



## **Description of the ERSA and IDA instruments**

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## 1 EAD

The European Active Dosimeter (EAD) is designed as a dosimeter, therefore the main data products are dosimetric quantities as the absorbed dose, the linear energy transfer (LET) spectra and the dose equivalent. For the assessment of these radiation protection dosimetry quantities the EAD uses a combination of two silicon diodes + an additional INSTADOSE detector + an additional RadFet detector for high dose determination.

(Courtesy of T. Berger, U. Straube, M. Dieckmann, ESA Patent 410: WO2015/024591 AI published 02.26.2015, PCT EP2013/ 067 307).

I: Thick and Thin Diode	Thick Diode	Thin Diode
Dimension (cm <sup>2</sup> )	0.3	0.3
Thickness (μm)	300	0.7
Energy deposition range (in Si)	55keV – 16496keV	163keV – 27613keV
Count rate (particles/area/time)	Combination of thick and thin diode	
LET range (in H <sub>2</sub> O)	0.09 – 1470 keV/μm	
Absorbed dose rate $\dot{D}$ (in H <sub>2</sub> O) (μGy/h)	Combination of thick and thick diode	
Dose equivalent rate $\dot{H}$ (in H <sub>2</sub> O) (μSv/h)	Combination of thin and thick diode	
Lowest detection threshold	nGy (example background radiation on Earth)	

II: INSTADOSE	INSTADOSE
Size	~60mm <sup>3</sup>
Absorbed dose rate $\dot{D}$ (in H <sub>2</sub> O) (μGy/h)	Comparison to thick + thin diode absorbed rate
Lowest detection threshold	~10μGy

III: RadFet	RadFet
Size	0.65 x 0.65 x 0.5 mm <sup>3</sup>
Absorbed dose rate $\dot{D}$ (in Si)	Cumulative over mission duration (high dose detector for Solar Particle Events)
Lowest detection threshold	~5mGy

Parameters	Value
Particle types	Protons, helium, heavy ions, electrons (depending on relevant shielding above the diodes). 0.9mm PE converter for neutrons above thin diode
Count rate range (<10% dead time)	1 cts up 10.000 cts/second (thick + think diode)
LET in water range in H <sub>2</sub> O	0.09 – 1470 keV/μm (thick + thin diode)

<b>Deposited energy range in Si</b>	55keV – 16496keV (thick diode) 163keV – 27613keV (thin diode)
<b>Minimum adsorbed dose rate in H<sub>2</sub>O</b>	nGy/hour
<b>Maximum adsorbed dose rate in water</b>	Up to 100s mGy/hour (thick + thin diode) Up to Gy (RadFET)

## 2 SREM

The Standard Radiation Environment Monitor (**SREM**) is a particle detector that measures high energy electrons and protons in 15 energy channels. It consists of 3 silicon diodes working as detectors (D1, D2 and D3) to measure the energy deposition caused by charged particles. The D1 and D2 detectors are arranged in a telescope configuration. If used in a coincidence mode, the particle has to deposit the energy in both of them simultaneously. Events detected by this configuration are divided into 10 bins, (including four proton coincidence bins) and one heavy ion bin. SREM is incapable of discriminating between various heavy ion particle types and identifies particles as heavy ions.

<b>Parameters</b>	<b>Values</b>	
<b>Particle types</b>	Electrons, Protons, Heavy Ions	
<b>Mass</b>	2.5 kg	
<b>Dimension</b>	96 mm x 122 mm x 217 mm	
<b>Power consumption</b>	< 2W	
<b>Floating bus voltage</b>	20 V – 50 V DC	
<b>Temperature range operational</b>	-20 °C up to +55 °C	
<b>Temperature range non-operational</b>	-55 °C up to +80 °C	
<b>Data</b>	~2 kBits per accumulate period (typically 1-5 minutes)	
<b>Electron count rate</b>	>0.75 to >8.18 MeV	
<b>Proton count rate</b>	>11 to >160 MeV	
	<b>diode D1/D2</b>	<b>diode D3</b>
<b>Opening angle</b>	20°	20°
	<ul style="list-style-type: none"> <li>Covered with 2 mm aluminium</li> <li>A 1.7 mm aluminium &amp; 0.7 mm tantalum layer separate the diodes</li> </ul>	<ul style="list-style-type: none"> <li>Covered with 0.7 mm aluminium</li> </ul>
<b>Lower energy threshold for electrons</b>	1.5 MeV	0.5 MeV
<b>Lower energy threshold for protons</b>	20 MeV	10 MeV



A particle depositing energy in one of the silicon diodes is registered in one or several of the 15 channels. The SREM energy deposition discrimination levels and detected proton energy range are shown in the table below:

Counter	Detector	Energy deposition discrimination levels (MeV)	Proton energy (MeV)	
			Min	Max
<b>TC1</b>	D1	0.085 - $\infty$	27	$\infty$
<b>S12</b>	D1	0.25 - $\infty$	26	$\infty$
<b>S13</b>	D1	0.6 - $\infty$	27	$\infty$
<b>S14</b>	D1	2.0 - $\infty$	24	542
<b>S15</b>	D1	3.0 - $\infty$	23	434
<b>TC2</b>	D2	0.085 - $\infty$	49	$\infty$
<b>S25</b>	D2	9.0 - $\infty$	48	270
<b>C1</b>	D1&D2	0.6 - $\infty$ & 2.0 - $\infty$	43	86
<b>C2</b>	D1&D2	0.6 - $\infty$ & 1.1 - 2.0	52	278
<b>C3</b>	D1&D2	0.6 - $\infty$ & 0.6 - 1.1	76	450
<b>C4</b>	D1&D2	0.085 - 0.6 & 0.085 - 0.6	164	$\infty$
<b>TC3</b>	D3	0.085 - $\infty$	12	$\infty$
<b>S32</b>	D3	0.25 - $\infty$	12	$\infty$
<b>S33</b>	D3	0.75 - $\infty$	12	$\infty$
<b>S34</b>	D3	2.0 - $\infty$	12	$\infty$

### 3 NGRM

The Next Generation Radiation Monitor (**NGRM**) is a radiation monitor used for space weather research and forecast and consists of two sensor heads that are configurable. The electron sensor (electron detector ED) is a 16-channel circular-strip Silicon-detector with a step collimator and measures predominately electrons. The proton sensor (high energy particle detector HEP) consists of a stack of 7 detectors separated by multiple absorbers and measures protons and heavy ions. Furthermore, they are able to do particle discrimination between electrons, protons and heavy ions. In addition, NGRM has several electron-proton cross-contamination free channels to detect and characterize rapidly changing particle flux conditions in near-real time.

Parameters	Values
<b>Particle types</b>	Electrons, Protons, Particle Heavy Ions (Cosmic Rays, Solar Event Ions)
<b>Mass</b>	1.4 kg
<b>Dimension</b>	68 mm x 132 mm x 150 mm
<b>Power consumption</b>	2 W
<b>Bus voltage</b>	28 V – 50 V
<b>Temperature range operational</b>	-40 °C up to +65 °C
<b>Data</b>	a few kBits per acquisition (typically 1 -5 minutes)
<b>Electron energy rate</b>	0.1 to 7 MeV
<b>Electrons maximum flux rate</b>	$10^7 \text{ cm}^{-2}\text{s}^{-1}$ - $10^9 \text{ cm}^{-2}\text{s}^{-1}$ (at 100 keV)
<b>Proton energy rate</b>	2 to 200 MeV
<b>Protons maximum flux rate</b>	$10^6 \text{ cm}^{-2}\text{s}^{-1}$ – $10^8 \text{ cm}^{-2}\text{s}^{-1}$ (at 2 MeV)
<b>Heavy ion LET spectrum</b>	0.1 to 10 MeV / $\text{cm}^2$ / mg
<b>Quasi-logarithmic channels</b>	16
<b>HEP detector</b>	
<b>7 Silicon cylindrical diodes</b>	thickness ~ 300 $\mu\text{m}$
<b>→ Separated by Aluminium &amp; Tantalum degraders of different thicknesses</b>	
<b>Sensitive area</b>	20 $\text{mm}^2$ each
<b>Opening angle</b>	$\pm 20^\circ$
<b>ED unit</b>	
<b>16 individual diodes as ring shaped micro strips</b>	with 0.5 mm pitch
<b>Aluminium part of the collimator</b>	concentric succession of 12 circular stairs (different thicknesses)
<b>Opening angle</b>	$\pm 10^\circ$

### 4 MEDIPIX

The MediPix instrument is a TIMEPIX-based detector device that consists of two main components, the chipboard and the processing board. Hereby the chipboard consists of the TPX3 ASIC chip bump-bonded to a semiconductor sensor and the Minipix-TPX3 (a miniaturized radiation camera). The device provides photon-counting sensitivity, spectrometric particle tracking and radiation imaging capabilities. The



main data products are the radiation field composition, the event rate, the flux, the dose rate, angular distributions, the LET spectra and the dose.

Parameters	Values
<b>Particle types</b>	Electrons, Protons, X-rays, Gamma-rays, He
<b>Dimensions</b>	80 mm x 21 mm x 14 mm
<b>Weight</b>	41 g
<b>Power consumption</b>	2.5 – 0.7 W
<b>Readout chip detector</b>	Timepix3 ASIC
<b>Sensor area</b>	14 mm x 14 mm
<b>Sensor material</b>	Si, CdTe
<b>Sensor thickness</b>	100, 300, 500 $\mu\text{m}$ (Si), 1000 $\mu\text{m}$ (CdTe)
<b>Pixel matrix</b>	256 x 256 (65.356 pixels)
<b>Pixel size</b>	55 $\mu\text{m}$ x 55 $\mu\text{m}$
<b>Signal channels per pixel</b>	2 channels: spectrometry, time, counting
<b>Dynamic range in frame mode</b>	1022 events count per pixel
<b>Sensitivity/pixel energy threshold</b>	3 keV for 300 $\mu\text{m}$ sensor
<b>Energy resolution</b>	8% (3.5 keV for 60 keV X ray)
<b>Time resolution pixel level</b>	1.56 ns
<b>Time resolution detector level</b>	50 ns
<b>Maximum frame rate</b>	16 fps (full frames)

The TPX3 detector enables to resolve radiation field components in terms of event types as listed as follows:

#	Event type	LET [keV/ $\mu\text{m}$ ]	HL [keV/ $\mu\text{m}$ ]	H [keV]	R [a.u.]	$\beta$ [deg]
1	X rays; electrons/muons LE-OD, HE-PP	0.07 – 1.8	0.004 – 1.0			
2	protons LE-OD, HE-PP	3.0 – 8.0	0.14 – 0.55	140 – 700	> 0.87	
3	alpha particles LE-OD, HE-PP	15 – 40	0.73 – 1.27	700 – 2000	> 0.87	
4	ions LE-OD, HE-PP	> 40	> 1.27	> 2000	> 0.87	
5	electrons/muons HE-nPP	< 1.8	0.005 – 0.8			> 20
6	protons HE-nPP	2.3 – 7.0	0.04 – 0.6			> 20
7	alpha particles HE-nPP	7.7 – 47	0.3 – 4.0			> 20
8	ions HE-nPP	20 – 110	0.1 – 2.0			> 20

LE = low energy, HE = high energy, OD = omnidirectional, PP = perpendicular ( $\beta < 20$ ), nP = non-perpendicular ( $\beta \geq 20$ ), LET = linear energy transfer [keV/ $\mu\text{m}$ ], HL = height to length [keV/ $\mu\text{m}$ ], H = height [keV/px], R = roundness [a.u.],  $\beta$  = elevation angle [deg]

## 5 ICARE-NG

The Influence of Space Radiation on Advanced Components-New Generation 2 (ICARE-NG<sup>2</sup>) is intended to measure the radiation flux in the space environment. It consists of three configurable sensor heads that are solid state silicon detectors (SSD). These detectors measure electrons and protons. The main data outcomes are energy level spectrums with programmable integration times and periods and high rate event counters.

Parameters	Values
<b>Particle types</b>	Electrons, Protons
<b>Mass</b>	3.3 kg
<b>Dimension</b>	218 mm x 148 mm x 105 mm
<b>Power consumption</b>	6W
<b>Temperature range operational</b>	-30 °C up to +70 °C
<b>Data</b>	12 kBits per acquisition (default 1 minute)
<b>Electron energy range</b>	>0.25 to >3.25 MeV
<b>Proton energy range</b>	13 to 200 MeV
<b>2 RADFETS</b>	The acquisition period can be adjusted for each dosimeter from 64s and 48 days 13h 5mm
<b>Solid State Detectors (SSD)</b>	
<b>Sensor PE2</b>	Proton Electron with 2 SSDs with a 500µm intermediate shielding
<b>Sensor PE1</b>	Proton Electron with 1 SSD
<b>Sensor PE2_S</b>	Proton Electron with 2 SSDs and a 4 mm intermediate shielding
<b>View cone</b>	30°

## 6 MAGNETOMETER

The MAGIC (**Magnetometer**) is based upon 2 anisotropic magnetoresistance (AMR) sensors, one on an electronic board and the other one connected by harness. Furthermore, it includes power regulation circuitry and a processor for instrument control, command reception and telemetry generation. It makes three-dimensional magnetic field measurements.

Parameters	Values
<b>Measurements</b>	Magnetic field in all 3 dimensions
<b>Range</b>	±60,000nT
<b>Resolution</b>	114pT (20 bits)
<b>Noise spectral density</b>	<500pT / √Hz at 1 Hz
<b>Sampling rate</b>	0.1Hz to 25 Hz (single sensor or gradiometer modes) 1 vector/ second normal mode
<b>Data</b>	~11 bytes/sec (normal mode)

<b>Electronics Board</b>	
<b>Dimensions</b>	95mm × 87mm × 10mm
<b>Mass</b>	38g (card only, electronics populated)
<b>Power</b>	<0.5 W
<b>Temperature range operational</b>	-30°C to +40°C
<b>Temperature range non-operational</b>	-60°C to +125°C
<b>Sensor</b>	
<b>Dimension</b>	21 mm x 21 mm x 12 mm
<b>Mass</b>	23g (including harness and connector)
<b>Temperature range operational</b>	-60°C to +60°C

## 7 TRITEL

TRITEL is a three-dimensional silicon detector telescope that consists of three pairs of silicon detectors connected as gate in coincidence to provide total and coincidence energy deposition spectra and time spectra in three orthogonal directions. From these data the linear energy transfer (LET) spectra in three directions, the mean quality factor of the radiation in three directions and the absorbed dose rate (in Si and water) and the dose equivalent rate in water are derived.

### General specifications:

	<b>Detector Unit</b>	<b>Central Handling Unit</b>
<b>Power</b>	2.6 W	2.0 W
<b>Mass</b>	~ 0.9 kg	~ 1.3 kg
<b>Dimensions (H, W, L)</b>	83 mm, 107 mm, 155 mm	215 mm, 160 mm, 52 mm
<b>Operational temperature range</b>	-40°C...+40°C	-40°C...+70°C
<b>Non-operational temperature range</b>	-40°C...+85°C	-40°C...+85°C
<b>Operational pressure range</b>	105 Pa...10 <sup>-4</sup> Pa	105 Pa...10 <sup>-4</sup> Pa
<b>Outgassing rate</b>	<1% TML   <0.1% CVCM	<1% TML   <0.1% CVCM
<b>Data rate</b>	0.33 MB/day	N/A
<b>Handling environment humidity</b>	20...65% relH	20...65% relH

### Environmental specifications:

<b>Parameters</b>	<b>Values</b>	
<b>Thermal-vacuum</b>	<b>Temperature environment</b>	-40°C...+85°C
	<b>Vacuum environment</b>	<10 <sup>-3</sup> Pa
	<b>Max. depressurisation rate</b>	5.0 kPa/s
<b>Vibration</b>	<b>Sine vibration environment for 3-axis</b>	20...100 Hz, 16.0 g

	<b>Random vibration environment for 3-axis</b>	5...2000 Hz, 17.0 gRMS
	<b>Shock pulse for 3-axis</b>	100 g, 0.25 ms
<b>EMC</b>	<b>EMC environment</b>	Tailored ECSS-E-ST-20-07C Rev.1
<b>Radiation</b>	<b>Used components</b>	COTS
	<b>Proven lifetime</b>	>3 years proven lifetime in LEO

#### Interfaces:

Parameters	Values
<b>Input power bus*</b>	17.0 V...34 V (non-redundant or redundant)
<b>TM/TC interface*</b>	<b>CAN Bus / RS-232 / RS-485</b> (non-redundant or redundant)
* For Detector Unit and Central Handling Unit as well.	

#### Measurement capabilities:

Parameters	Values
<b>Particle types</b>	electrons, protons, heavy ions
<b>Flux range (isotropic)</b>	$1.5 \cdot 10^{-1} - 4.5 \cdot 10^4 \text{ cm}^{-2}\text{s}^{-1}$
<b>Count rate range (&lt;10% dead time)</b>	0-50,000 cps
<b>LET in water range</b>	0.2 – 120 keV/ $\mu\text{m}$
<b>Deposited energy range</b>	60 keV – 80 MeV
<b>Minimum absorbed dose rate in water</b>	50 nGy/h
<b>(for relativistic protons with energy deposit of <math>\approx 100</math> keV in Si)</b>	10 mGy/h
<b>Maximum absorbed dose rate in water</b>	0.5 Gy/h
<b>(for relativistic protons with energy deposit of <math>\approx 100</math> keV in Si)</b>	7 Gy/h

#### Three-dimensional Telescope system specification:

Parameters	Values
<b>Detector material</b>	Si
<b>Effective detector radius</b>	8.4 mm
<b>Effective detector area</b>	222 mm <sup>2</sup>
<b>Geometric factor G (for one telescope axis in <math>4\pi</math>)</b>	5.1 cm <sup>2</sup> sr
<b>Maximum angle of incidence (for one detector pair)</b>	62.1°
<b>Average path length in the detector (assuming an isotropic field)</b>	361 $\mu\text{m}$

## 8 PADLES

Space radiation fields have broadly distributed linear energy transfer (LET), and space radiation with LET greater than several keV/ $\mu\text{m}$  (high-LET radiation) causes more serious damage to living things than does low-LET radiation. Therefore, measurements of LET distributions are essential for investigating biological effects, assessing radiation risks to astronauts, and improving modelling with radiation transport codes.

The Passive Dosimeter for Life Science Experiments in Space (**PADLES**) consists of two types of passive and integrating radiation detectors: MSO-S ( $\text{Mg}_2\text{SiO}_4\text{:Tb}$ ) thermoluminescent dosimeters (TLDs) and antioxidant-doped CR-39 plastic nuclear track detectors (PNTDs). PADLES can measure absorbed doses, dose equivalents based on LET distributions and mean quality factors as well as absorbed doses in space radiation fields by using a combination of its CR-39 PNTDs and TLDs. The PADLES package has several advantages: it is light, compact, electronics free and easy to attach close to biological samples or an astronaut's body even inside extravehicular activity (EVA) suits.

(Courtesy of: Nagamatsu A, Casolino M, Larsson O, Ito T, Yasuda N, Kitajo K, Shimada K, Takeda, Tsuda S and Sato T, Space radiation dosimetry to evaluate the effect of polyethylene shielding in the Russian segment of the International Space Station. *Physics Procedia* 80, 25–35 (2015) / Doke T et al. (1995), Tawara H et al. (2008, 2011), Nagamatsu A et al. (2006, 2009, 2011, 2013, 2015)).

Parameters	Values
<b>Particle types</b>	Galactic cosmic radiation (GCR), solar particle events (SPEs), neutrons, X-rays, gamma rays
<b>Dimensions</b>	25 mm (W) $\times$ 25 mm (L) $\times$ 4 mm (T)
<b>Weight</b>	4 g
<b>Power consumption</b>	N/A: no battery and no data downlink
<b>Temperature</b>	$-80^\circ\text{C}$ to $+65^\circ\text{C}$
<b>Sensor material</b>	CR-39 PNTDs (HARZLAS TD-1; Fukuvi Chemical Industry, Japan) and TLDs (TLD-MSO-S; Kasei Optonix, Japan)
<b>Measurements</b>	Averaged or total LET distributions/day $>$ 4 keV/ $\mu\text{m}$ , absorbed doses (rates), dose equivalents (rates), mean quality factors, particle tracking for total measurement durations
LET range (in water)	0.2–1000 keV/ $\mu\text{m}$
<b>Minimum adsorbed dose rate in water</b>	0.1 $\mu\text{Gy}$
<b>Maximum adsorbed dose rate in water</b>	$\sim$ 2 Gy

## 9 D-SPACE

D-Space has been developed as an active and portable dose monitor with graphic display, Bluetooth wireless downlink system and long-term continuous operation for two years without an external power source using a Li button cell. In the IDA Phase 1 mission, D-Space has no button cell because power resources and data interfaces are to be provided from the central electronic unit in Gateway HALO. D-Space can measure absorbed dose variations every minute (in minimum, d, w, m) both inside and outside the spacecraft during lunar activity (EVA). D-Space consists of two Si PIN diodes with different threshold levels, one mainly for protons and the other for heavy ions.

Parameters	Values
<b>Particle types</b>	Galactic cosmic radiation (GCR), solar particle events (SPEs), X-rays, gamma rays
<b>Dimensions</b>	~38 mm (W) × 98 mm (L) × 14 mm (T) (desired)
<b>Weight</b>	~ 46 g (desired)
<b>Power consumption</b>	3.3 V, 100 mW (TBD)
<b>Temperature</b>	-80°C to +65°C (without a button cell)
<b>Sensor material</b>	Si PIN diodes (Hamamatsu Photonics K.K., Japan)
<b>Measurements</b>	Absorbed doses (rates) and count values (rates) obtained from two different threshold levels
LET range (in water)	0.2–1000 keV/μm
<b>Minimum adsorbed dose rate in water</b>	0.01 μGy/h
<b>Maximum adsorbed dose rate in water</b>	2000 μGy/h