FLYDOS

Grant Giovani CSN 5

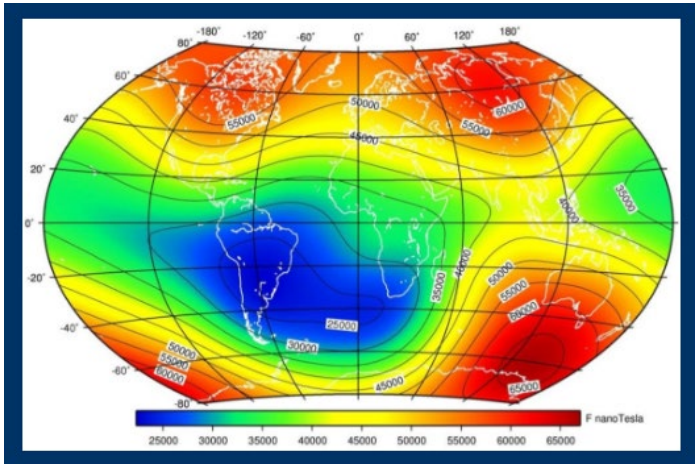
Neutron dosimetry for aircrew and onboard electronic components

06/07/2023

Alessandro Calamida (& LEMRAP Group - INFN)
IEAv (Brazil) – Instituto De Estudos Avançados

Framework

Data gap on neutron measurements at flight altitudes.



Sensitive targets:

- Aircrew radiation protection:
  2013/59/EURATOM and D. Lgs. 101/2020;
- Single Event Effects (SEE):
  Affecting on-board electronics;

Collaboration:

- INFN-LNF;
- IEAv (Brazil), Instituto De Estudos Avançados.

Importance of **neutron spectrometry and dosimetry at flight altitude** in the SAA:

- Very few data available;
- Barycentre now in South Brazil - Van Allen Belts closest to the Earth's surface:
  - ✓ Minimum geomagnetic field;
  - ✓ Highest flux of neutrons (95% of SEE in satellites occur in SAA + poles).

Objectives:

Validation of:

- **Codes for aircrew dosimetry:**
  - ✓ New code REP by IEAv;
- **Models for SEE in aircrafts.**

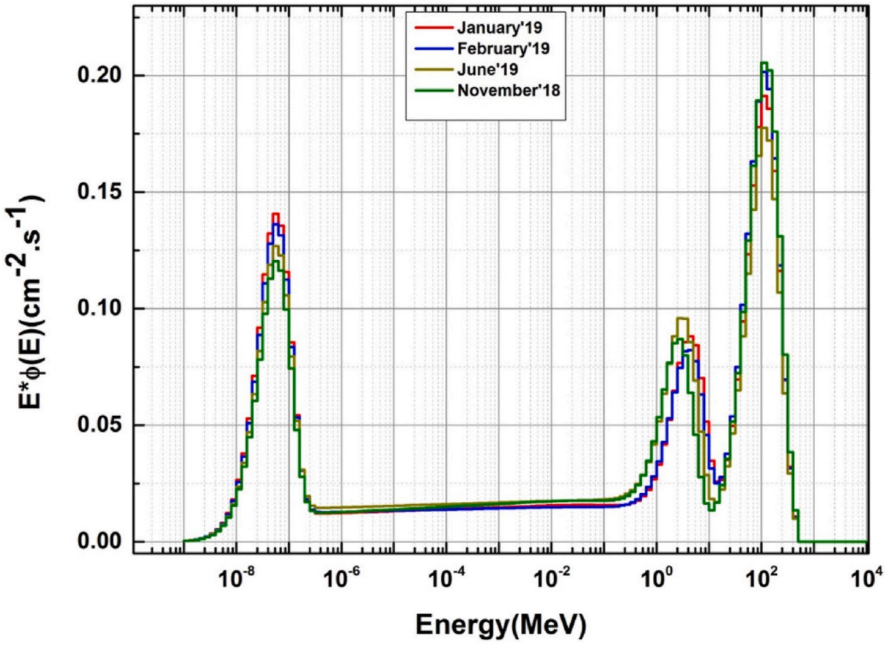
Through neutron measurements function of the elevation *(dedicated flight up to 12 km).*

1. Neutron Spectrum – Compact ERBSS;
2. Individual Dose –personal dosimeter extended to high-E;
3. Organ Dose – Sensors in anthropomorphic phantom;
4. Ambient dose – Commercial dosemeters from IEAv;
5. Thermal neutron mapping on-board aircraft (SEE-related);
6. Validation of a new aircrew dosimetry code (REP).

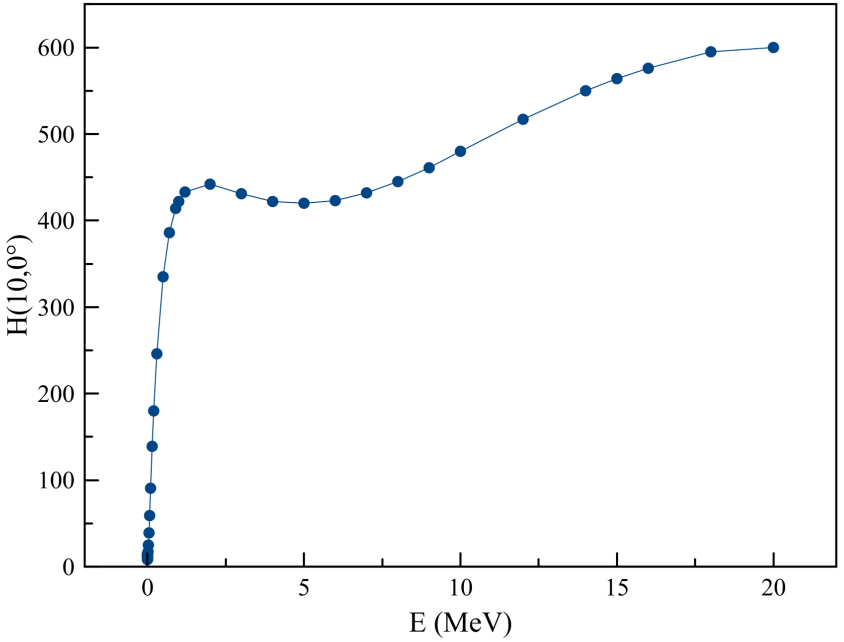
Neutrons at High Elevations

According to the IEC 62396 Part 5, almost $\sim 50 \div 60\,\%$ of the dose equivalent at high elevations is due to neutrons.

Cosmic neutron spectra, Gulmarg, India, ~2600 m.

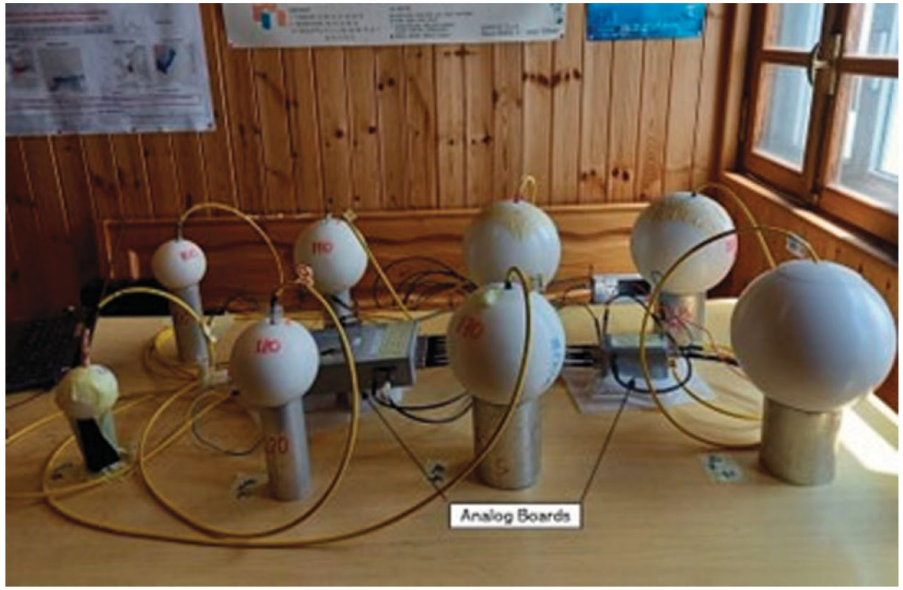


Fluence to Dose coefficients for neutrons.



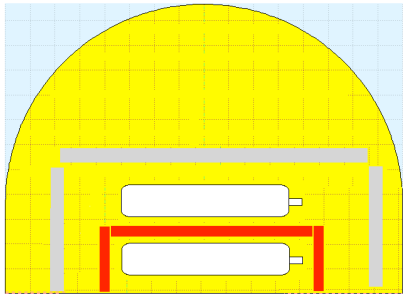
Neutron Spectrum with **Extended Range Bonner Sphere Spectrometer** (ERBSS)

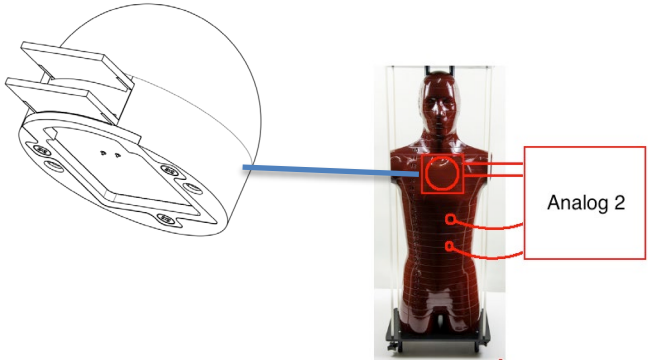
- ^{3}He based, 8 spheres (2 high-energy);
- Compact and stand-alone (no PC allowed);
- Calibrated in ISO reference neutron fields;
- Tested at high altitudes at Testa Grigia lab (~3500 m);
- Final measurement in the SAA at high altitudes with a dedicated flight from 8 km to 12 km.



Individual dosimetry

1. DOIN patented design will be:
   - Extended to high-Energy;
   - Calibrated in reference ISO fields;
   - Tested at high-elevation (Testa Grigia);
   - Final measurements onboard the dedicated flight (8 km to 12 km);
2. IEAv will develop an anthropomorphic phantom (RANDO-type) for:
   - Allocating DOIN-H;
   - Allocating internal neutron sensors for organ-dose measurements.





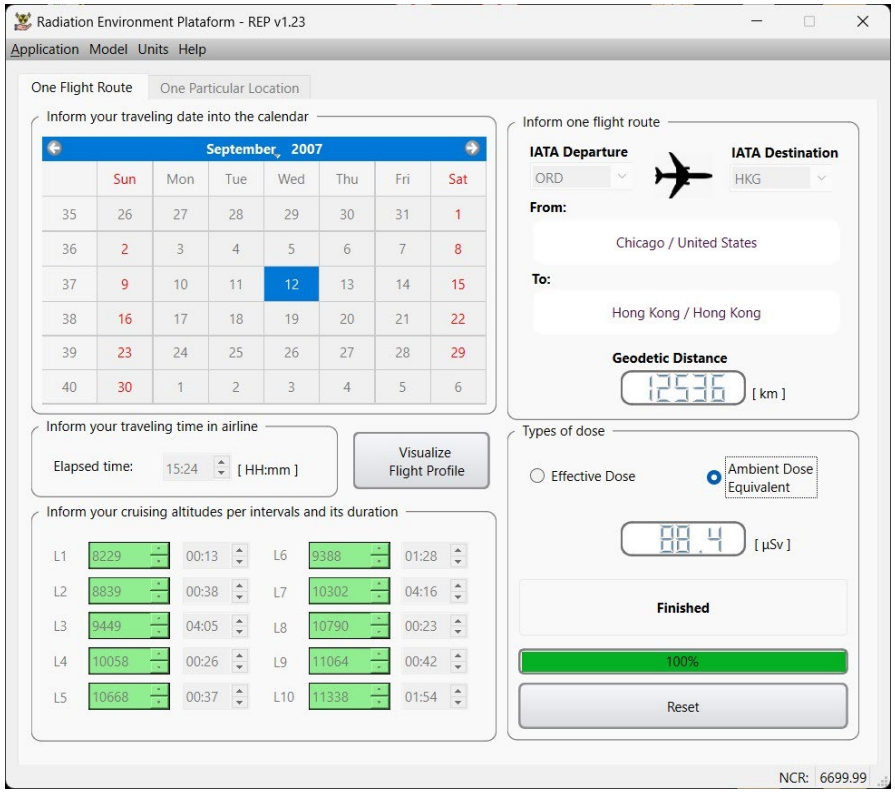
Thermal neutron mapping on-board

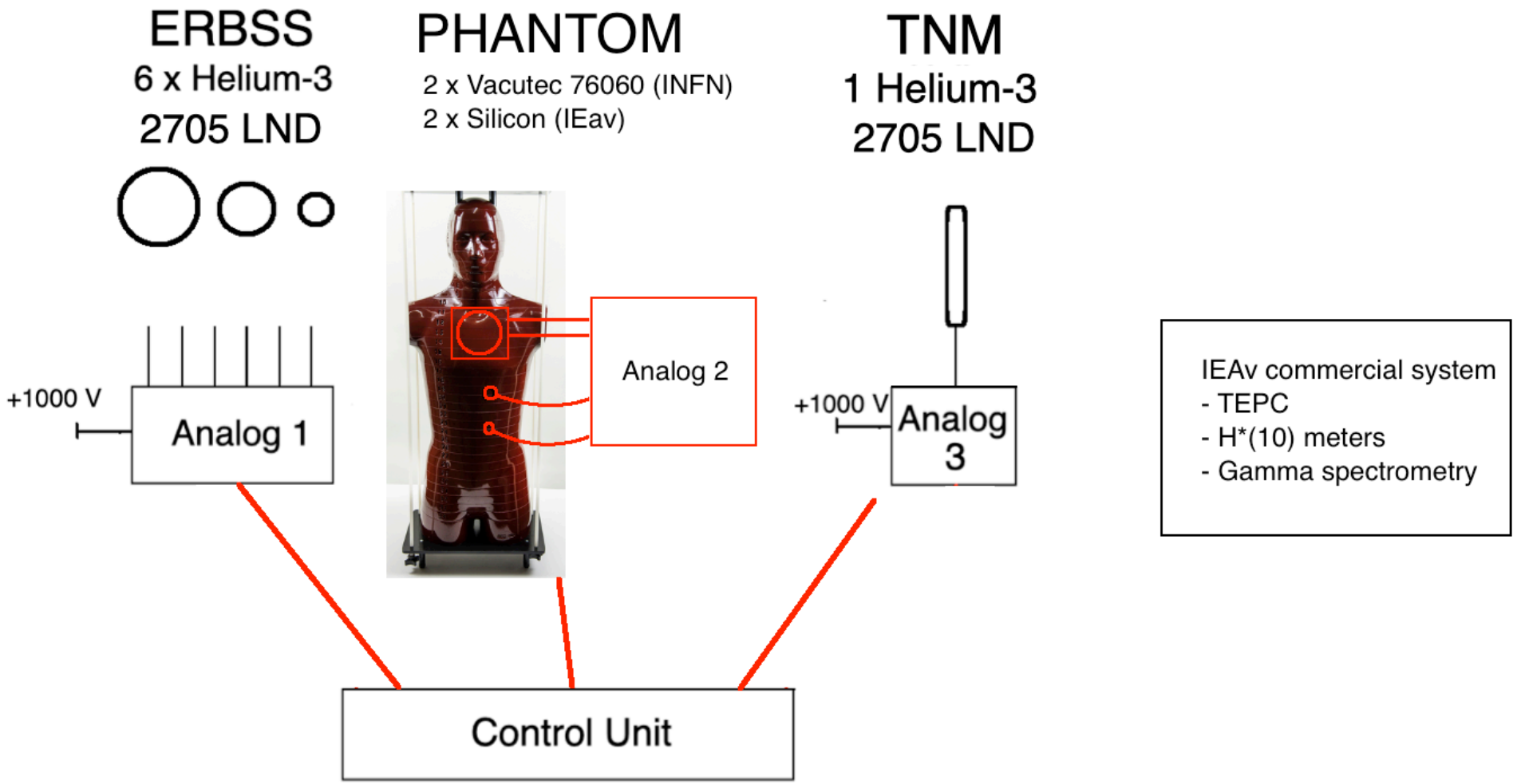
1. According to International IEC and Aeronautic EASA Standards, thermal neutrons are mainly responsible for SEE onboard;
2. Only numerical works were done to estimate the distribution of the thermal neutron field onboard;
3. The dedicated flight will comprise an ^{3}He based thermal neutron detector mapping their distribution onboard with the purpose of providing MEASURED data for the first time.

Aircrew dosimetry

IEAv developed a new code (REP) for aircrew dosimetry:

- Possibility to change nuclear models;
- Directional distributions are given up to 80 km;
- FLYDOS measurements will be fundamental for the validation of REP and other existing aircrew dosimetry codes.




ERBSS
6 x Helium-3
2705 LND
PHANTOM
2 x Vacutec 76060 (INFN)
2 x Silicon (IEav)
TNM
1 Helium-3
2705 LND
+1000 V
Analog 1
Analog 2
+1000 V
Analog 3
Control Unit
IEAv commercial system
- TEPC
- H*(10) meters
- Gamma spectrometry

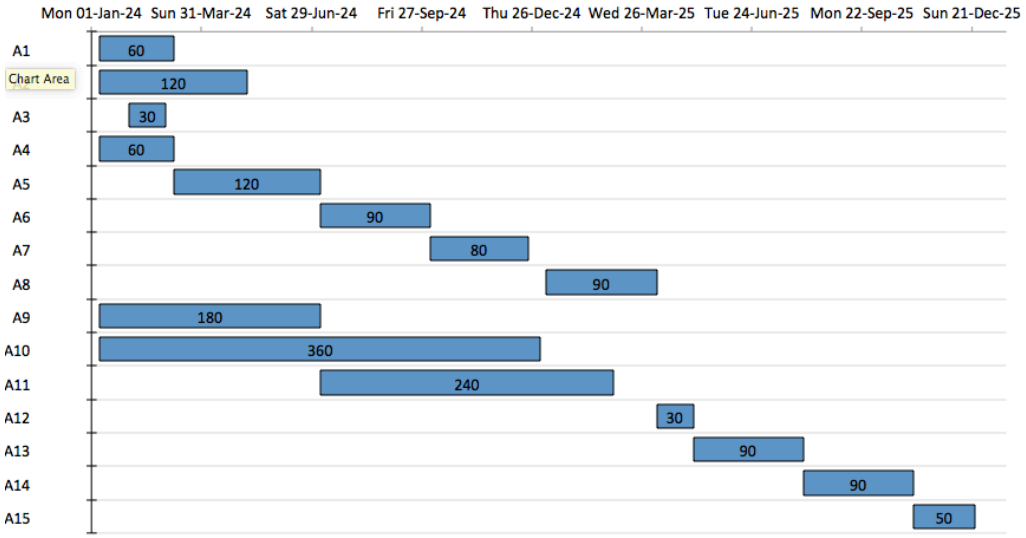
FLYDOS Participants

PI of the Project

Name	Institution	FTE
Alessandro Calamida	INFN-LNF (assegnista)	1
Roberto Bedogni	INFN-LNF (T.I., Ric. II)	0.5
Claudio Cantone	INFN-LNF ()	0.3
Jose-Maria Gomez-Ròs	INFN-LNF (associato)	0.3
Antonino Pietropaolo	INFN-LNF (associato)	0.3
Claudio Antonio Federico	IEAv Brazil (senior Res.)	0.3
Odair Lelis Gonçalez	IEAv Brazil (senior Res.)	0.2
Adriane Cristina Mendes Prado	IEAv Brazil (junior Res.)	0.3
Williams Principe Fernandes	IEAv Brazil (junior Res.)	0.3
Felipe B. Gaspar	IEAv Brazil (Master Student)	0.5
Maurizio T. Pazianotto	IEAv Brazil (senior Res.)	0.3
Guilherme Gazolla Santana	IEAv Brazil (Master Student)	0.2
TOTAL		4.5

FLYDOS Activities

Activity	Numbe	Resp.	Pers.
Simulation of the device rsponses	A1	INFN	AC, JG
Supply ^{3}He Detectors	A2	INFN	AC, RB
ERBSS, TNM and DOIN-H: Mechanical Design	A3	INFN	AC, RB, CC
ERBSS, TNM and DOIN-H: Electronics Design	A4	INFN	AC, RB, CC
ERBSS, TNM and DOIN-H: Meccanics and Electronic Manufacturing	A5	INFN	AC, external companies
ERBSS, TNM and DOIN-H: assembling and electronics/radiation testing at INFN/ Frascati	A6	INFN	AC, RB, AP
ERBSS, TNM and DOIN-H: calibration in reference neutron fields	A7	INFN	AC, RB, AP,B
ERBSS, TNM and DOIN-H: testing at 3480 m at Testa Grigia station	A8	INFN	AC, RB, AP, CC
Supply: RANDO phantom and semiconductior neutron detectors	A9	B	AC, B
Simulation of radiation environment for dedicated flight	A10	B	AC, JG, B
ORGAN DOSE: assemblying detectors in phantom and calibration in reference fields	A11	B	AC, B
ERBSS, TNM and DOIN-H: shipping to Brazil	A12	INFN+B	AC, RB, CC, B
ALL DEVICES: EMC testin and mounting on-board in Brazil	A13	INFN+B	AC, RB, B
Dedicated flight in the SAA in Brazil	A14	INFN+B	AC, RB, AP, B
Data analysis	A15	INFN+B	AC, B



FLYDOS Budget

Year 1	74.97
Consumable	
7 Helium-3 counters LND mod. 2705 for ERBSS	42.5
2 Helium-3 counters Vacutec mod. 76060 for DOIN-H	2.7
Mechanics - manufacturing 6 ERBSS spheres / DOIN-H	12.2
Cabling, connectors, components	1.0
Calibration beam time cost	1.0
Compact electronic	14.6
Subtotal Consumable	74.0
Missions	
ENEA-Bo calibration	0.5
POLIMI calibration	0.5
Subtotal Missions	1.0

Year 2	22
Transportation	
Material transportation towards Brazil, temporary export	5
Subtotal Consumable	5.0
Missions	
Testa Grigia High-E testing	5
Brazil assembly and pre-test	6
Brazil dedicated flight	6
Subtotal Missions	17
TOTAL Project INFN	96.97

The IEAv group will co-fund the project in-kind by providing the following equipment and facilities for 74 k€:

- The RANDO human phantom, 36 k€;
- The dedicated flight, for an estimated cost of 20 k€;
- The semiconductor detectors that will be installed in the phantom organs, 1 k€;
- The beam time for the Organ Dose system calibration, 1 k€;
- The manufacturing of the mechanical support for the FLYDOS in the aircraft, 5 k€.
- The WENDI system for ambient dose equivalent measurement onboard, 11.5 k.

The systems for acquiring micro-dosimetric spectra (TEPC) and total deposited dose in Silicon (LIULIN) are already available at IEAv.

Flight Confirmation

Good news about the flight

Da Claudio Federico il 2023-07-03 14:50

Dettagli Testo semplice

Dear Dr. Alessandro.

I have good news! I would like to inform you that I received an internal report from IPEV confirming flight support for the experimental mission requested for 2025.

I will keep you informed about any news.

Best regards!
Claudio

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CLAUDIO ANTONIO FEDERICO, Prof. Dr.
Gerente do Projeto ERISA-D
Instituto de Estudos Avançados - IEAv
Departamento de Ciência e Tecnologia Aeroespacial - DCTA
Trevo Coronel Aviador José Alberto Albano do Amarante, n.1 - Bairro Putim
São José dos Campos - SP - Brasil
CEP 12228-001
tel: (12)3947-5510 / 98124-9377
Fax: (12)3944-1177
claudiofedericocaf@fab.mil.br
claudiofederico@ieav.cta.br
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Conclusions

- The data gap for neutrons in the SAA will be filled;
- The dose measurements will allow to assess accurately the effective dose delivered to the aircrew, allowing to solve a long-term problem for the aircrew safety;
- The dose data will allow to experimentally validate a new MC code for the effective dose estimation developed by IEAv, the REP code;
- The mapping of the thermal neutrons in the aircraft will be the first experimental measurement of this kind ever made and it will allow to have a better understanding of SEE occurrence inside the aircraft.

Thanks you all for the Attention!!!