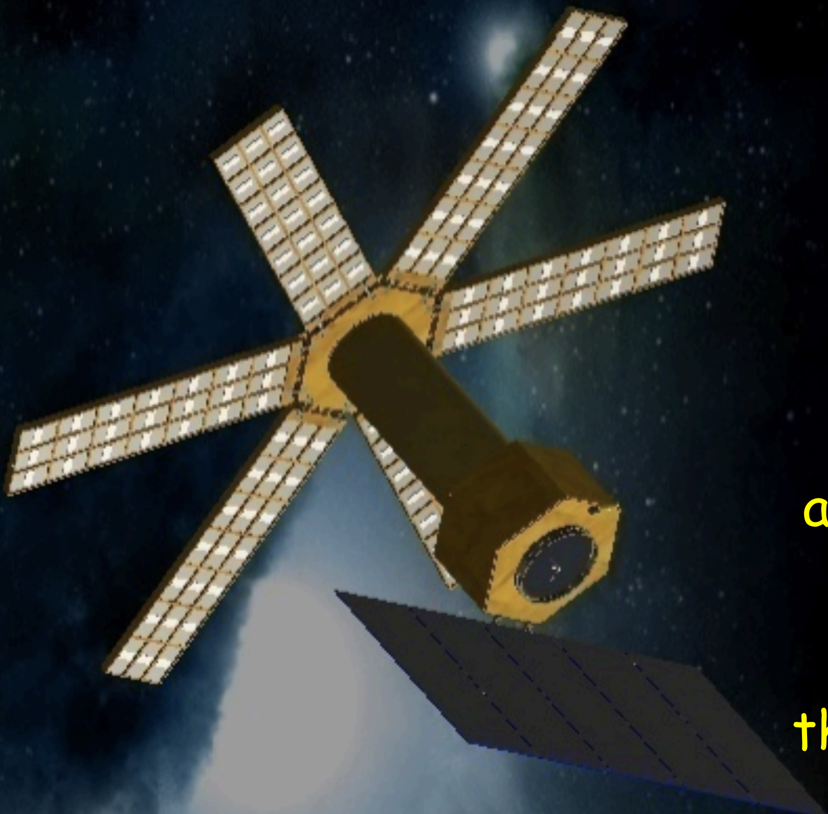
# LOFT
# Large Observatory For x-ray Timing



A mission proposal selected by ESA
as a candidate Cosmic Vision M3 mission
devoted to X-ray timing
and designed to investigate
the space-time around collapsed objects

Chris Tenzer (IAAT, University of Tübingen)
on behalf of the LOFT Consortium

# LOFT Organization Structure

| LOFT ESA Payload Manager |
| --- |
| **A. Short** (ESA) |
| **LOFT ESA Study Manager** |
| **C. Corral van Damme / M. Ayre** (ESA) |
| **LOFT ESA Study Scientist** |
| **D. Lumb** (ESA) |

| Study lead |
| --- |
| **Jan-Willem den Herder** (SRON, The Netherlands) |
| **Project Manager** |
| **Enrico Bozzo** (ISDC, Switzerland) |
| **System Engineering/Payload** |
| **Marco Feroci** (INAF-IASF Roma & INFN Tor Vergata, Italy) |
| **Science Team** |
| **Luigi Stella** (INAF-OAR, Italy) |
| **Michiel van der Klis** (Univ. of Amsterdam, The Netherlands) |
| **Peter Jonker** (SRON, The Netherlands) |

| Large Area Detector (LAD) |
| --- |
| **Silvia Zane** (MSSL, United Kingdom) |
| **Wide Field Monitor (WFM)** |
| **Soren Brandt** (DTU, Denmark) |
| **Margarita Hernanz** (IEEC-CSIC, Spain) |
| **Scientific and instrument simulations** |
| **Jöern Wilms** (Univ. of Erlangen-Nuremberg, Germany) |
| **Jean in 't Zand** (SRON, The Netherlands) |
| **Digital Electronics** |
| **Andrea Santangelo** (Univ. of Tuebingen, Germany) |
| **Silicon detectors** |
| **Martin Pohl** (Univ. of Geneva, Switzerland) |
| **Andrea Vacchi** (INFN, Italy) |

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*on behalf of scientists from:*
*Brazil, Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Ireland, Israel, Italy, Japan, the Netherlands, Poland, Spain, Switzerland, Turkey, United Kingdom, USA*

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# ESA Cosmic Vision Selection

**L1 Slot**

ATHENA: X-ray Observatory (formerly IXO)

JUICE: Mission to Jupiter and its moons (formerly EJSM-Laplace)

NGO: Gravitational Waves Observatory (formerly LISA)

**M3 Slot**

EChO: (Exoplanet Characterisation Observatory)

STE-QUEST: (Space-Time Explorer and Quantum Equivalence Principle Space Test)

MarcoPolo-R: return a sample of material from a primitive near-Earth asteroid

LOFT: Large Observatory for X-ray Timing

9.3.2012: Call for **S-class** missions, launch in 2017

# M3 (LOFT) ESA Programmatics

## Anticipated Mission Timeline (if further selected)

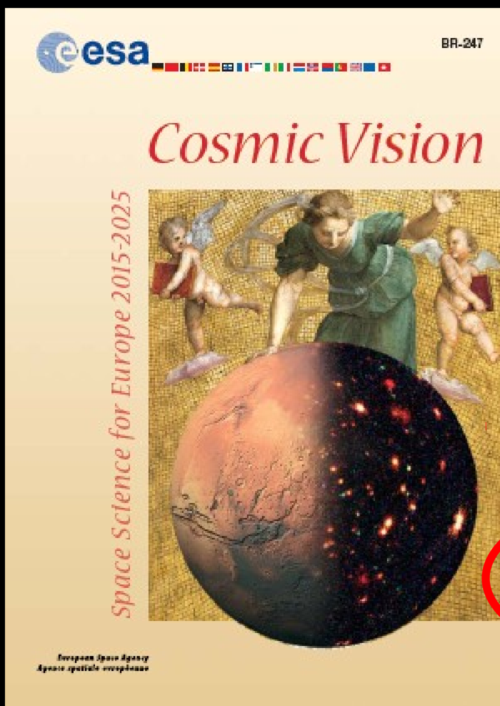
Following this Call for Missions, four new M missions, one of which being LOFT, have been recommended by the Space Science Advisory Committee (SSAC) for further assessment. These candidate M missions for the 2022 launch slot will enter a competitive process according to the following schedule:

- Assessment Phase in 2011-2013
- Down selection to enter in Definition Phase in 2013
- Definition Phase completed by 2014
- Adoption of M3 mission in 2015
- Start of Implementation Phase by the end of 2015
- Launch by 2022.

## Goal of the Assessment Phase (2011-2013)

The objective of the Assessment Phase is to provide all the elements for enabling the down-selection process, in particular the space segment definition for meeting the assigned science objectives, the implementation schedule, the mission Cost at Completion, the technology readiness evaluation and the implementation risk assessment.

# LOFT will address Fundamental Question 3.3 "Matter under extreme conditions" in ESA's Cosmic Vision program




**3. What are the fundamental physical laws of the Universe?**

**3.1 Explore the limits of contemporary physics**

Use stable and weightless environment of space to search for tiny deviations from the standard model of fundamental interactions

**3.2 The gravitational wave Universe**

Make a key step toward detecting the gravitational radiation background generated at the Big Bang

**3.3 Matter under extreme conditions**

Probe gravity theory in the very strong field environment of black holes and other compact objects, and the state of matter at supra-nuclear energies in neutron stars

## LOFT Core Science

Strong Gravity

Dense Matter

Observatory Science

To match ESA Cosmic Vision Theme:
Matter under extreme conditions

- Does matter orbiting close to a Black Hole event horizon follow the predictions of General Relativity?
- What is the Equation of State of matter in Neutron Stars?

# Observatory Science

LOFT lifetime: 4 years

~50% of the time LOFT will be Observatory for virtually all classes of relatively bright sources (> few x $10^{-12}$ erg/cm$^2$/s): including

- X-ray bursters,
- High mass X-ray binaries
- X-ray transients (all classes)
- Cataclismic Variables
- Magnetars
- Gamma ray bursts (serendipitous)
- Nearby galaxies (SMC, LMC, M31, …)
- Bright AGNs

# The LOFT Mission

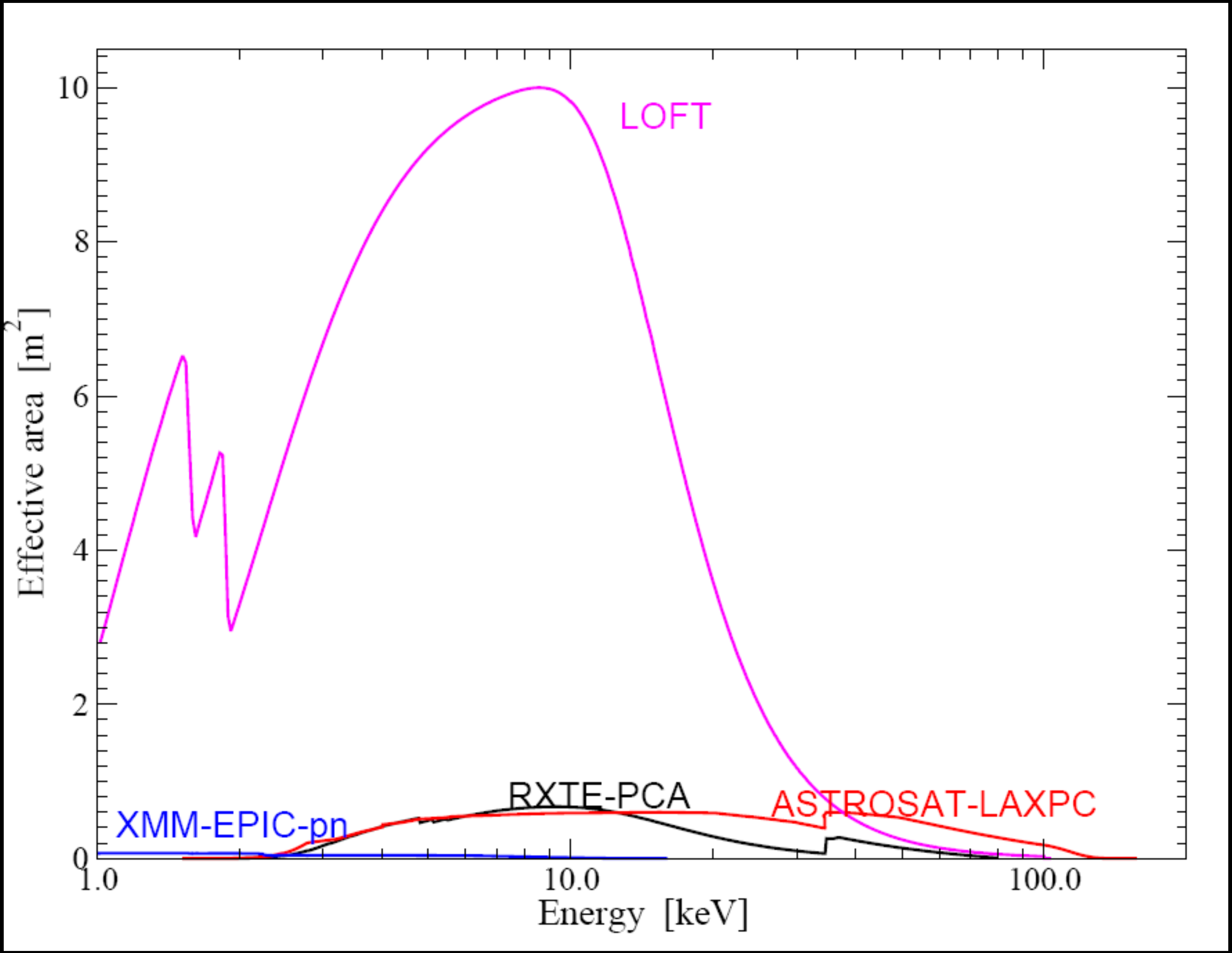
LOFT is specifically designed to exploit the diagnostics of very rapid X-ray flux and spectral variability that directly probe the motion of matter down to distances very close to black holes and neutron stars, as well as the physical state of ultradense matter.

LOFT will investigate variability from submillisecond QPO's to years long transient outbursts.

The LOFT LAD has an effective area ~20 times larger than its largest predecessor (the Proportional Counter Array onboard RossiXTE) and a much improved energy resolution.

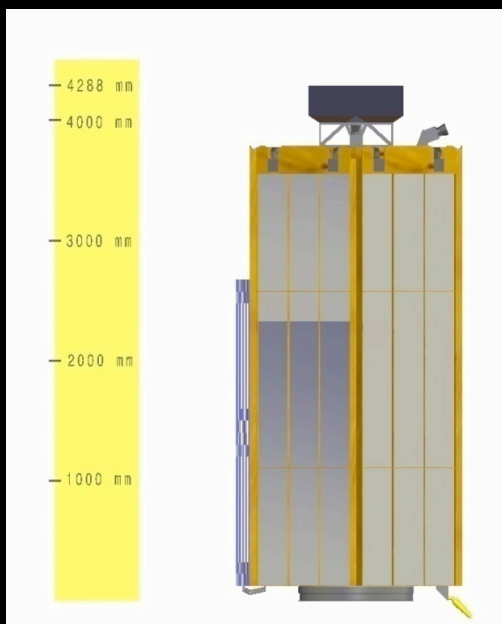
The LOFT WFM will discover and localize X-ray transients and impulsive events and monitor spectral state changes, triggering follow-up observations and provide important science in its own.

# LOFT in one Plot

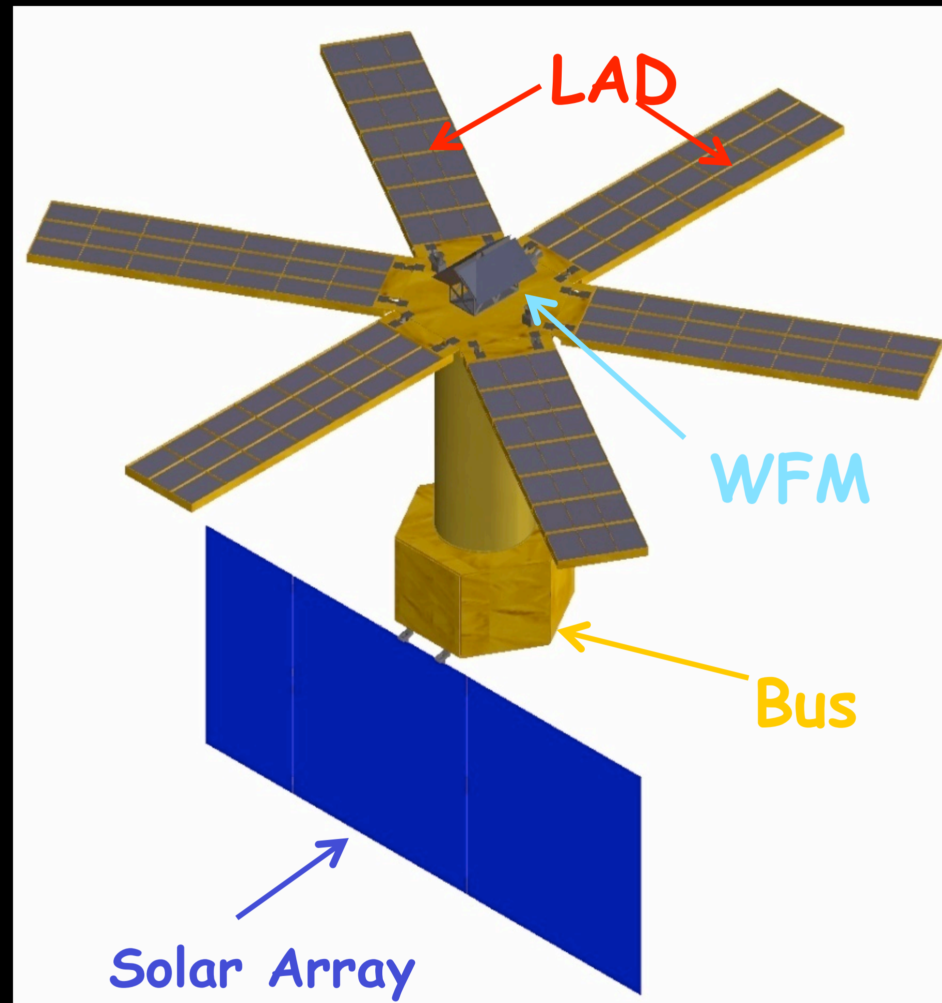


# LOFT current configuration

Industrial study by Thales
Alenia Space – Italia



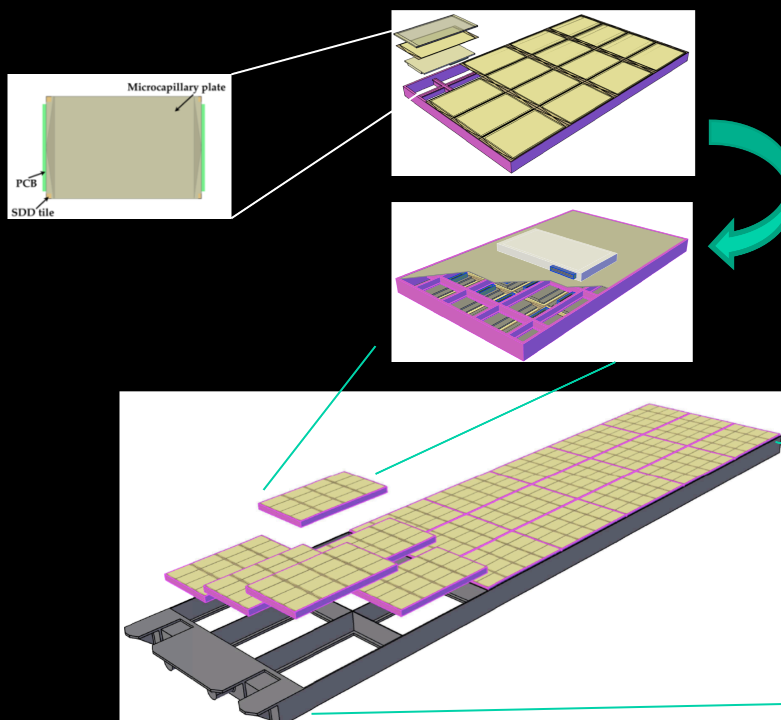

folded

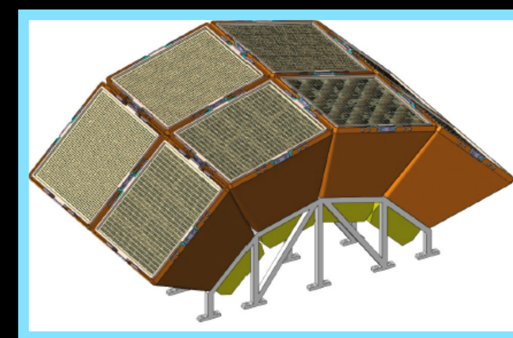


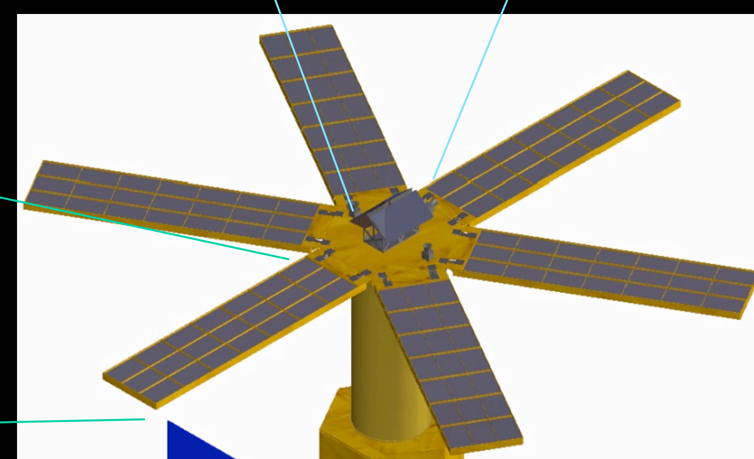
# LOFT Instruments

**WFM:**
4 Units
2 Cameras per Unit
4 detectors per Camera

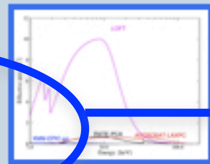
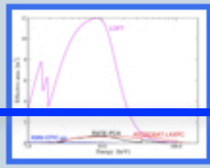
**LAD:**
16 Detectors per Module
21 Modules per Detector Panel
6 Detector Panels per LAD





# Large Area Detector Requirements

| Item | Requirement | Goal |
|---|---|---|
| Effective area | 4 $m^2$ @ 2 keV<br>8 $m^2$ @ 5 keV<br>10 $m^2$ @ 8 keV<br>1 $m^2$ @ 30 keV  | 5 $m^2$ @ 2 keV<br>9.6$m^2$ @ 5 keV<br>12 $m^2$ @ 8 keV<br>1.2 $m^2$ @ 30 keV  |
| Calibration accuracy area | 15% | 10% |
| Energy range | 2 – 50 keV | 1 – 50 keV |
| Energy resolution | 260 eV @ 6 keV<br>200 eV (singles, 40%)<br>2 keV above 30 keV (allows for binning) | 200 eV @ 6 keV<br>160 eV (singles, 40%) |
| knowledge energy scale | $10^{-2}$ | 0.8 $10^{-2}$ |
| Collimated FoV (FWHM) | 1 degree | 0.5 degree |
| Transparency of collimator | ~1% at 30 keV | 0.5% at 30 keV |
| Flat top | 12 arcmin, ± 2% | 12 arcmin, ± 1% |
| Time resolution | 10 μs | 7 μs |
| Absolute time | 1 μs | 1 μs |
| Dead time | < 1% @ 1 Crab,<br>< 10% @ 10 Crab | < 0.5% @ 1 Crab,<br>< 5% @ 10 Crab |
| Calibration knowledge deadtime | Less than the statistical precision of power spectrum for 1 day at 15 Crab (TBC) | Factor 2 better |
| Background | < 10 mCrab | < 5 mCrab |
| Background knowledge | 10% | 5% |
| Max flux (continuous, no loss of info) | > 500 mCrab | > 500 mCrab |
| Max flux (continuous, re-binned) | 15 Crab | 30 Crab |

Instrument Size

Good Energy Resolution

Great Timing Performance

High Count Rates

# Wide Field Monitor Requirements

| Item | Requirement | Goal |
|---|---|---|
| Location accuracy | 1 arcmin | 0.5 arcmin |
| Angular resolution | 5 arcmin | 3 arcmin |
| Sensitivity (5 μ) | 1 Crab (1 s)<br>5 mCrab (50 ks) | 0.2 Crab (1s)<br>2 mCrab (50 ks) |
| Calibration accuracy (sensitivity) | 20 % | 15 % |
| Field of view | 50% of the accessible part of the sky of the LAD | Same, as improvement of the sensitivity is the prime goal |
| Energy range | 2 – 50 keV | 1 – 50 keV |
| Energy resolution | 500 eV | 300 eV |
| Energy scale knowledge | 4% | 1% |
| Number of energy bands for compressed images | 8 | 16 |
| Time resolution | 300 sec for normal<br>10 μsec for triggered | 150 sec for normal<br>5 μsec for triggered |
| Absolute time calibration | 1 μsec | 1 μsec |
| duration for rate triggers | 0.1 sec - 60 sec | 0.1 - 60 sec |
| Rate meter data | 16 msec | 8 msec |
| Transient event down-link | < 3 hours (2 orbits) | < 1.5 hour (1 orbit) |
| Availability of triggered WFM data | 3 hours | 1.5 hours |
| Onboard memory | 5 min @ 100 Crab | 10 min @ 100 Crab |

FoV,
Coded Mask

Possibly Instant Notification?
Automatic Slew?

# The LOFT Mission Profile

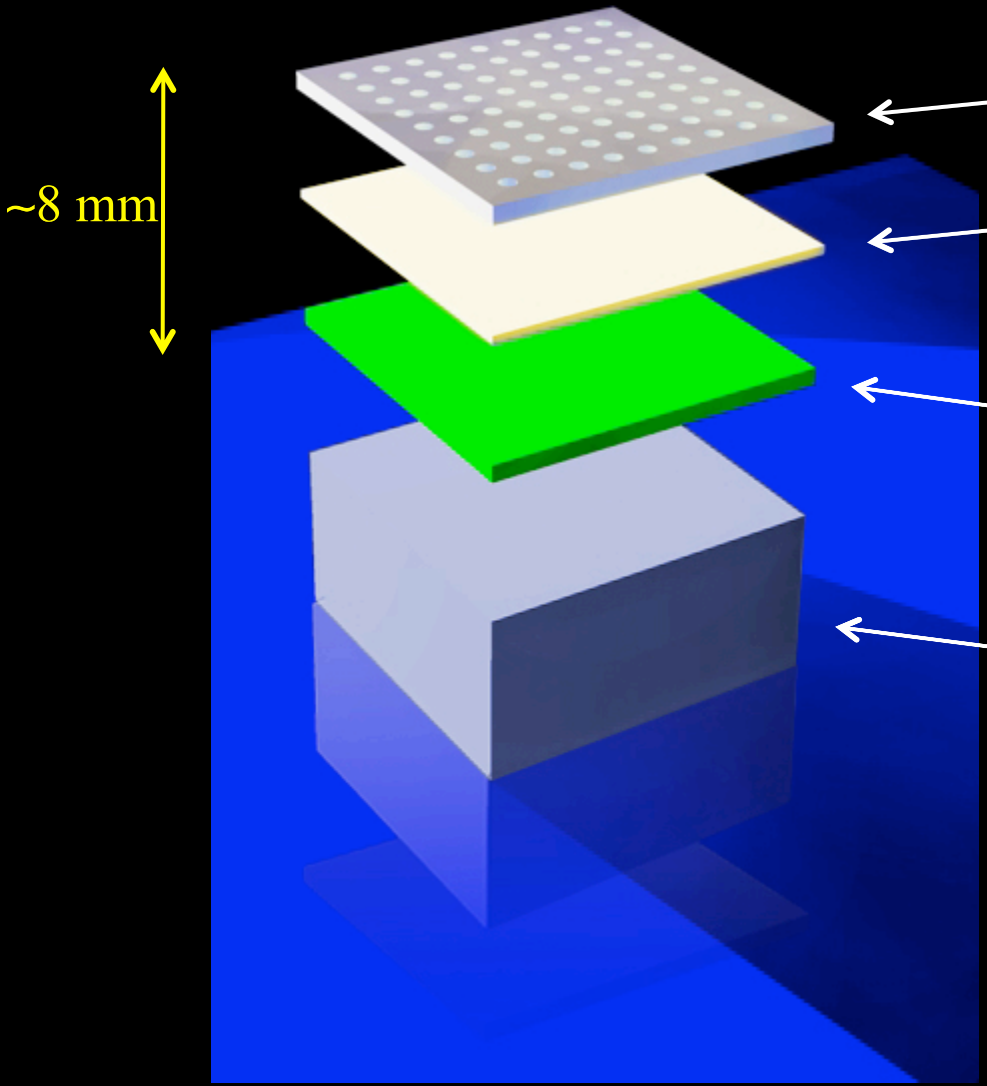
| | |
|---|---|
| Orbit | Low earth (≤600 km), equatorial (<5°), circular |
| Launcher | Soyuz from Kourou |
| Satellite Mass | ~2000 kg (with margins) |
| Satellite Power | ~1800 W (with margins) |
| Slew rate | >6° /minute |
| Telemetry | 8 Mbps |
| Ground Stations | Kourou, Malindi |
| Nominal Lifetime | 4 years |

# The LOFT Technologies

1. Large Area Silicon Drift Detectors

2. Capillary plates X-ray collimators

# The Key to LOFT:
# low weight/power/volume per unit effective area




Capillary Plate Collimator
(~3 kg/m²)

Silicon Drift Detector
(~1.3 kg/m²)

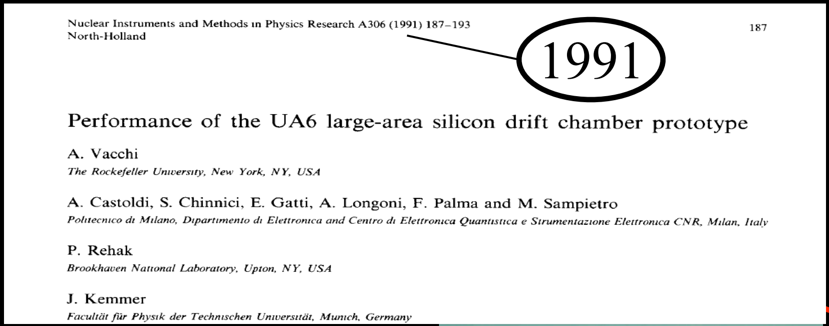
Readout electronics
(~2.5 kg/m²)

Mechanical support,
Power Distribution,
Interfaces, …

# The Large Area Silicon Drift Detector for LOFT

## A heritage of the ITS of the ALICE experiment at the Large Hadron Collider (CERN)

INFN Trieste, in collaboration with Canberra Inc., designed, built, tested and calibrated 1.5 $m^2$ of SDD detectors, now operating since ~2 years.


Nuclear Instruments and Methods in Physics Research A306 (1991) 187–193
North-Holland
187

1991

Performance of the UA6 large-area silicon drift chamber prototype

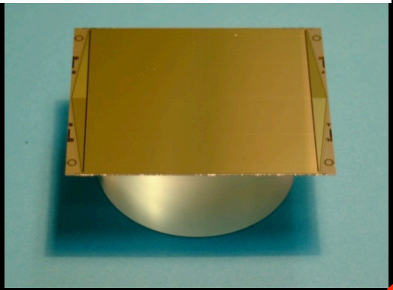
A. Vacchi
*The Rockefeller University, New York, NY, USA*

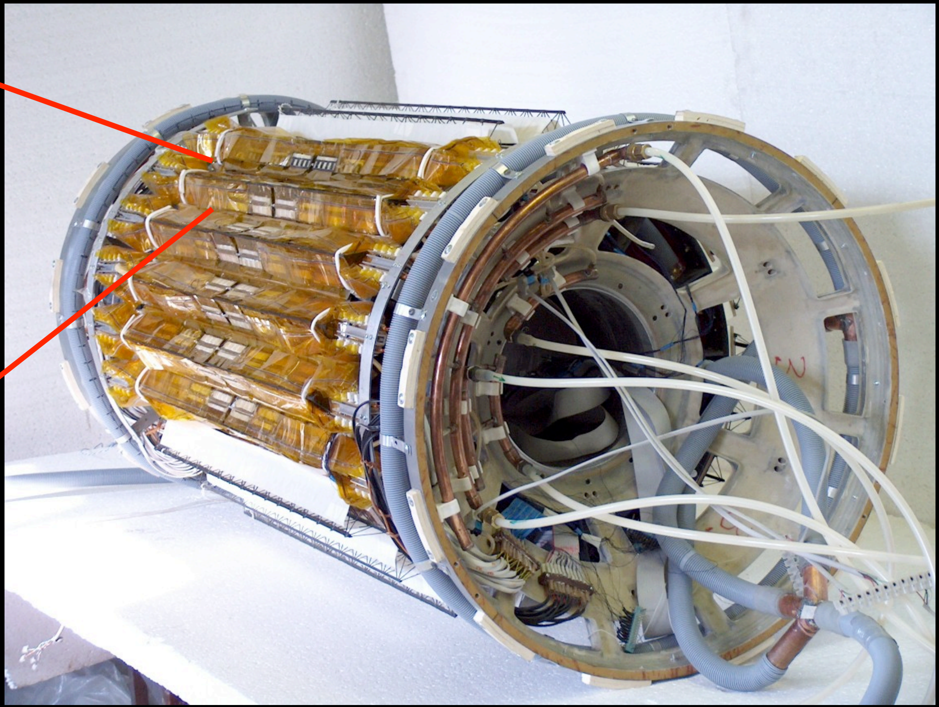
A. Castoldi, S. Chinnici, E. Gatti, A. Longoni, F. Palma and M. Sampietro
*Politecnico di Milano, Dipartimento di Elettronica and Centro di Elettronica Quantistica e Strumentazione Elettronica CNR, Milan, Italy*

P. Rehak
*Brookhaven National Laboratory, Upton, NY, USA*

J. Kemmer
*Facultät für Physik der Technischen Universität, Munich, Germany*

Mature Technology. High TRL.
Proven mass production.

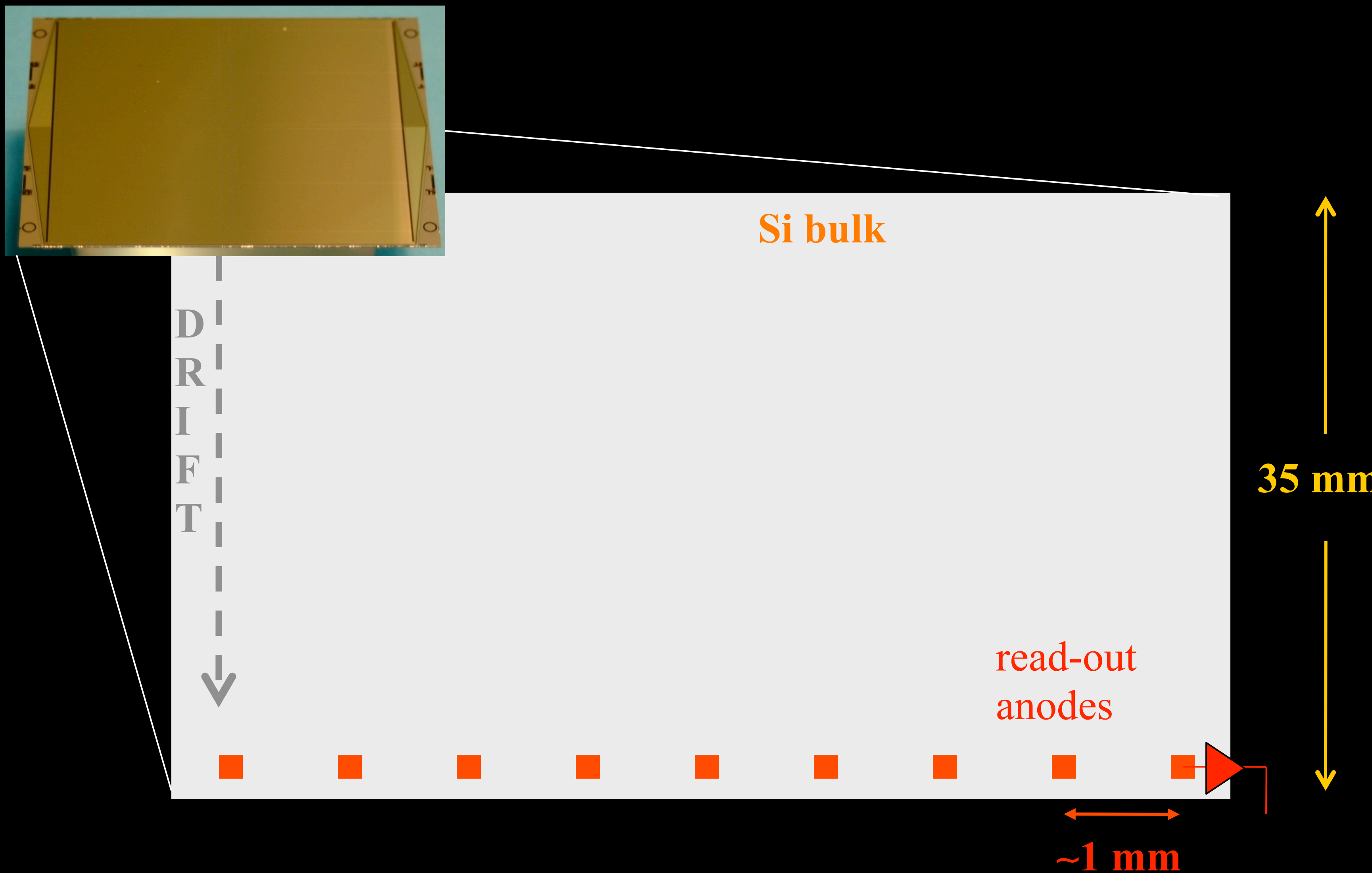




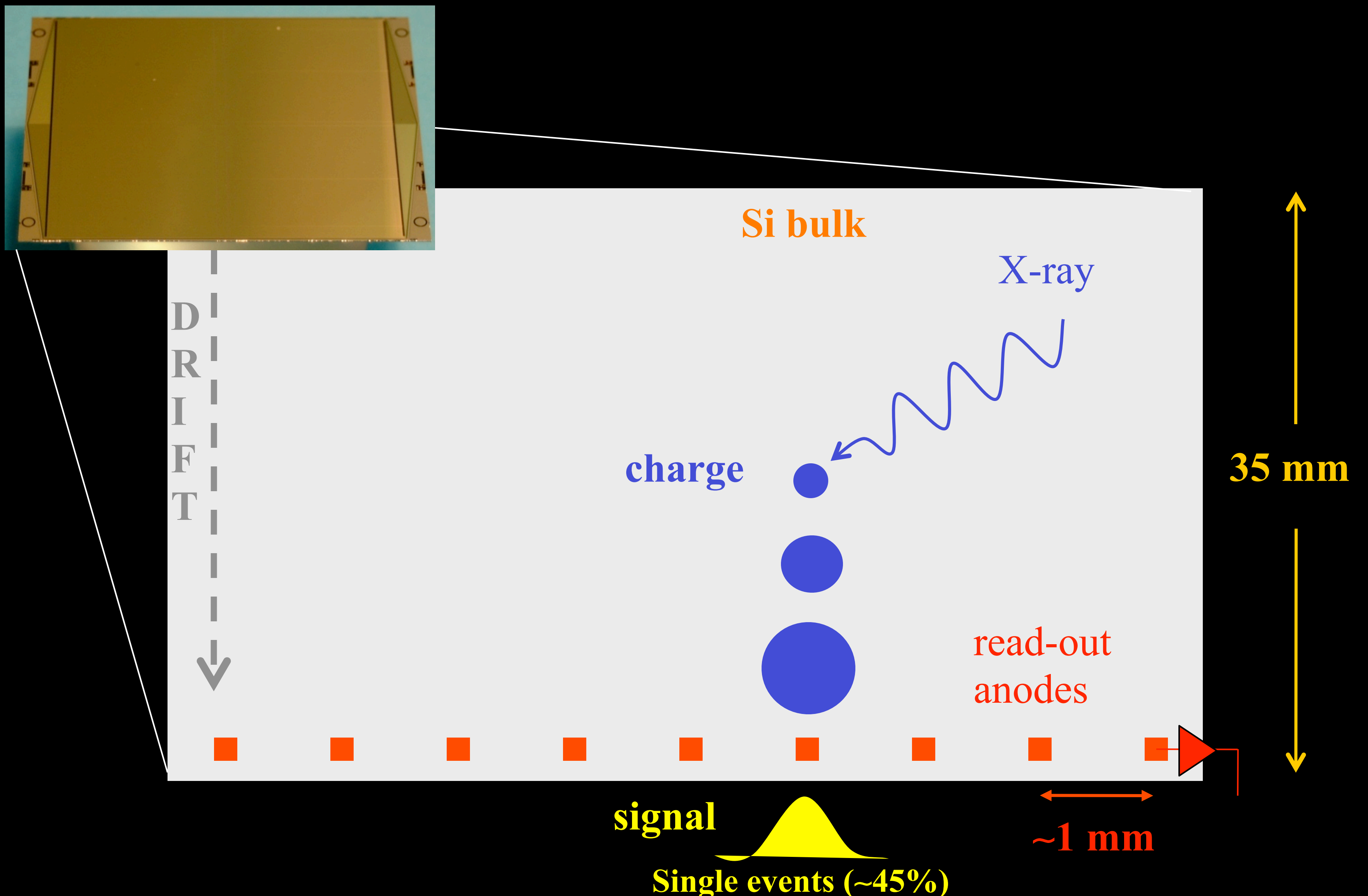
**LOFT Baseline**

| | |
|---|---|
| Thickness | 450 μm |
| Monolithic Active Area | 76 $cm^2$ |
| Drift time | <5 μs |
| Single-channel area | 0.3 $cm^2$ |

# The Working Principle of the LOFT Si Drift Detector



# The Working Principle of the LOFT Si Drift Detector



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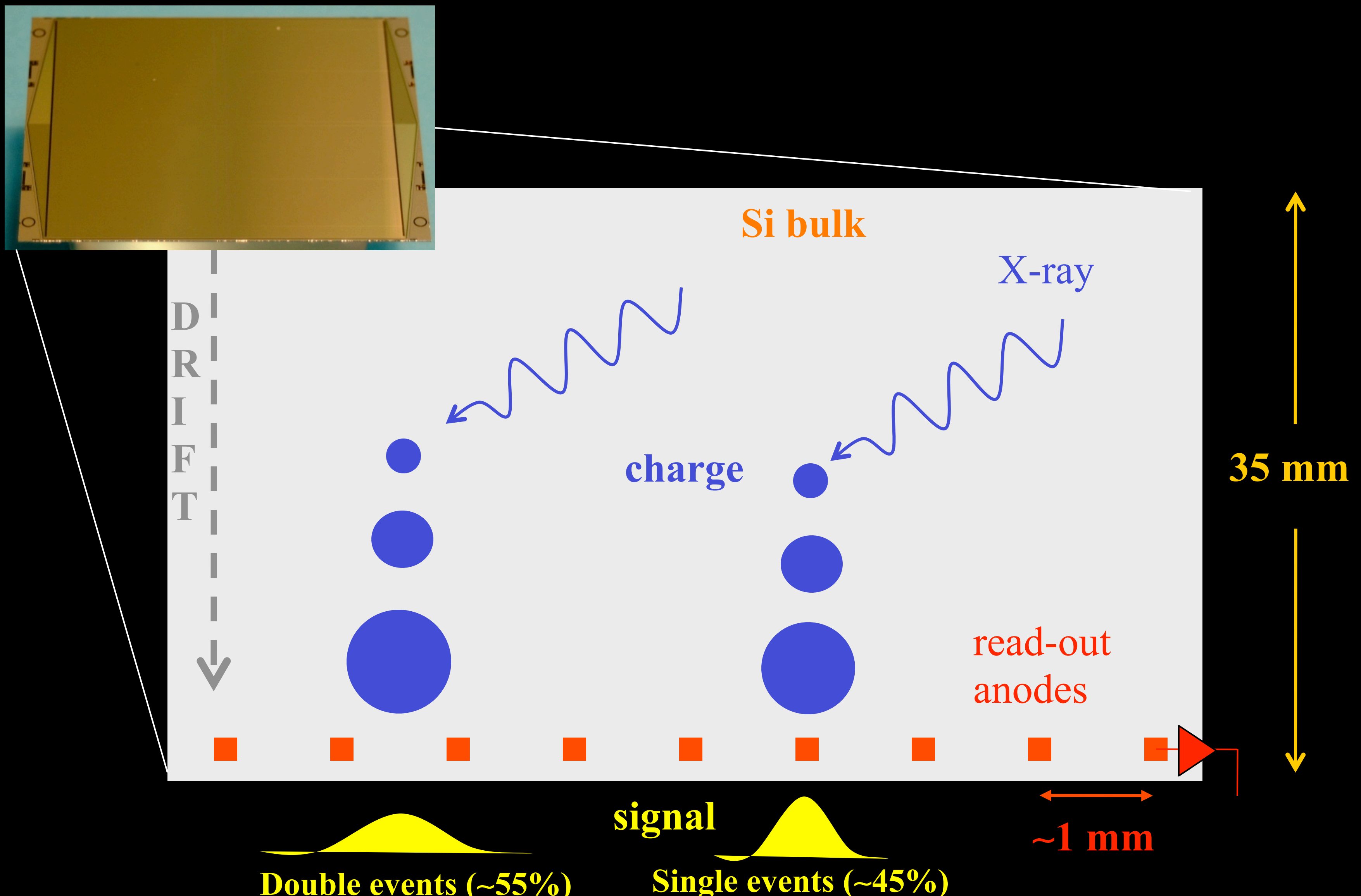
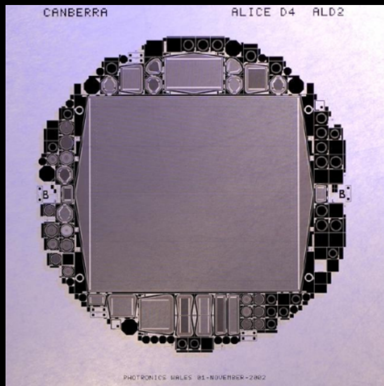
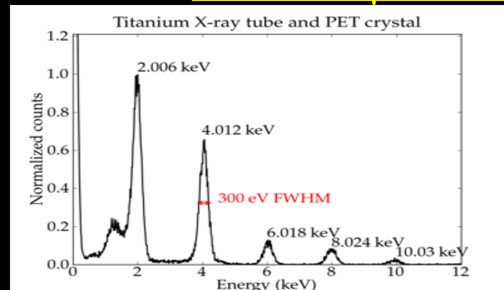


# The development of LOFT Si Drift Detector

2009



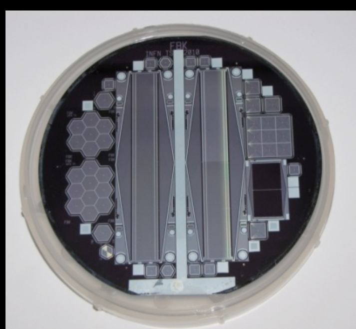

ALICE spare model - discrete read-out - Room Temperature

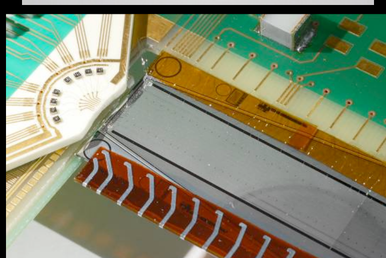


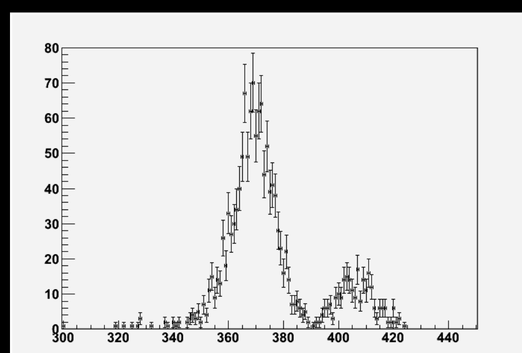

2010

$1^{st}$ LOFT Protoype

$Fe^{55}$ source (5.9-6.4 keV)

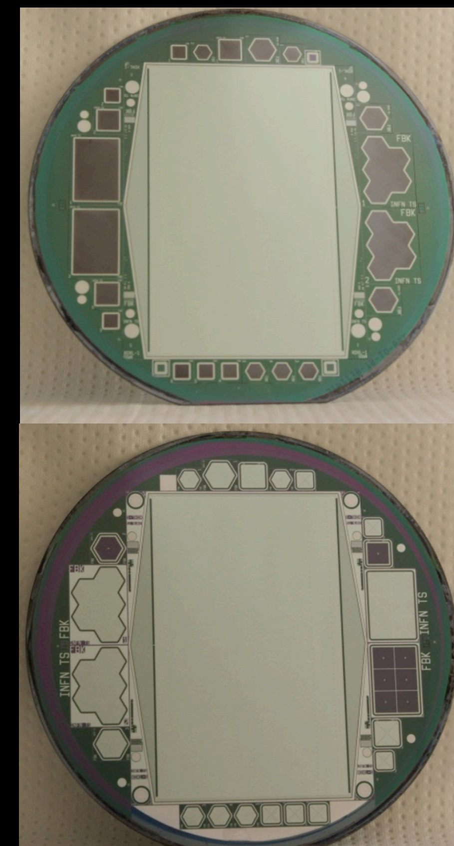




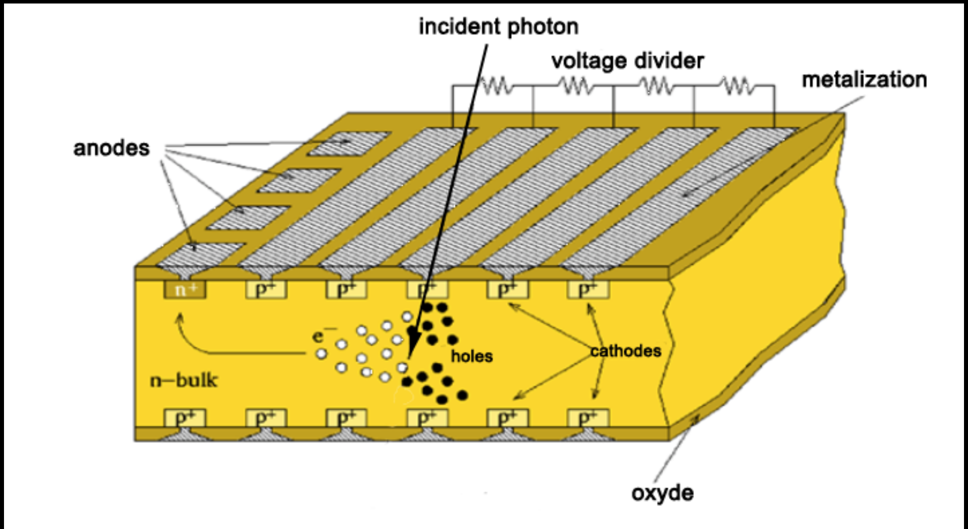


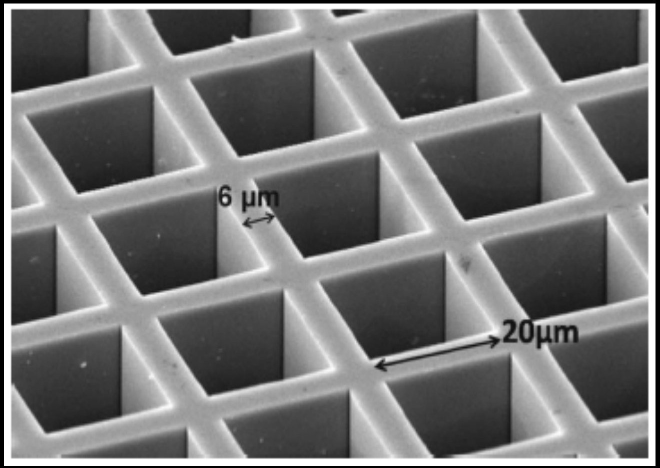

2011

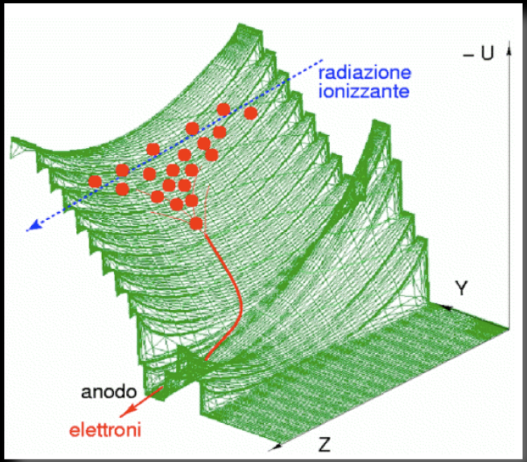
$2^{nd}$ LOFT Protoype

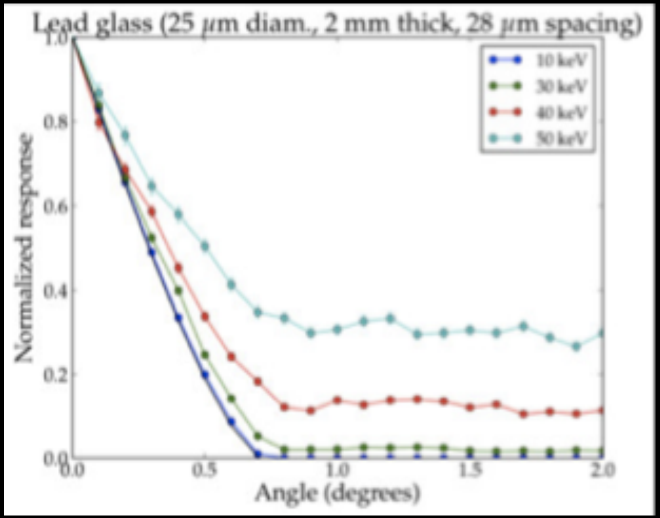


# Si Drift Detectors and Capillary Plate Collimators

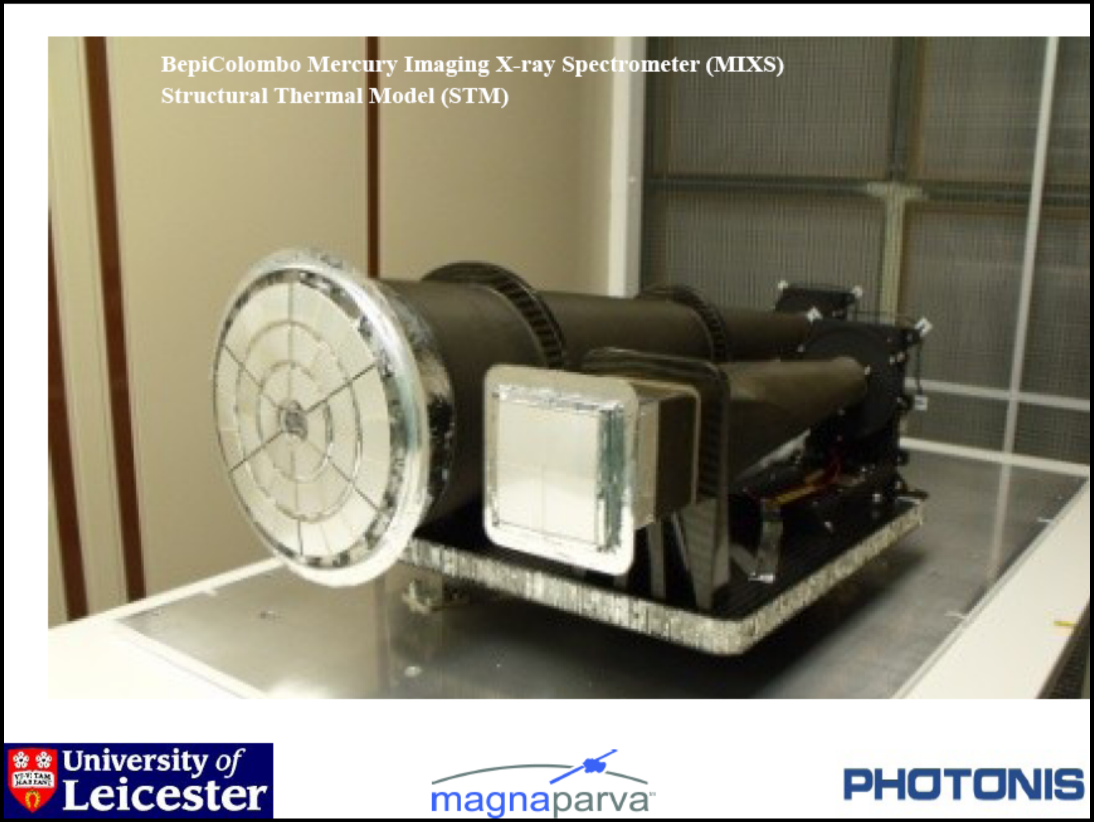


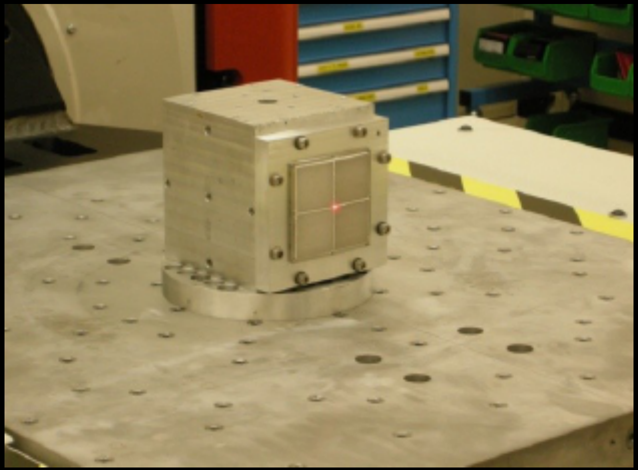



# The LOFT capillary plate collimator at Univ. of Leicester



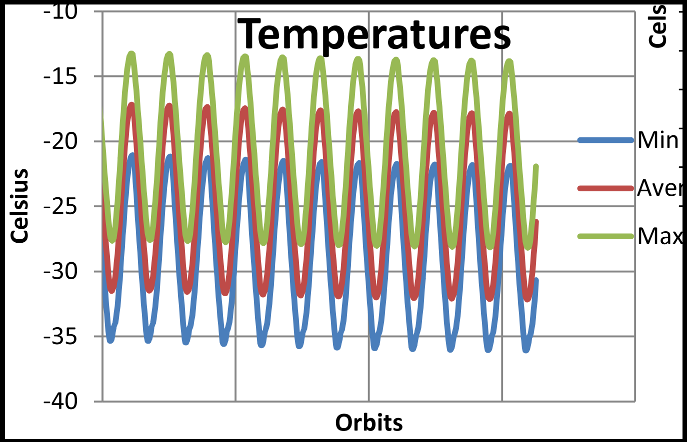



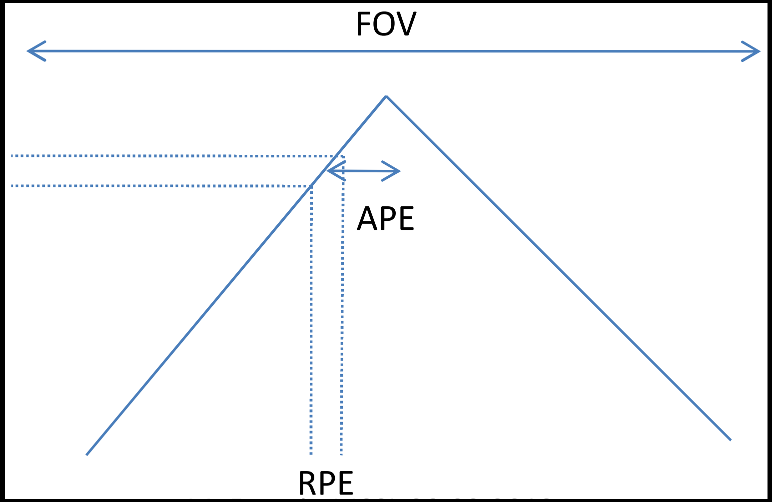
The MIXS-C model during vibration tests at RAL

Courtesy G.W. Fraser, Univ. of Leicester

# Critical Mission Parameters Linked to Calibration

- Background / Radiation Environment
- Source Confusion
- Absolute Pointing Knowledge and Stability
- Degradation of Energy Resolution due to Radiation Damage
- Temperature Stability



# Critical Mission Parameters Linked to Calibration

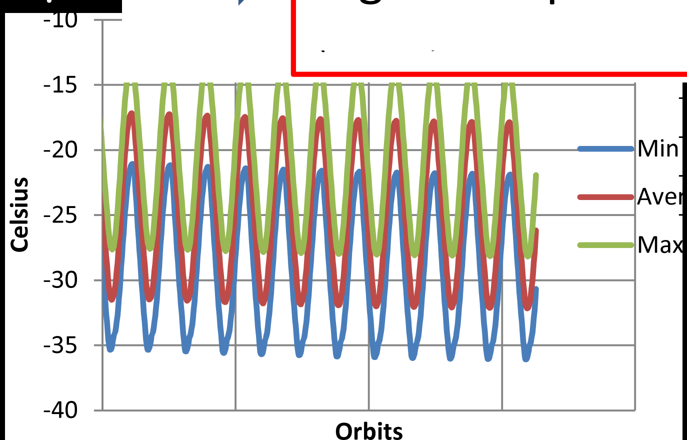
- Background / Radiation Environment
- Source
- Absolut
- Degrad
- Temper

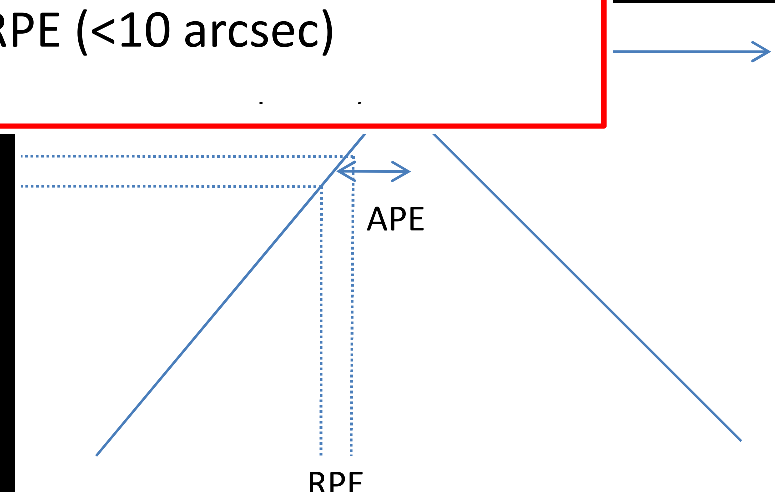
Baseline collimator

5 mm thick, 80 µm pore size, 10 µm wall (80% OAR)

(and on a single tile -> higher effective area)

Tighter requirement on RPE (<10 arcsec)



# Critical Items for Calibration

## Critical Parameters for Ground and in-Flight Calibration

- Effective area as f(Energy) (10 $m^2$ @ 8 keV)
- Energy resolution as f(Energy) (@ 6 keV: Singles 200eV, Overall 260 eV)
- Knowledge of energy scale (1e-2), Temperature effects
- Collimator performance as f(Angle, Energy) (measured up to 50 keV)
- Dead time, pileup effects as f(Countrate)

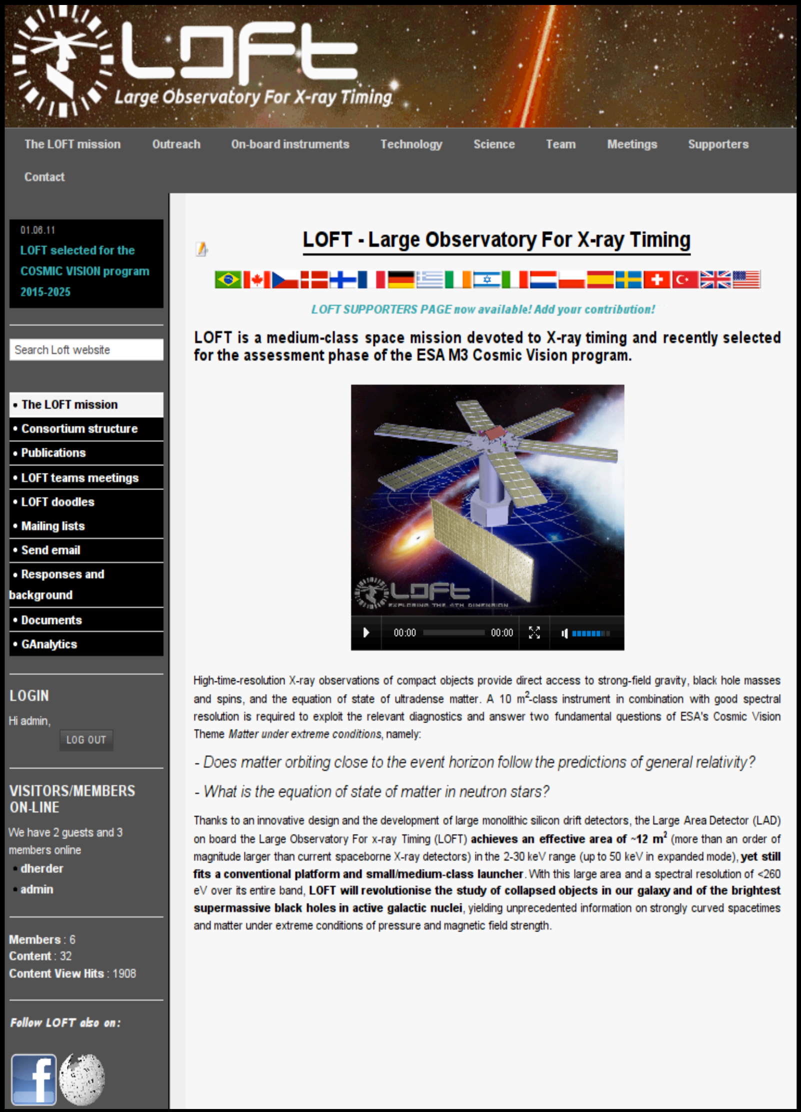
# LOFT Web Page

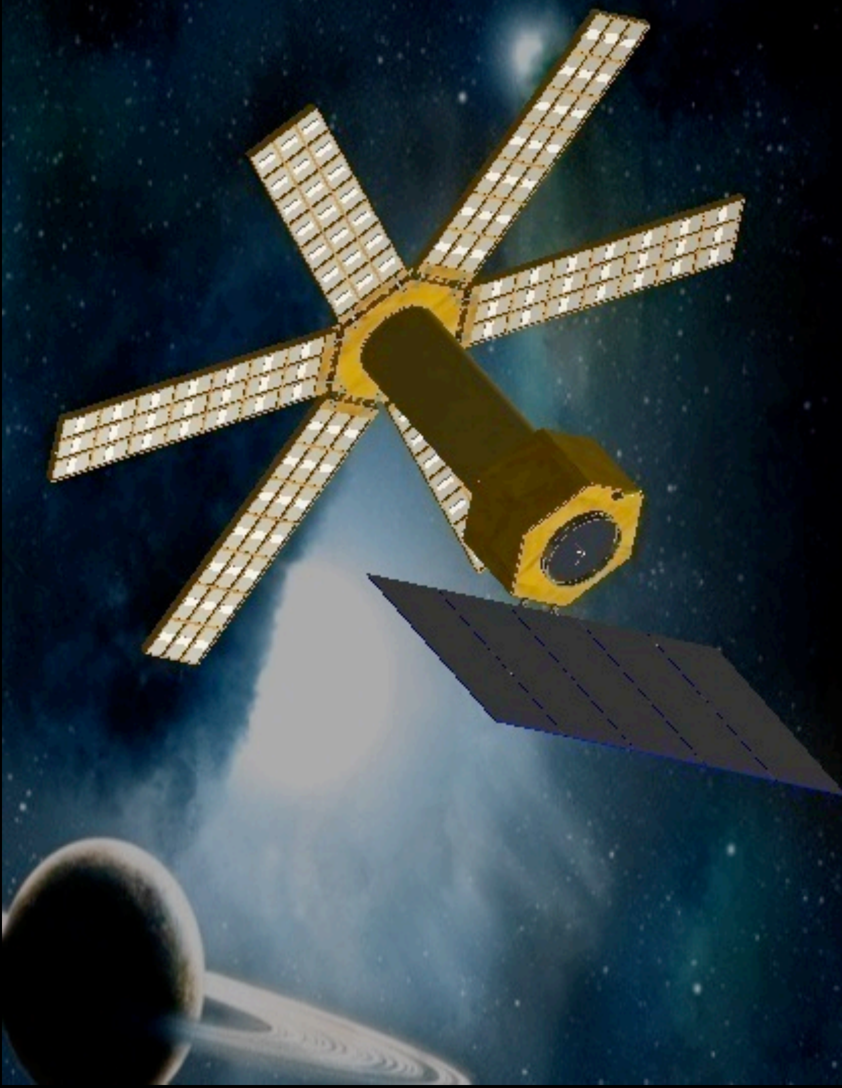
http://www.isdc.unige.ch/loft

- Mission info
- Simulation Tools
- Project status updates
- Public Outreach

2nd LOFT Science Meeting:
24-27.9.2012 Toulouse

LOFT International Support Team:





LOFT is a simple mission, relying on solid hardware heritage, offering both breakthrough and observatory science.

LOFT is one of the 4 mission concepts selected by the ESA Advisory Structure as a candidate in CV-M3

http://www.isdc.unige.ch/loft

Thank you