DEVELOPMENT OF RADIATION AND MAGNETIC FIELD MEASUREMENT PAYLOAD RadMag

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Outline

- Objectives of RadMag development
- Detector concept
- RADCUBE: a demonstration CubeSat mission
- Summary and future outlook
## Primary RadMag Mission Objectives

<table>
<thead>
<tr>
<th>Objective ID</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>RadMag-O-01</td>
<td>To demonstrate – through successful mission operation – the future use and applicability of the RadMag instrument in strategically important fields, such as space weather research, forecast and general radiation damage monitoring for commercial use as a service.</td>
</tr>
<tr>
<td>RadMag-O-02</td>
<td>To demonstrate – through successful mission operation – the operability of the RadMag cosmic radiation and magnetic field measuring instrument for future CubeSat missions in order to provide global coverage of the near-real-time cosmic radiation and magnetic field data.</td>
</tr>
<tr>
<td>RadMag-O-03</td>
<td>To perform in-situ measurements of the cosmic radiation field environment in LEO.</td>
</tr>
<tr>
<td>RadMag-O-04</td>
<td>To demonstrate the technical feasibility of the magnetic field measurements as a part of the RadMag instrument package.</td>
</tr>
</tbody>
</table>
RadMag conceptual approach
RadMag instrument setup

- **Compact design:**
  - to be realised in 1U standard dimensions (10x10x10 cm$^3$)
  - mass: below 1 kg
  - power consumption: below 5 W
  - modularity
RadMag radiation detector – RADTELE telescopes

► **Telescopes:**
  » to be realised with ion implanted fully depleted planar silicon detectors
    • thin lightproof Ti entrance window
    • $\Delta E$ and $E$ detectors
    • Al absorber(s)
    • coincidence/anti-coincidence logic

► **Analyses (to be) performed:**
  » First analysis performed based on stopping power approximations/numerical calculations
  » Monte Carlo simulations just to be started
**RADTEL logic**

**Entrance window**

- **Ti-0.025**
  - **D1 (Si-0.1)**
  - **D2 (Si-1.5)**
  - **D3 (Si-1.5)**
  - **D4 (Si-0.3)**
- **Al-6**
- **D5 (Si-0.3)**
- **Al-4**

**Abbreviations:**
- **D1-D5** - detector number; **Am** - preamplifier;
- **ADC** - analogue-to-digital converter;
- **MCA** - multichannel analyzer; **Di** - discriminator

**Diagrams:**
- **Di1 > 1**
- **Di2 > 0.2**
- **Di3 0.06-0.26**
- **Di4 0.06-0.12**
- **Di5 > 1.9**
- **Di6 0.06-1.6**
- **Di7 > 0.19**
- **Di8 > 0.06**
- **Di9 > 0.06**

**Energy is given in MeV**

- **Sp1**
- **Sp2**
- **Sp3**
- **Sp4**
- **Sp5**
- **Sp6**

- **D1**
- **D2**
- **D3**
- **D4**
- **D5**
- **D6**
- **D7**
- **D8**
- **D9**

**Total flux, dose**

- **Protons 4-23 MeV**
- **Protons 23-300 MeV**
- **Electrons 0.2-1.6 MeV**
- **Electrons 1.6-8 MeV**

**LET spectrum**
The targeted energy ranges

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Values, ranges</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Particle types</strong></td>
<td>electrons, protons, ions</td>
</tr>
<tr>
<td><strong>Electron energy range (number of channels)</strong></td>
<td>0.2 MeV – 1.6 MeV (≤24, TBC)</td>
</tr>
<tr>
<td></td>
<td>1.6 MeV – 8 MeV (≤11, TBC)</td>
</tr>
<tr>
<td><strong>Proton energy range (number of channels)</strong></td>
<td>4.0 MeV – 23 MeV (≤19, TBC)</td>
</tr>
<tr>
<td></td>
<td>23 MeV – 300 MeV (≤28, TBC)</td>
</tr>
<tr>
<td></td>
<td>&gt;100 MeV – 10 GeV (4-5)</td>
</tr>
<tr>
<td><strong>He ion energy range (number of channels)</strong></td>
<td>100 MeV/n – 10 GeV/n (4-5)</td>
</tr>
<tr>
<td><strong>C&amp;N&amp;O ion energy range (number of channels)</strong></td>
<td>100 MeV/n – 10 GeV/n (4-5)</td>
</tr>
<tr>
<td><strong>Fe ion energy range (number of channels)</strong></td>
<td>100 MeV/n – 10 GeV/n (4-5)</td>
</tr>
</tbody>
</table>

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**PRELIMINARY ESTIMATIONS**
RADTEL logic

Entrance window

Ti-0.025
D1 (Si-0.1) → Am D1 → ADC D1 → MCA1/D1 → Di10 >0.06 → Di10 → TSp3

D2 (Si-1.5) + D3 (Si-1.5) → Am D2 → ADC D2+3 → MCA2/D2+3 → Di11 >0.06 → Di10, Di11 → TSp1

D4 (Si-0.3) → Am D4 → ADC D4 → MCA3/D4

Di8 >0.06 → Di8, Di9 → TSp2

Al-6

D5 (Si-0.3) → Am D5 → ADC D5 → Di Analyzer/D5

Di9 >0.06

Abbreviations:
D1-D5 - detector number; Am - preamplifier;
ADC - analogue-to-digital converter;
MCA - multichannel analyzer; Di - discriminator

Energy is given in MeV

coinc. gating
anticoinc. gating
RadMag radiation detector – dose rate measurements

EURORAD 7mm² Si diodes for high flux measurements (pulse and current measurement mode)

Abbreviations:
- S3 - sensor number
- D1-D3 - detector number
- TSp - time spectra
- Dimensions in mm

Dose rate up to 1 kGy/h
RadMag Magnetometer

Three-axis fluxgate magnetometer (one possible solution: Spacemag-Lite)
Noise from platform (dipole approximation):

<table>
<thead>
<tr>
<th>Distance from the centre of the dipole (cm)</th>
<th>20 mA·m²</th>
<th>40 mA·m²</th>
<th>60 mA·m²</th>
<th>80 mA·m²</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>16,000</td>
<td>32,000</td>
<td>48,000</td>
<td>64,000</td>
</tr>
<tr>
<td>10</td>
<td>2,000</td>
<td>4,000</td>
<td>6,000</td>
<td>8,000</td>
</tr>
<tr>
<td>30</td>
<td>74</td>
<td>148</td>
<td>222</td>
<td>296</td>
</tr>
<tr>
<td>100</td>
<td>2</td>
<td>4</td>
<td>6</td>
<td>8</td>
</tr>
<tr>
<td>200</td>
<td>0.25</td>
<td>0.5</td>
<td>0.75</td>
<td>1</td>
</tr>
</tbody>
</table>

Sensor on boom + internal reference sensor?
### RadMag Magnetometer Goals

<table>
<thead>
<tr>
<th>Measurement levels</th>
<th>Level 1 in nominal operation mode</th>
<th>Level 2 in high resolution mode</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Scientific goals</strong></td>
<td>- overall mapping of the geomagnetic field to support radiation data analysis.</td>
<td>- geomagnetic field region localization to support radiation data analysis (SAA, FACs – auroral oval);</td>
</tr>
<tr>
<td></td>
<td>- data contribution for attitude determination.</td>
<td>- inputs for geomagnetic field model validations/comparison.</td>
</tr>
<tr>
<td><strong>Range</strong></td>
<td>±60000 nT</td>
<td>±60000 nT</td>
</tr>
<tr>
<td><strong>Accuracy</strong></td>
<td>1000-5000 nT</td>
<td>1-10 nT</td>
</tr>
<tr>
<td><strong>Sampling rate</strong></td>
<td>0.05-0.5 Hz</td>
<td>0.5-10 Hz</td>
</tr>
</tbody>
</table>
# RadMag Technical Details – Budgets

<table>
<thead>
<tr>
<th>Technical constraints</th>
<th>Preliminary limits</th>
<th>Margin</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume</td>
<td>Lenght $\leq 14$ cm (Cross-section $10 \times 10$ cm$^2$)</td>
<td>With 20% included</td>
</tr>
<tr>
<td>Mass</td>
<td>$\leq 1.1$ kg</td>
<td>With 20% included</td>
</tr>
<tr>
<td>Power consumption</td>
<td>$\leq 5.5$ W</td>
<td>With 20% included</td>
</tr>
<tr>
<td>Provided data rate</td>
<td>$\leq 170$ kByte/orbit</td>
<td>With 20% included</td>
</tr>
<tr>
<td>Operational temperature range</td>
<td>Operational: $[-40; +40]$ °C</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>Non-operational: $[-40; +60]$ °C</td>
<td></td>
</tr>
</tbody>
</table>

### Design Maturity and Margins

<table>
<thead>
<tr>
<th>Category</th>
<th>Design maturity</th>
<th>Margins</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Existing hardware</td>
<td>±5%</td>
</tr>
<tr>
<td>B</td>
<td>Design based on existing hardware with minor modifications</td>
<td>±10%</td>
</tr>
<tr>
<td>C</td>
<td>Detailed Design</td>
<td>±15%</td>
</tr>
<tr>
<td>D</td>
<td>Preliminary Design</td>
<td>±20%</td>
</tr>
</tbody>
</table>
RadMag Science Operation and Data Centre

Science Operation Centre (SOC)
- Operation Centre
  - Operation planning
  - Solar activity monitoring
  - Interpretation
  - TC scheduling
  - Satellite orientation scheduling
  - Alerts
  - Failures checking/Unusual data

Data Centre
- Database
- User interfaces
  - Usual data reports
- Data archivation
- Data visualisation
- Data interpretation
- Data evaluation/validation
- Calibration data set

Mission Operation Centre (MOC)

RADCUBE satellite

Ground Station
RadMag Science Operation and Data Centre

**RADCUBE Scientific Database**

- **User interfaces**
  - General public
  - Scientific community
  - Contractual partners

**Level 0**
- General public
- Public access

**Level 1**
- Scientific community
- Research access

**Level 2**
- Contractual partners
  - ESA
  - C3S
  - TBD
  - ESA SSA SWE
RADcube: demonstration CubeSat mission for the RadMag instrument
3U/6U CubeSat Platform by C3S LLC

Key features

- Single-point failure tolerant
- Double redundancy in all subsystems
- High reliability and availability
- 3 year design lifetime in LEO

Planned first IOD mission: 2018

<table>
<thead>
<tr>
<th>Technologies</th>
<th>Provider</th>
<th>Availability</th>
<th>ESA support</th>
</tr>
</thead>
<tbody>
<tr>
<td>STRU</td>
<td>C3S</td>
<td>TRL 7</td>
<td>✓</td>
</tr>
<tr>
<td>OBC</td>
<td>C3S</td>
<td>TRL 7</td>
<td>✓</td>
</tr>
<tr>
<td>EPS</td>
<td>C3S</td>
<td>TRL 3</td>
<td></td>
</tr>
<tr>
<td>COM-UHF TX/RX</td>
<td>C3S</td>
<td>TRL 7</td>
<td>✓</td>
</tr>
<tr>
<td>COM-S TX</td>
<td>C3S</td>
<td>TRL 3</td>
<td></td>
</tr>
<tr>
<td>ADCS</td>
<td>3rd party</td>
<td></td>
<td></td>
</tr>
<tr>
<td>GNS RX</td>
<td>3rd party</td>
<td></td>
<td></td>
</tr>
<tr>
<td>IPC</td>
<td>C3S / 3rd party</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Payload(s)</td>
<td>C3S / 3rd party</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
3U/6U CubeSat Platform by C3S LLC

Less than 10 min. integration time for any subsystem

PC 104 compatible converter

Space qualified connectors

Deployable solar arrays and antennas

3 years design lifetime in LEO

Up to 60W Input Power

Up to 60% Payload Bay

Integration of cards and boxes of various sizes
Summary and future outlook
Future space weather services using fleet of CubeSats
RADCUBE – GSTP 6.3 IOD CUBESAT MISSION

Phase A/B1 is being realised under ESA contract No. 4000117620/16/NL/LF/as
Thank you for your attention

www.radcube.hu