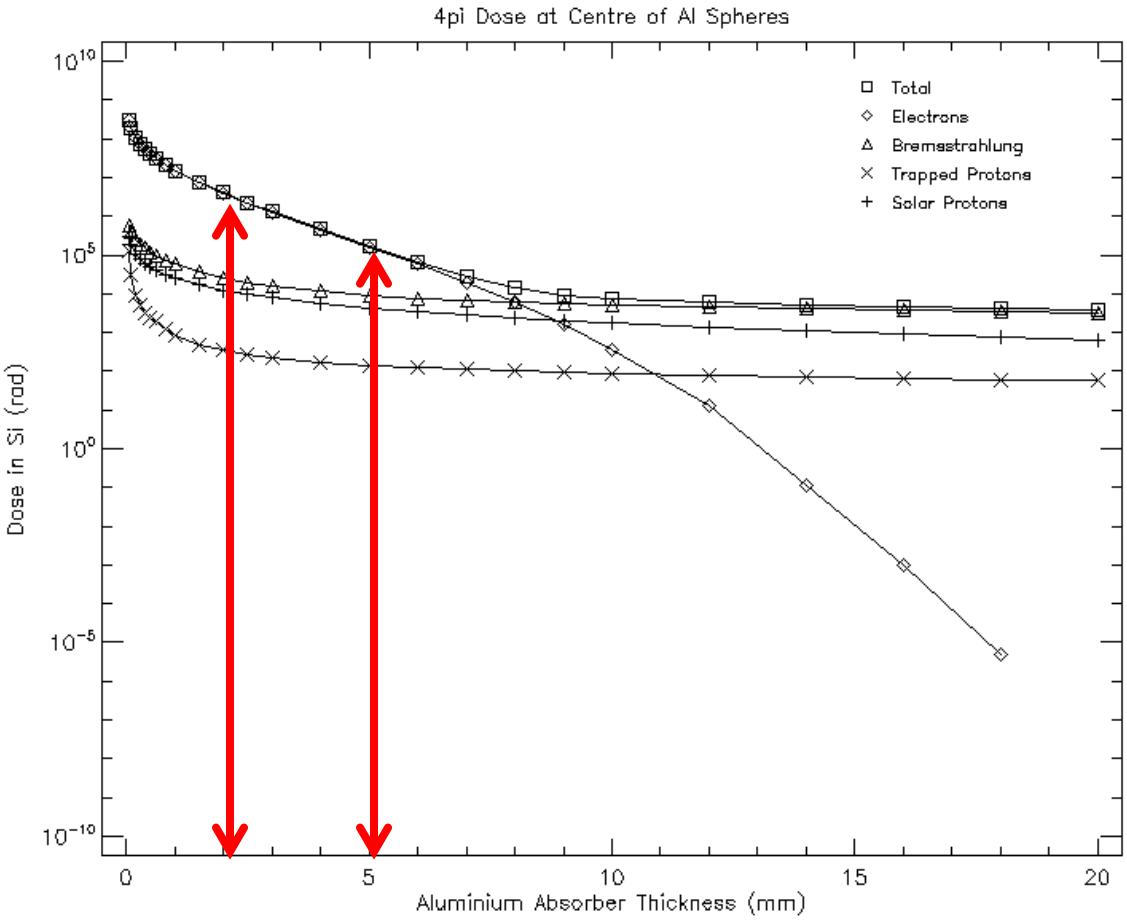


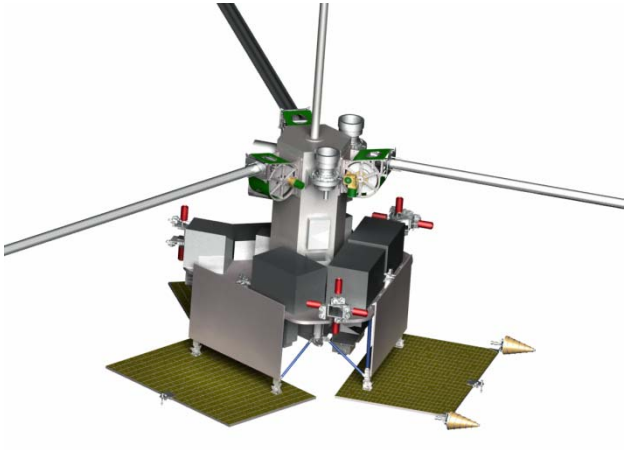
Changes of mission design

Have a good margins for radiation design



Joint scientific load design





for typical unit 20x15x10 cm3

+3 mm Al shielding -> +1 kg

- 25 * TID