DEB1EQ On EuTEF: preliminary results

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• After 50 years of space activities, there are ~ 15,000 orbiting objects larger than 10 cm regularly tracked and catalogued by the U.S. Space Surveillance Network.
• 56% of the catalogued population originated by in-orbit fragmentations, 20% are spacecrafts and 24% can be attributed to spent rocket upper stages and mission-related objects.
• In addition there are many millions more items too small to be monitored from the ground. Those can be analysed by retrieved devices or active in-situ detectors.
• The impact average velocity of debris is ~ 10 km/s. The impact velocity of micrometeoroids is between 10 km/s and 70 km/s, average is 20 km/s. Impact with a satellite can be catastrophic.

STS-92 mission to ISS (2000):
a crater of 10-mm diameter and 1.9-mm deep was found on one of the thermal panes windows. Analysis indicated that the impact was caused by a 0.76 mm paint chip.
DEBIE is a standard low-resource instrument that can provide in-situ real-time data for space debris modelling.

DEBIE has been manufactured by Patria Systems and is able to monitor the sub-millimetre size space debris and micrometeoroid population in space and its variation with time and position.

Data from models flying on different orbits and spacecrafts can be compared.

DEBIE1 was launched on PROBA to a polar orbit. Flying since Oct 2001.

Data from DEBIE 1 and 2 instruments are collected to European Detector Impact Database.

DEBIE consists of 1 Data processing Unit and up to 4 Sensor Units:
- DEBIE1 → 2 Sensor Units
- DEBIE2 → 3 Sensor Units

http://gate.etamax.de/edid/index.shtml
Sensors Main Properties

- Detects particle impacts on an aluminium foil (thickness 6 µm) combining detection of impact ionisation (plasma channels), momentum (PZT channels) and foil penetration (plasma channel).
- Relative timing measurement between Plasma and PZT channels.
- Active sensor area: 10 x 10 cm² per Sensor Unit.
- If signals are detected in ion and momentum channels good information on velocity and mass of impact can be obtained.
- Sensitivity (velocity dependent):
  - Plasma: better than 10-15 g
    Signal $\propto m v^{3.5}$
  - PZT: better than 10-11 g
    Signal $\propto m v$

- One side open to environment
- In front of the aluminium foil: 1) Grounded wire grid for protection, 2) Plasma 1e (electrons) and 3) Plasma 1i (positive ions) wire grids biased to +50 V and -50 V respectively
- On the foil: PZT1 and PZT2 (piezoelectric) sensors
- Behind the foil: Plasma 2e (electrons) wire grid biased to +50 V

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EuTEF post-flight symposium

ESTEC 16/03/2010
# DEBIE2 Location on EuTEF

<table>
<thead>
<tr>
<th>Sensor Unit</th>
<th>FoV</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>SU1</td>
<td>Starboard</td>
<td>50 μm Al foil</td>
</tr>
<tr>
<td>SU2</td>
<td>Zenith</td>
<td>6 μm Al foil</td>
</tr>
<tr>
<td>SU4</td>
<td>Ram</td>
<td>6 μm Al foil</td>
</tr>
</tbody>
</table>
Columbus/EuTEF launch

- STS-122 launched on 7/02/2008
- EuTEF installed during EVA#3 on 15/02/2008
- DEBIE2 commissioning successfully performed on 29/02/2008
Data Acquisition Operations

- Limited data taking in 2008 due to an incorrect setting of DEBIE2 max science data packet size in the EuTEF DHPU on-board SW which was causing frequent TM/TC IF (RS-422) link errors.
- Carlo Gavazzi Space modified the on-board SW and uploaded it successfully on 16.01.2009.
- As soon as DEBIE2 started acquiring data at higher rate another problem was detected: after some time (random) DEBIE2 was stopping sending Science Data (i.e. only SC empty packets).
- Tests with DEBIE2/EuTEF EM at Erasmus USOC reproduced the anomaly. DEBIE2 was going into a “locked” status, caused by several different CPU interrupts occurring almost at the same time or in some specific sequence which in turn can cause the SW to hang.
- The root cause is not yet fully understood. Nevertheless the very noisy plasma environment at ISS is believed to play definitively a role in this anomaly.
- Recovery of this anomaly consisted in power-cycling DEBIE2.
- A work around solution was found in collaboration with the Erasmus USOC team simply by switch-off/on DEBIE2 as soon as possible after occurrence of the anomaly.
Data Acquisition Time in 2009

DEBIE2 Science Acquisition Time

Percentage of Acquisition Time per week

Week 3, Week 5, Week 7, Week 9, Week 11, Week 13, Week 15, Week 17, Week 19, Week 21, Week 23, Week 25, Week 27, Week 29, Week 31, Week 33, Week 35

Science Acquisition Time in 2009
DEBIE2 typical orbit

90 min = ISS orbit

Data from Week 21 2009

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DEBIE2 typical orbit - SU4

14/05/2009
DEBIE2 typical orbit - SU1
DEBIE2 typical orbit - SU2
During STS-119 (docking on 17/03/2009, undocking on 26/03/2009) we noticed an interesting behaviour of the noise events on DEBIE2 on SU4 (Ram).
Noise discrimination

- DEBIE2 classifies the events with on-board SW (classification levels from 1 (low) to 9 (high))
- However this is not a good discrimination
- DEBIE measures four ‘time delays’:
  - Delay between PL1e and PL1i trigger (Delay1)
  - Delay between PL1e and PZT trigger (Delay2)
  - Delay between PL1i and PZT trigger (Delay3)
  - Risetime of the PL1e signal.
- Observed during calibration that:
  - -10 < Delay1 < 10 μs (but not zero)
  - 150 < Delay2 < 200 μs
  - 150 < Delay3 < 200 μs
  - Risetime > 0 μs
- A filter based on these criteria removes most of the noise.
- In 2009 over a total of 1260109 events recorded only 931 are filtered as potential impact events (0.07%)
  - SU1 (STARBOARD) = 152 events
  - SU2 (ZENITH) = 693 events
  - SU4 (RAM) = 86 events
Number of Impacts on DEBIE2

- SU1
- SU2
- SU4

Week 3, Week 5, Week 7, Week 9, Week 11, Week 13, Week 15, Week 17, Week 19, Week 21, Week 23, Week 25, Week 27, Week 29, Week 31, Week 33, Week 35

Number of impacts per week
DEBIE2 Impact Flux

Impact Fluxes on DEBIE2 in 2009

Flux [m²/yr]

Week 3  Week 5  Week 7  Week 9  Week 11  Week 13  Week 15  Week 17  Week 19  Week 21  Week 23  Week 25  Week 27  Week 29  Week 31  Week 33  Week 35

SU1  SU2  SU4
SARJ cleaning operation

- During STS-126 several EVAs were spent to fix the starboard SARJ (one of the 2 rotating joint between the ISS truss and the solar panels). A year back this was found to be consuming more power and vibrating more than normal, due to an insufficient lubrication. Side effect of the cleaning operations was the release of debris material which could have also contaminated EuTEF.

- The EVAs took place on the nights (GMT) of 18-19, 20-21, 22-23 and 24-25 November.

- DEBIE2 was kept on during the SARJ cleaning operation and we found some interesting data potentially indicating the detection of the generated debris.

- In particular there is a cluster of 5 PZT events (i.e. particle impacts producing PZT detection) acquired during week 48 on SU2 (science data starting at November 24th 2008 17:51:03 GMT time)
EuTEF/DEBIE2 retrieval

- EuTEF and DEBIE2 were retrieved during STS-128 EVA#1 on 02/09/2009 after 18 months of operations
- Unique opportunity for a space debris monitor which allows to combine in-situ measurements and analysis of the retrieved hardware
High resolution pictures taken by astronauts Danny Olivas and Nicole Stott during STS-128 EVA#1

SU1 (STARBOARD)

SU4 (RAM)
DEBIE2 Space pictures

SU2 (ZENITH)
DEBIE2 Post-flight analysis

- The visual inspection performed on EuTEF at KSC soon after the shuttle landing identified one broken wire on the DEBIE2 SU2 (zenith sensor).
- Analysis of the pictures taken during retrieval EVA showed that the wire was already broken in space.
- In correspondence with the broken wire there is also a trace that from first analysis is thought to be due to an impact.
Conclusions

- DEBIE2 has been in-orbit for 18 months, collecting valuable data on sub-millimetre micro-meteoroids and space debris population flux.
- A first analysis of potential impact events has been performed.
- DEBIE2 data are highly dominated by noise events. False events on DEBIE2 are mainly due to the space environment (plasma, thermal, etc) and ISS.
- Background noise rejection criteria based on the timing between the different signals leaves only 0.07% of the original data sample. However the remaining data still contain noise and more refined filtering is needed.
- First post-flight analysis of the retrieved Sensor Units has been performed, showing a broken wire in the Zenith sensor, believed to be due an impact. Further analysis needed.
- Complete electrical and functional tests on the retrieved hardware planned in the near future to fully characterize the instrument performances in-orbit.
- Possibly we will start looking for another flight opportunity for DEBIE2!
Thanks!

- Thanks to Juha Kuitunen (PATRIA) for his indispensable support on DEBIE2 operations, EM debugging and data analysis.
- Thanks to Kalle Bunte and etamax team for providing the conversion to ISS attitude information and EDID database.
- Thanks to Carlo Gavazzi Space for their support in solving our data acquisition issues.
- Last but not least thanks to the wonderful ERASMUS USOC team for their excellent work and relentless support!