Recent Radiation Environment Studies aboard Biological Satellites

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International Collaboration

Passive detectors

- **IBMP** (TLD and TLD+TASTRACK)
- **NIRS**, Chiba, Japan (TLD + CR-39)
- **Nuclear Physics institute**, Prague, Czech Republic (TLD + CR-39)
- **DLR** (TLD + CR-39)
- **MTA EK**, Budapest, Hungary (TLD + CR-39)
- Oklahoma State University, USA (CR-39)
- **Thessaloniki University**, Greece (Mosfet detectors)
- **UOIT,** Ontario, Canada, Bubble detectors

Active detectors

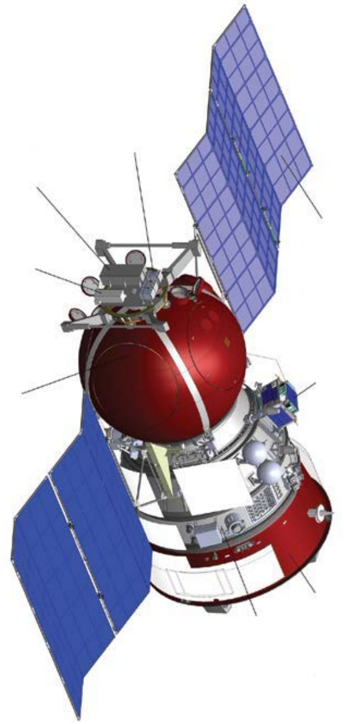
SRTI BAN, Sofia Bulgaria

- RD3-B3 dosimeter (silicone detector)

Recoverable capsule

Orbit parameters for recoverable biological satellites

Parameter	Bion-M1	Foton-M4	Bion-M2
Flight dates	April 19 – May 19, 2013	July 19 – September 1, 2014	In 2020
Flight duration, days	30	45	30
Orbit inclination, º	64.8	64.5	51.6 or 64.8
Apogee, km	583	565	~1000
Perigee, km	563	260	~800
Orientation stabilization	Yes	Yes	Yes
Passive detectors (inside and outside)	Yes	Yes	Yes
Active detectors inside	Yes	Yes	Yes
Active detectors outside	No	No	Yes

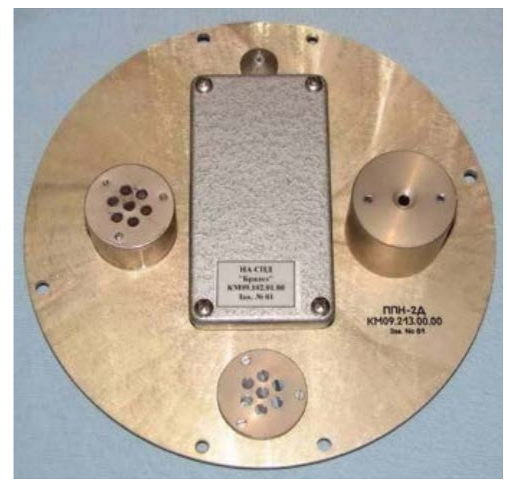


Launching mass ~7 t, Recoverable capsule mass ~ 2 t

Radiation dosimetry instruments used aboard Biosatellites

Passive detectors inside the capsule in 4 SPD boxes

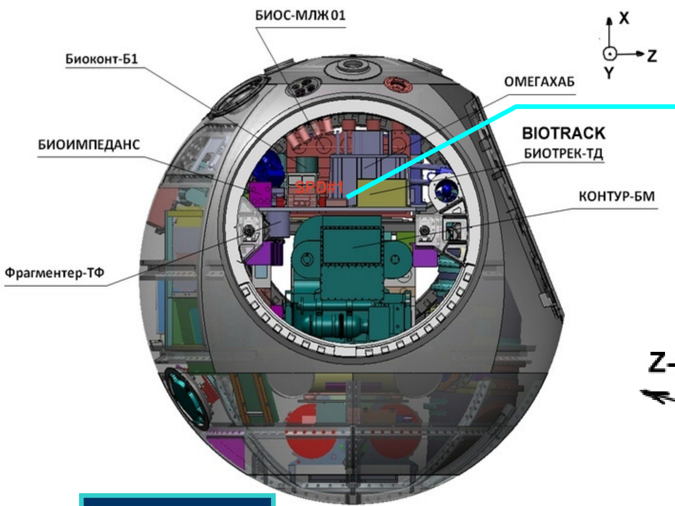
Battery powered RD3-B3 silicon dosimeter inside



Passive detectors on the outer surface of the capsule in special containers

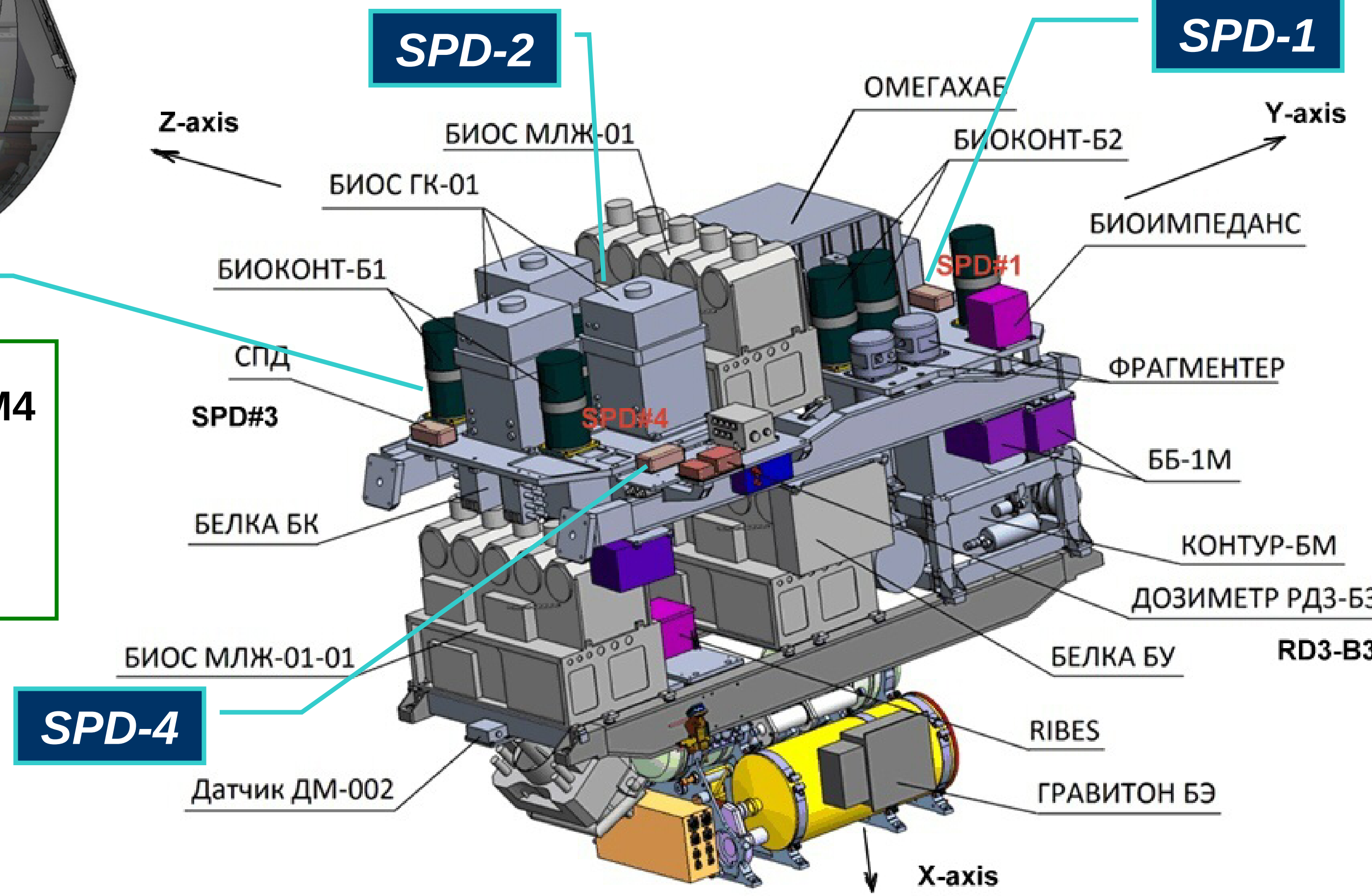
Space qualified Bubble detectors

Locations of SPD Boxes inside BION-M1 Satellite



Internal view of the box

Al wall is 0.3 g/cm^2



BION-M1 and Foton-M4 capsule wall is ~5 g/cm^2 Al

Absorbed and equivalent dose rates and quality factors inside the Bion-M1 recovery module as measured by SPD assemblies

Assembly ##	Absorbed dose rate, mGy/day	Equivalent dose rate, mSv/day	Radiation quality factor ICRP 60
SPD # 1	2.4 ± 0.2	3.4 ± 0.2	1.4 ± 0.2
SPD # 2	1.1 ± 0.1	2.0 ± 0.1	1.7 ± 0.2
SPD # 3	1.6 ± 0.2	2.6 ± 0.2	1.8 ± 0.2
SPD # 4	2.0 ± 0.1	3.1 ± 0.1	1.6 ± 0.1

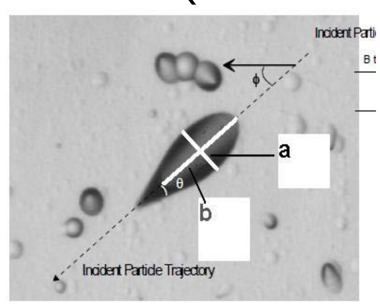
D_{max}/ D_{min} ~ 2.5

H_{max}/ H_{min} ~ 1.7

Typical ISS dose ~0.25 mGy/day

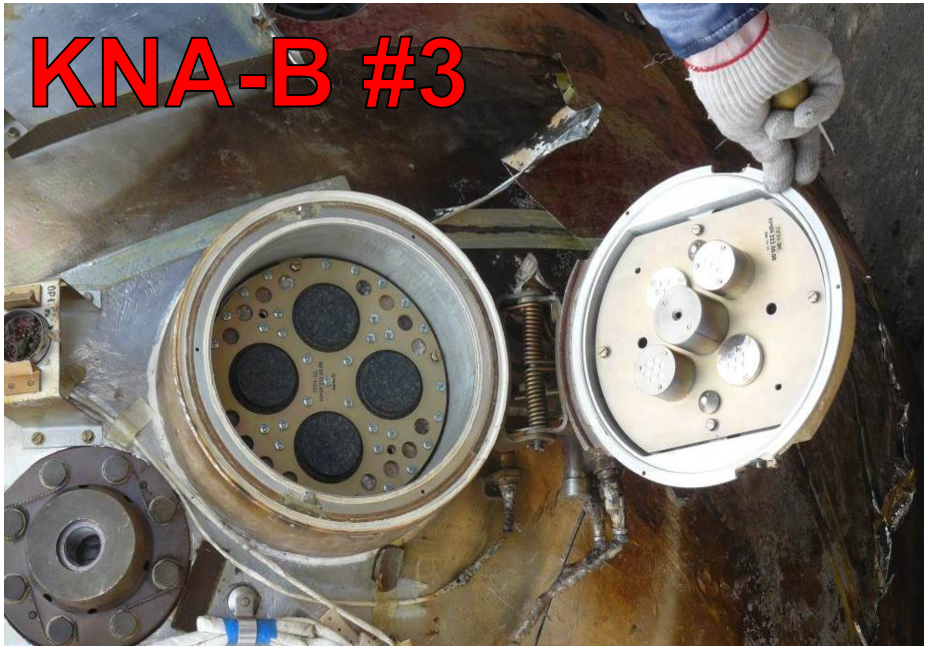
D_{Bion}/D_{ISS} = 6

Combined method TLD (LiF:Mg,Ti) and SSTD (CR-39 Tastrack 30x30x1) mm^3

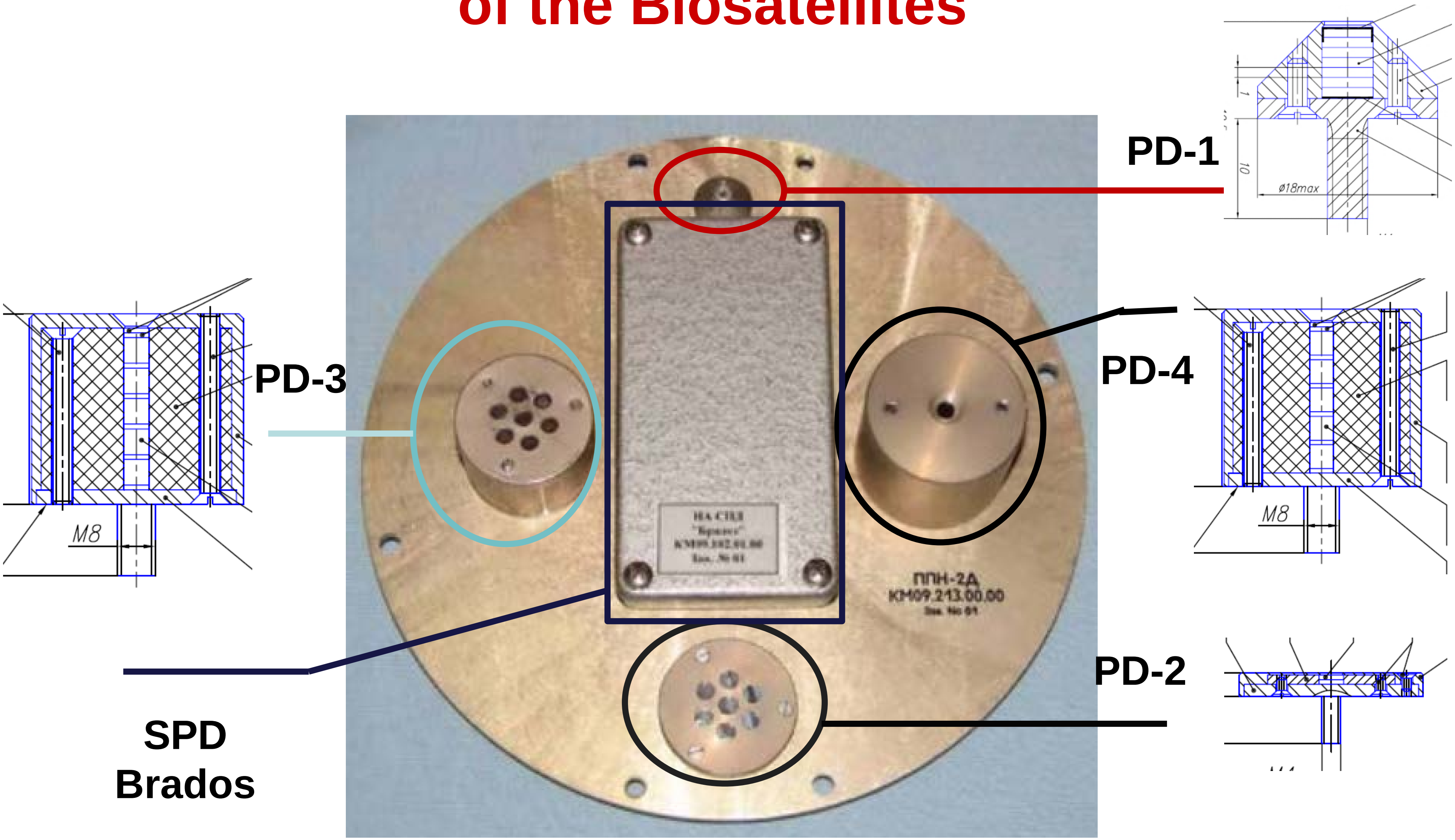


Inozemtsev K.O., Kushin V.V., et al., 2014

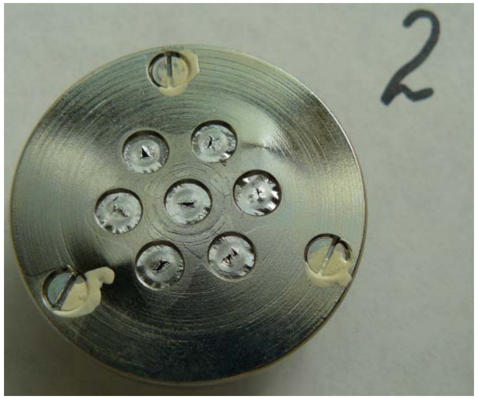
Locations of TLD and SSTD packages on the outer surface in special containers



Detector packages on the outer surface of the Biosatellites



Thermal damage of the detector packages on the outer surface of the Biosatellites



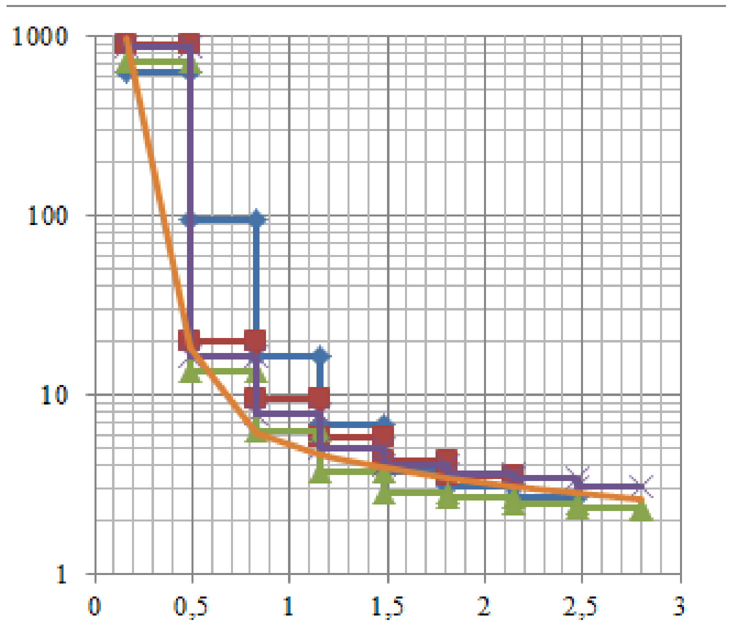
Uncontrolled temperature conditions caused the detector annealing in some containers

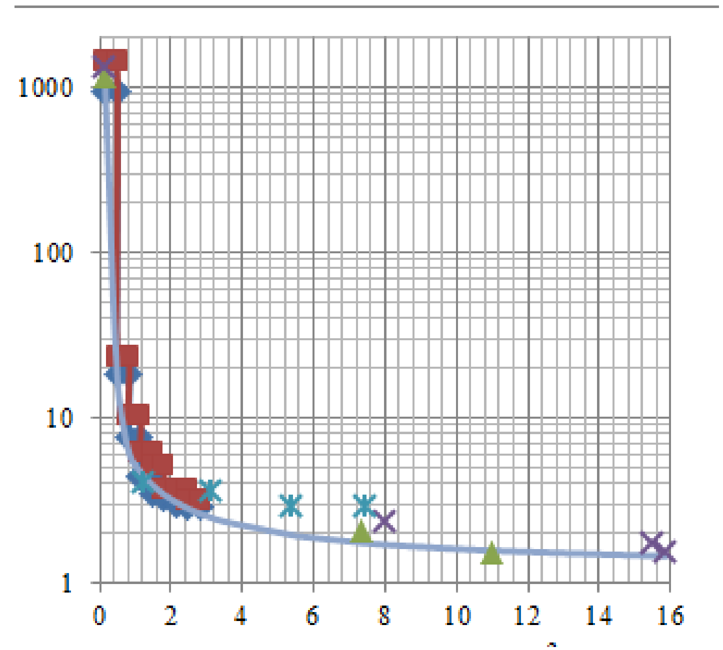
Example of Measured and Calculated Depth-dose Curves

KNA-B #1 (lid)

KNA-B #2 (lid)

Dose rate, mGy/day

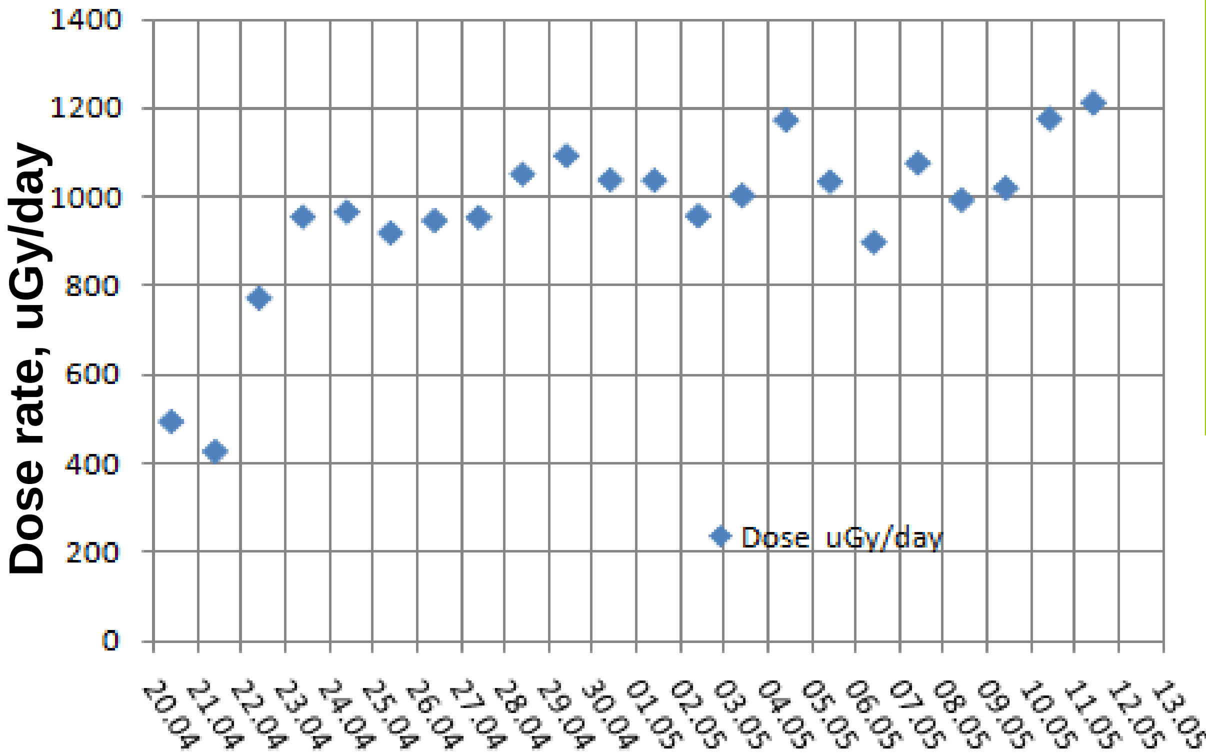




Shielding thickness, g/cm^2 Al

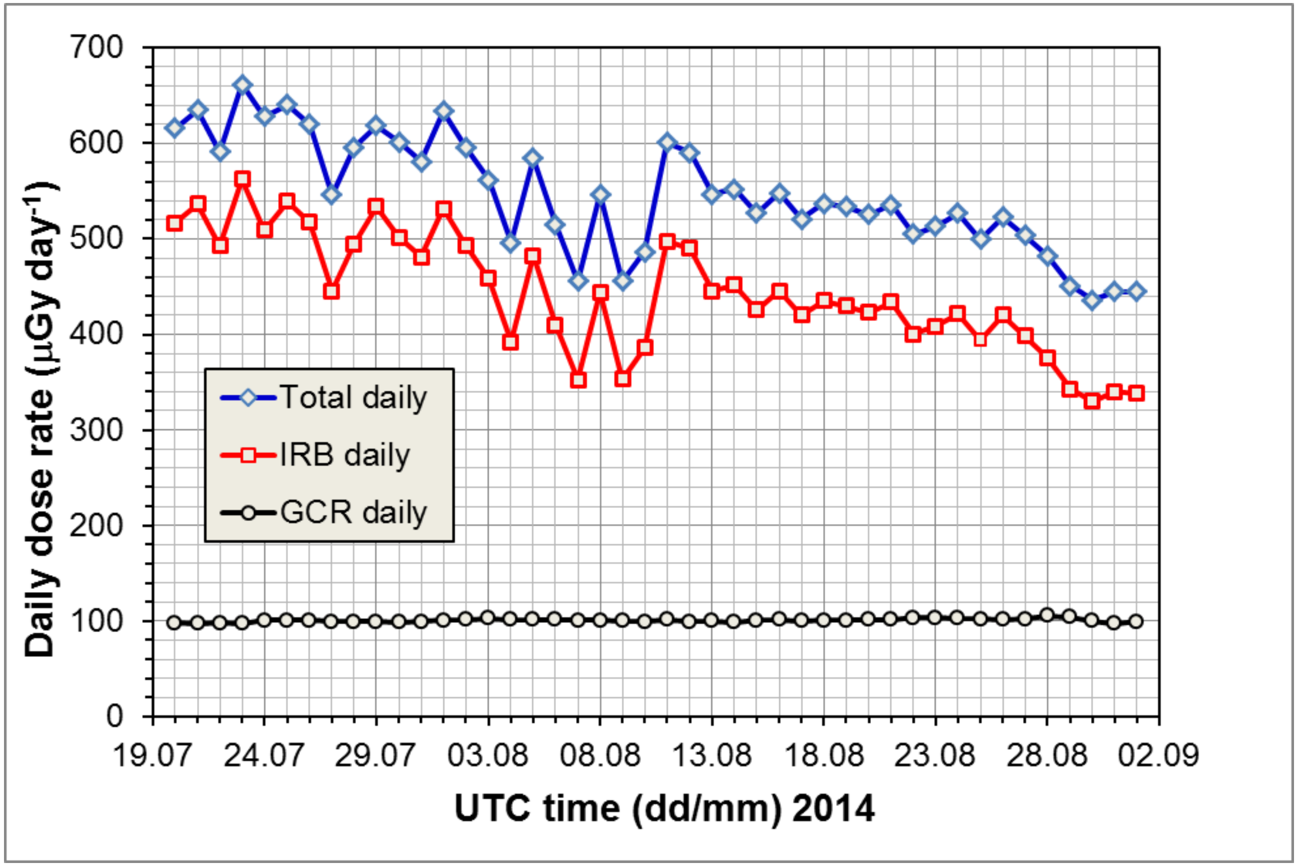
$D_{max}/ D_{min} \sim 10^3$

Bion-M1 dose rate as obtained by RD3-B3 instrument inside the recoverable capsule



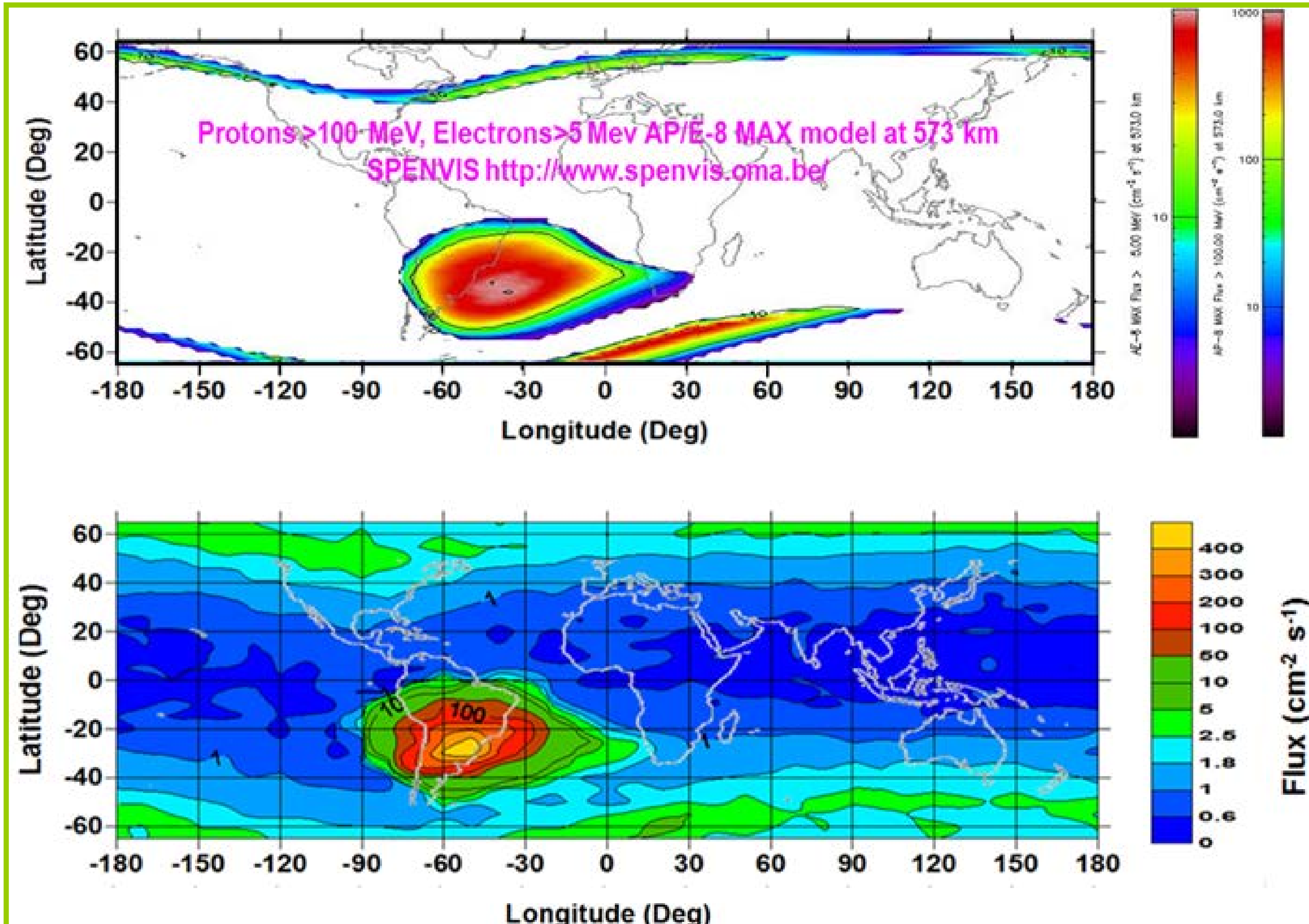
<D> = 1.1±0.1 mGy/day
$<D_{GCR}>$ = 0.1 mGy/day
$<D_{ERB}>$ = 1.0 mGy/day

Foton-M4 dose rate as obtained by RD3-B3 instrument inside the recoverable capsule



$\langle D \rangle = 0.55 \pm 0.05$ mGy/day
$\langle D_{GCR} \rangle = 0.10$ mGy/day
$\langle D_{ERB} \rangle = 0.45$ mGy/day

Comparison of Global Proton Flux Distribution Obtained by RD3-B3 aboard Bion-M1 and AE/AP model data



Bubble detectors inside the Biosatellite

Before flight: no bubbles in the bulb

After the flight: a lot of bubbles!

Bubble Reader was used exactly at the landing place

Bubble detector dose rate is 0.12±0.01 mSv/day (the same as for ISS!),

Averaged SPD dose rate is ~2.5 mSv/day

H_n/H_z < 5 % !

Comparison of neutron dose rates inside different space vehicles

Year	Spacecraft	Orbit parameters			Dose rate, uSv/day
		Apogee, km	Perigee, km	Inclination	
1989	Bion-9*	294	216	82.3	130
1993	Bion-10*	397	226	62.8	227
1993	Mir*	419	399	51.6	149
1996	Bion-11*	401	225	62.8	130
2006	ISS	370	350	51.6	100
2013	ISS	430	410	51.6	180
2013	Bion-M1	585	565	64.8	116
2014	Foton-M4	565	260	64.5	70

*The data are borrowed from Yu.A. Akatov's archives. Measurements performed in cooperation with Bubble Technology Industries Inc., Canada.

Correction factor of 1.62 was applied to all data to account difference of AmBe neutron source from energy spectrum of space neutrons

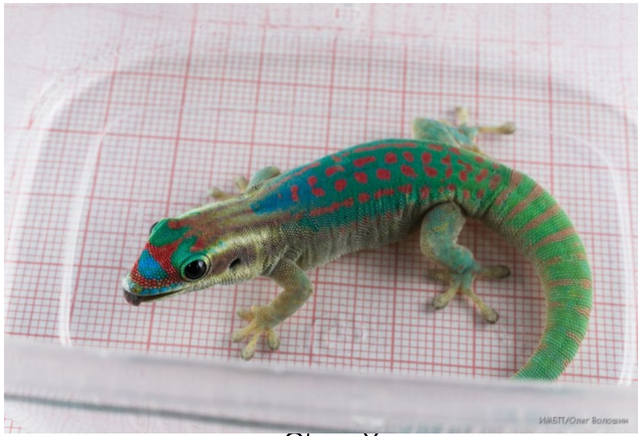
Concluding Remarks

- A special radiation dosimetry study was carried out on board the Bion-M1 and Foton-M4 biological satellites by international partners in 2013 and 2014
- Only a part of the results has been presented here:
  - Space radiation doses were measured inside and outside the recoverable capsule with passive detectors (TLD and STD))and inside the satellites with active Si detector
  - Absorbed doses measured outside the satellites vary from 1 Gy/day to 0.3 mGy/day as dependent on the detector shielding
  - Internal doses are about 6 times higher that that in ISS and have the following variation scale,
    $D_{max}/D_{min} \sim 2.5$, and $H_{max}/H_{min} \sim 1.7$
  - Both aboard Bion-M1 and Foton-M4, measured neutron dose are about 5% of charged-particle doses

Concluding Remarks (2)

- The Bion-M4 and Fotom-M4 space experiments should be followed by detailed data analysis and intercomparison
- In the next Bion-M2 mission
  - Modernization of the outside containers to provide power supple for active instruments is necessary
  - New active instruments should be used inside and outside the satellite
  - Neutron dose measurements should continued with spectrometric detectors
  - The lessons learned should be accounted for the future space experiment aboard Bion-M2 in 2020
- New international collaboration team should be established

The End



Otava Yo