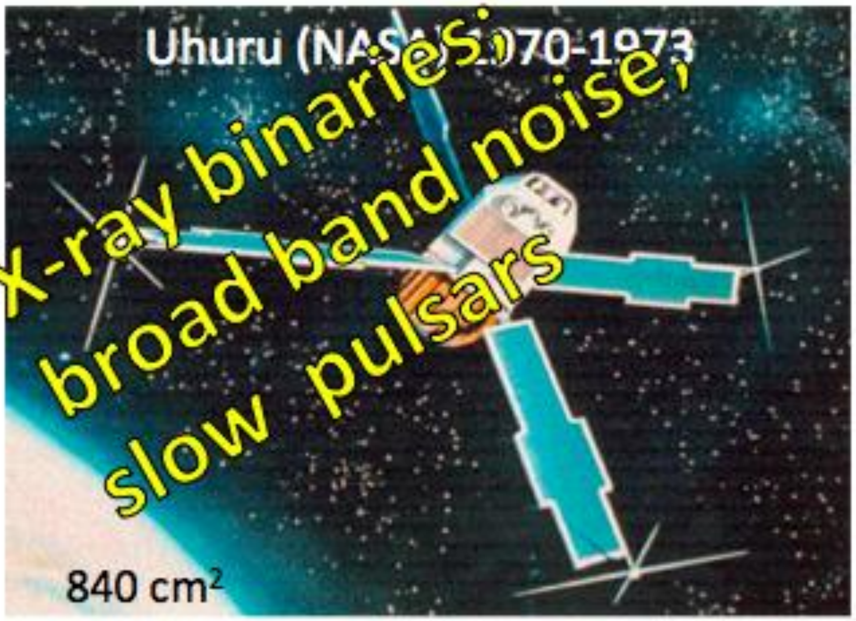
LOFT: Large Observatory For x-ray Timing

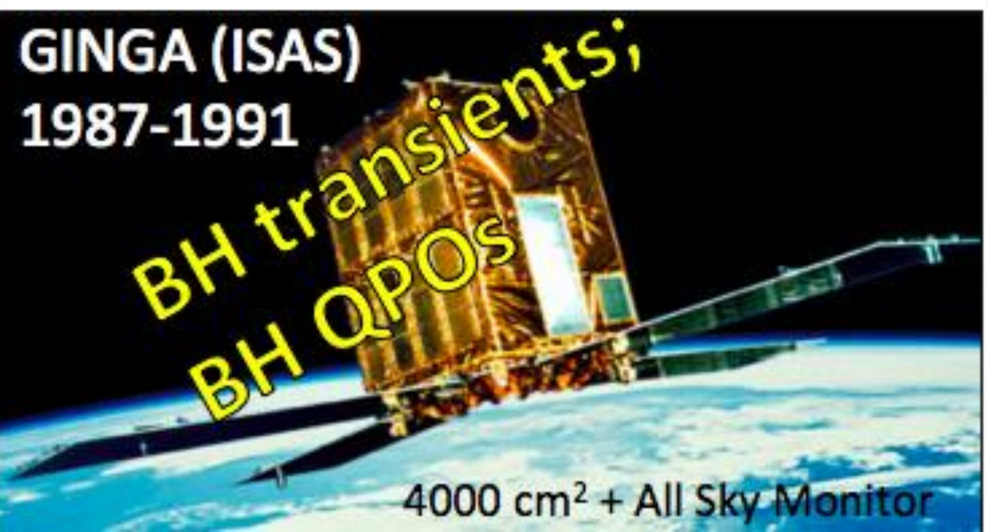
A mission selected by ESA
as a candidate CV M3 mission
Devoted to X-ray timing
and designed to investigate
the space-time around collapsed objects

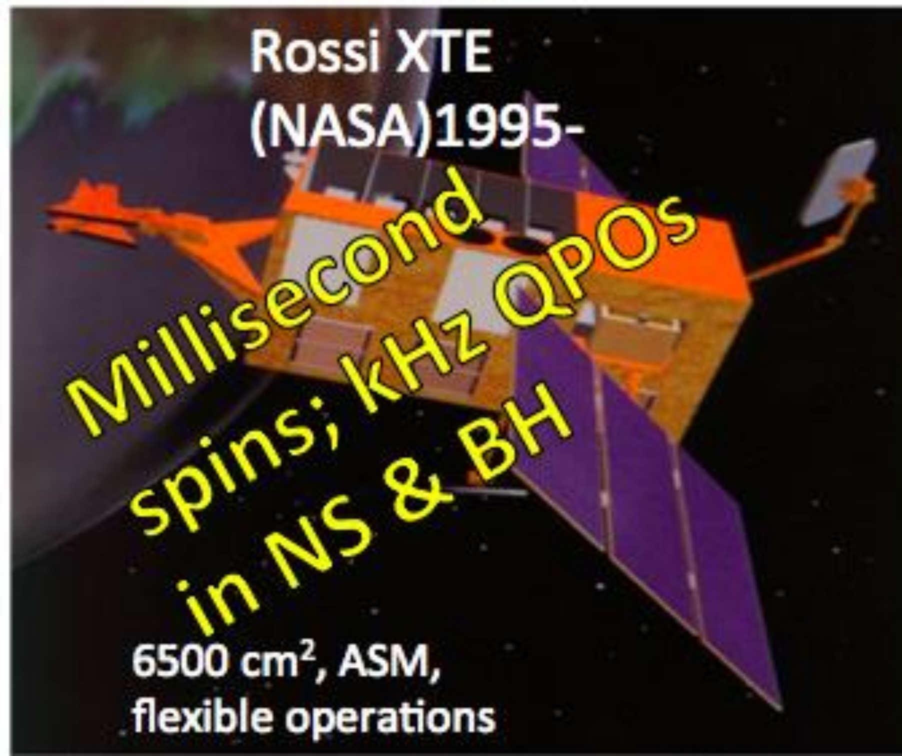
S. Zane (MSSL/UCL)
on behalf of the LOFT Consortium

The First UK LOFT Science Meeting, London, 24-25 June 2013

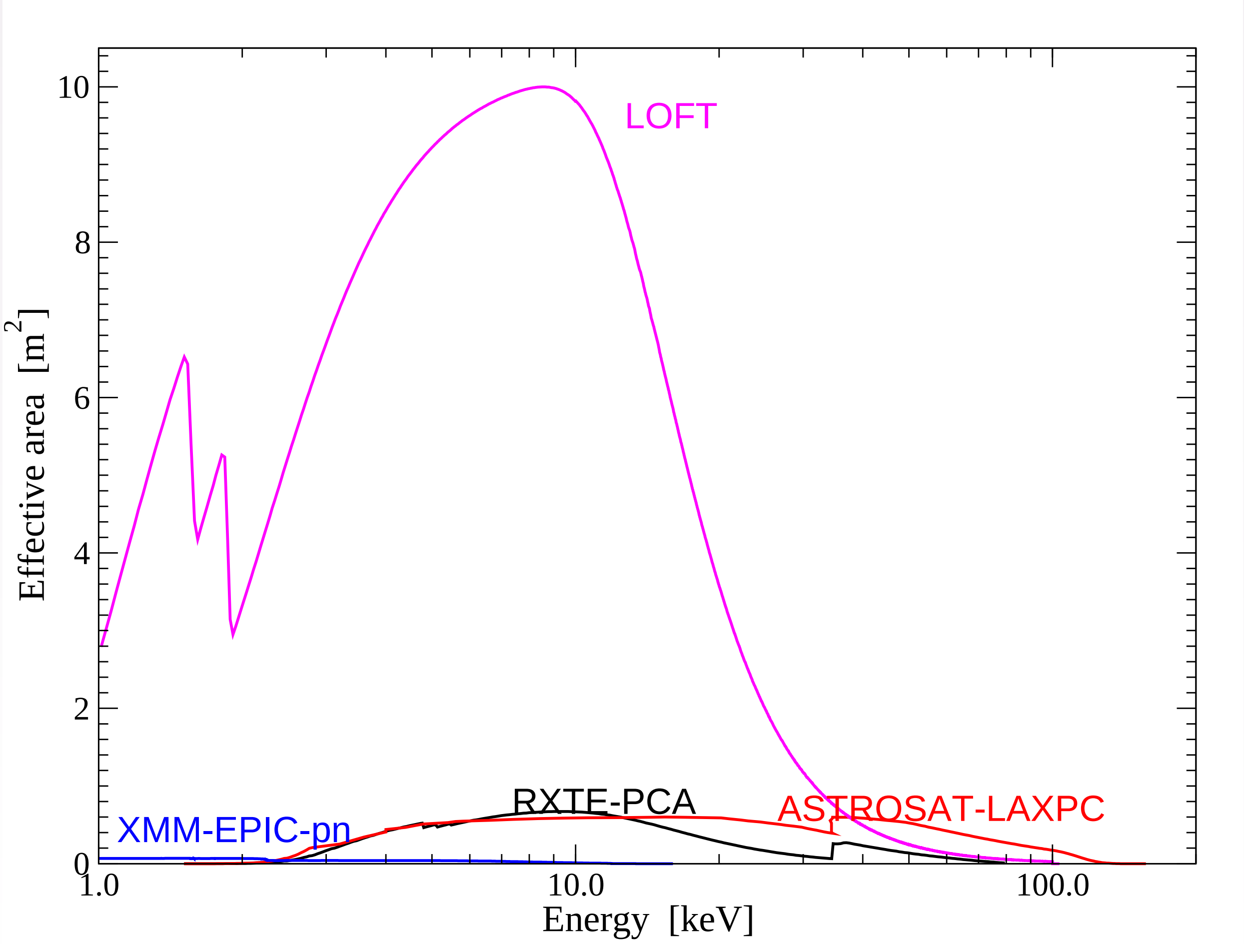
Missions & discoveries





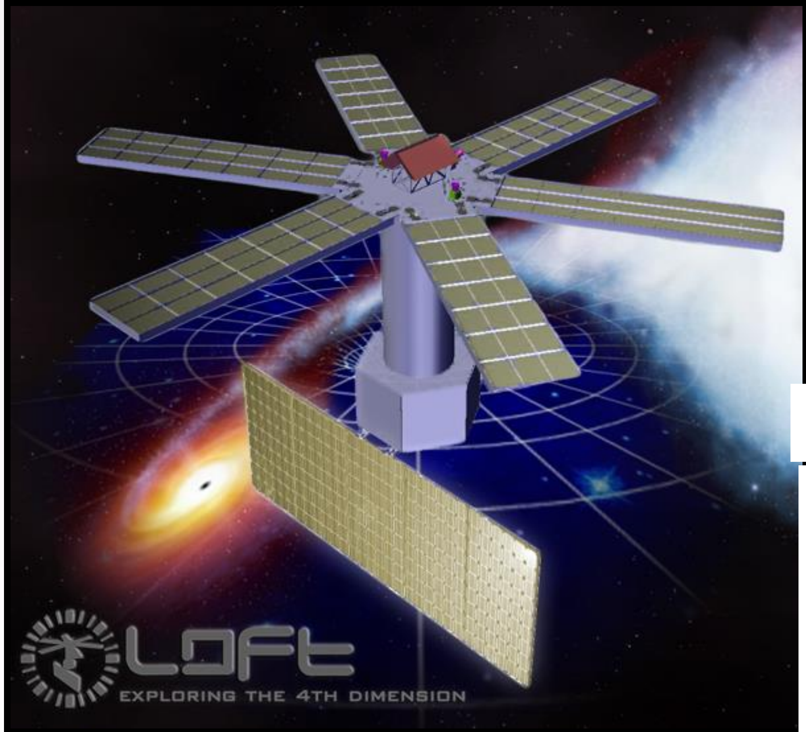


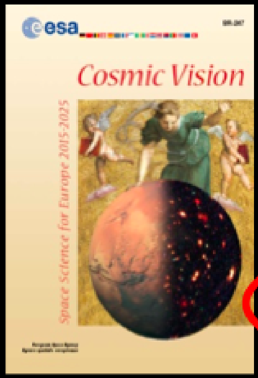
LOFT in 1 plot:



S/N ∝ Area, 1 sigma becomes 20 sigma (for uncoherent detection regime)

The LOFT consortium





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 Science Team composed of scientists from:

Australia, Brazil, Canada, CzechRepublic, Denmark, Finland, France, Germany, Greece, Ireland, Israel, Italy, Japan, theNetherlands, Poland, Spain, Sweden, Switzerla[nd], Turkey, United Kingdom, USA

THE LOFT SCIENCE TEAM

Jan-Willem den Herder	SRON, the Netherlands
Marco Feroci	INAF/IASF-Rome, Italy
Luigi Stella	INAF/OAR-Rome, Italy
Michiel van der Klis	Univ. Amsterdam, the Netherlands
Martin Pohl	Univ of Geneve, Switzerland
Silvia Zane	MSSL, United Kingdom (LAD)
Margarita Hernanz	IEEC-CSIC, Spain (WFM)
Søren Brandt	DTU, Copenhagen, Denmark (WFM)
Andrea Santangelo	Univ. Tuebingen, Germany
Didier Barret	IRAP, Toulouse, France
Alex Short	ESA
Carlos Van Damme/ Mark Ayre	ESA
David Lumb	ESA

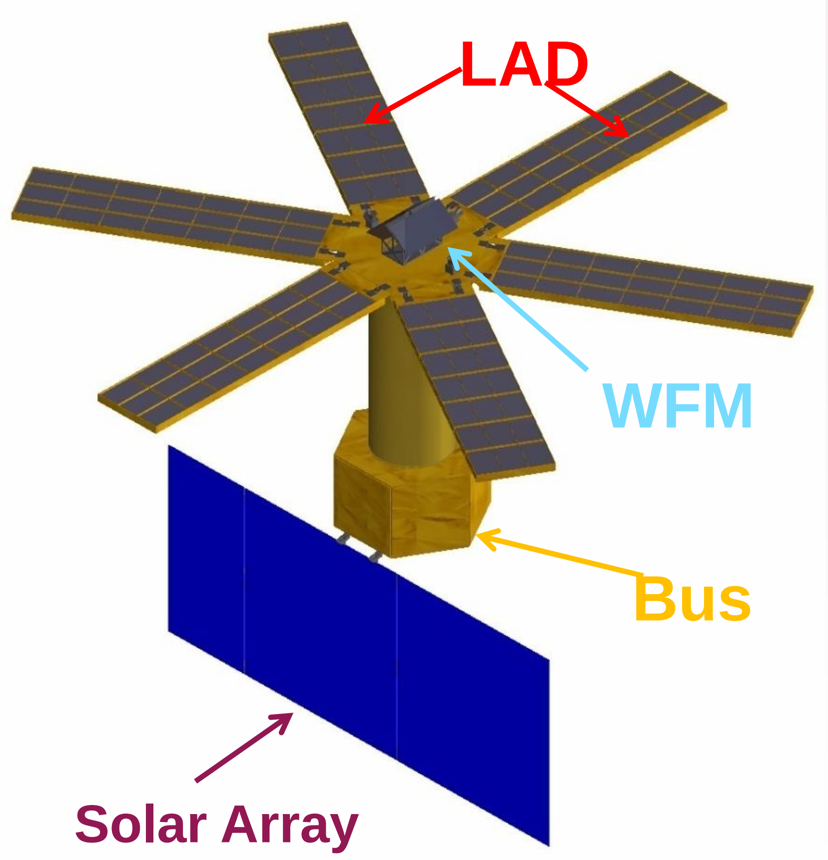
The LOFT payload

Large area detector (LAD):

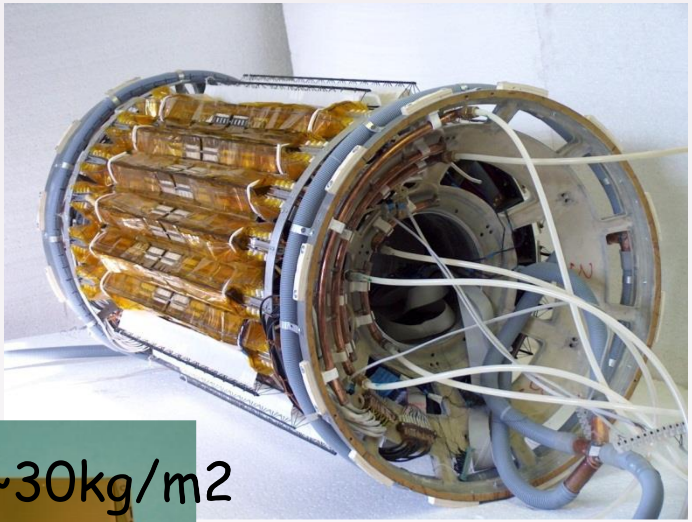
- 6 deployable panels
- $10m^2$ collimated area,
- 2-30 keV, SSD+MCP,
- time res 10μs,
- ΔE ~ 260 eV @6keV

Wide field Monitor (WFM):

- coded mask detector
- 2-50 keV, 50% sky
- source localization 1′
- visibility to identify strong transients



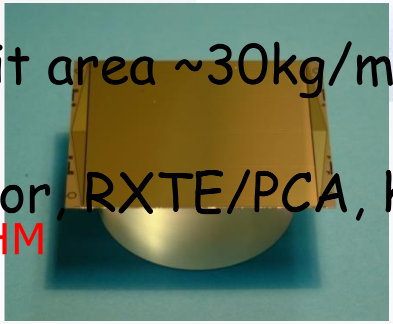
Silicon Drift Detector heritage of the Inner Tracking System of the ALICE experiment, Large Hadron Collider (CERN)



INFN Trieste, in collaboration with Canberra Inc., designed, built, tested and calibrated 1.5 m^2 of SDD detectors (~300 units), now operating since ~2 yrs. High TRL, proven mass production.

Thickness	450 µm
Monolithic Active Area	76 cm^2
Low power requirement (~60 W/m2)	
Good spectral performance 260 eV FWHM	
Drift time	<5 µs
Single-channel area	0.3 cm^2

LAD has a mass per unit area ~30kg/m2 (the largest predecessor, RXTE/PCA, has >100kg/m2)

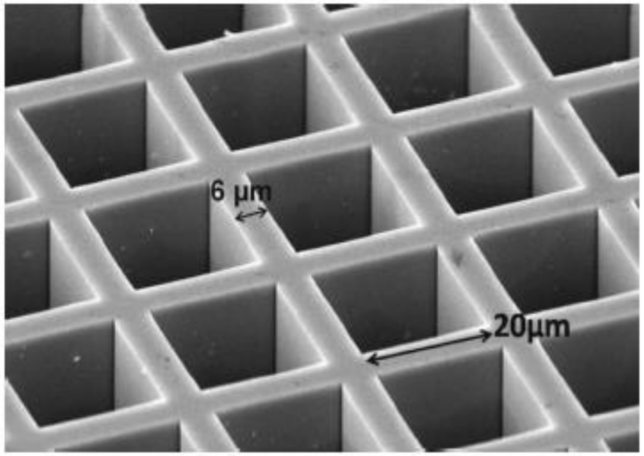


LAD Collimator

Built at Leicester SRC basing on Heritage BC MIXS-C

Capillary plate, High Pb content glass

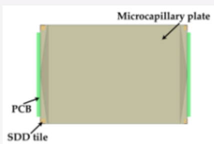
MCP covered with Al filter

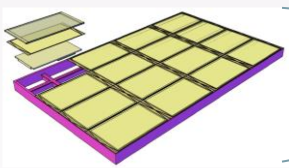


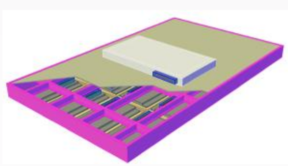
Achieving 10 m^2 effective area (~18 m^2 geometrical)

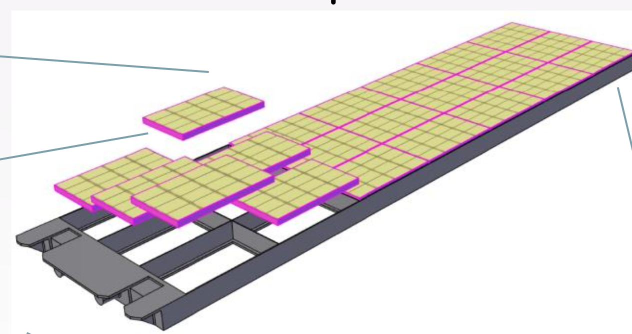
modular and redundant approach:

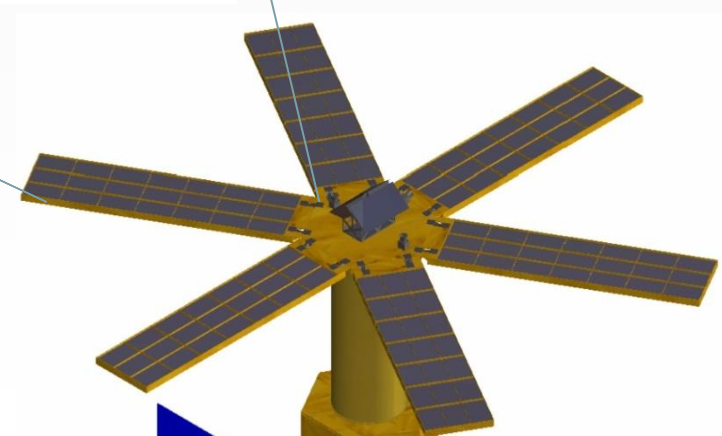
- 16 independent detectors per Module
- 21 independent Modules per Detector Panel
- 6 independent Detector Panels per LAD
- Total panel surface 21 m^2











- 336 SDDs per panel
- 2016 SDDs in totals
- 1 MCP tiles per SDD

LOFT Large Area Detector

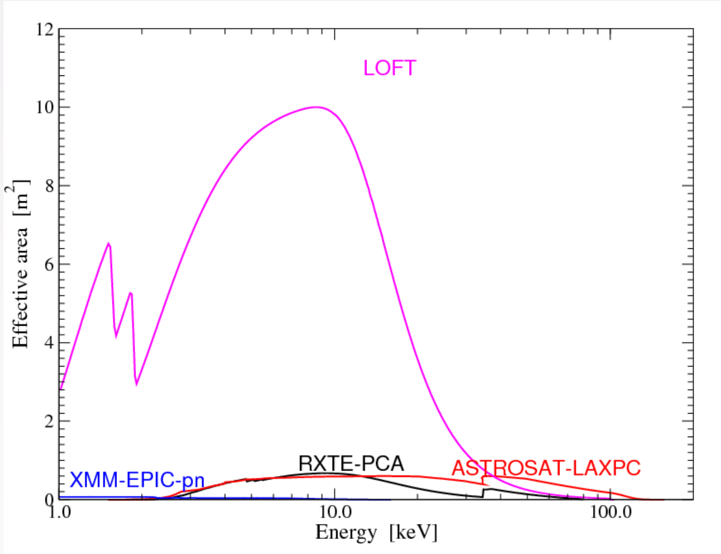
- Effective area 10 m^2 @ 8 keV
  - 0.25 10^6 c/s/Crab
  - 1σ timing feature becomes 20σ

    → detect QPOs in the time domain !

- 200-260 eV resolution
  - resolve relativistic Fe lines at huge S/N

    → see line profile fluctuate at GR timescales !

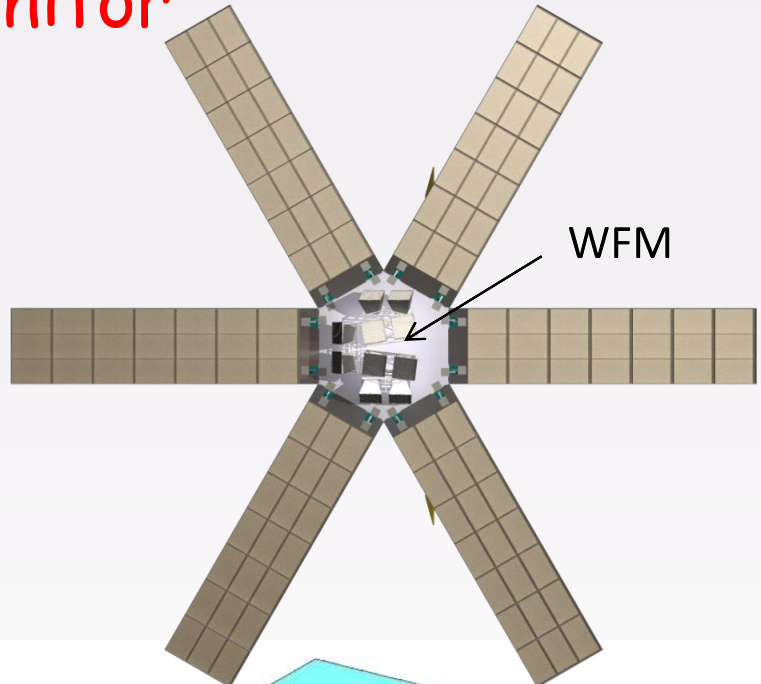
  - See all [sub] msec spins
  - Routine neutron star seismology
  - Measure pulse profiles at enormous precision

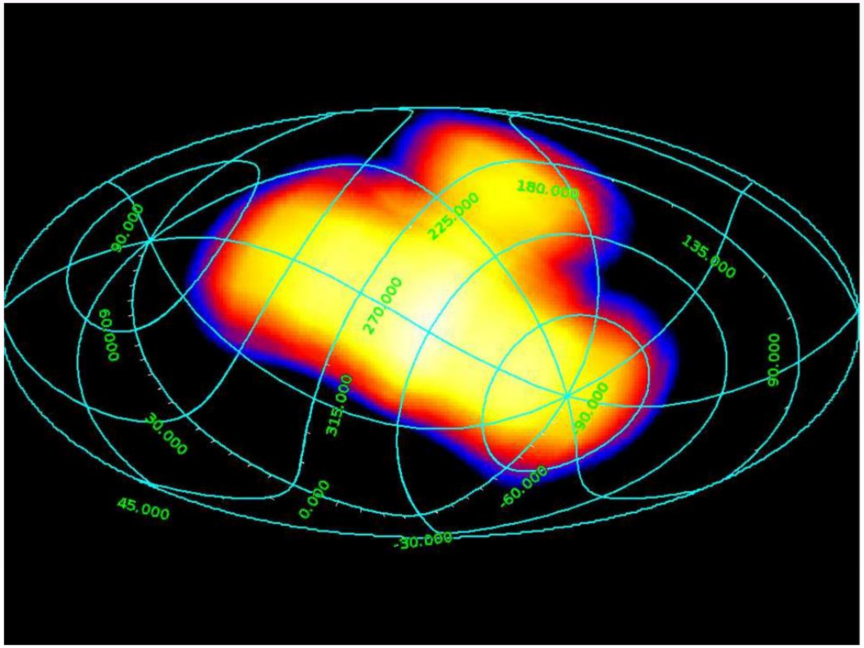


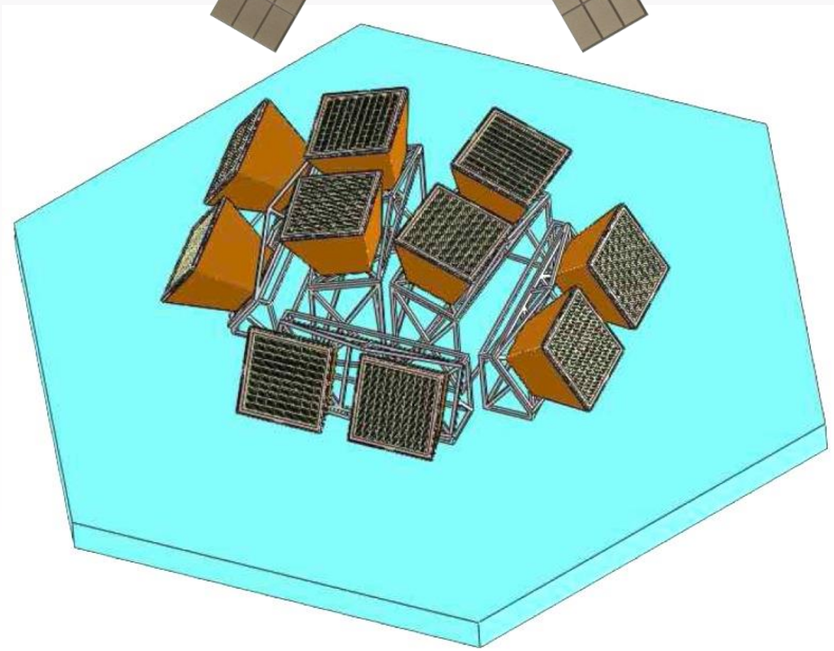
LOFT Wide Field Monitor

- 1820 cm^2 Si drift detectors
- 2-50 keV (-80 for b/g)
- 0.25 Crab in 3 sec, 2 mCrab in 60 ks

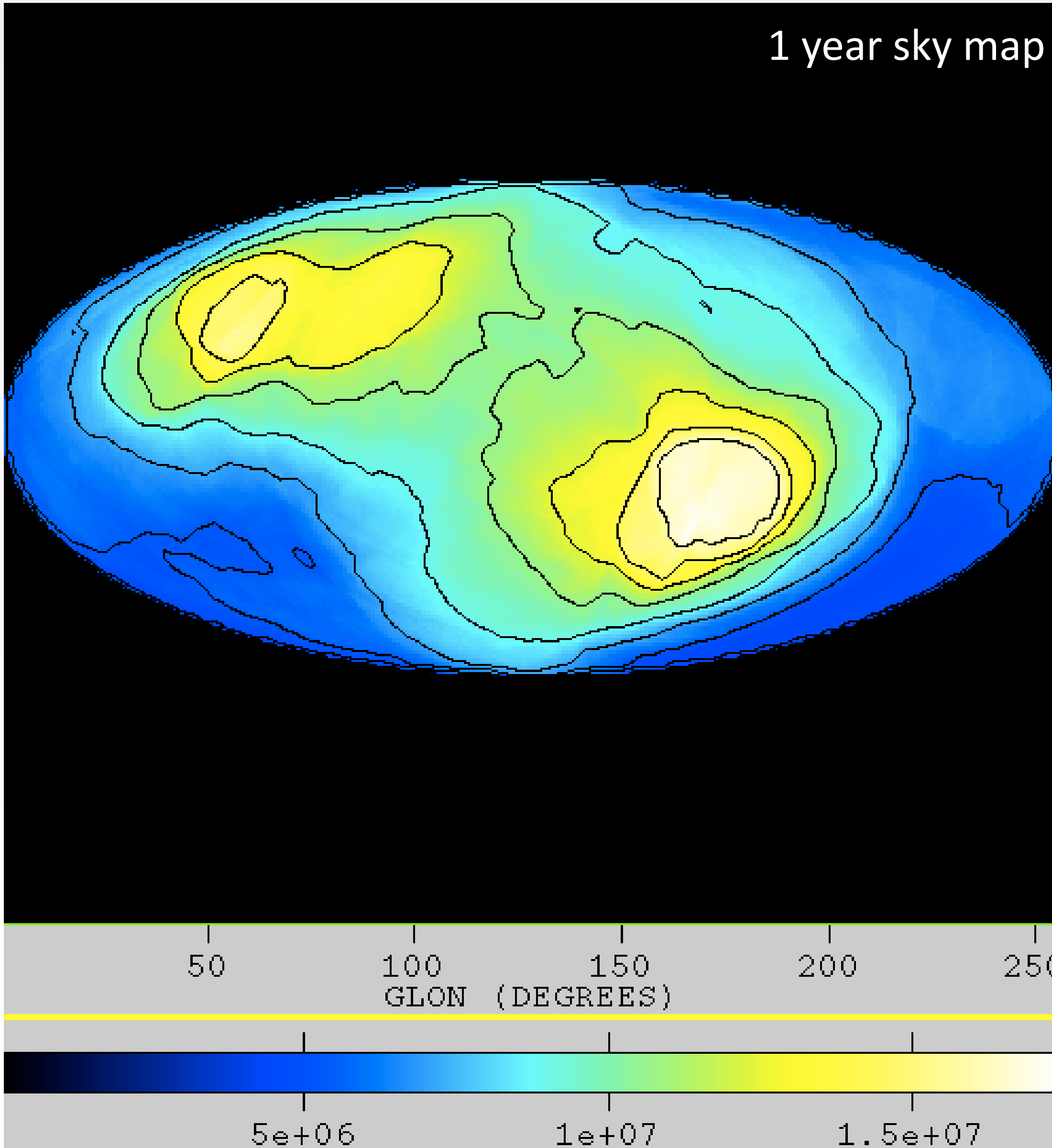
- 1 arcmin positions (5 arcmin res)
- 300-500 eV energy resolution
- 10 μs time resolution, 1 μs absolute timing

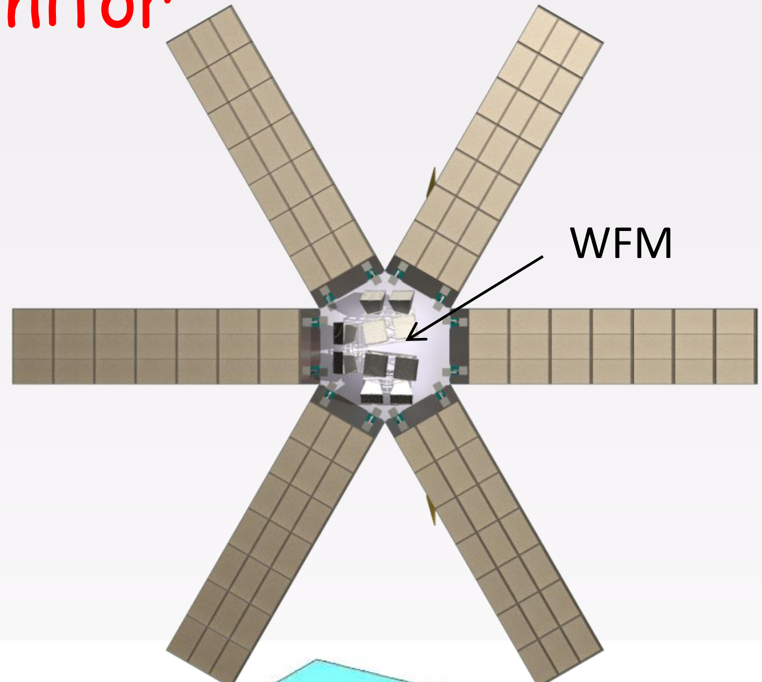


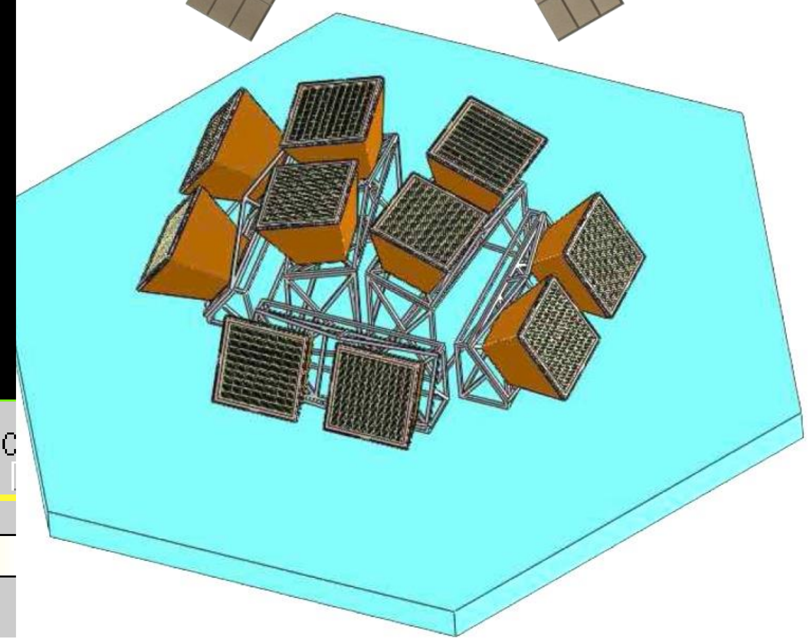




LOFT Wide Field Monitor



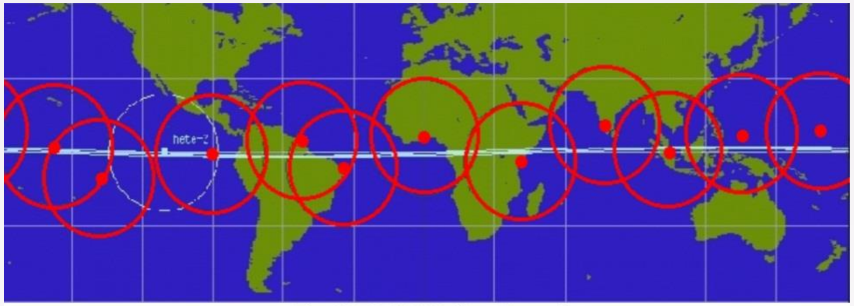




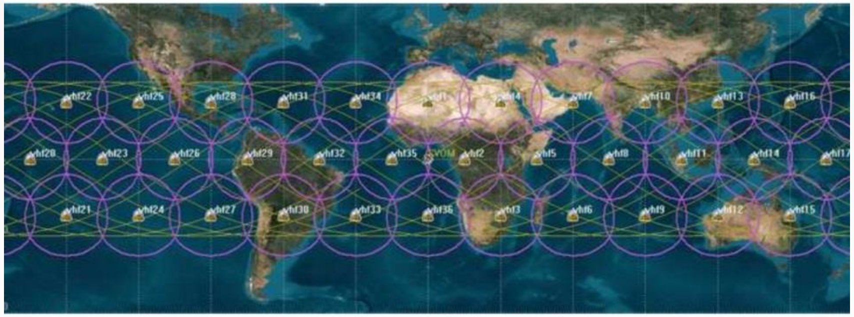
LOFT burst alert system

Automatic triggers for bright events on-board:

- Few to few 10 triggers/ day:
  ~1 arcmin location via VHF network within 30 s (onboard to end user)
- All triggers:
  - Full spectral and timing resolution
  - Pre-trigger data
  - Triggered data available within 1.5-3 hr



The HETE-II VHF Alert Network.



SVOM theoretical VHF network.

Expected: ~ 150 GRBs yr^{-1}

~ 5000 thermonuclear X-ray bursts yr^{-1}

…

See talk by L. Amati

More on the LOFT Payload

- See talk tomorrow by Jan Willem den Herder
- 2 posters on WFM/LAD by the two instrument teams (upstairs)
- Brochure with instrument specifications

ACTIVITIES

- ESA is studying mission in house
- 2 parallel industrial studies started early in 2012 and ended this month

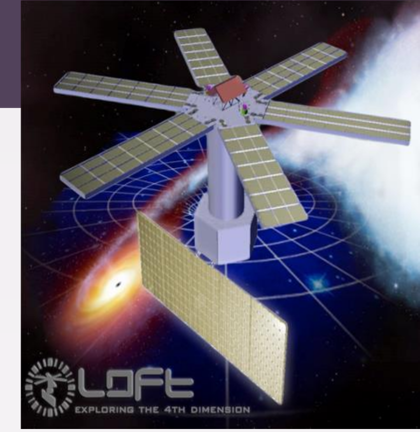
- Instrument consortium is working on payload:
  - WFM: Hernanz (IEEC/CSIC) and Brandt (DTU)
  - LAD: Zane/Walton/Kennedy (MSSL)

- Science case
  - Coordinated by Stella (INAF), vd Klis (UvA) and Jonker (SRON)
  - **Yellow book for ESA down selection: Nov 2013**

- **Selection of M3 mission beginning 2014**

In the UK:

- MSSL/UCL is leading the LAD payload –UKSA supporting
- Leicester SRC (G. Fraser) leading the collimator study
- Southampton, Durham, Manchester, Cambridge on the science working groups



LOFT objectives

1. Dense matter – supranuclear EOS

- Pulse profiles
- Spin measurements
- Seismology

msec pulsations, seismics in XRB, SGR

2. Strong field gravity – GR in action

- Broad Fe line variability
- Epicyclic motion
- QPO waveforms

QPOs & Fe lines in XRB & AGN

3. Observatory science

- Broad-ranging programme using LOFT unique capabilities

- All three areas mainly open-time & proposal-driven

Dense matter

RXTE discovered the signals:

- accreting millisecond pulsars
- thermonuclear burst oscillations
- SGR seismic oscillations (in giant flares)

LOFT uses them to characterize neutron stars

- neutron star spin distribution
  [discover many more spins]
- pulse profile modeling
  [measure M and R]
- SGR seismic oscillations in *intermediate* flares
  [NS interior]

See talk by Nils Andersson on activities of DM WG

Strong gravity

Previous missions discovered the signals:

- relativistic Fe lines (in binaries and AGN)
- dynamical and epicyclic timescale QPOs
  - black hole high-frequency QPOs (barely)
  - neutron star kiloHertz QPOs
  - BH&NS low-frequency QPOs

LOFT uses them to probe strong field gravity

- Relativistic line profile variability
  - Merges spectral / timing diagnostics into one
  - Tomography & reverberation
- Relativistic epicyclic motions
- Relativistic distortions of QPO waveforms

See talk by Luigi Stella on activities of SG WG

Observatory Science

As for RXTE/PCA (but at much higher sensitivity), with a high flexibility in its observing program, LOFT will also be an Observatory for virtually all classes of relatively bright sources.

These include:

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

- Useful for a broad range of studies in X-rays
- Synergies with many other instruments projected for the 2020's

Observing program

UCL

Source Type	TOO	Sources	Pointings	Total Time (ks)
BH transient outbursts	Yes	4	800	2400
Persistent BH	No	2	400	1600
AGN	No	30	50	8000
Msec pulsar outburst	Yes	3	250	1000
NS transient bright outburst	Yes	3	250	1800
Persistent bright NS	No	12	350	4800
NS transient weak outburst	Yes	6	6	120
Persistent weak NS	No	14	14	280
Bursters	Yes	10	40	1000

Total: 4 years with a goal of 5 years. Significant part (50%) available for observatory science

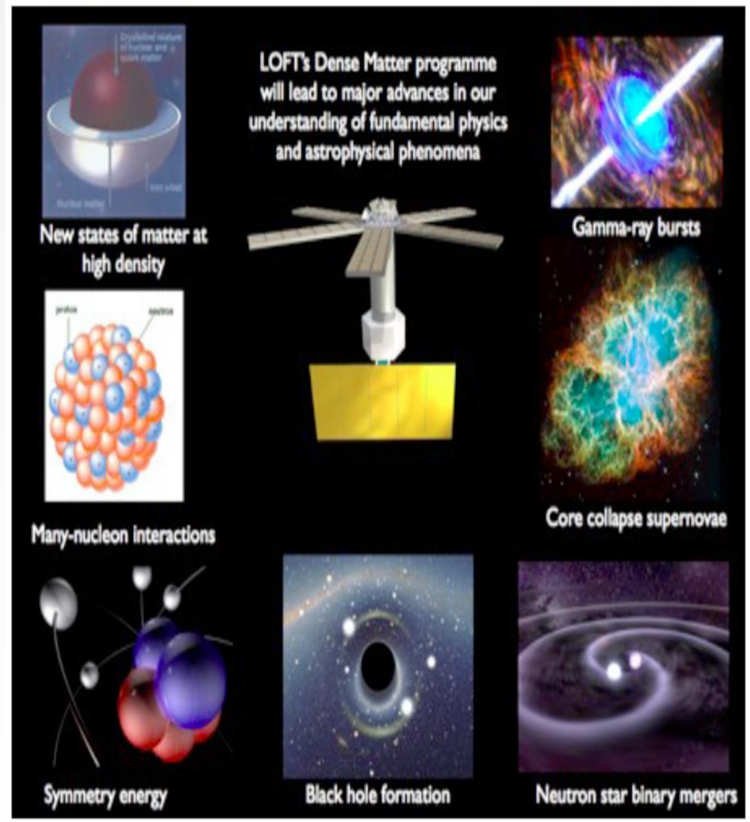
See talk by Roberto Mignani on activities of OS WG

Yellow Book Outline (to be delivered Mid Nov)

esa

ESA/SRE(2014)X
December 2013

Large Observatory for X-ray Timing



Assessment Study Report

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35 pages for Science objectives

LOFT Large Area Detector

Item	Requirement	Goal
Effective area	4 m^2 @ 2 keV 8 m^2 @ 5 keV 10 m^2 @ 8 keV 1 m^2 @ 30 keV	5 m^2 @ 2 keV 9.6 m^2 @ 5 keV 12 m^2 @ 8 keV 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 200 eV (singles, 40%) 2 keV above 30 keV (allows for binning)	200 eV @ 6 keV 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, < 10% @ 10 Crab	< 0.5% @ 1 Crab, < 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
Onboard memory (transmit ted over more orbits)	15 Crab, 3 orbits	30 Crab, 3 orbits

instrument size

SDD and orbit

Collimator, alignment

TM rates

LOFT Wide Field Monitor

Item	Requirement	Goal
Location accuracy	1 arcmin	0.5 arcmin
Angular resolution	5 arcmin	3 arcmin
Sensitivity (5 σ)	1 Crab (1 s)	0.2 Crab (1s)
	5 mCrab (50 ks)	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	150 sec for normal
	10 µsec for triggered	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

Camera dimensions

FoV, camera location

Detector, coded mask

Ground contacts

The Mission

UCL

Item	Requirement	goal
Net observing time core science	21 Msec	33 Msec
Additional open observing time observatory science	20 Msec	30 Msec
Calibration time	5%	2%
minimum science observing times (during night time)	1 minute (1 source during 2 weeks per year) 10 minutes (10 sources during 2 weeks per year)	
Accessible sky fraction (daytime)	>50 %	75%
Mission duration	4 year	5 year
Pointing accuracy (satellite + instruments combined)	1 arcmin	0.5 arcmin
Relative pointing error (RPE over observation)	1 arcmin	0.5 arcmin
Pointing knowledge for each axis over the full orbit (AMA, 3σ, 10 Hz)	<20 arcsec	<5 arcsec
ToO (following alert of SOC)	24 hours for 70% of the time	< 8 hours for 33% of the time + 24 hours for 66% of the time
Orbit	LEO, <600 km, < 5 deg	LEO, 550 km, <2 deg
Slews per orbit (average)	0.5	2
Instrument data rate (typical)[1)]	LAD: 200 kbps (~ 150 mCrab) + WFM: 100 kbps	WFM in event mode
Instrument data rate (sustained)	LAD: 600 kbps (~ 500 mCrab) + WFM 100 kbps[1)]	LAD: ~1 Crab
data transfer per orbit	6.5 Gbit/orbit	14 Gbit/orbit

Sun constraints

consumables

ToO response time

The First UK LOFT Science Meeting

STFC-RAS-UCL funded

Main goal is to strengthen and corroborate interactions between UK LOFT science teams and the International LOFT community

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