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The energetic electron instrument (IDEE) onboard the TARANIS spacecraft to search lightning-connected energetic electron populations

Lubomir Prech (lubomir.prech@mff.cuni.cz) [1]
Pierre-Louis Blelly[2], Pierre Devoto[2],
Jean-Andre Sauvaud[2], Kingwah Wong[2],
Guillaume Orttner[2], Nathalie Baby[2], and Ivo Cermak[3]
[1]Charles University, Prague, Czech Republic
[2]IRAP CNRS/ Université de Toulouse III Paul Sabatier, Toulouse, France
[3]CGC-Instruments, Chemnitz, Germany

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Abstract

- TARANIS (Tool for the Analysis of RAdiations from lightNIngs and Sprites) is a French CNES microsatellite dedicated to the study of the impulsive energy transfer between the Earth's atmosphere and the space environment as widely observed above the active thunderstorm regions. After years of development and testing, the satellite is approaching to its launch (expected in August 2020).
- The comprehensive satellite scientific payload incorporates optical, field, and particle sensors including the **energetic electron instrument** (IDEE) with very high sensitivity and time resolution. Its main scientific tasks are: to measure high resolution energetic electron spectra (70 keV to 4 MeV) and pitch angle distributions, to separate upward accelerated electrons and downward precipitated electrons, to detect burst of electrons associated with Terrestrial Gamma ray Flashes, to identify Lightning-induced Electron Precipitation (LEP), and to provide alert signals about high-energy electron bursts to other TARANIS experiments.
- The aim of this contribution is to describe the final design and expected performance of the IDEE experiment, including the data products. We also want to show how we are going to enhance the today's scientific knowledge of the thunderstorm related phenomena in synergy with other ground-based and space-born experiments.

TARANIS mission overview

Credit: CNES/ illus. D . Ducros

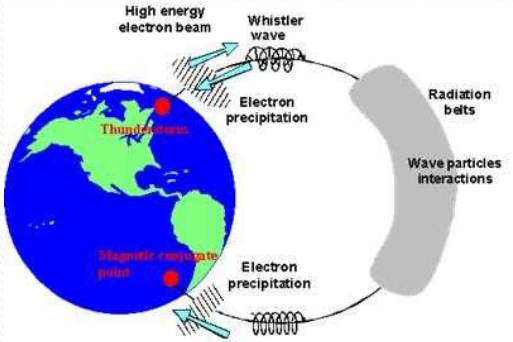
- Christophe **Bastien-Thiry** - CNES project manager, Jean-Louise **Pinçon** (LPC2E) - mission PI
- CNES/MYRIADE microsatellite (same class as DEMETER), ~160 kg
- Sun-synchronous orbit, 2230-0200 and 1030-1400 LT, altitude ~700 km

- Science objectives [TAR-SP-SY-0-6013-LPC2E]:

(1) Advance physical understanding of the links between TLEs and TGFs, in their source regions, and the environmental conditions (lightning activity, variations in the thermal plasma, occurrence of extensive atmospheric showers, etc);

(2) Identify the generation mechanisms for TLEs and TGFs and, in particular, the particle and wave field events which are involved in the generation processes or which are produced by the generation processes;

(3) Evaluate the potential effects of lightning, TLEs, TGFs, and bursts of precipitated and accelerated electrons (in particular lightning induced electron precipitation and runaway electron beams) on the Earth atmosphere or on the radiation belts.



Transfers of energy between the radiation belts and the atmosphere.
Credit: D. Lagoutte, LPC2E, TAR-SP-SY-0-6013-LPC2E

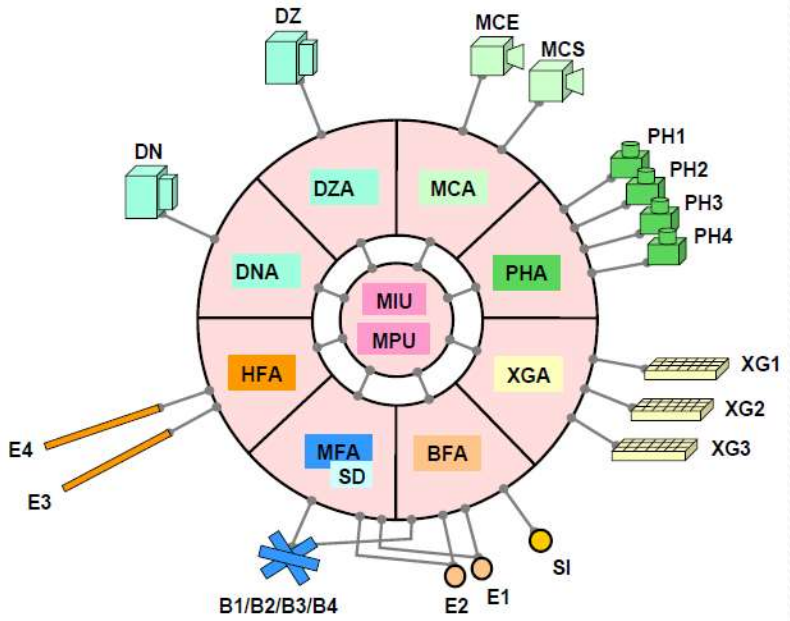
TARANIS project status

- TARANIS Flight Acceptance Review ongoing – W18-19
- Further schedule depends on Covid-19 measures relaxation (notably, resume of CNES & ArianeSpace activities)
  - Finalization of spacecraft AIT, transport preparation – May-June
  - Prelaunch activities – July
  - Launch from French Guyana – **August 7th 2020 or later**
    (VEGA VV17, dual launch TARANIS + ….)
  - In-orbit commissioning – August-September
  - Nominal science observations starting in October 2020

TARANIS spacecraft during AIT. Credit: CNES

TARANIS instruments

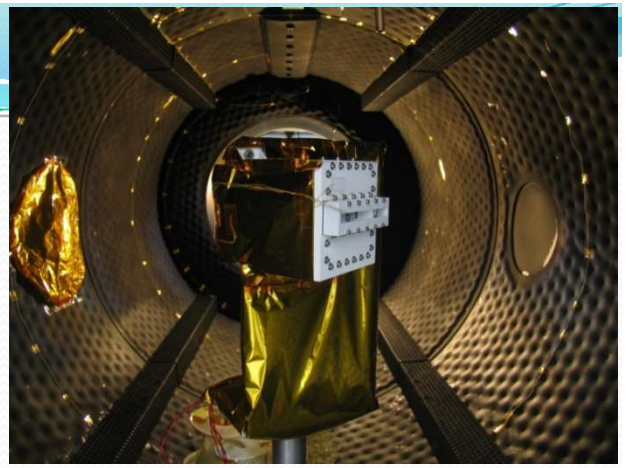
- MCP-MP – 2 camera units [CEA/CNES]
- MCP-PH – 4 photometers [CEA/CNES]
- XGRE – x-ray, gamma and relativistic electron instrument (3 sensors) [IRAP, APC, CNES]
- IDEE – energetic electron spectrometer (nadir and zenith sensors) [IRAP, CUNI]
- IME-BF – low and medium frequency electric field (dipolar antenna) and Langmuir ion probe [LATMOS, GSFC]
- IME-HF – high frequency electric field (Hertz dipole) [LPC2E, IAP]
- IMM – low and medium frequency magnetic field (2 mono-band coils, 1 dual-band coil) [LPC2E, Univ. Stanford]
- MEXIC 1,2 – power modules (MPU), instrument interface unit (MIU) and instrument control & data processing units ("analyzers") [LPC2E, SRC]



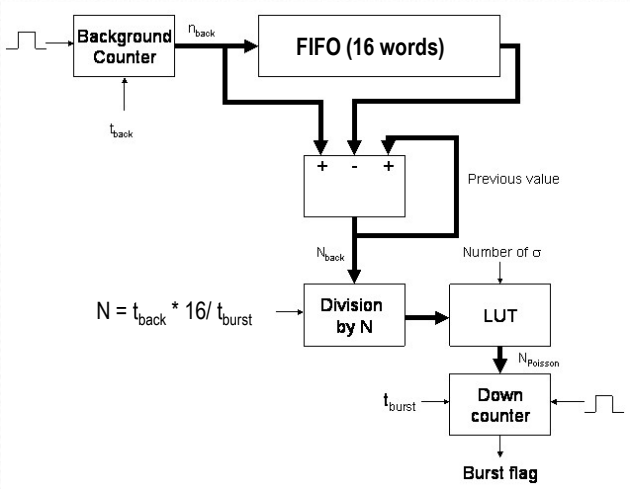
TARANIS payload block diagram.
Credit: D. Lagoutte, LPC2E, TAR-SP-S-7-6014-LPC2E

IDEE / energetic electron spectrometer

- Two sensor units (IDEE-N 60° from nadir, IDEE-Z 60° from zenith) with dual energy range
- Each sensor - stack of multisector thin Si foil with collimators and larger CdTe thick array (8 bar sectors) – full energy range 90 keV – 4.9 MeV
- The IDEE instrument uses a dynamical algorithm which evaluates a floating background (in preselected energy range and Si/CdTe cell type) over selected time periods, based on Poisson distribution assumption and using a dynamic threshold – 2 burst triggering processes running in parallel in both sensors
  - RRE (Relativistic Runaway Electrons) aka TGF associated electron beams (TEB) - initial setup: energy > 1.8 MeV, 4-ms count above 3.5σ in CdTe detector/16 * 128-ms floating window background
  - LEP (Lightning-induced Electron Precipitation) - initial setup: > 200 keV, 256-ms count above 2σ in Si detector/16 * 256-ms floating window background
- The IDEE instrument will self-trigger on RRE/TEB and/or LEP events, that will also trigger all the instruments of the TARANIS payload (including XGRE). IDEE will be also externally triggered by alerts distributed by MIU (based on other instrument triggers)
- Variable geometrical factor
  - Nominal – Si 4.1 cm^2 + CdTe 64 cm^2 (raw detection area)
  - Reduced – Si 0.1 cm^2 – SAA region studies
- IDEE instrument PI - P.L. Blelly (IRAP)



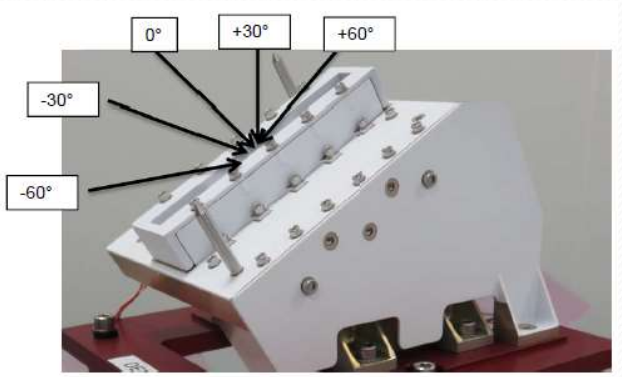
IDEE sensor STM during thermo-vacuum testing

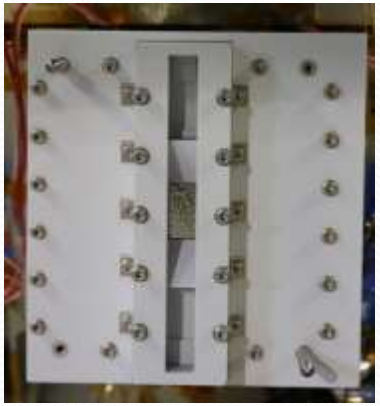


IDEE burst search algorithm.

IDEE – sensor design

- Each sensor contains stack of a multisector thin Si foil (0.3 mm, hidden behind Al foil 6 µm w. supporting grid) with collimators (Titanium alloy) followed by larger CdTe thick array (8 sectors á 8 detectors, 10x10x5 mm^3 each)
  - **Si foil** – Low Energy (LE) range, 5 sectors, FOV 150° x 40°, (4 x 1 + 0.1) cm^2
  - **CdTe matrix** – High Energy (HE) range, 8 cells, FOV 150° x 150° (w/o coincidence, behind 0.6 mm Al cover), 64 (8 x 8) cm^2
- The sensor electronics consists of
  - Front-end electronics (5+8 inputs ASIC w. programmable Si/CdTe input thresholds)
  - HV power supplies for the Si and CdTe detectors (2 control DACs)
  - FPGA interface between sensor electronics and IDEE analyzer (2 fast science data serial lines, one duplex command/hsk data line)
  - Housekeeping ADC circuit
  - LV power supplies
- 1W power consumption
- Weight ~1.5 kg incl. radiator





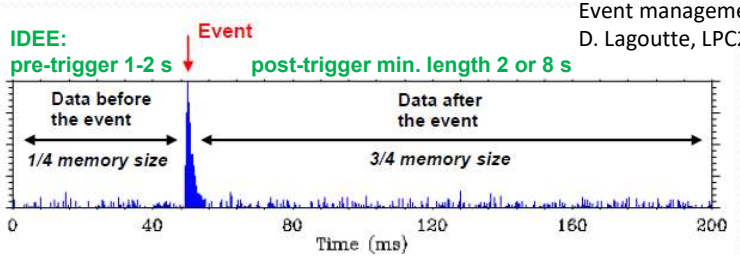
IDEE sensor FM1 top view & FOV (FM2).
Credit IRAP, CNES.

IDEE – analyzer design

IDEE analyzer FM1.

- Analyzer tasks (2 parallel units for IDEE-N and IDEE-Z sensors)
  - Electron spectra onboard generation (Survey mode data)
    - LE (Si foil) –> 3 angular sectors, typ. 80-100ms time resolution
    - HE (CdTe bars) –> no angular resolution when coincidence off, typ. 80-100 ms res., opt. on-board sector energy offset correction
    - HE+LE coincidence – >3-5 ang. sectors (LUT dependent), 125-200 ms res. (52/32 energy bins)
  - Event memory buffer handling (Event mode data) 8/16 MB
    - Records up to 2-4 × 10^6 particles/half orbit with 1 µs resolution (full energy/sector info)
    - Memory dynamically allocated for up to 90 events per half orbit (background dependent, event record length typ. 2-8 s)
    - Event types
      - External – from other TARANIS payload triggers (via MIU)
      - RRE and LEP burst search – 2 trigger processes
  - Housekeeping data monitoring and instrument health surveillance
  - TC reception / TM generation
  - Attached IDEE sensor switching, configuration, and digital data reception/processing

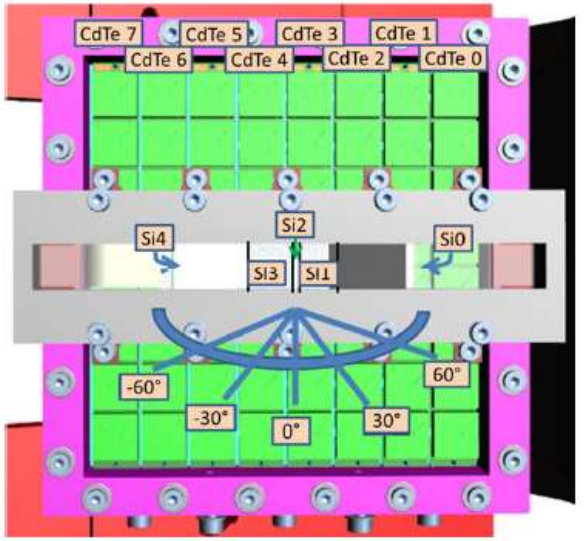
- Max. data throughput 10^6 particles/s
- 0.7 W power consumption
- Weight 500 g incl. frame



Event management concept. Adopted from D. Lagoutte, LPC2E, TAR-SP-S-7-6014-LPC2E

IDEE performance

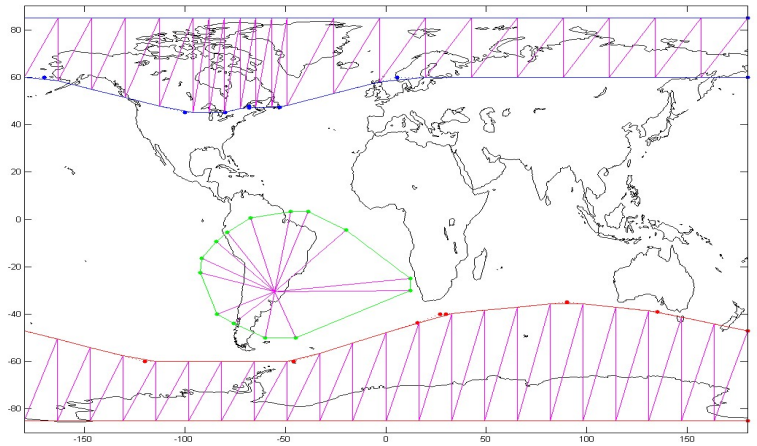
- Energy range 94 keV .. 4.9 MeV
  - LE (Si foil) – 94 keV .. 670 keV [ΔE = 9 keV]
  - HE (CdTe bars) – 560 keV .. 4.1 MeV [ΔE = 62 keV]
  - LE+HE coincidence – 900 keV .. 4.9 MeV [ΔE = 64 keV]
- Fluence 2 × 10^5 s^{-1} (LE), 2.5 × 10^4 s^{-1} (HE)
- Angular resolution
  - LE – 3 sectors [< -30°, -30°..+30°, > +30°]
  - LE+HE (coincidence) – min. 3 eff. sectors [-60°, **-30°, 0°, 30°**, 60°]
- Effective area TEB ~22 cm^2 (Sarria et al., 2017)
- Time resolution
  - Onboard spectra – resolution min. 12.5 ms, typ. 100 – 250 ms
  - Event buffer memory – resolution 1 µs (max. 2-4 × 10^6 part./half orbit, 90 RRE/LEP burst events)
- Physical calibration
  - ONERA electron accelerator
  - ^{207}Bi and ^{133}Ba radioactive sources for performance checking during AIT



IDEE detectors identification & FOV

IDEE in-orbit commissioning plans

- Instrument health check
- Payload auto-compatibility test
- Sensor functional tests, ASIC threshold adjustments
- RRE/LEP burst search setup & thresholds adjustment
- Analyzer flight SW patch - look-up tables, burst search etc.(opt.)



Initial TARANIS nominal operation region (polar regions excluded, SAA indicated). Credit LPC2E, TAR-ME-G-9-CM-6741-LPC2E

References

- D. Lagoutte, F. Lefeuvre et J.L. Pinçon, TARANIS Mission Specification, LPC2E, TAR-SP-SY-0-6013-LPC2E v2.4, 2011
- D. Lagoutte, TARANIS Scientific Instrument Consortium Technical Specification, LPC2E, TAR-SP-S-7-6014-LPC2E v3.2, 2014
- Equipes CIS et CMST du LPC2E, TARANIS CIS/CMST - Manuel d'exploitation, Recette en vol – validation fonctionnelle, TAR-ME-G-9-CM-6741-LPC2E, v1.0, 2019
- Sarria et al., TARANIS XGRE and IDEE Detection Capability of Terrestrial Gamma-Ray Flashes and Associated Electron Beams, *Geosci. Instrum. Method. Data Syst.,* 6 (2): 239–256, 2017 [doi:10.5194/gi-6-239-2017]