The
Making of LEAP

Lessons Learned

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LEAP Principal Investigator

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LEAP Fact Sheet

Primary Institutions

University of New Hampshire (UNH)
- Principal Investigator
- LEAP Polarimeter Modules (LPMs)
- Passive Shield Assembly (PSA)
- Instrument Operations

Marshall Space Flight Center (MSFC)
- Deputy Principal Investigator
- Project Management
- Project Systems Engineering
- Project Scientist
- Safety and Mission Assurance
- Power Adapter Box (PAB)

University of Alabama (UAH)
- Ground Segment Lead
- Science Operations

Southwest Research Instutute (SwRI)
- Instrument Project Management
- Instrument Systems Engineering
- LPM Digital Electronics
- Central Electronics Box (CEB)

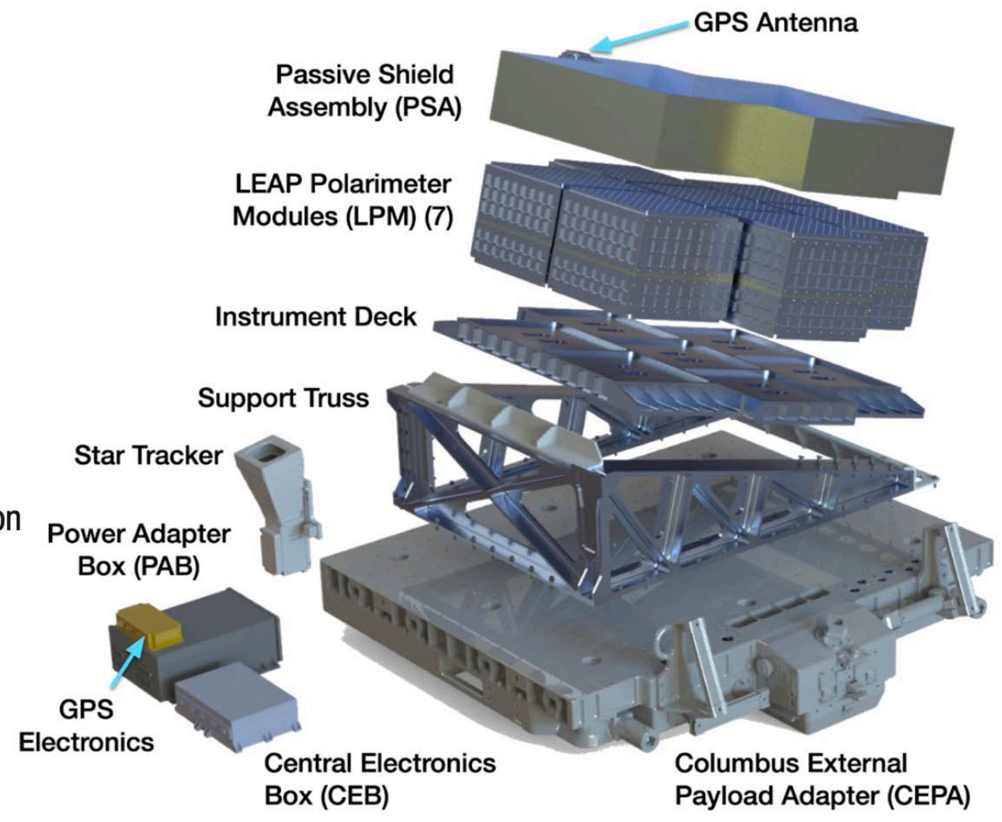
Teledyne Brown Engineering (TBE)
- Instrument Deck
- Supporting Truss Structure
- Payload Integration & Test

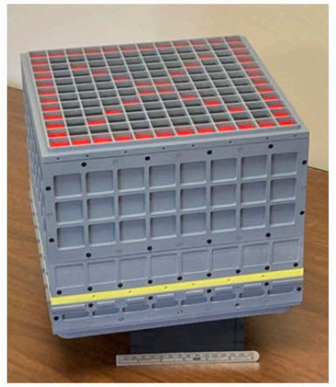
LEAP is a straightforward, low-risk, passive instrument that is readily acco-modated on the *ISS*.

Quick Facts

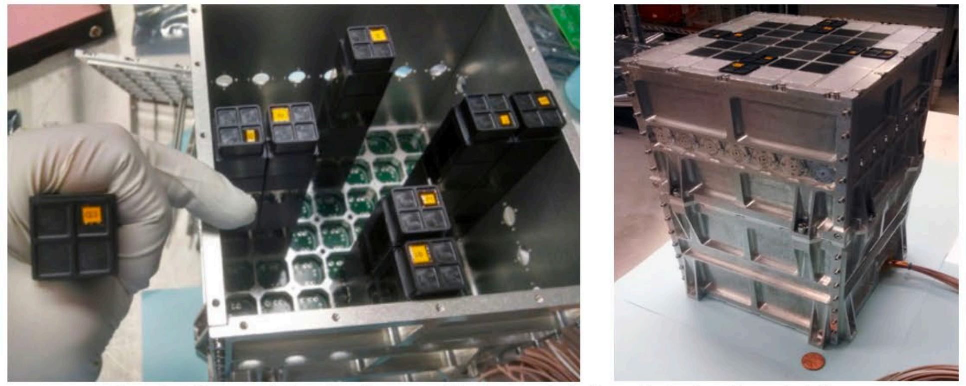
- Polarimetry: 50-500 keV
- Spectroscopy: 20 keV – 5 MeV
- Field-of-view: ±75° (1.5π sr)
- Fixed pointing, near-zenith
- GRB localization: $< 5°$ (1σ) for brightest events
- Payload mass (CBE): 327 kg
- Average power (CBE): 207 W
- Launch ready date: Dec 2027
- Launch vehicle: Falcon 9 / Dragon (or similar CRS2 vehicle)
- Robotic installation on *ISS*
- Compatible with several zenith-viewing *ISS* sites
- COL-SOZ is baselined
- Mission Duration: 3 years

Payload Description





3d printed LPM model

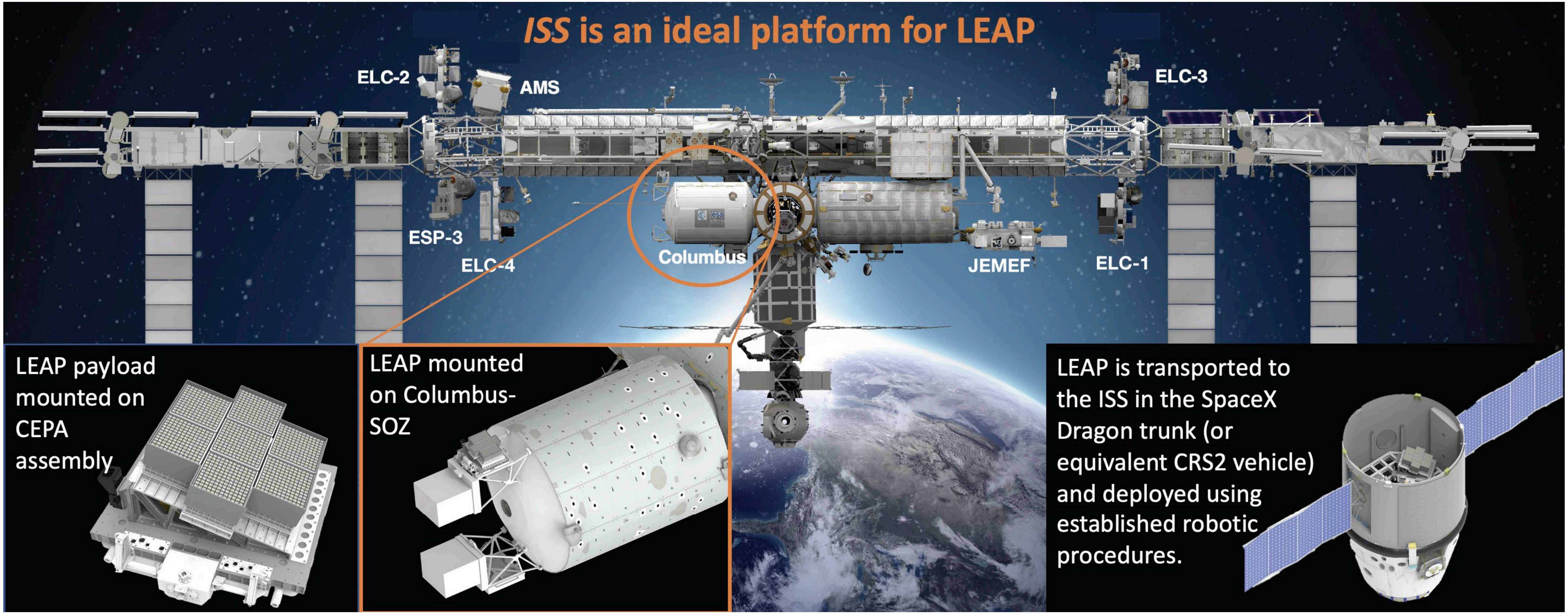


A scaled-down prototype has been used to demonstrate the polarimeter characteristics

LEAP is a GRB polarimeter project that is currently in a Phase A Concept Study.

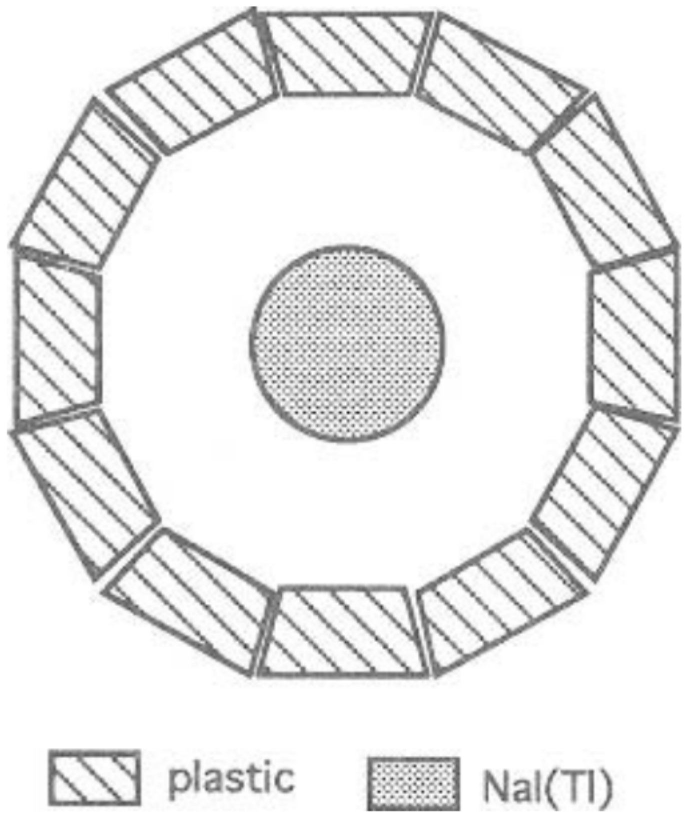
The CSR is due in June with selection expected early next year.

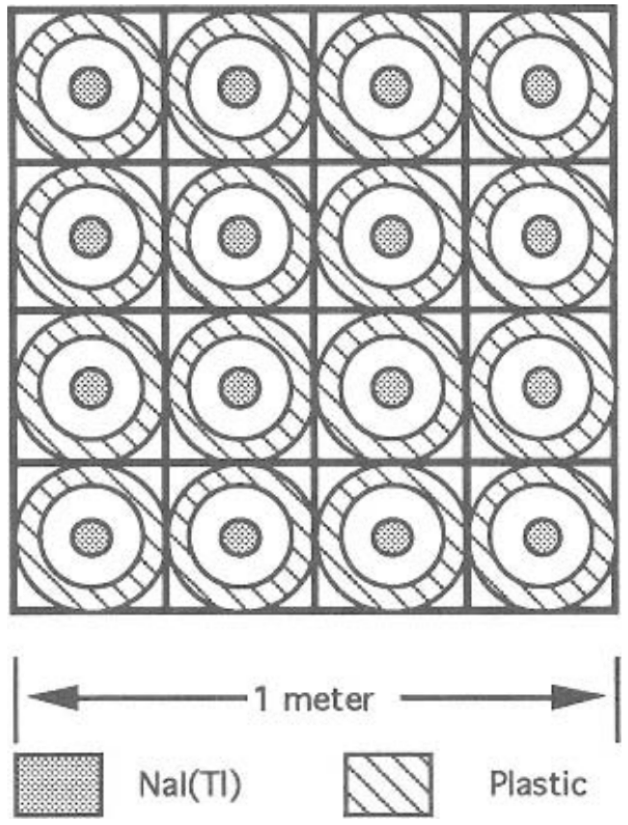
Project Overview



Earliest Publication

McConnell, M. L., Forrest, D. J., Levenson, K. & Vestrand, W. T. The design of a gamma-ray burst polarimeter. *AIP Conf. Proc.* **280**, 1142–1146 (1993).





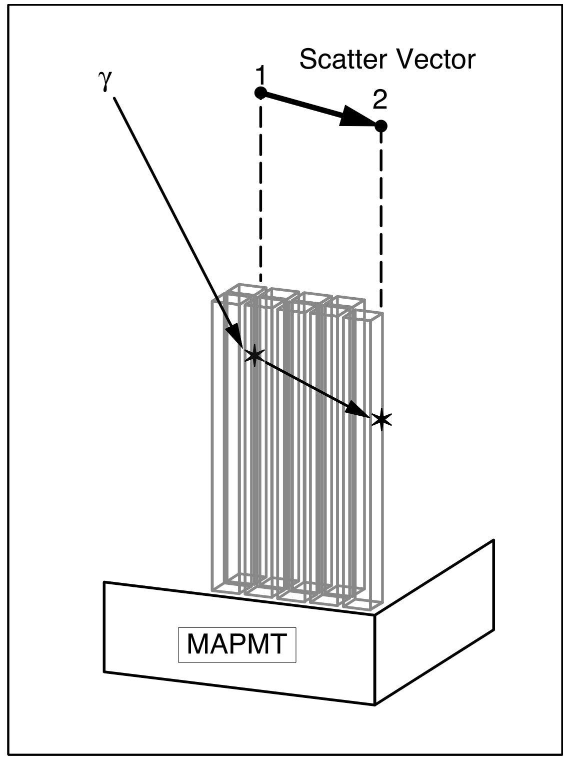
"The simplicity of this design, along with its minimal pointing and service requirements, would make such an experiment ideally suited for deployment on Space Station Freedom."

This was 10 years before the first report of GRB polarization by Coburn & Boggs (2003) and 5 years before the launch of the first components of ISS (1998).

GRAPE Balloon Program

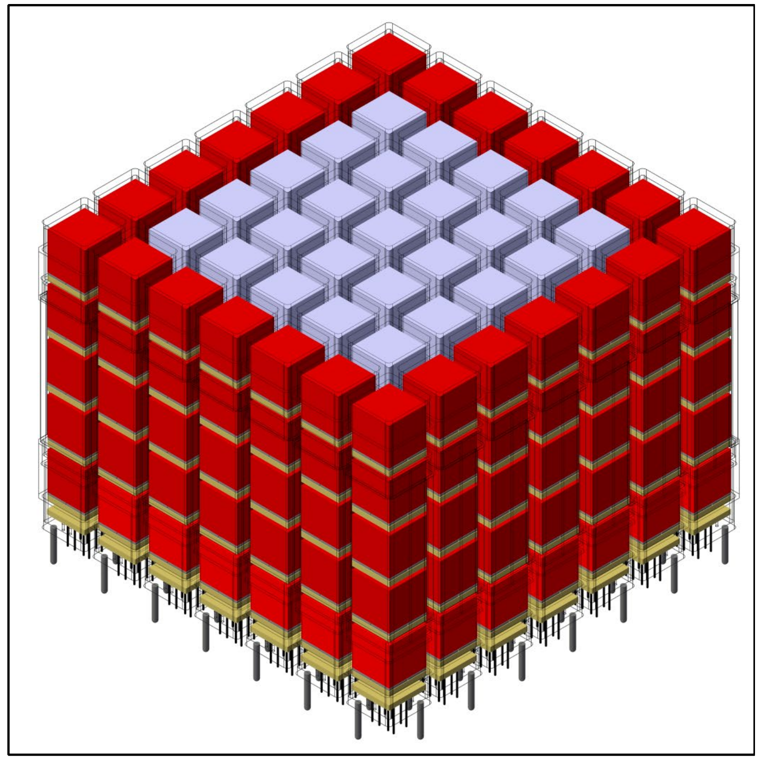
Funded since the 1990's, the goal of this program has always been to use long duration balloon flights to measure GRB polarization.

2007, 2011, 2014



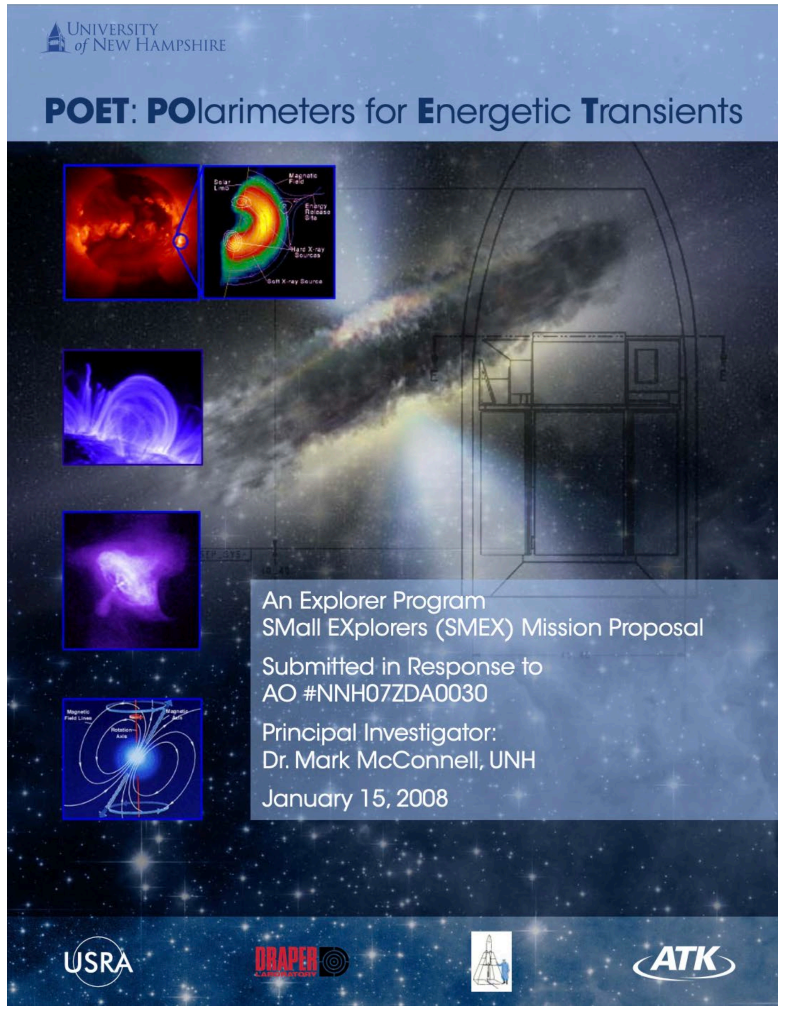
64 elements (8x8)
5 mm x 5 mm x 50 mm
single MAPMT

2023



245 elements (7x7x5)
12.5 mm x 12.5 mm x 12.5 mm
245 SiPMs

Before LEAP (the "POET Era")



2008 – POET
SMEX Proposal

2012 – PETS
MoO Proposal

2014 – POET
SMEX Proposal

THE UNIVERSITY OF ALABAMA IN HUNTSVILLE · NASA · University of New Hampshire · SwRI SOUTHWEST RESEARCH INSTITUTE · TELEDYNE BROWN ENGINEERING

LEAP

2016 – LEAP
MoO Proposal

2019 – LEAP
MoO Proposal

2021 – LEAP
MoO Proposal

Evolution of LEAP

What can we learn about mission proposals from this experience?

Year	Project	Type	Rating	Notes
2008	POET	SMEX	Category II	Included low-energy polarimeter (GSFC)
2012	PETS	MoO – ISS	program not funded	Separate instrument for localization
2014	POET	SMEX	Category IV	Included low-energy polarimeter (GSFC)
2016	LEAP	MoO – ISS	Category II	Single instrument (with MSFC)
2019	LEAP	MoO – ISS	Category I – Phase A	Single instrument (with MSFC)
2021	LEAP	MoO - ISS	Category II – Phase A	Single instrument (with MSFC)

Science Traceability Matrix

LEAP Science Goal	LEAP Science Objectives	Scientific Measurement Requirements: Physical parameters	Scientific Measurement Requirements: Observables	Instrument Functional Requirements	
The LEAP science goal is to improve our understanding of astrophysical jets and the environment surrounding newborn compact objects.	1. LEAP determines the jet magnetic field structure (ordered or random) 2. LEAP determines the jet composition (dominated by matter or Poynting flux) 3. LEAP determines the jet energy dissipation process (internal shocks or reconnection) 4. LEAP determines the prompt emission mechanism(s) 5. LEAP enables rapid community follow-up to better understand GRBs and their environments.	Number of GRBs	GRB Prompt Emission	FoV	±75° (1.5 π)
				Burst Triggers (in 3-year mission)	300
		GRB Time History	Photon Arrival Time	Absolute Time Accuracy	1 ms
		GRB Localization	Photon Arrival Direction	Localization Error (1σ) for polarization analysis of GRBs with < 30% MDP	<15° for all zenith angles in the FOV
				Localization error (1σ) for GRB follow-up	<5°
		GRB Spectrum (incl. E_p)	Photon Energy	Energy Range	20 keV – 1 MeV
				Energy Bins $(E_{max} - E_{min})/\Delta E_{FWHM}$	8
		GRB Polarization	Photon Polarization	Energy Range	50 – 300 keV
				Polarization Measurements < 30% MDP in 3 years	65 GRBs
				Energy Bins $(E_{max} - E_{min})/\Delta E_{FWHM}$	3
				Time Resolution	0.1 s

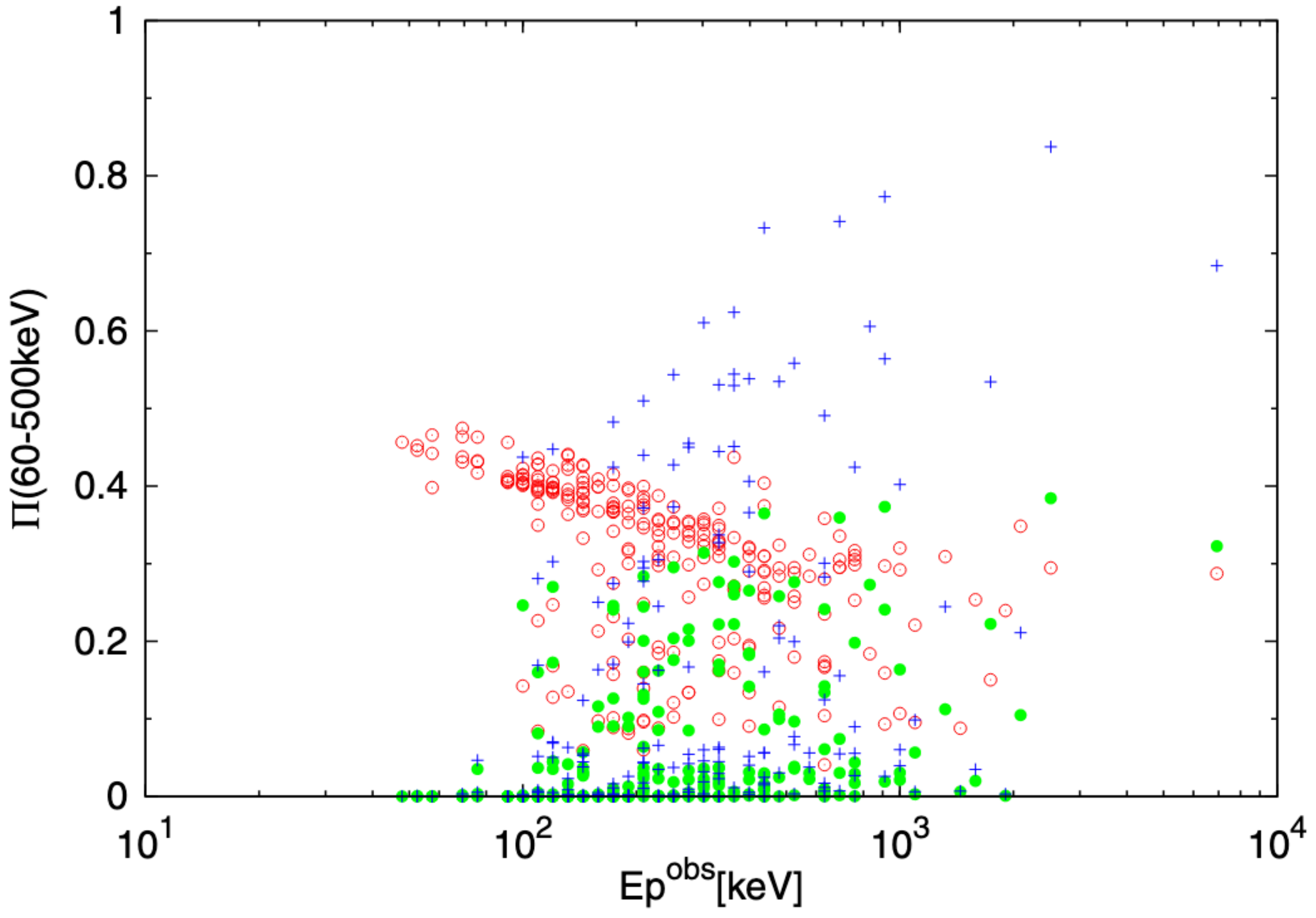
The project must be driven by the science, not by an instrument in need of an application.

This must be clearly demonstrated in the Science Traceability Matrix, which shows how the mission design is driven by the science.

Well-Defined Science Objectives

The original "Toma plot" was developed for the 2008 POET proposal. Although a powerful tool, the ability to distinguish between models was not well-quantified.

"POET will accumulate GRB polarization measurements at a rate of ~50/year, permitting studies that will distinguish between the geometric and physical models. Given a sufficiently large number of events, it may even be possible to distinguish between the two geometric models (SR and CD)."

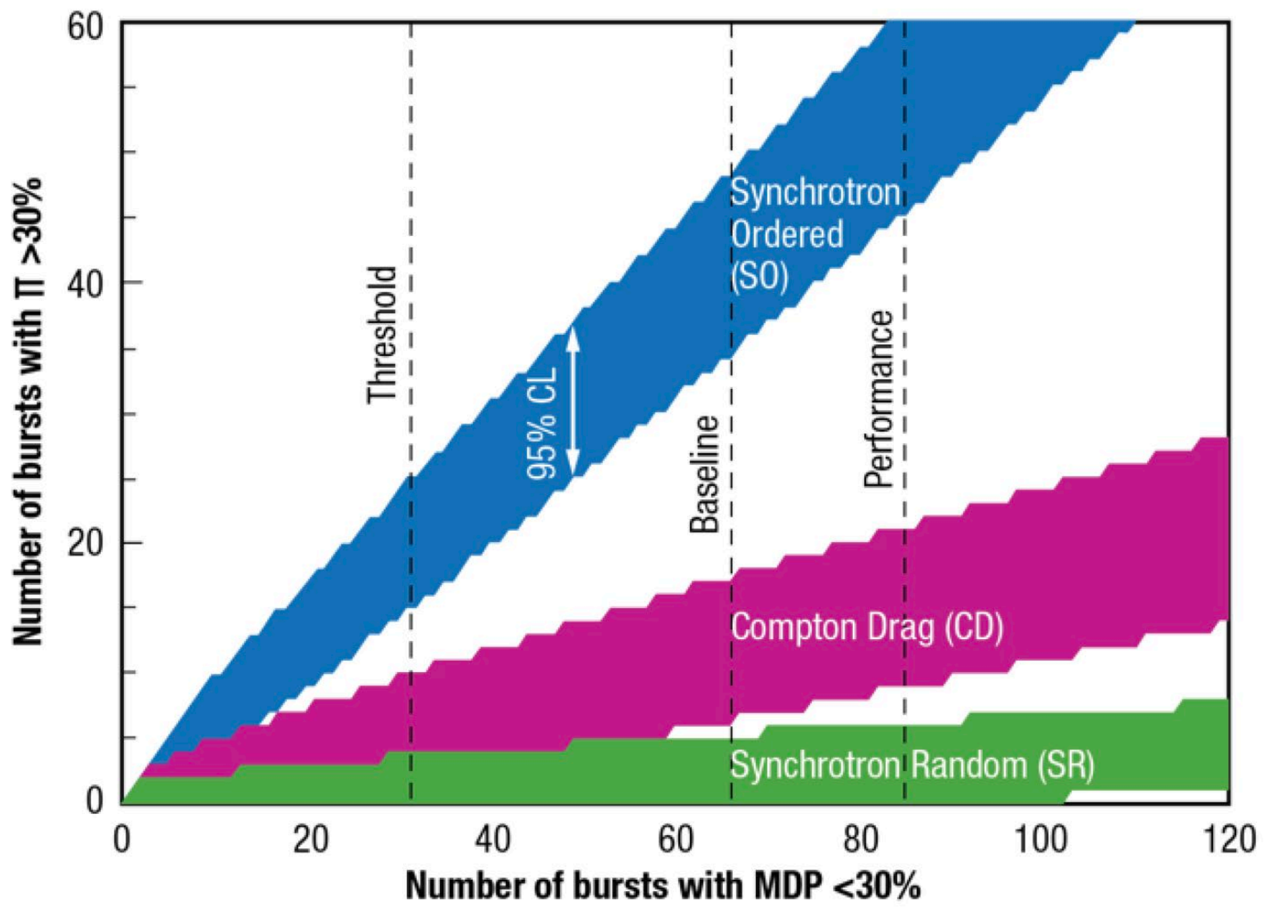


Toma, K. *et al.* Statistical Properties of Gamma-Ray Burst Polarization. *Ap. J.*, **698**, 1042–1053 (2009).

Well-Defined Science Objectives

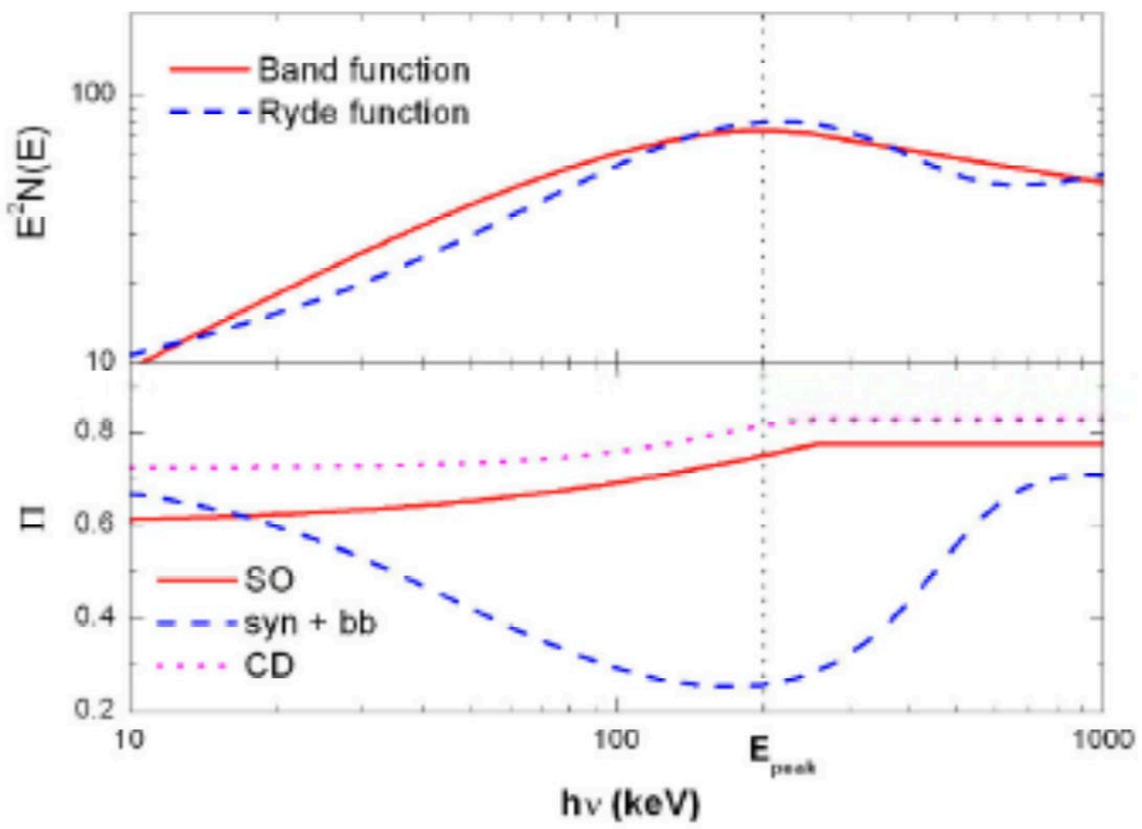
The science objective(s) must be well-defined in terms of knowledge to be gained and the measurements that are required. It is not sufficient to say that "LEAP will study GRBs."

"The investigation will distinguish between Poynting-flux dominated (SO) and matter-dominated (SR, CD) classes of models at 99.99% CL and to further distinguish between two matter-dominated classes (SR, CD) at 95% CL. This requires 65 GRBs measured with a minimum detectable polarization (MDP) of 30% or better."

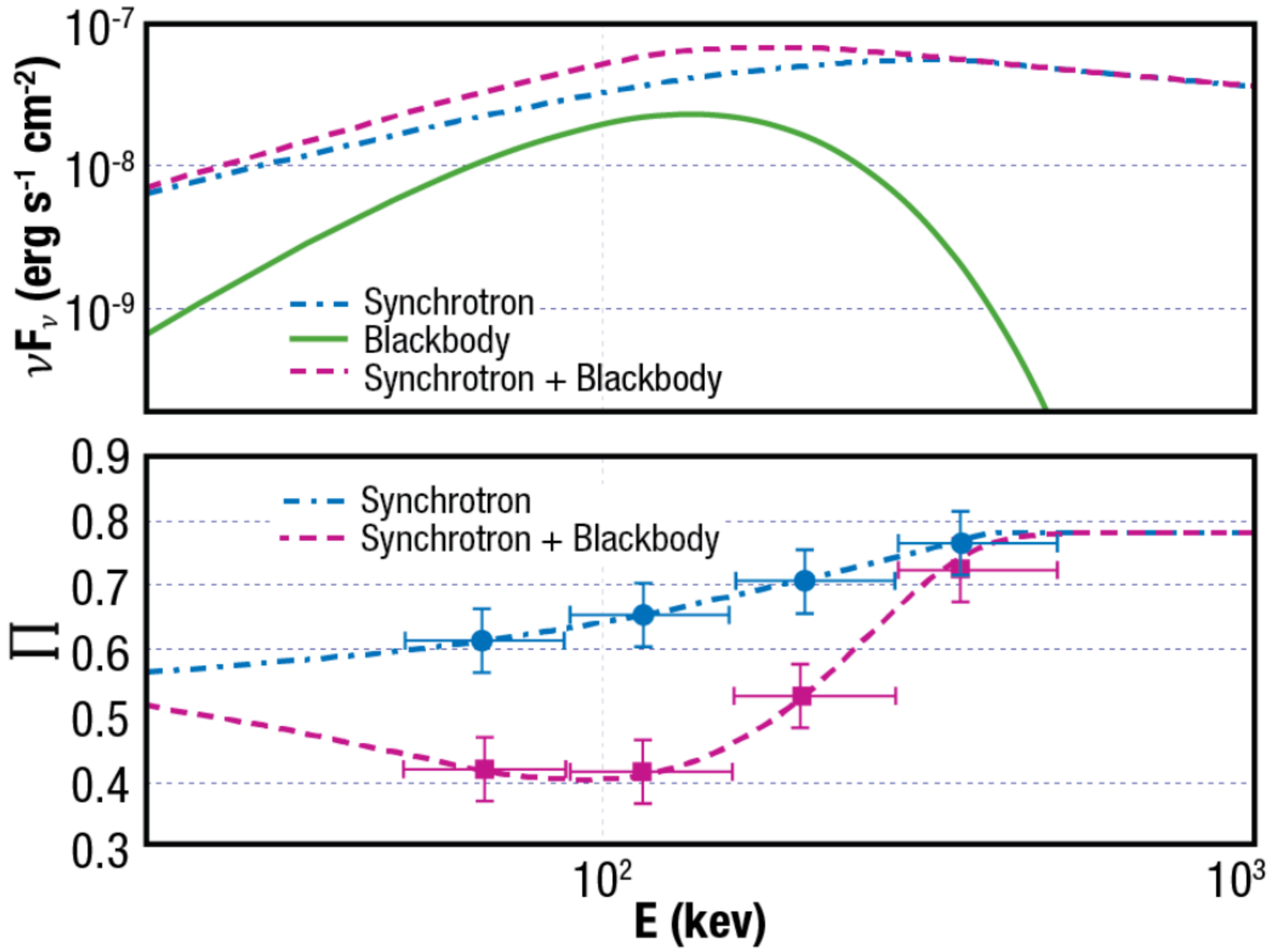


Achievable Science Objectives

The ability to achieve the science objective(s) must be quantified.
Don't have objectives which are not quantified.

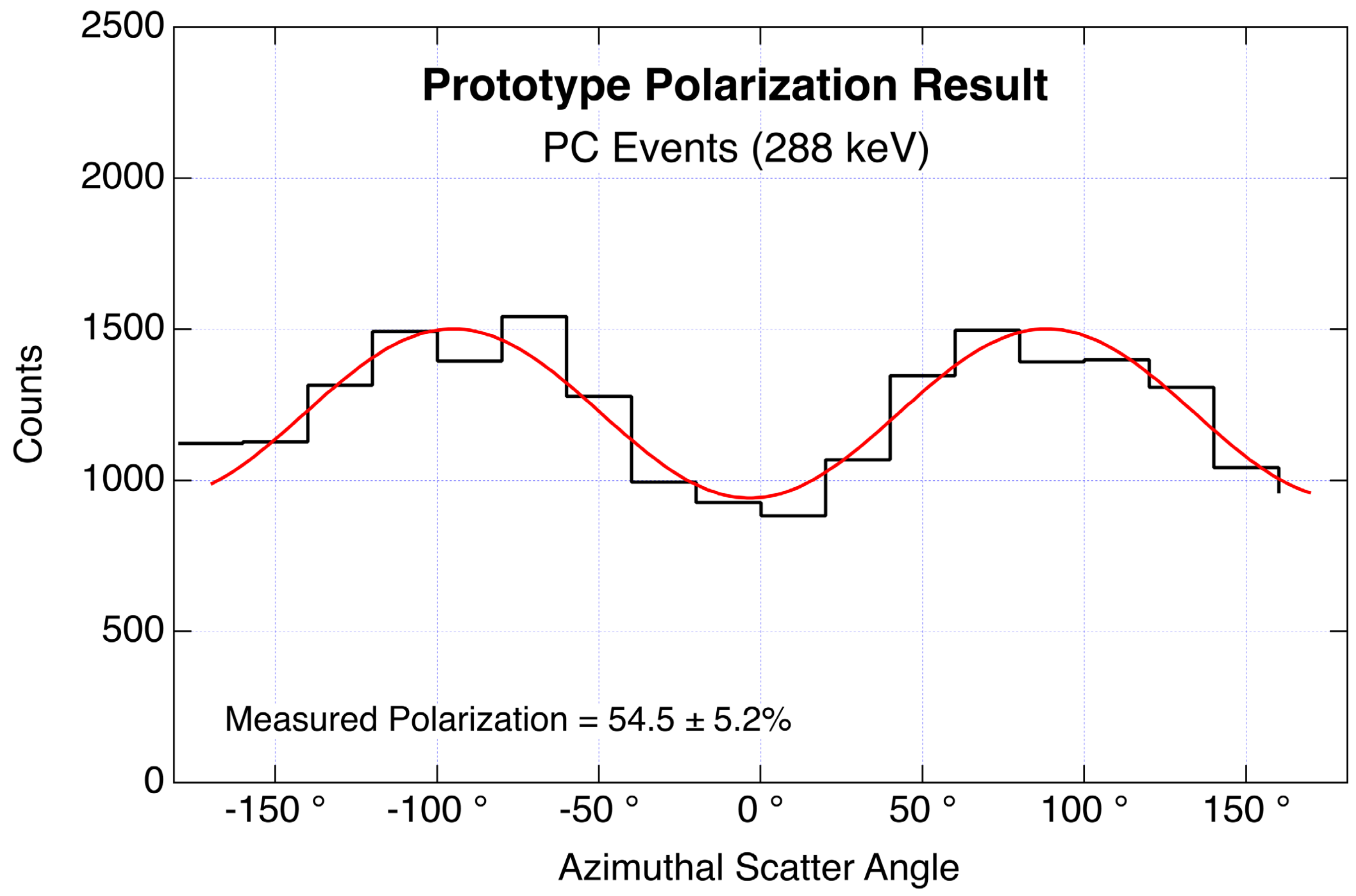


POET 2008



Achievable Science Objectives

The ability to achieve the science objective(s) must be quantified. An understanding of the error budget can influence the instrument design and help to define the simulation and calibration plans.



Having good lab data is crucial, but on-orbit measurements can be very different. Showing that you understand the error budget demonstrates that you understand the instrument.

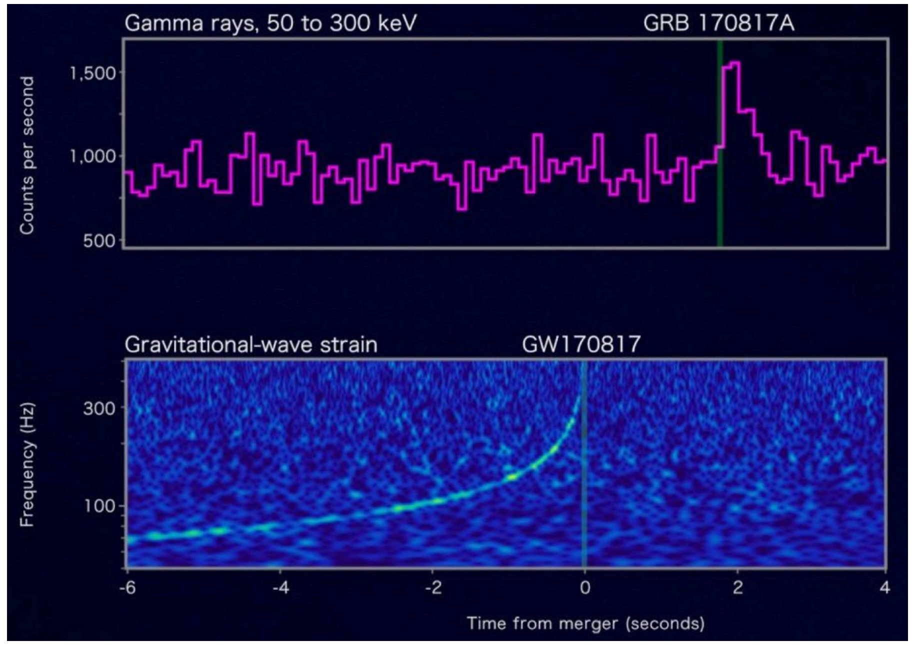
Breadth of Science

Broad science objectives can be important, especially for larger missions. More focused objectives may work for smaller missions.

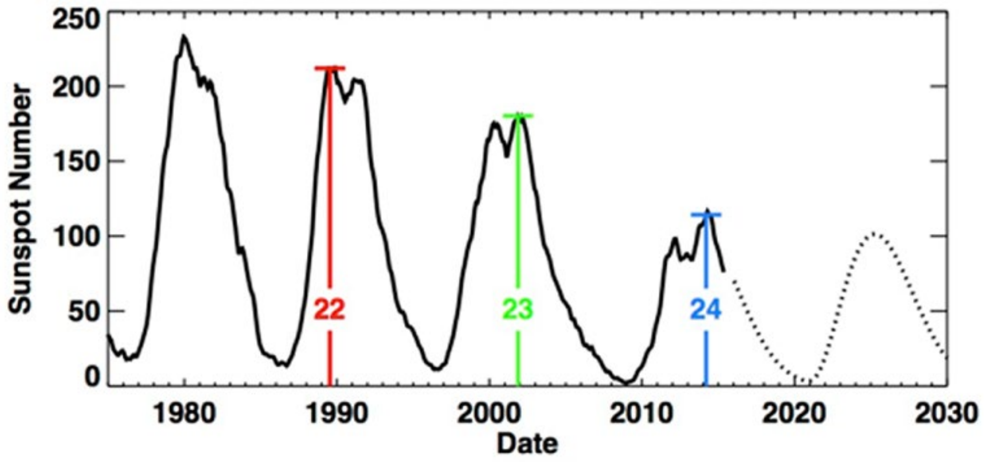
A GRB polarimetry mission is too narrowly focused for a MIDEX and maybe also a SMEX mission. Even as a MoO, it is important to insure broader science capabilities.

Any additional science objectives need to be quantified.

Gravitational Waves



Solar Flares

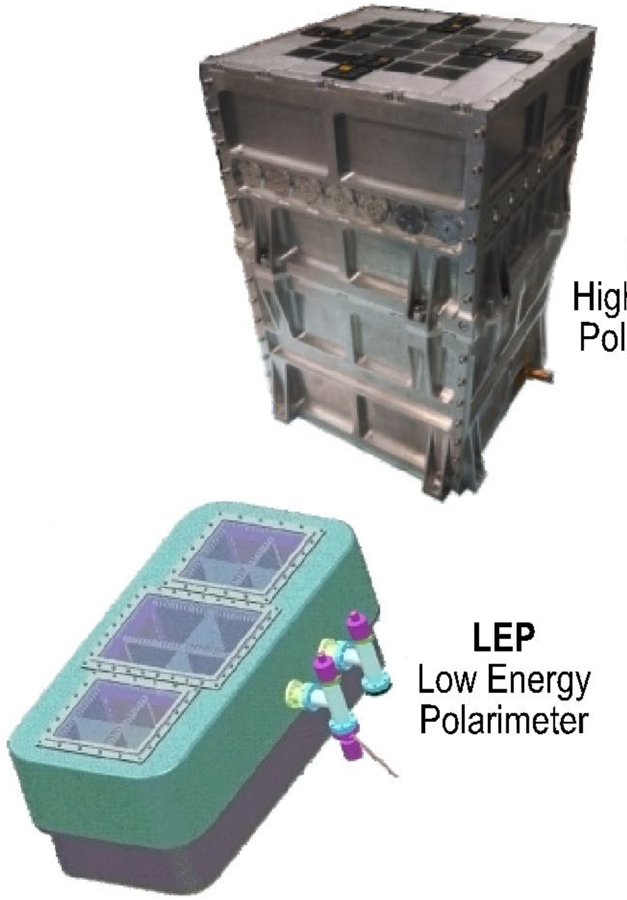


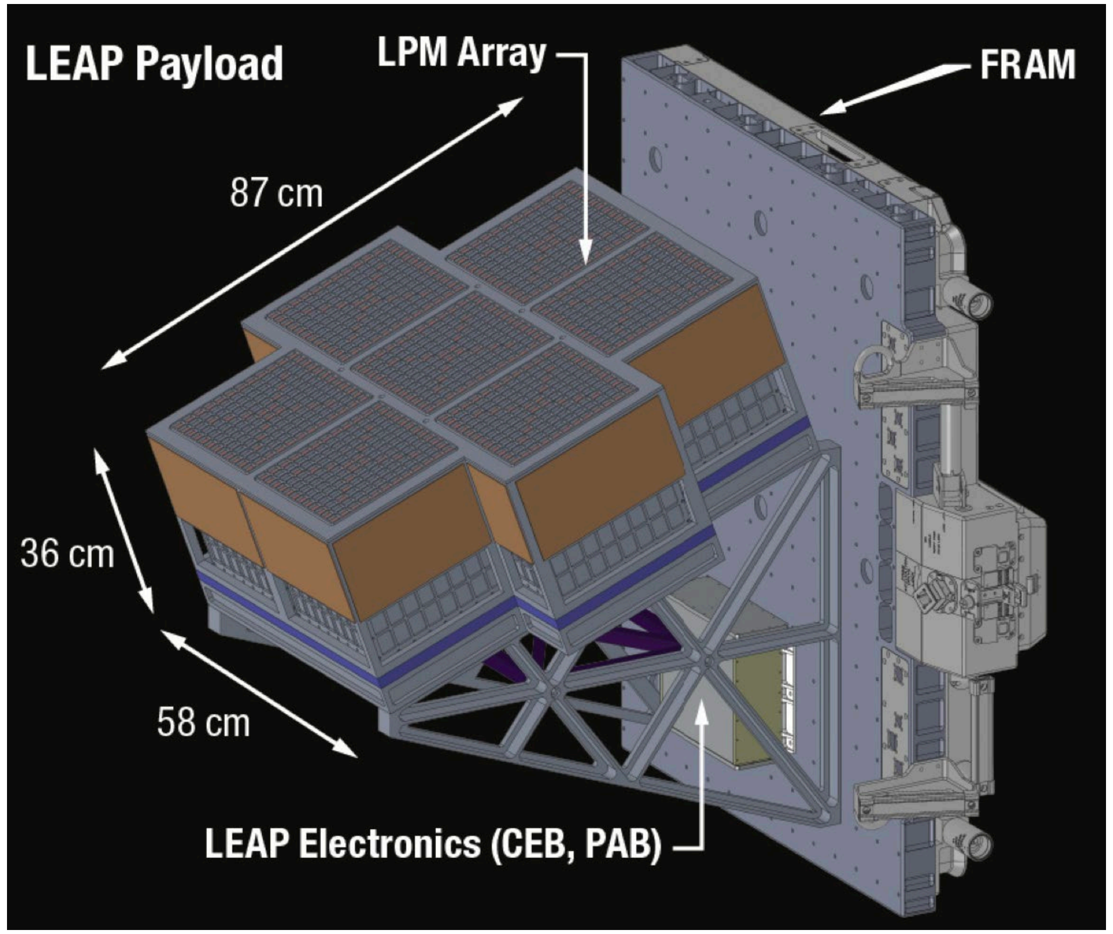
Be Careful About the "Christmas Tree"

It may be better to make fewer measurements with better sensitivity rather than more measurements with limited sensitivity.

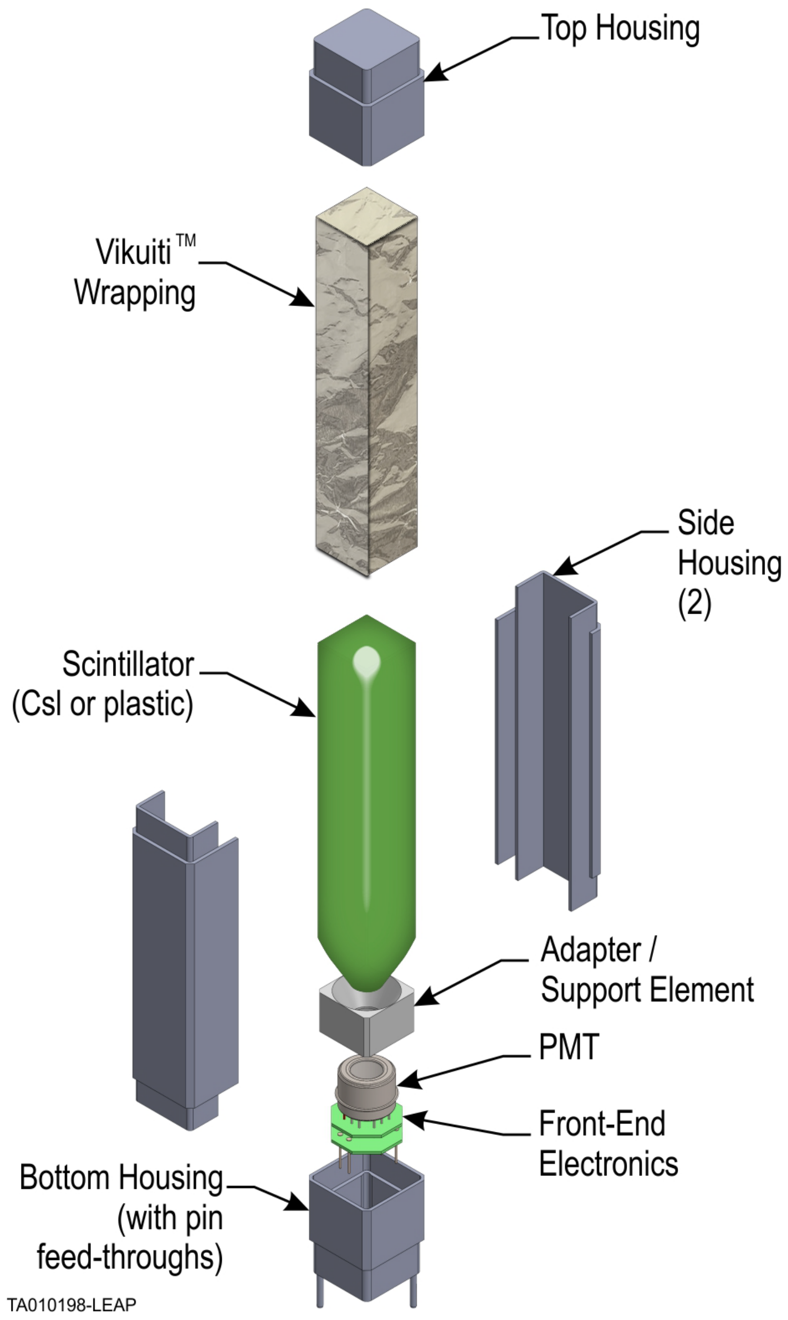
Again, let the science drive the mission design.

POET 2014



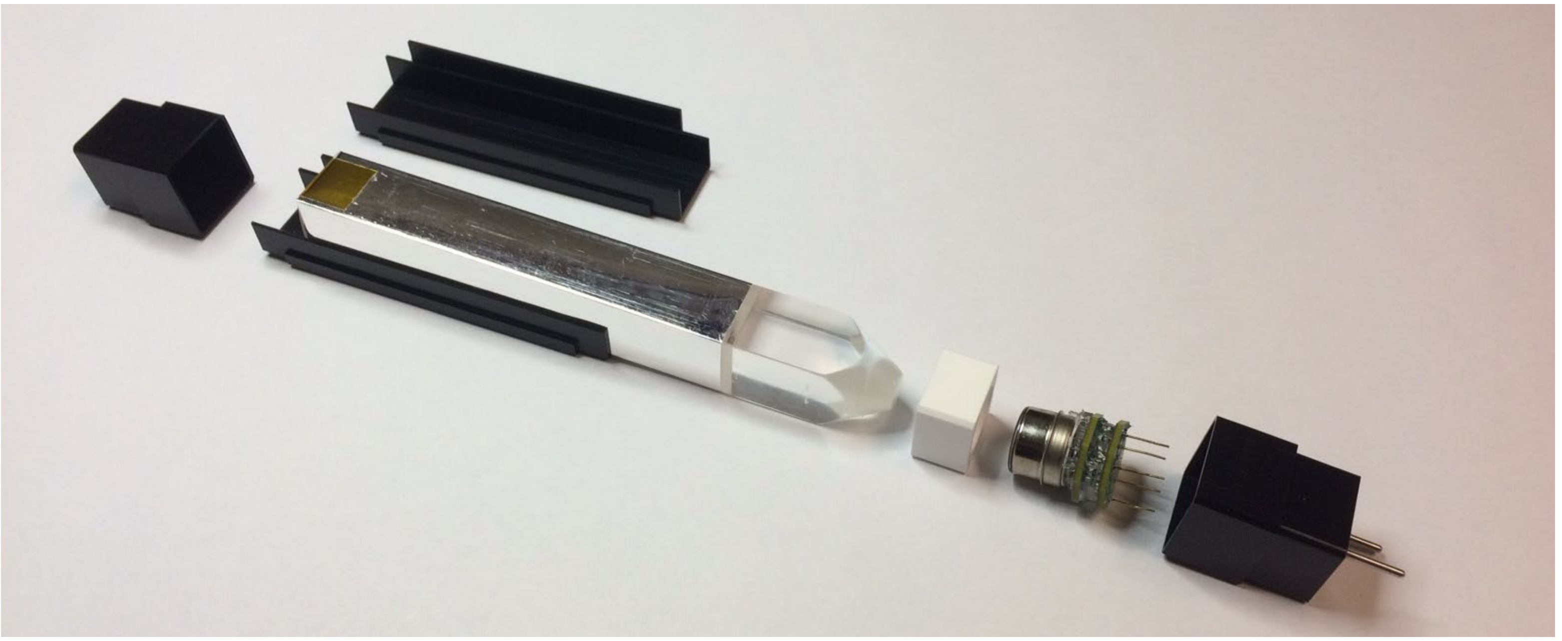


Well-Established Technology



Proposing to use new technology can be a really big risk, which must have a good plan for TRL advancement.

LEAP detector elements (> 1000 of them) are based on PMT scintillator technology. The use of SiPMs is a good alternative, but they carry a significant risk for radiation damage.

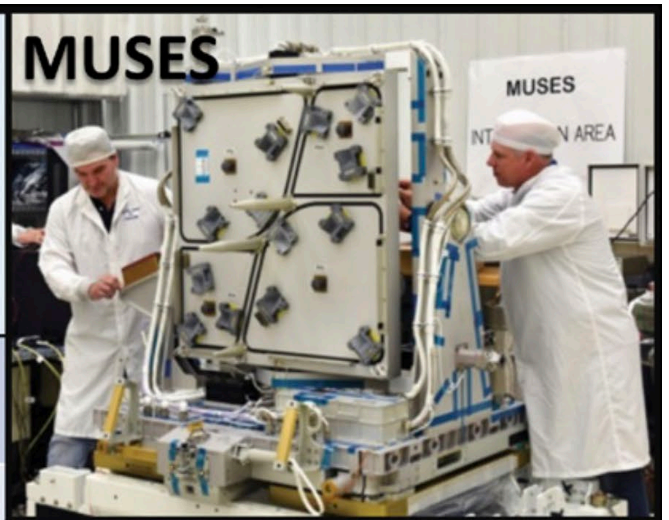


Don’t Overstate the Heritage

Heritage is important, but the case for heritage should make clear and direct connections to the current project. It should not be overstated.

Univ of New Hampshire (UNH)
Southwest Research Institute (SwRI)
Marshall Space Flight Center (MSFC)
Univ of Alabama – Huntsville (UAH)
Teledyne Brown Engineering (TBE)

Instrument	**LEAP Polarimeter Modules (LPMs)** provided by UNH
	Central Electronics Box (CEB) provided by SwRI
	Passive Shield Assembly (PSA) provided by UNH
Support Structure	**Power Adaptor Box (PAB)** provided by MSFC
	Supporting Structure provided by TBE
	FRAM Hardware provided by NASA (GFE)



Heritage includes not just technology, but also individual and institutional experience.

The Right Team

Assembling the right team is crucial.

- > 30 years of experience in building high energy polarimeters
- > 30 years of experience in building and operating GRB detectors on orbit
- > 30 years of experience in the simulation of orbiting gamma-ray detectors
- extensive experience in fabricating and operating space missions
- extensive experience in developing missions for ISS

The team must bring together the proper experience and needed resources.

The team should not be any larger than needed.

Proposal Inflation

Explorer-Class proposals are not cheap, especially good ones. Proposals have become more and more costly over the years, as teams attempt to out-do one another, and more seems to be expected by the review teams.

- Most (if not all) universities are hard-pressed to provide the necessary resources on their own. Government and commercial entities are needed to fill the gap.
- Be careful about "putting off until tomorrow what can be done today." Saying that a particular issue will be studied later can result in a weakness during the review.

Finally… Other Useful Things

- PERSISTENCE (stubbornness?)
- Lots of friends to provide support and encouragement
- Being able to figure out when to give up and move on to something else

A 3d-printed full-scale model of one LEAP Polarimeter Module.