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РКК ЭНЕРГИЯ

STUDY OF DOSE DISTRIBUTION IN A HUMAN BODY IN SPACE FLIGHT WITH THE SPHERICAL TISSUE-EQUIVALENT PHANTOM

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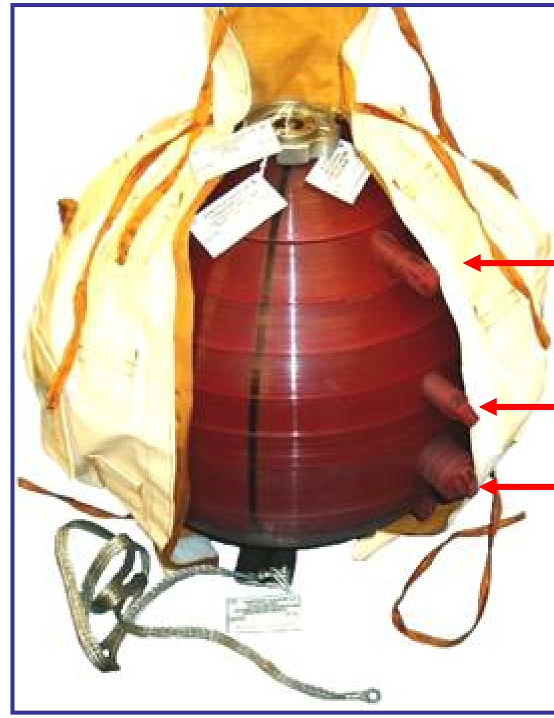
Main goals of the MATROSHKA-R space experiment

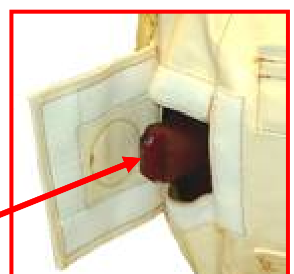
- Long-term dose measurements inside the phantoms, in the habitat module, and outside the ISS;
- Verification of the shielding models and transport codes for calculating the dose distribution inside the ISS and inside the phantoms

Spherical phantom
Size: 370x370x390 mm; mass: 32 kg

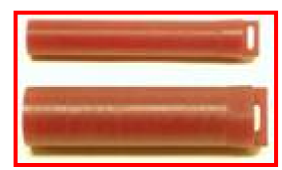


Working jacket with

TLDs and CR-39 in pockets



Container



Containers

- **Phantom package:**

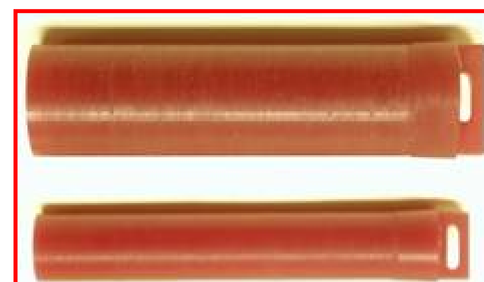
1. **Working jacket**
2. **Container set**
3. **Grounding band**

1

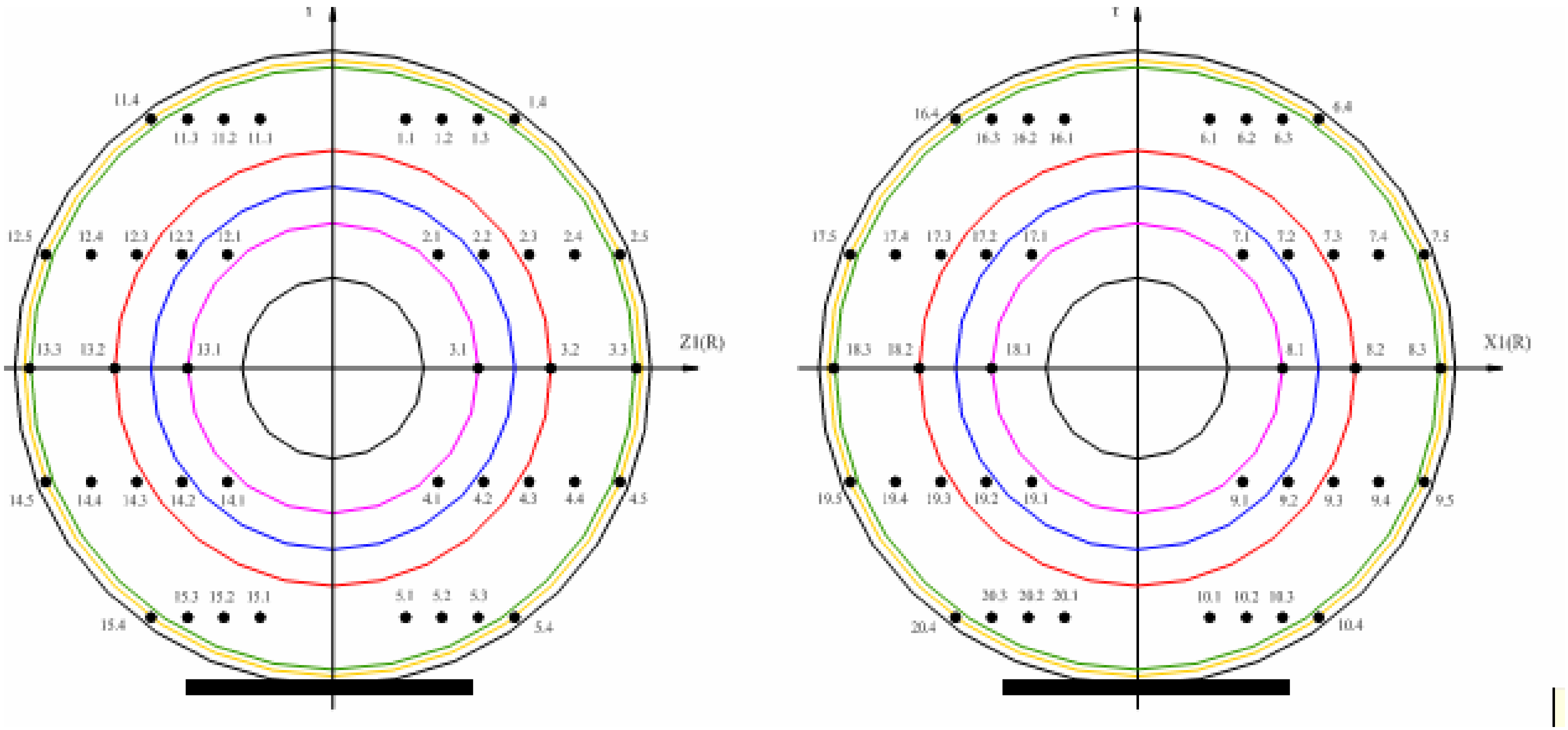
2

3

Containers with detectors

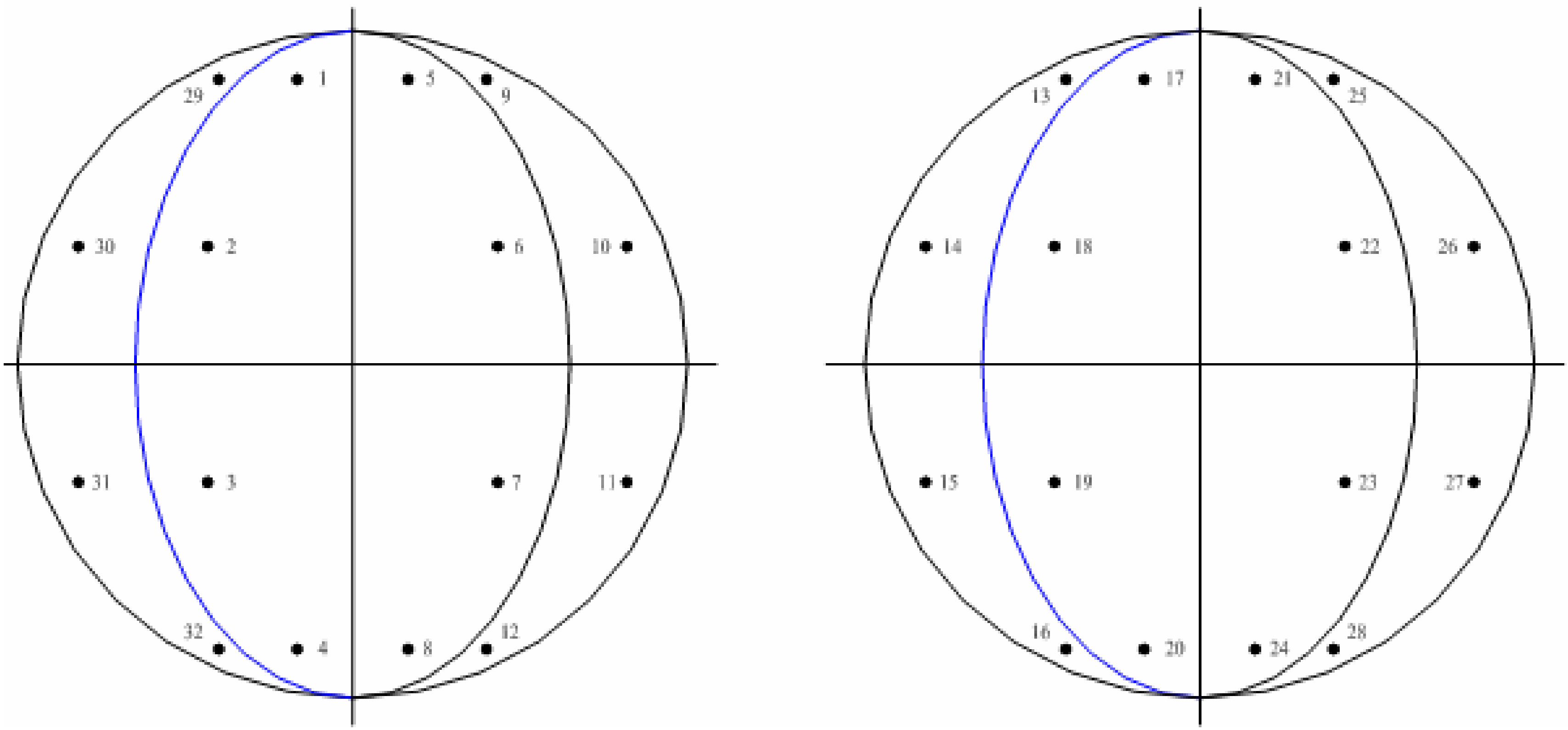


Locations of the container detectors



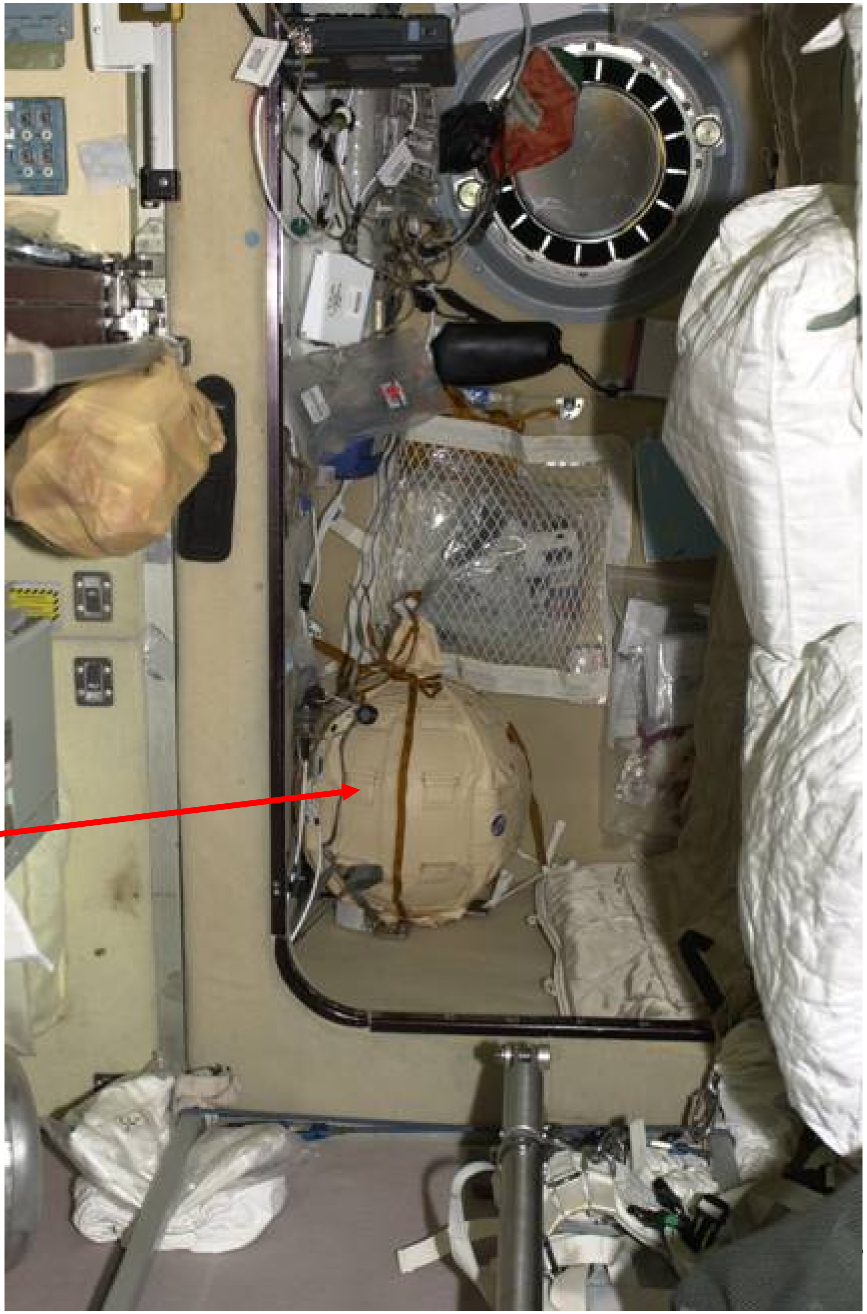
20 containers with the detectors inside the phantom

Locations of the jacket detectors



32 pockets with the detectors on the phantom surface

Spherical phantom in the crew cabin (right board)



Comparison of the spherical and anthropomorphic phantom properties

	Spherical phantom	**Anthropomorphic phantom**
Mass	32 kg	Full body is 70 kg; The torso with head is about 60 kg
Size	35 cm diameter	Full height is 170 cm; The torso with head height is about 90 cm
Detector placement and retrieval	Easy retrieval of the detector containers from the radial holes without full disassembling	Special locations for the detectors distributed throughout the phantom body. Full disassembling is required for the detector retrieval

Crew working with the phantoms

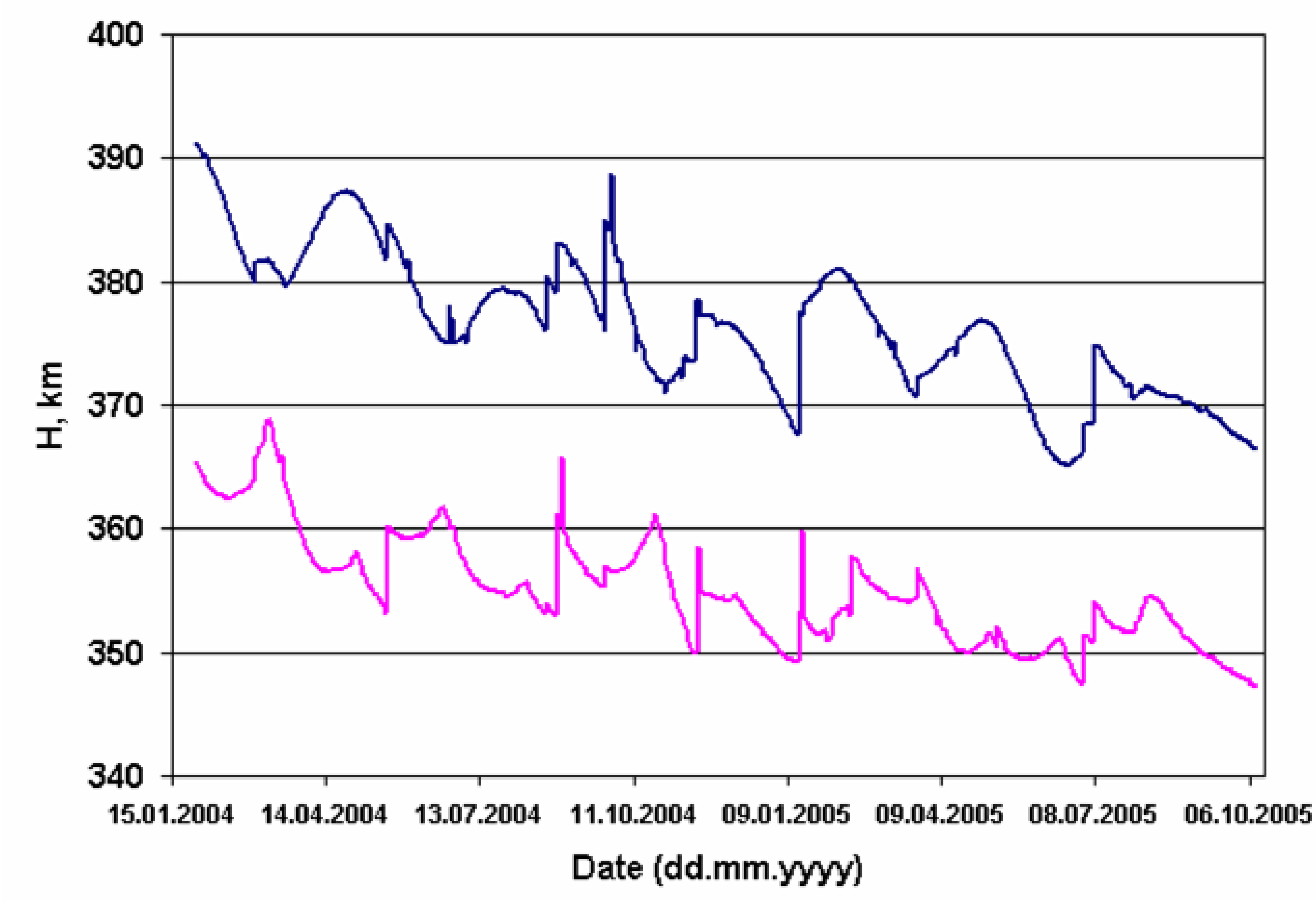
0.5 crewmember working hour

8 working hours

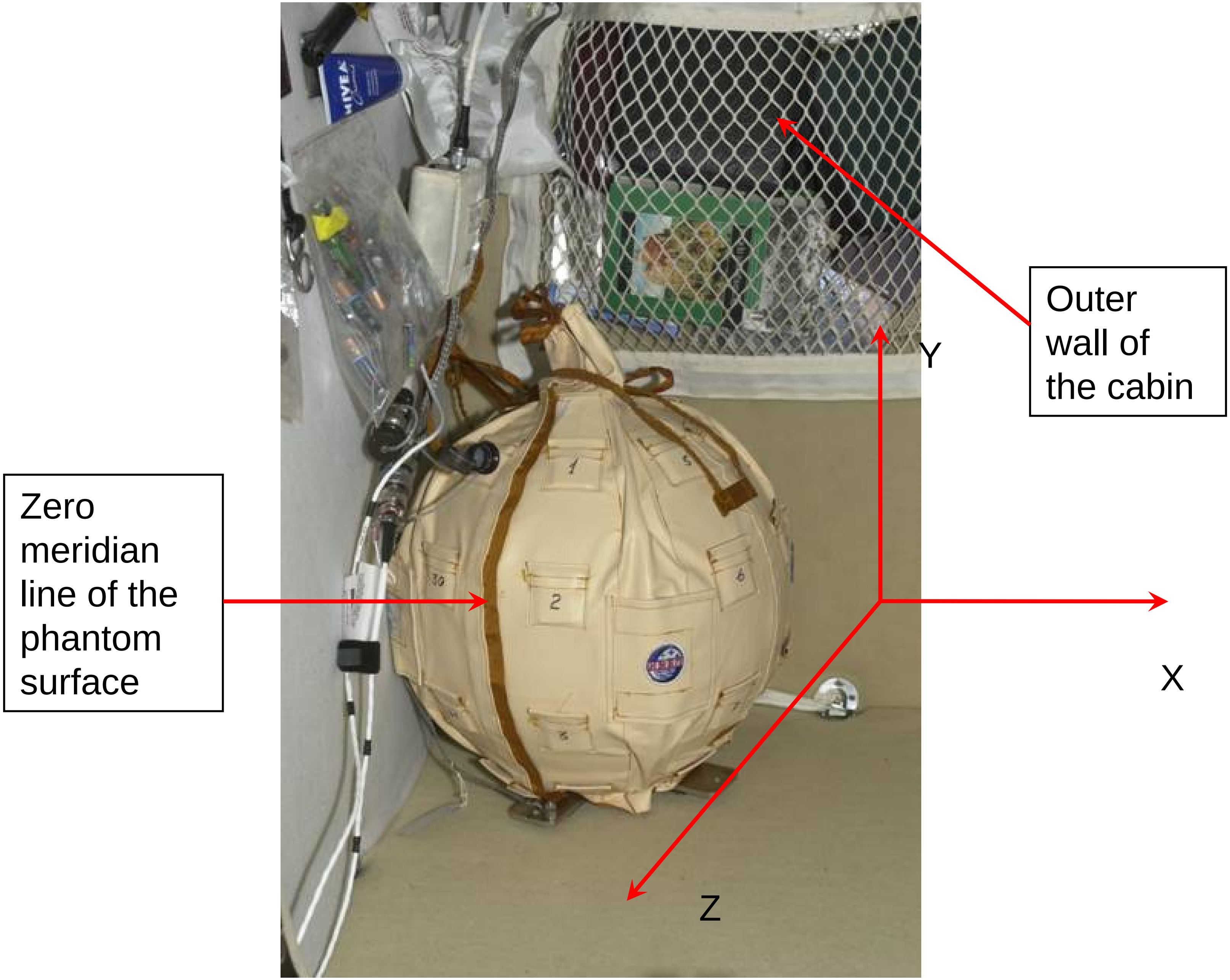
Chemical composition of the phantom tissue

Chemical element	Standardized phantom	ESA phantom (Rando)	The Russian Spherical phantom
	%		
H	10	9.2	8.6
N	2.6	2.5	2.6
O	61.3	20.3	32.3
C	23.1	67.8	56.5

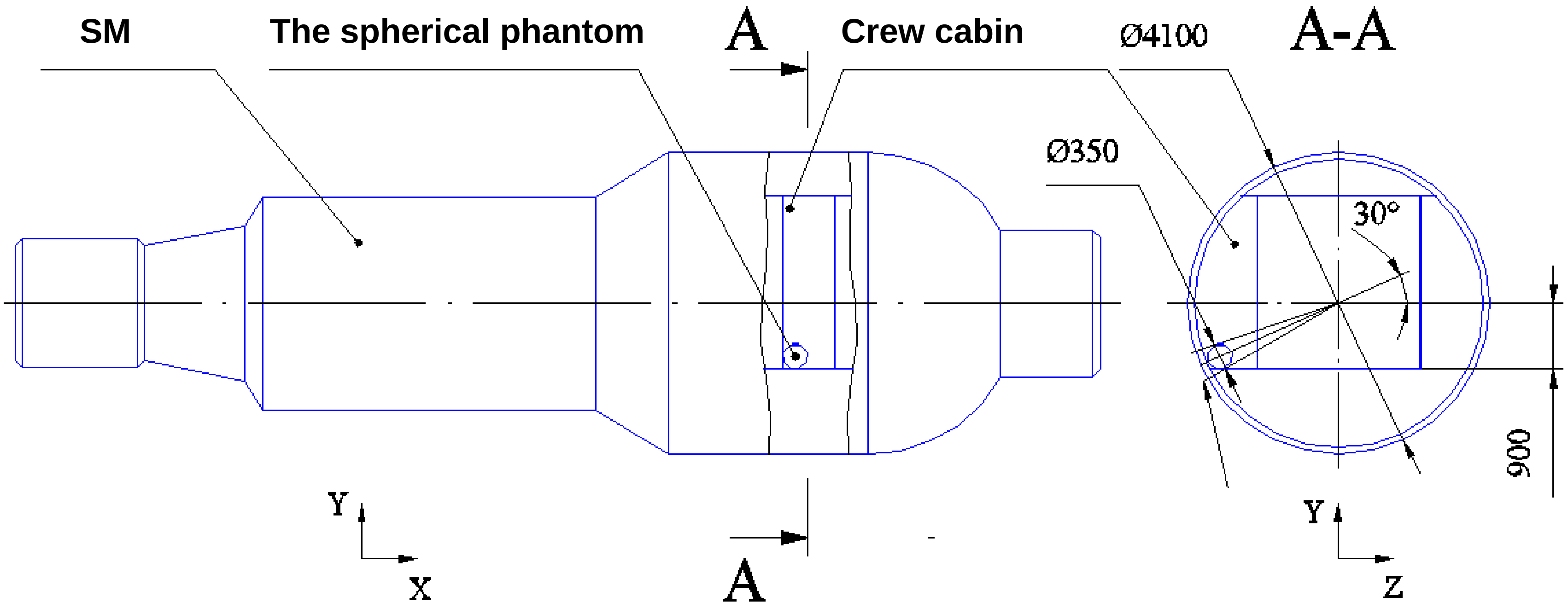
Apogee and perigee altitudes during Matroshka-R session (425 days)



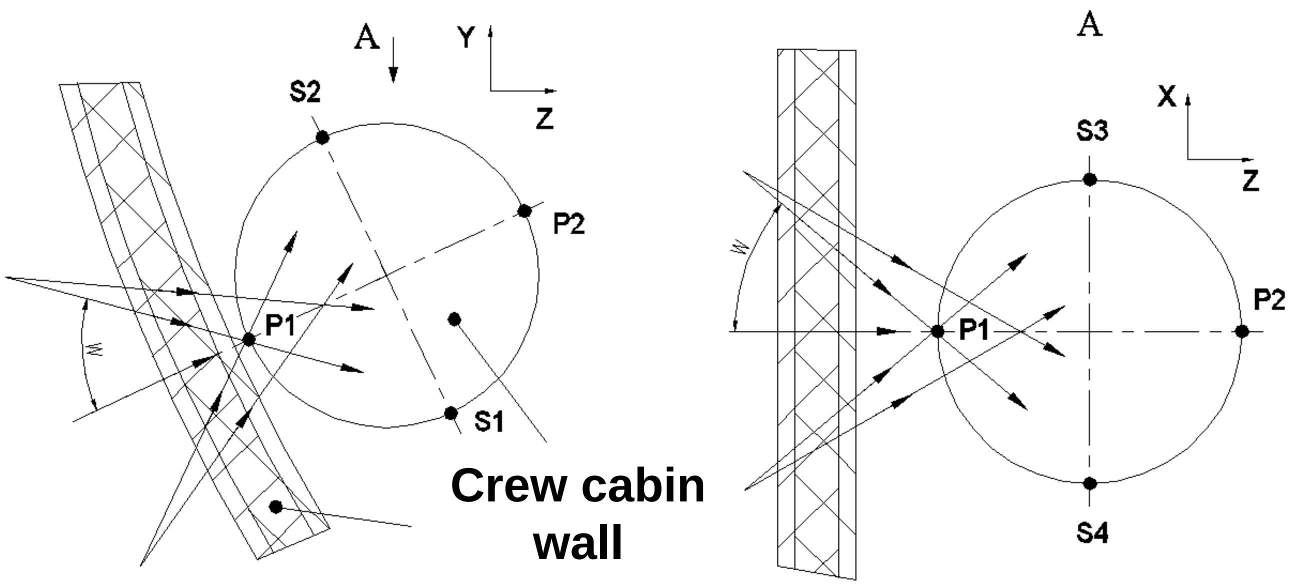
Detectors Returned On-ground in Oct. 2005


Outer wall of the cabin
Zero meridian line of the phantom surface
Y
X
Z

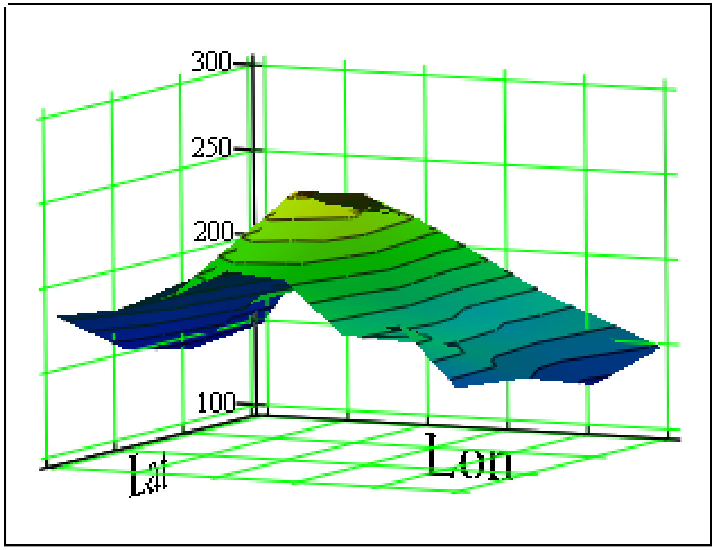
The spherical phantom location in the Service Module

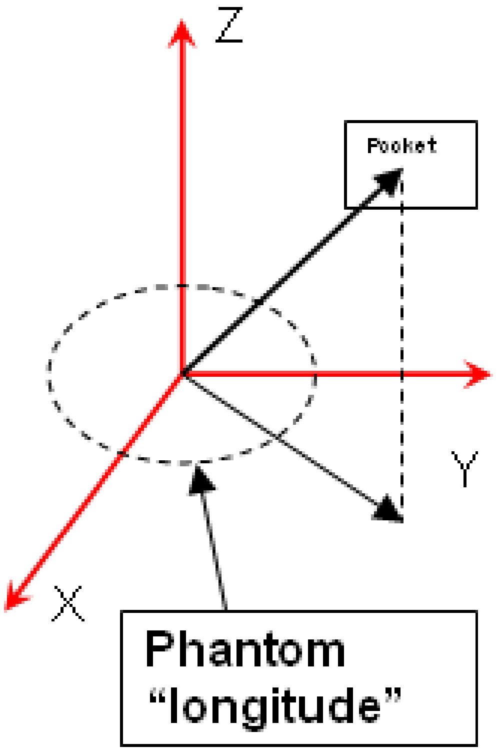


The phantom near the cabin wall



Dose distribution in the phantom jacket pockets



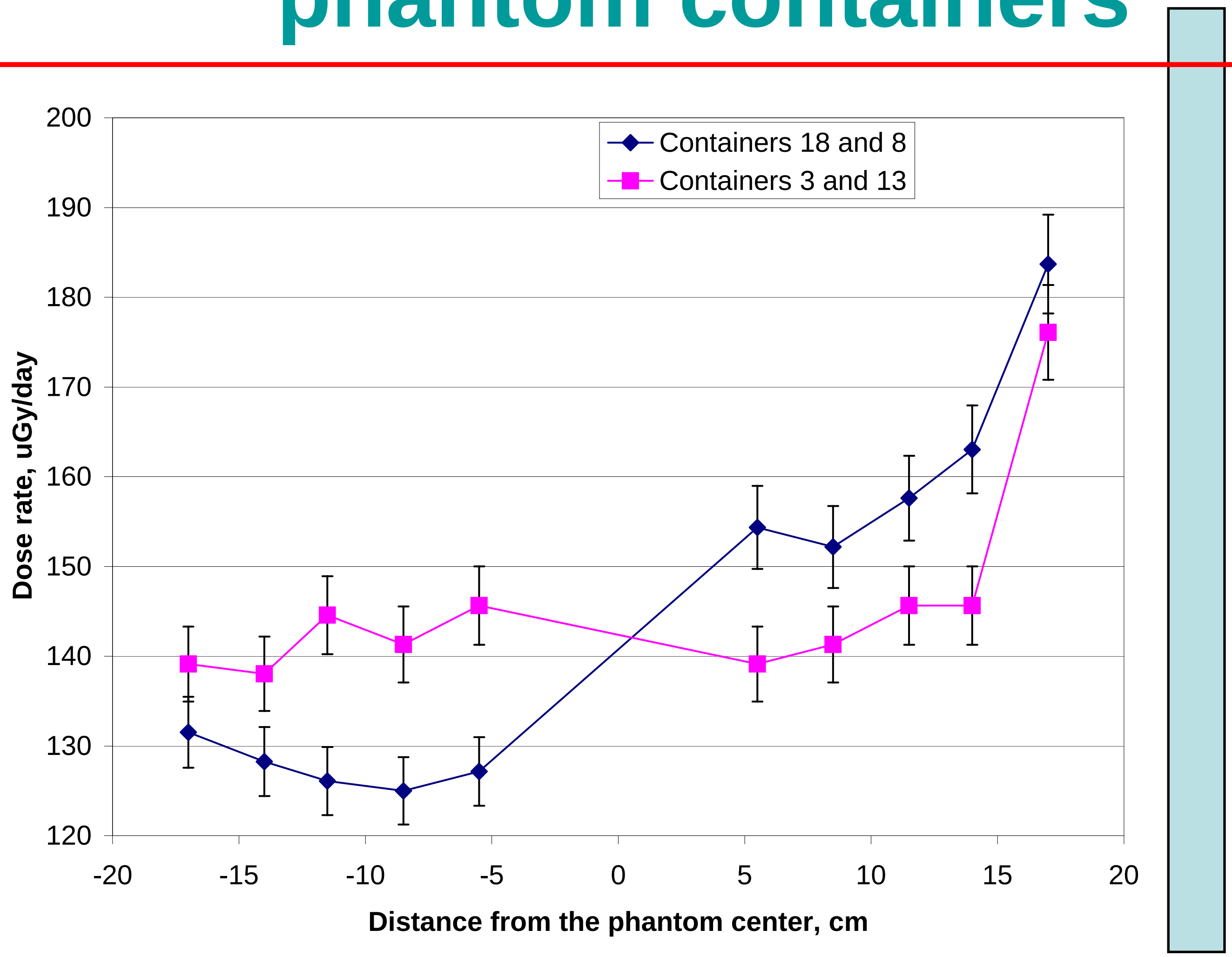


D_{mean} = 140 μGy/day

D_{min} = 103

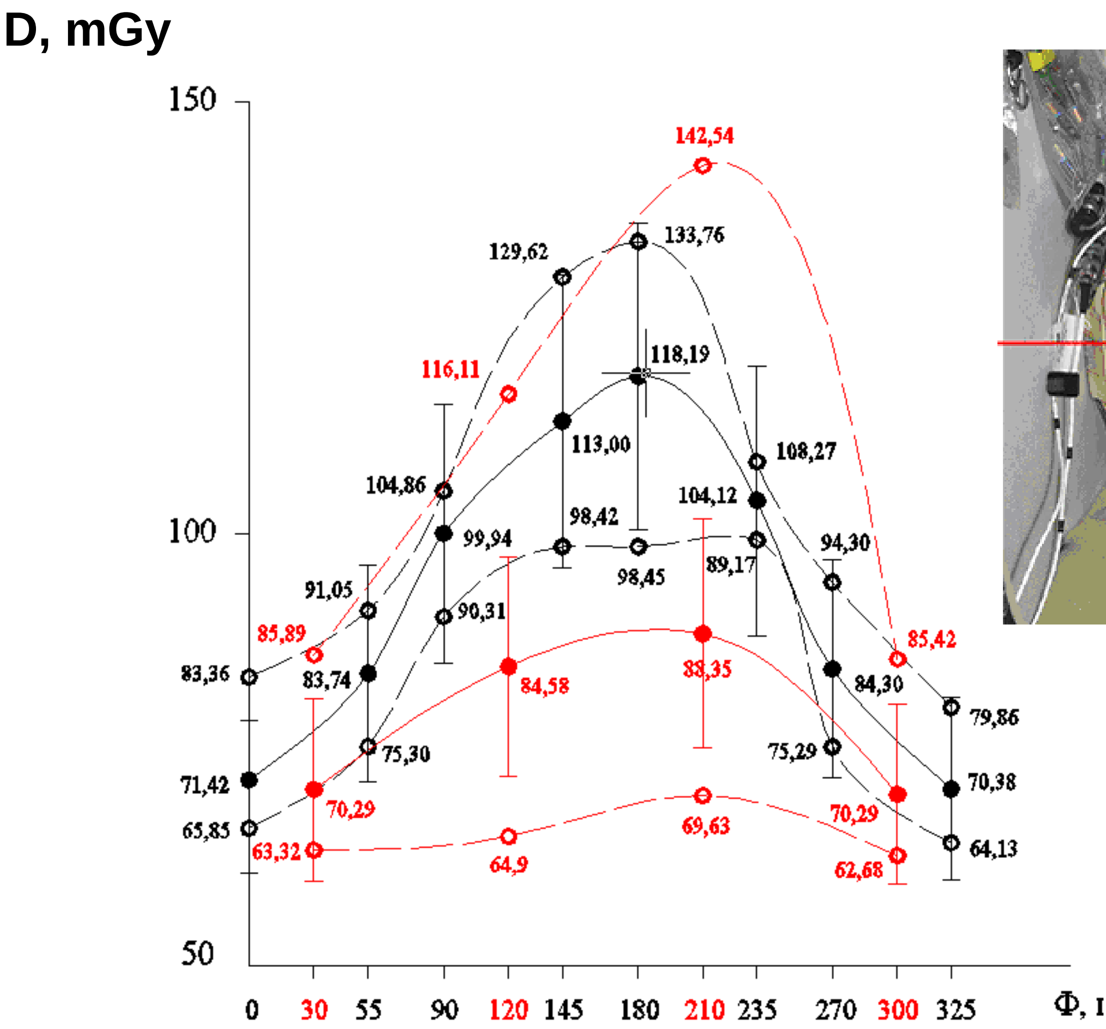
D_{max} = 191

The dose rates measured in the phantom containers

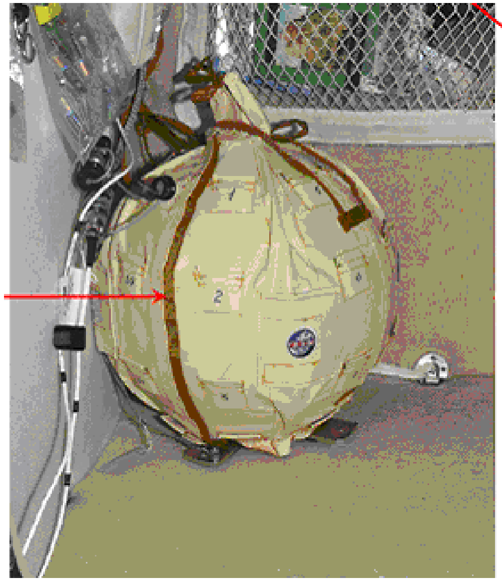


Crew cabin outer wall

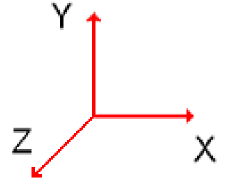
Dose distribution (XZ-plate)



XZ plate

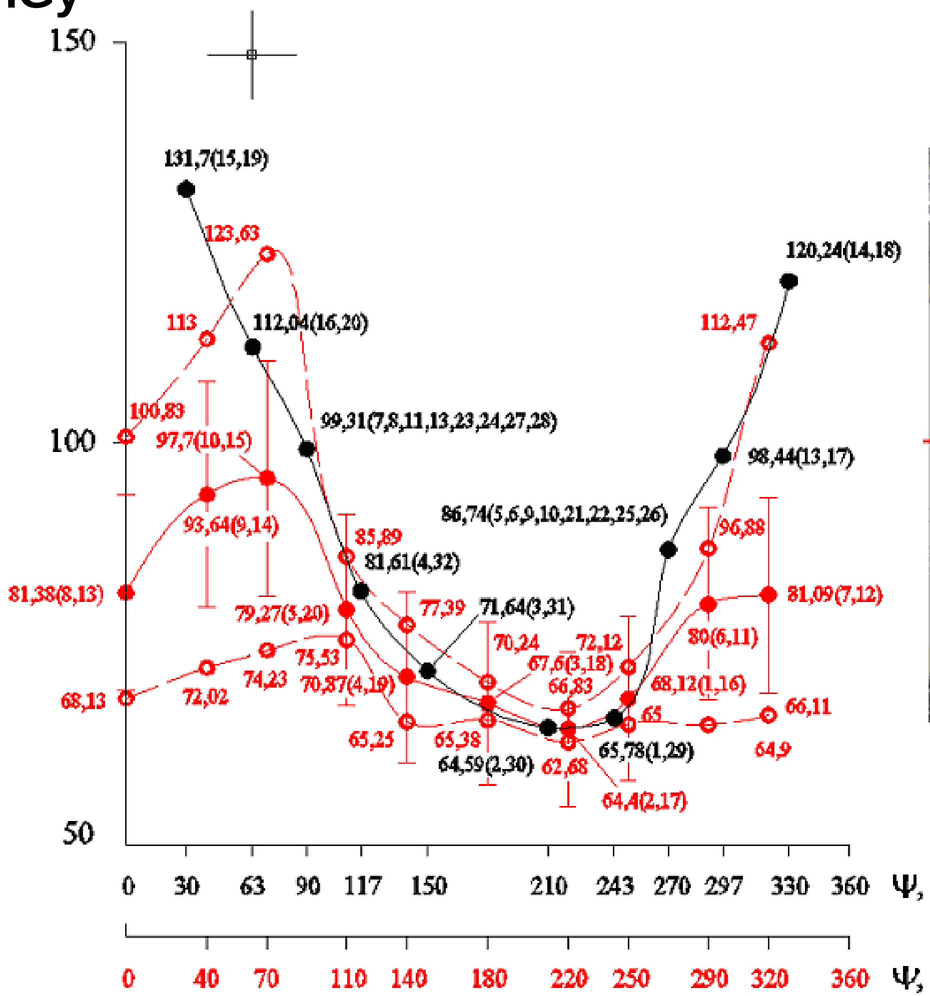


Crew cabin outer wall

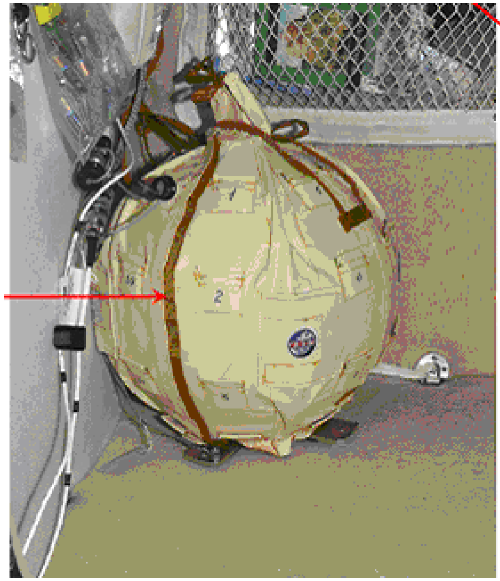


Dose distribution (YZ-plate)

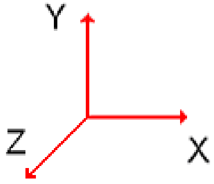
D, mGy



YZ plate



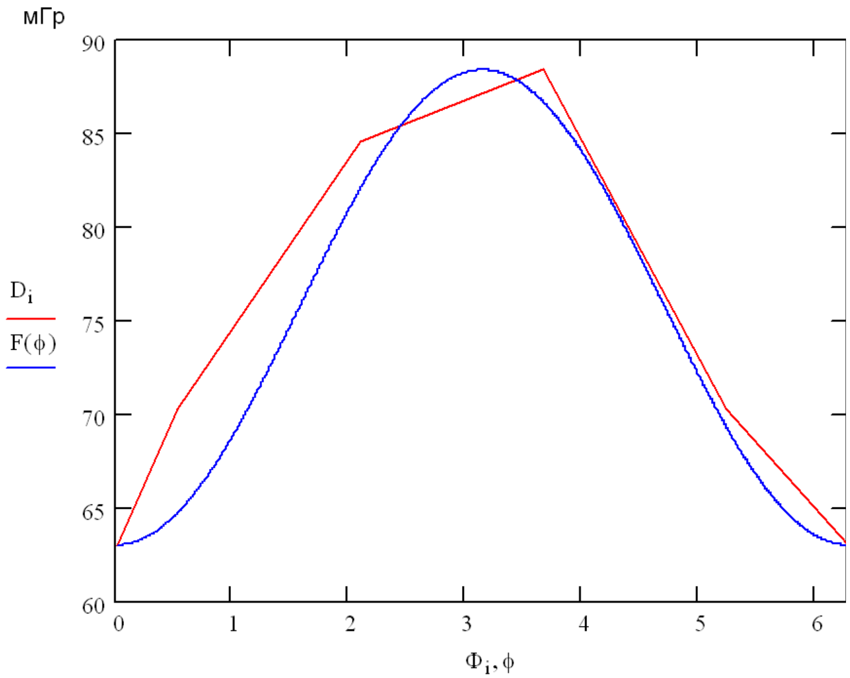
Crew cabin outer wall

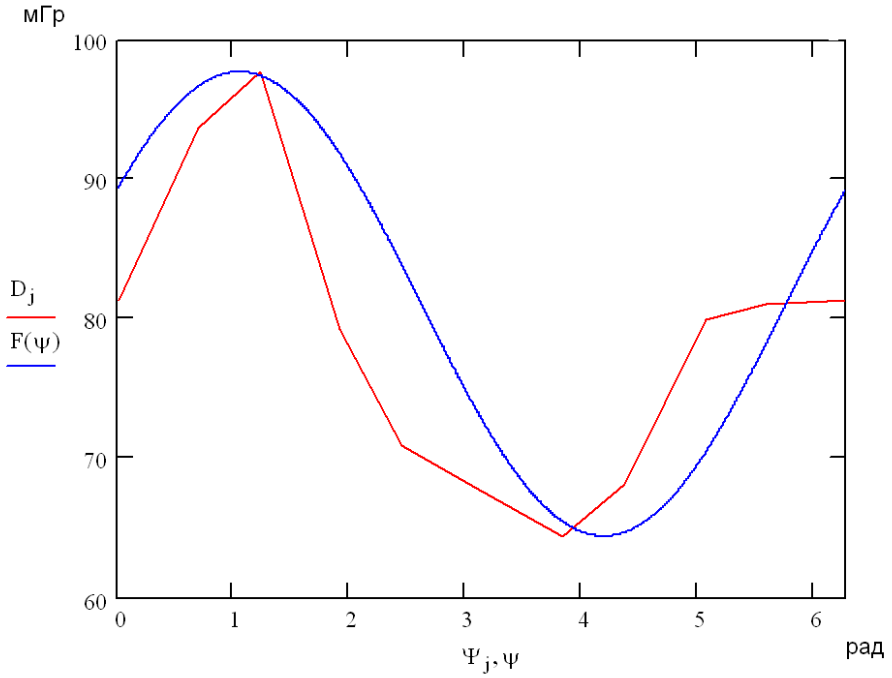


Parameterization of dose distribution versus angles

$$F(\varphi) = \frac{D\max - D\min}{2} \cdot \sin\left(\varphi + \frac{3\pi}{2}\right) + \left(D\min + \left(\frac{D\max - D\min}{2}\right)\right)$$ **XZ plate**

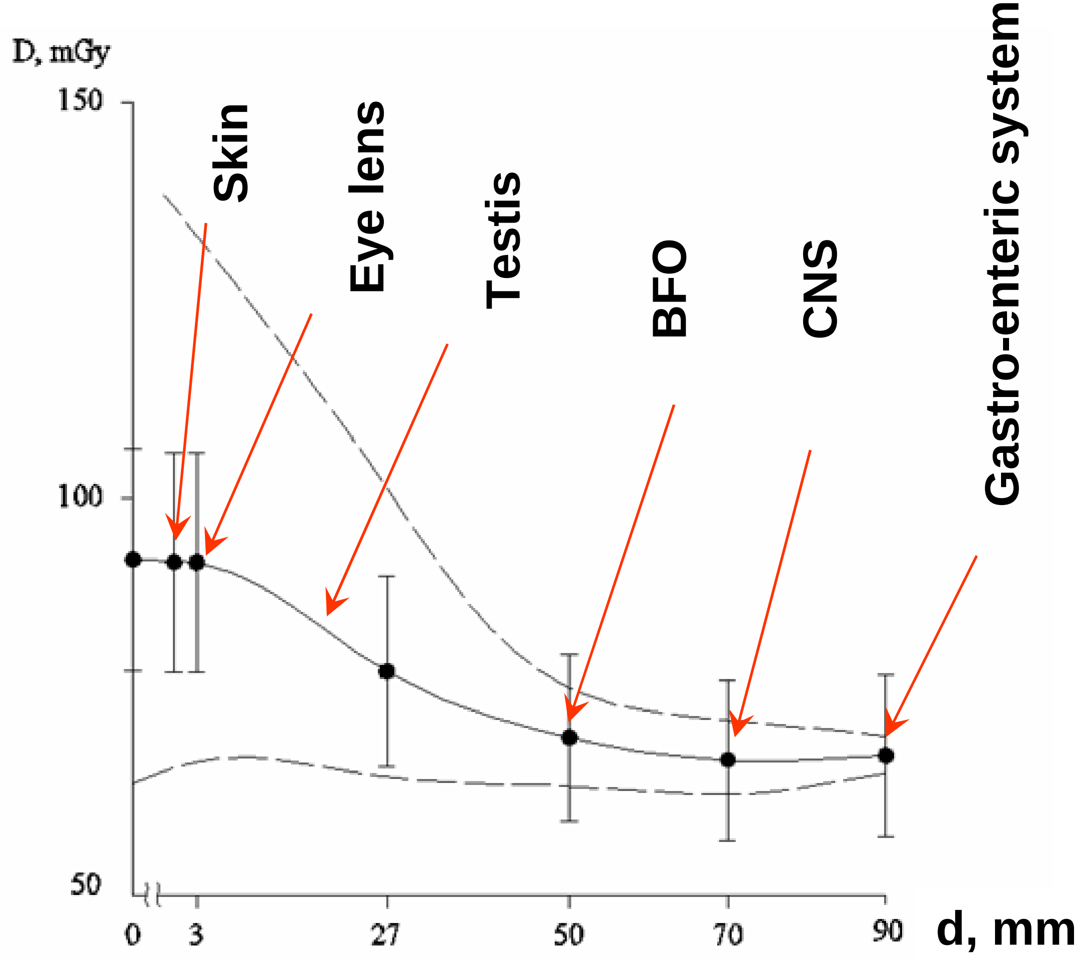
$$F(\psi) = \frac{D\max - D\min}{2} \cdot \sin\left(\psi + \frac{\pi}{6}\right) + \left(D\min + \left(\frac{D\max - D\min}{2}\right)\right)$$ **YZ plate**





Doses in critical organs as obtained in the spherical phantom

Organ	Depth, mm
Skin	1
Eye lens	3
Testis	20
BFO	50
CNS	70
GES	90



Mean-tissue and effective dose estimation

$$D_{mean-tissue} = \frac{\int D(\vec{r})dm}{\int dm}$$

$$D_{eff} = \sum_i w_i D_i$$

- $D_{mean\text{-}tissue}$ = 81 mGy (for an arbitrary phantom attitude)
- D_{eff} = from 83 to 86 mGy
  or from 2.5 to 5% higher than $D_{mean\text{-}tissue}$ as dependent on the testis attitude to the crew cabin wall

Conclusion

- The spherical phantom and its tissue-equivalent material have passed the successful test in conditions of a real space flight at the Russian Segment of ISS.
- Critical organ doses of a crew member in the crew cabin were estimated with the spherical phantom
- Mean-tissue and effective doses were also estimated in the crew cabin
- The spherical phantom can be widely used in future space exploratory missions as a witness of the crew' radiation exposure

The End