

NASA's Physics of the Cosmos Program

Jamie Bock

California Institute of Technology

*Chair of the Physics of the Cosmos
Program Analysis Group*

pcos.gsfc.nasa.gov

Summary of PhysPAG Probe Findings (#1)

We find broad and enthusiastic support in the PCOS community for furthering the development of probe-class missions, conceived as a new large mission class of the PI-led competed missions in the Explorer program.

- As an example of this enthusiasm, we have received 14 white paper concepts from the community spanning PCOS science themes.
- We believe a scientific niche has been missing in the APD portfolio for competed, cost-capped missions in this price range. The success of the ESA M-class mission category testifies to the scientific effectiveness of such a program. We also note several NASA missions close to this cost point that have been successful in carrying out astronomical science (e.g. Fermi, Kepler, Spitzer).
- In the PCOS community, there is widespread support for the Explorer program in carrying out cost-effective science.

Summary of PCOS Probe White Papers (1/2)

Name	First Author	Type	Spectral Range	Science	Cost	Launch & ops?
High-Energy X-Ray Probe (HEX-P)	F. Harrison	X-Ray	2-200 keV	Resolve X-Ray background, evolution of black hole spin, faint X-ray populations in nearby galaxies	\$500M	Included
A Wide-Field X-Ray Probe	A. Ptak	X-Ray	~1-10 keV	Measure mass and spatial distribution of clusters and AGN, define LF of AGN	\$540M / \$740M	Not included
An X-Ray Grating Spectroscopy Probe	M. Bautz + R. McEntaffer	X-Ray	5-50 Angstrom	Role of SMBH feedback in galaxy formation, distribution of hot baryons, characteristics of Galaxy's hot halo, GW counterparts	\$784M	Included
AMEGO: A Medium-Energy Gamma-Ray Surveyor	J. McEnery	Gamma-Ray	0.2 MeV - 10 GeV	Time-domain GW counterparts, improved MeV surveying, nuclear line emission	\$600-\$800M	Included
Advanced Particle-Astrophysics Telescope (APT)	J. Buckley	Gamma-Ray	100 MeV - 50 GeV	Definitive dark matter search, all-sky transient survey, GW counterparts	Probe-class	Not stated
A Large Observatory for X-Ray Timing Probe (LOFT-P)	C. Wilson-Hodge	X-Ray timing	2 - 30 keV	Strong gravity and BH spins, matter in neutron stars, surveying the dynamic X-Ray sky, multi-messenger studies	\$770M	Included
Death of Massive Stars (DoMaS)	P. Roming	Transients	X-ray/UV/IR	Study massive stars at reionization via GRBs and SNe.	\$760M	Not stated

Summary of PCOS Probe White Papers (2/2)

Name	First Author	Type	Spectral Range	Science	Cost	Launch & ops?
Transient Astrophysics Probe (TAP)	J. Camp	Transients	X-ray/IR	Epoch of reionization from high-z GRBs and SNs, survey of the X-Ray sky, GW counterparts	\$750M	Included
The Time-Domain Spectroscopic Observatory (TSO)	J. Grindlay	Transients	0.4 - 5 um	Epoch of reionization from high-z GRBs studies, growth of SMBHs over cosmic time, GW counterparts, transient discoveries	\$650M	Included
GreatOWL: A Space-Based Mission for Charged-Particle and Neutrino Astronomy	J. Mitchell	Cosmic Ray	-	Nature of ultra-high energy cosmic rays, GZK-induced neutrinos	\$540M	Not included
The Inflation Probe	NASA IPSIG	CMB	30 - 300 GHz	Inflationary gravitational wave background, reionization, large-scale structure, neutrinos	Probe-class	Not stated
Probe-Class Mission Concepts for Studying mHz Gravitational Waves	M. Tinto	Gravitational-wave	1 mHz – 10 Hz	Spiraling massive and super-massive black holes, BH formation, tests of strong gravity, distribution of white dwarf binaries	\$560M / \$900M	Not stated
A Probe-Class Gravitational-Wave Observatory	S. McWilliams	Gravitational-wave	1 mHz – 10 Hz	Massive BH binary mergers, stellar-mass BH and NS mergers, probe dark energy via z-L measurements	\$830M - \$1.2M	Included
99 Luftballons	T. Eifler	UV/Optical	270 - 1000 nm	Nature of dark energy, neutrino masses, tests of gravity	Not stated	ULDB

Summary of PhysPAG Probe Findings (#2)

The PhysPAG endorses option 1 given in the charge, undertaking an initial study of ~10 1-year concept studies at ~\$100k each, as an initial step.

Summary of PhysPAG Probe Findings (#3)

However we are concerned that the cost information presented to the Decadal review will be insufficient.

- The initial \$100k studies will not have the financial resources and schedule required to achieve the level of cost fidelity required by the Decadal.
- We feel the second step in option 1 “conducting further one-year studies at a higher level of detail (and at a higher cost for each study) for a small number (~3) of medium mission concepts” needs to take place well before the Decadal survey. Costing these mission concepts during the Decadal study may not be successful given the inevitable time pressure of a Decadal review. We note the past practice of the Decadal cost and technical evaluation (CATE) process, in evaluating the fidelity of well-defined costed missions, may be problematic for probe mission concepts developed from these preliminary studies.
- Our interactions with commercial cost modelers indicate that cost studies should incorporate input from non-NASA modelers early on, to assure better agreement with the Decadal CATE process, which further extends the duration and complexity of the studies.

Summary of PhysPAG Probe Findings (#4)

We suggest that APD develop a second phase of studies to define costs for general probe missions, and to better determine the optimal cost point.

- Given the input we received on white papers, with many concepts in the lower end of the price range, it appears that certain concepts could fit well below the \$1B total. If so, this would be an important finding for Decadal survey planning as it bears on the frequency of mission opportunities.
- While the cost studies may be best developed on specific scientific concepts, the findings must apply generally to the probe mission class.

Summary of PhysPAG Probe Findings (#5)

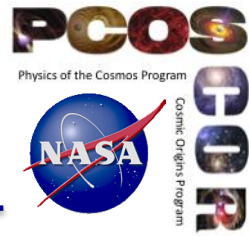
We note that the Inflation Probe is unique in that it was recommended by the 2010 Decadal Survey. Studies for its development would directly apply to developing the probe mission category for the 2020 Decadal Survey.

Path Forward on Cost Analysis

There are several (possibly overlapping) options available to develop a reliable cost model. We do not have a finding for a preferred option.

- 1) Provide sufficient support for the 10 studies to produce costs
- 2) Select a reduced number for a second-phase cost analysis
- 3) Cost “exemplar” concepts that are scientifically defined but apply to general types of likely probe missions
- 4) Use the inflation probe as one “exemplar” concept

PhysPAG EC membership



Name	Institution	Topical Area	Term end
J. Bock, Chair	Caltech/JPL	CMB	December 2016
M. Bautz, Vice Chair	MIT	X-rays	December 2016
R. Bean	Cornell Univ.	Dark Energy	December 2016
R. Kraft	SAO	X-rays	December 2018
J. Conklin	Univ. of Florida	Gravitational Waves	December 2017
N. Cornish	Montana State	Gravitational Waves	December 2016
O. Doré	JPL	Dark Energy	December 2017
H. Krawczynski	Washington Univ. in St. Louis	Gamma-rays	December 2017
M. McConnell	U. of New Hampshire	Gamma-rays	December 2016
A. Miller	Columbia Univ.	CMB	December 2017
I. Moskalenko	Stanford	Astroparticles	December 2018
Eun-Suk Seo	U. of Maryland	Astroparticles	December 2016
E. Wollack	NASA/GSFC	CMB	December 2017

New members added since last APS meeting

SIG Activities

PCOS General

PCOS mini-symposium at the APS, Salt Lake City, April 2016

Inflation Probe SIG

General interest:

US MO participation in Japanese LITEBIRD mission selected for phase A study

SPHEREx SMEX mission concept selected for phase A study (inflation & large-scale structure)

Ongoing activities:

DOE Stage-4 CMB polarization meeting held in Berkeley, CA 7-9 March 2016

Upcoming activities:

Upcoming CORE++ proposal for ESA M5 proposal opportunity

Inflation SIG special session at the APS, Salt Lake City, April 2016

Gravitational Wave SIG

General interest:

NASA L3 Study Team announced 29 January 2016

Detection of gravitational waves by Advanced LIGO 11 February 2016

LISA Pathfinder test masses released 16 February 2016

LISA Pathfinder being science mission 8 March 2016

Upcoming activities:

GW SIG special session at the APS, Salt Lake City, April 2016

LISA Symposium, Zurich, September 2016

SIG Activities

X-Ray SIG

General interest:

Two X-Ray polarimetry SMEX mission concepts (IXPE and PRAXys) selected for phase A study
Hitomi (aka ASTRO-H) launched 17 February 2016

Ongoing activities:

X-Ray Surveyor study underway

Upcoming activities:

SIG meeting at AAS/HEAD, Naples, April 2016

Gamma-Ray SIG

Ongoing activities:

Develop gamma-ray astronomy roadmap for input to the 2020 decadal survey focusing on
probe-class and explorer-class concepts, and including sub-orbital developments

Upcoming activities:

SIG meeting at AAS/HEAD, Naples, April 2016; instrument concepts

SIG Activities

Cosmic-Ray SIG

General interest:

ISS-CREAM completed testing at GSFC and delivered to KSC

Upcoming activities:

Cosmic-Ray SIG special session at the APS, Salt Lake City, April 2016

Cosmic Structure SIG

General interest:

Identify NASA programs that support CoSSIG science, e.g., sub-orbital, probes, flagship studies

SPHEREx SMEX mission concept selected for phase A study (inflation & large-scale structure)

Ongoing activities:

Webpage <http://pcos.gsfc.nasa.gov/sigs/cossig.php>

Email list CoSSIG-subscribe@lists.nasa.gov

Upcoming activities:

Reference Material

Summary of the Probes Charge

On 14 January 2016 the PAGs were charged to evaluate two options for developing probe-class missions for the Decadal survey:

1. Issue a solicitation through ROSES for Astrophysics Probe mission concept study proposals. The proposals will be evaluated via a peer-review process and APD will select a few (~10) for one-year studies. A modest (~\$100K) amount of funding would be allocated for each study; cost assessment mechanisms would need to be discussed. The results of the studies would be presented to the Decadal Survey Committee. The Decadal Survey Committee would have the option of asking NASA to conduct further one-year studies at a higher level of detail (and at a higher cost for each study) for a small number (~3) of medium mission concepts.
2. Do nothing and let the community self-organize. Most likely this will result in submission of many white papers to the 2020 Decadal Survey from interested individuals and groups, as during the 2010 Decadal Survey.

Joint PAG Statement on Probes

The COPAG, ExoPAG, and PhysPAG all agree that NASA should support the development of a probe class of competed missions for the Decadal survey. All three PAGs strongly support the first option proposed by Paul Hertz in his formal charge to the PAGs of January 14, 2016. Based on the input the three communities have received, there exists a wide range of community science goals that are both consistent with current National Academy priorities and that can be enabled with medium-class missions. The three PAGs also note that the work of preparing high quality white paper proposals to the 2020 Decadal Survey, for missions of this class, cannot be performed absent funding. In particular, all three PAGs agree that competed NASA HQ funds should allow at least 10 concepts for probe-class missions to be studied in some depth. However, the main concern associated with this first option is that limiting the funds available for each concept study to ~\$100K will likely severely limit the veracity of the CATE analyses at this early phase, even though funds would be provided for more detailed CATE analyses when requested at a later phase by the Decadal Survey committee. We recommend that APD consider apportioning sufficient funds to carry out multiple CATE analyses that would apply to the general category of probe missions in advance of the Decadal Survey.

Gathering Community Input and PAG Coordination

Date	Location	Meeting
1 July 2015	Chicago, IL	X-ray and Gamma-ray SIG meet at AAS High Energy Astrophysics Division
		High-energy astrophysics probe concepts developed
3 Jan 2016	Kissimmee, FL	Joint PAG open session on probes at AAS
3 January	Kissimmee, FL	PhysPAG EC meeting & probes discussion
		Presentation on CATE process from Aerospace
27 January	Email	PhysPAG issues call for 2-page probe white papers
8 February	Telecon	Joint PAG discussion about joint response
1 March	Email	14 probe white papers received from PCOS community