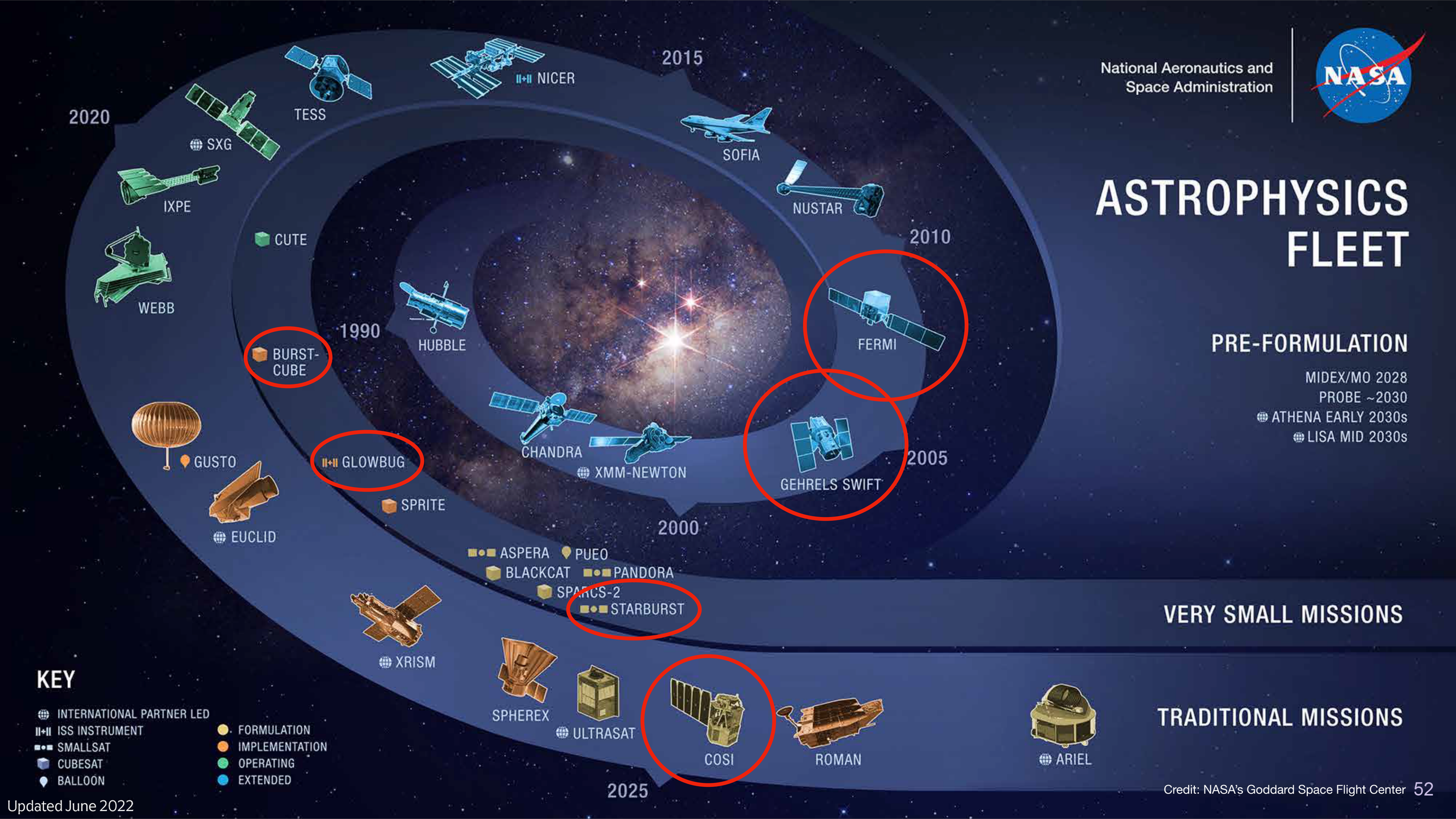
The Case for a Gamma-ray Roadmap

Jeremy S. Perkins (NASA/GSFC) on behalf of the
Gamma-ray Astrophysics Community*

*Aspirational


National Aeronautics and Space Administration
NASA
ASTROPHYSICS FLEET
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PROBE ~2030
ATHENA EARLY 2030s
LISA MID 2030s
VERY SMALL MISSIONS
TRADITIONAL MISSIONS
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STARBURST
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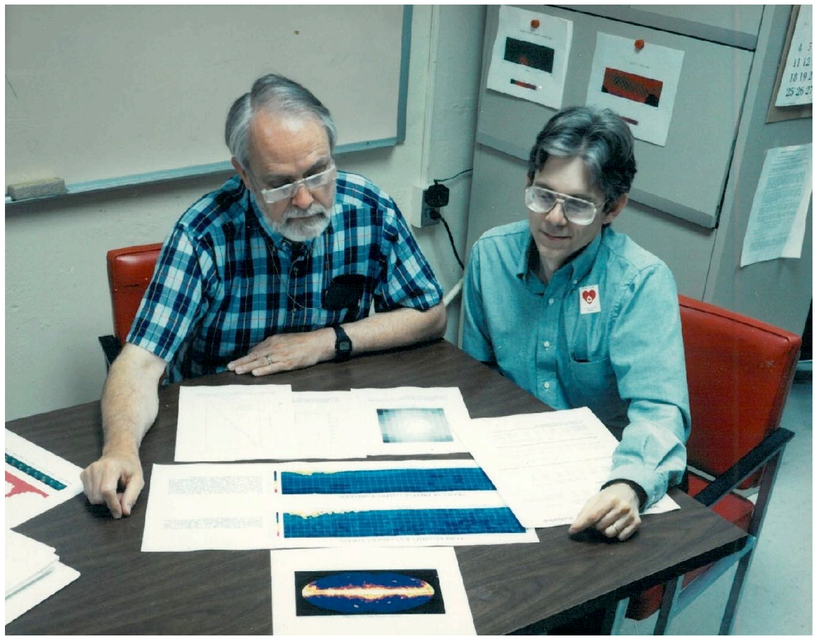
KEY
INTERNATIONAL PARTNER LED
ISS INSTRUMENT
SMALLSAT
CUBESAT
BALLOON
FORMULATION
IMPLEMENTATION
OPERATING
EXTENDED
Updated June 2022
Credit: NASA's Goddard Space Flight Center

1997

- Non-depressing things that happened in ’97:
  - Second Hubble Servicing Mission
  - United Kingdom banned all hand guns.
  - Deep Blue beat Kasparov in Chess (first time a computer beat a world champion).
  - The first episode of South Park aired.
  - The Spice Girls released their first single.
  - I graduated from High School.

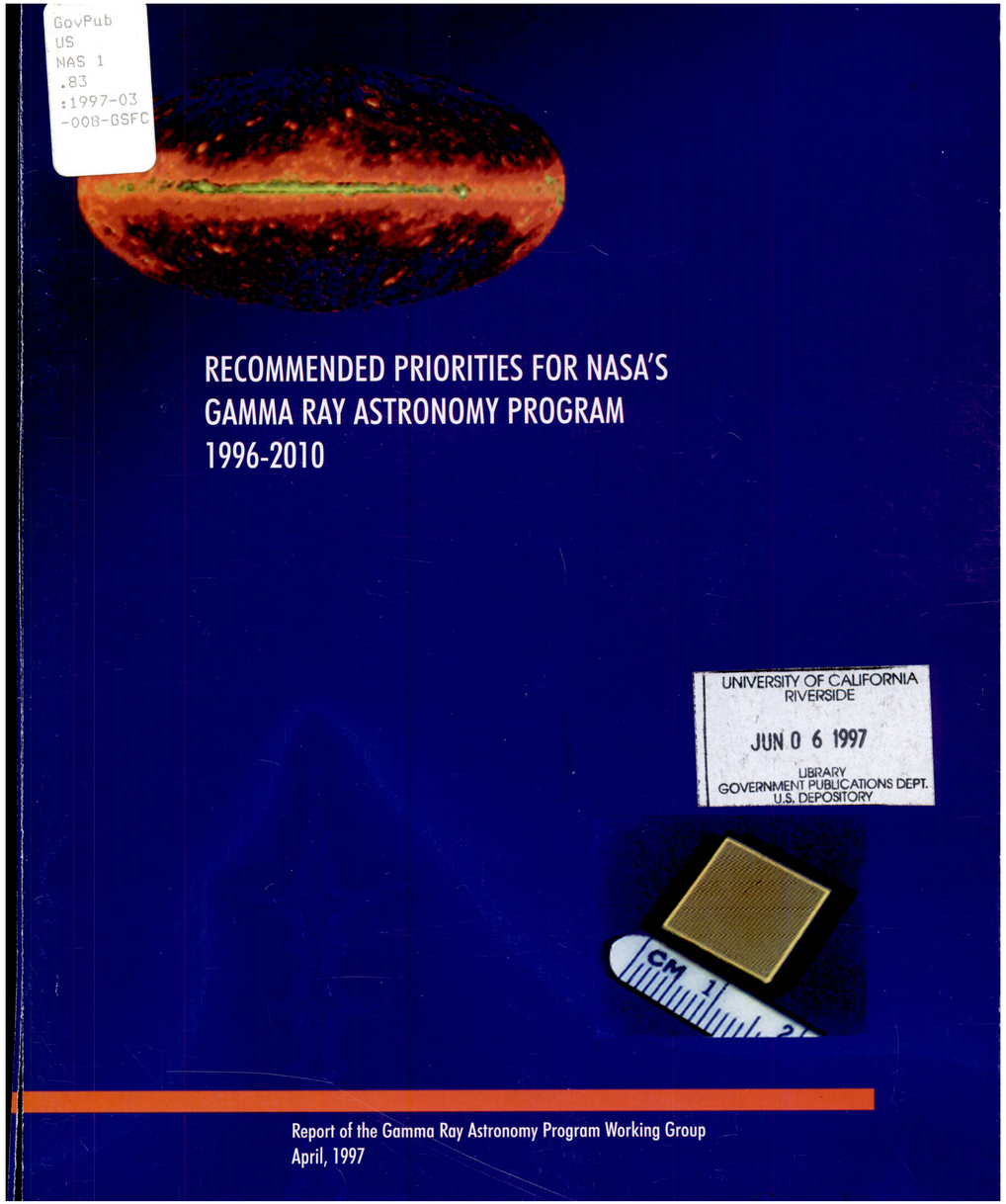
Me in 1997 (well, October 1996 but close enough)



Bob Hartman and Dave Thompson working on EGRET in 1993

Also in ‘97

“The mandate of the working group is to recommend a road map to the future for use as an input to the next NASA strategic plan…”



Compton Gamma-ray Observatory

- One of the original **Four Great Observatories.** Launched 1991 and de-orbited in 2000 (three years after the report).

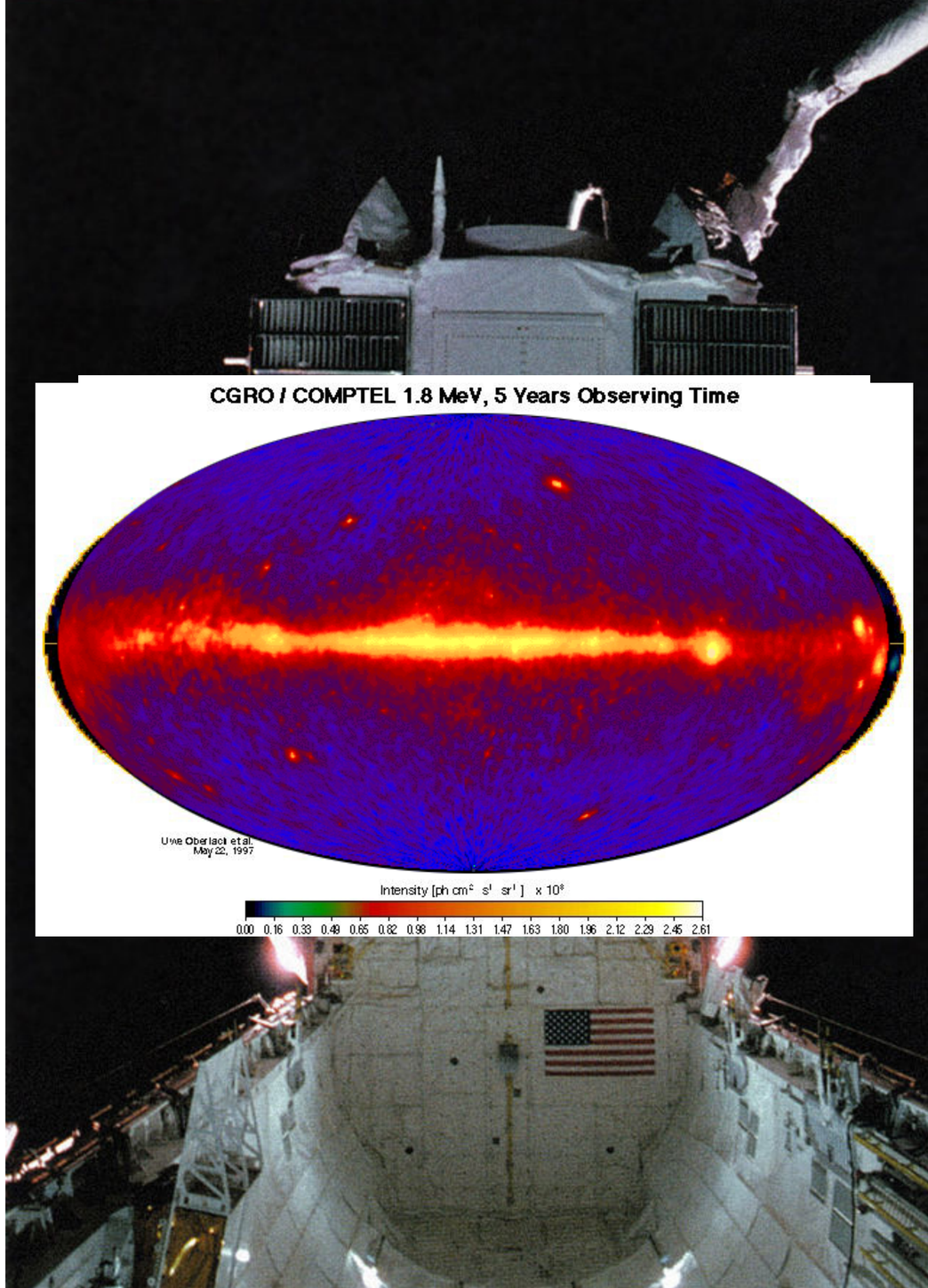
- Four Instruments:

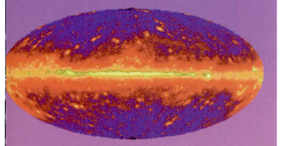
  - The Burst Alert and Transient Source Experiment (BATSE) an all sky monitor 20 keV to 1 MeV

  - The Oriented Scintillation Spectrometer Experiment (OSSE) for the 0.05 to 10 MeV range

  - The Compton Telescope (CompTel) in the 0.8 to 30 MeV range capable of imaging 1 steradian.

  - The Energetic Gamma-Ray Experiment Telescope (EGRET) in the 30 MeV to 10 GeV range.





EXECUTIVE SUMMARY

With new results from the Compton Gamma Ray Observatory (CGRO), the Rossi X-ray Timing Explorer (RXTE), and GRANAT, hard X-ray and gamma-ray astronomy are in a period of discovery and vigor unparalleled in their history. The CGRO mission in particular has made fundamental contributions to understanding many classes of galactic and extragalactic objects. The CGRO discoveries of gamma-ray blazars, an isotropic distribution of gamma-ray bursts, bright black hole and neutron star transients, sites of galactic nucleosynthesis, and a large class of unidentified high energy sources have intrigued astronomers and the public alike. These discoveries have prompted a wide range of correlated observations by X-ray satellites and ground-based radio, IR, and optical observatories, adding to our rapidly expanding knowledge of the nature of high-energy emission. We now have the beginnings of a better understanding of the astrophysics of gamma-ray sources, and this in turn has raised fundamental new questions about the origin and evolution of high-energy objects and about the nonthermal astrophysical processes that occur in them.

Looking ahead to the next decade, further discoveries in hard X-ray and gamma-ray astronomy are anticipated with further CGRO and RXTE observations and with the ESA INTEGRAL mission (launch ~2001). However, there are currently no major missions being planned beyond INTEGRAL and none being planned at all by NASA. Of particular concern is the high-energy regime (100 MeV - 100 GeV), where observations will soon come to a virtual halt in the next 2 years as the EGRET instrument on CGRO runs out of spark-chamber gas. Also of concern is the present lack of plans for missions that would 1) significantly improve on the BATSE capabilities to study gamma-ray bursts as well as conduct a full-sky survey and monitor transient source 2) follow-on the first exploration of the MeV band by COMPTEL with much better sensitivity, and 3) continue the important studies of nucleosynthesis begun by balloon instruments, OSSE, and COMPTEL. From a scientific standpoint, there is an urgent need for new observational missions. From a technical standpoint, the timing is excellent since powerful new detector and imaging technologies are in hand that promise major steps in observational capabilities.

With this in mind, the GRAPWG recommends the following program in hard X-ray and gamma-ray astronomy.

With new results from the **FERMI** Gamma Rav Observatory **FGRO**, the Rossi X-ray Timing Explorer **Swift**, and GRANAT, hard X-ray and gamma-ray astronomy are in a period of discovery and vigor unparalleled in their history. The CGRO mission in particular

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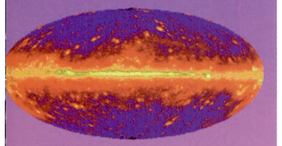
out of spark-chamber gas. Also of concern is the present lack of plans for missions that would 1) significantly improve on the **Fermi** apabilities to study gamma-ray bursts as well as conduct a full-sky survey and monitor transient source 2) follow-on the first exploration of the MeV band by COMPTEL with much better sensitivity, and 3) continue the important studies of nucleosynthesis begun by balloon instruments, **COSI** nd COMPTEL. From a scientific standpoint, there is an urgent need for new



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“With this in mind, the GRAPWG recommends the following program in hard X-ray and gamma-ray astronomy.”

GAMMA-RAY ASTRONOMY PROGRAM WORKING GROUP MEMBERS:

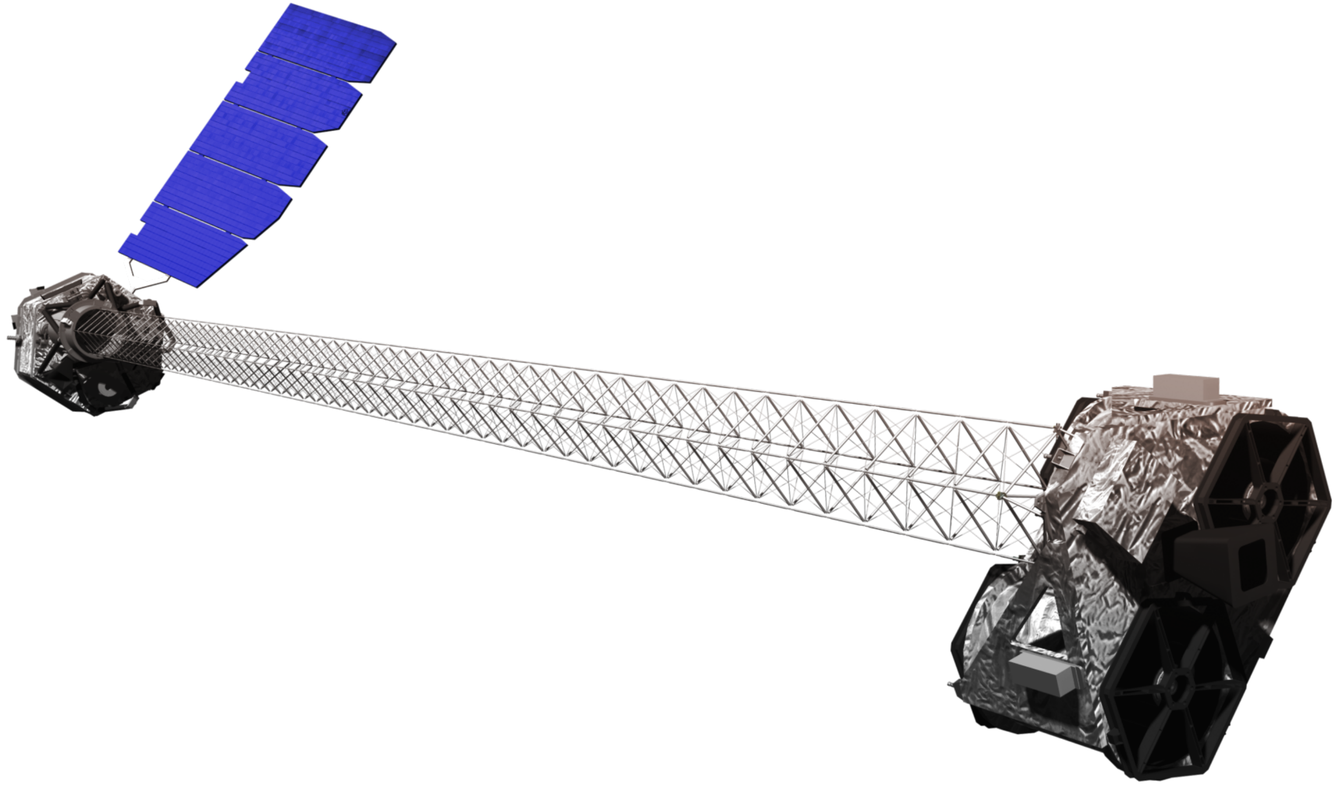
Elena Aprile (Columbia)
Alan Bunner (NASA) [Ex-Officio (NASA Headquarters)]
Neil Gehrels (GSFC) [Co-Chair]
Jonathan Grindlay (Harvard)
Gerald Fishman (MSFC)
W. Neil Johnson (NRL)
Kevin Hurley (UCB/SSL)
Steve Kahn (Columbia)
Richard Lingenfelter (UCSD)
Peter Michelson (Stanford)
Thomas Prince (Caltech) [Co-Chair]
Roger Romani (Stanford)
James Ryan (UNH)
Bonnard Teegarden (GSFC)
David Thompson (GSFC)
Trevor Weekes (Harvard/Smithsonian)
Stanford Woosley (UCSC)

Intermediate Missions

The HIGHEST PRIORITY recommendation is:

A next generation 10 MeV to 100 GeV gamma-ray mission such as GLAST. 1 to 2 orders of mag improvement in sensitivity compared to EGRET.

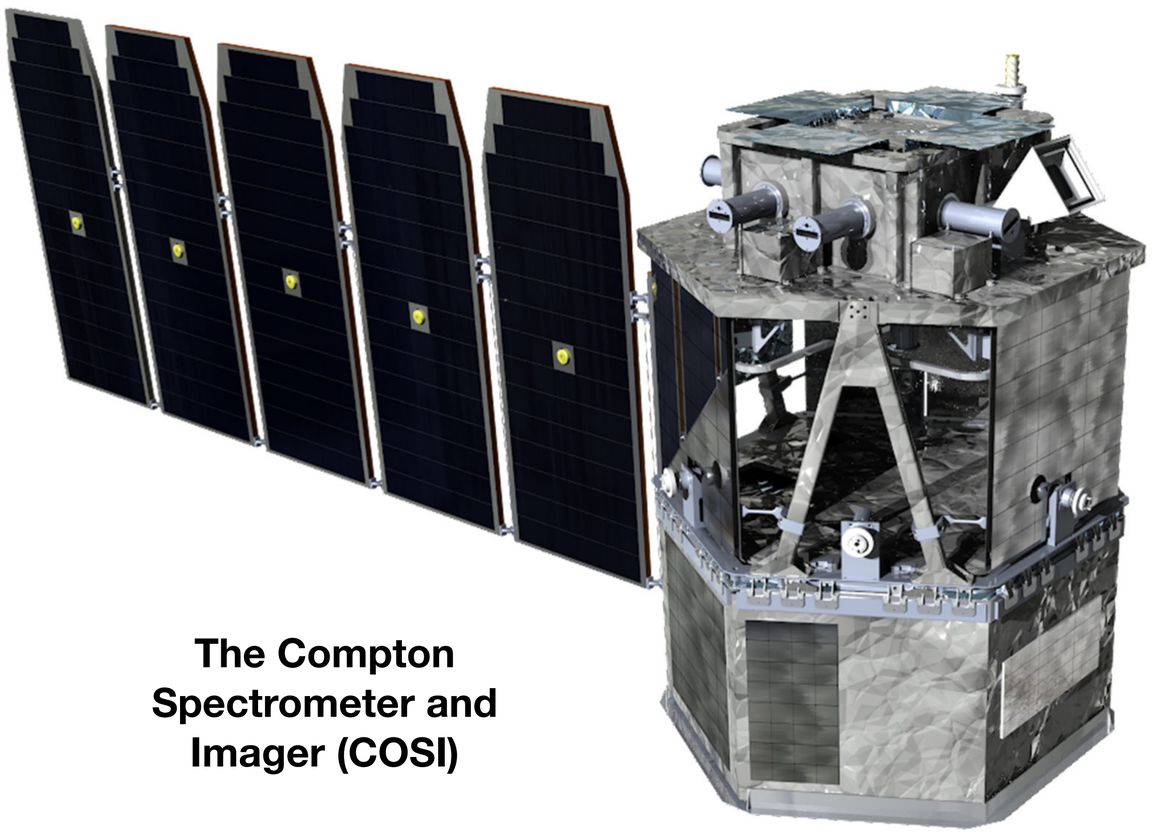
Intermediate Missions



Another very-high priority:

A Focusing Hard X-ray Telescope.

Intermediate Missions

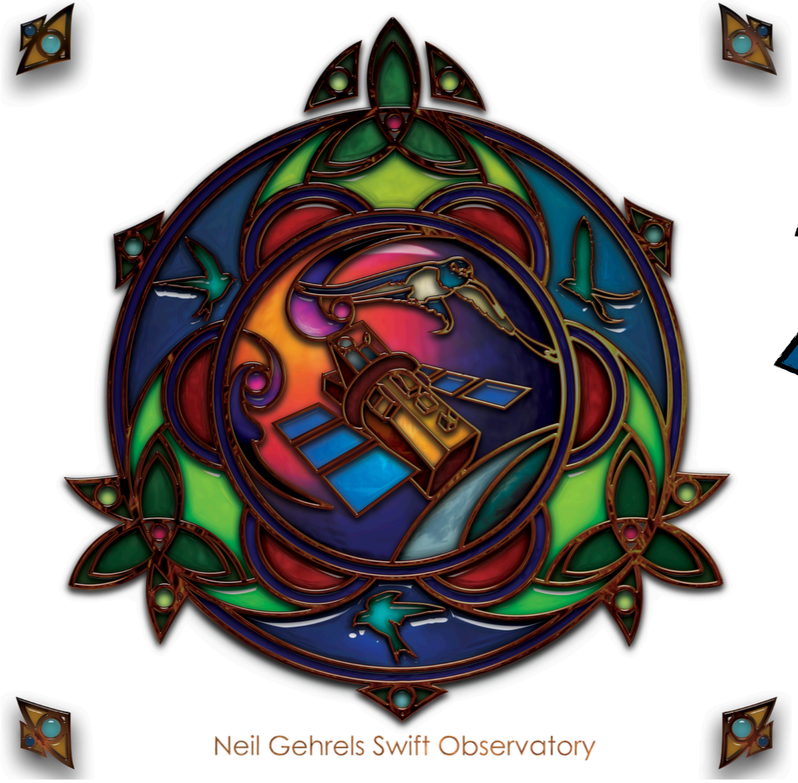


The Compton Spectrometer and Imager (COSI)

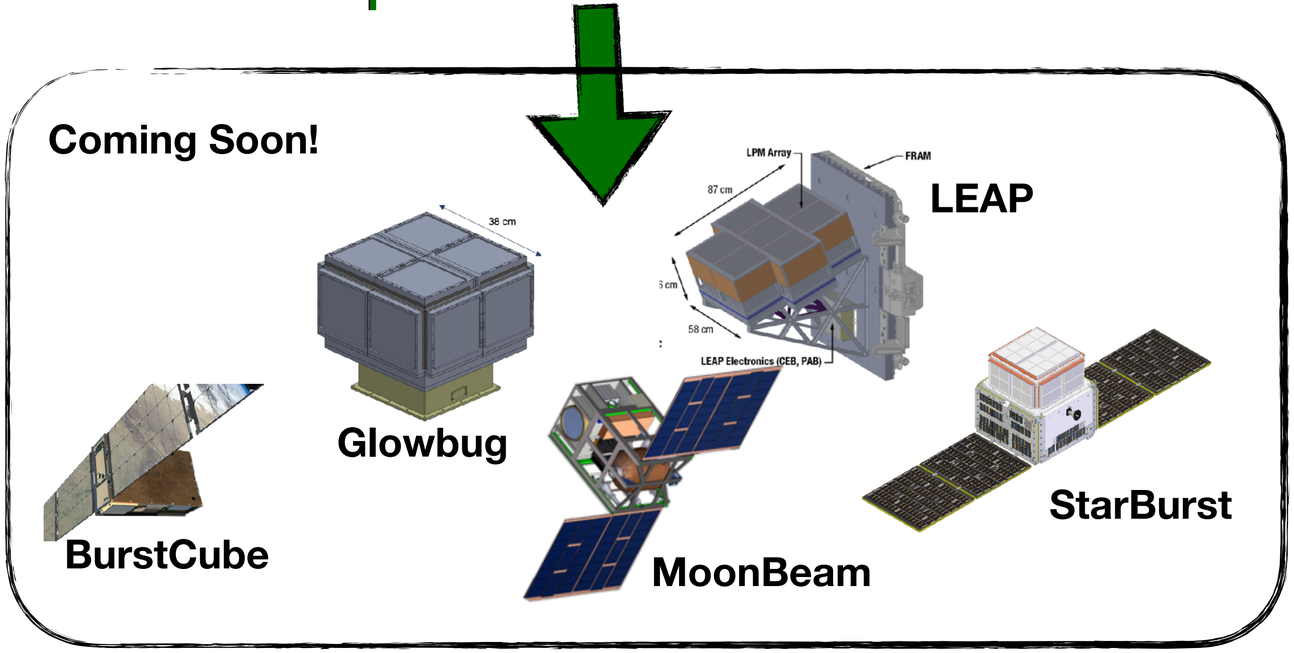
The second very-high priority:

A next-generation nuclear line and MeV continuum mission. A major step forward compared to INTEGRAL in both sensitivity and energy range.

Probe and SMEX Missions



A gamma-ray burst localization mission. Such a mission would address the origin of gamma-ray bursts. Missions with coding apertures or an array of small telescopes would fill this need.



KEY QUESTIONS IN GAMMA-RAY ASTRONOMY FROM 1997

- **What is the origin and nature of gamma-ray bursts?**
- **What are the physical conditions and processes near accreting black holes and neutron stars?**
- **How does matter behave in extreme conditions like those in neutron stars, supernova expulsions and active galactic nuclei?**
- **How do astrophysical accretion processes work and what are their instabilities, periodicities and modes?**
- **What is the nature of the jets emanating from galactic black holes and AGN and how are the particles accelerated?**
- **What is the origin of the diffuse gamma-ray background?**
- **What is the nature of the unidentified high energy gamma-ray sources?**
- **What are the sites of nucleosynthesis?**
- **How do supernovae work? What are the progenitors and explosion mechanisms? What has bene the rate in the last several hundred years?**
- **What and where are the sites of cosmic ray acceleration?**

Why did they recommend these missions?

- They developed a series of **Key Science Questions** that pointed to the need for this diverse set of missions.
  - Lesson: Lead with the Science
  - Lesson: Don’t shy away from the big problems
- Many of these questions are still open but we have made significant progress.

’97 Report Checklist

✓ Intermediate Missions: We got Fermi and NuSTAR

✓ MIDEX and SMEX: We got Swift but not EXIST (although you could count NICER)

✓ Technology: We have had a robust technology development program that supported Fermi and Swift and continues to build technology.

✓ Balloons: We got long duration balloons and I would say this directly led to the success of COSI and LEAP.

✓ Data Analysis & Theory: This was mainly supported through GI programs like those of Fermi and Swift.

✓ TeV Astronomy: We got VERITAS, HESS, HAWC, and MAGIC.

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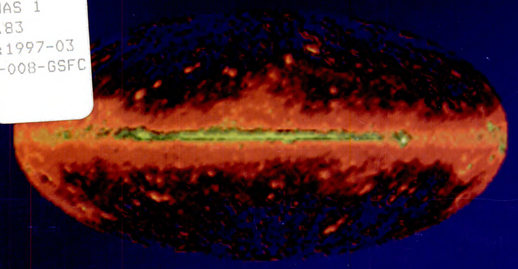

RECOMMENDED PRIORITIES FOR NASA'S GAMMA RAY ASTRONOMY PROGRAM 1996-2010

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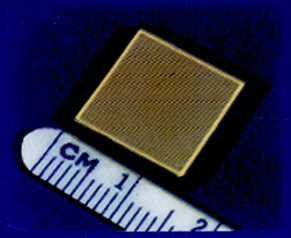

Report of the Gamma Ray Astronomy Program Working Group
April, 1997

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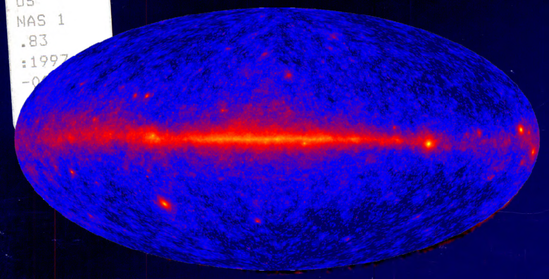

RECOMMENDED PRIORITIES FOR NASA'S GAMMA RAY ASTRONOMY PROGRAM 2024 - 2040

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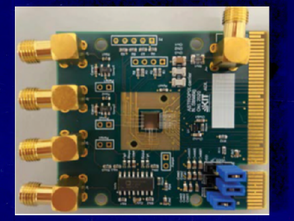


Report of the Gamma Ray Astronomy Program Working Group
April, 2024

- Advocate to NASA via the Physics of the Cosmos Program Analysis Group (PhysPAG). This is NASA's link to the community.

- Join the Gamma-ray Science Interest Group (GammaSIG) and advocate for a new Gamma-ray Roadmap.

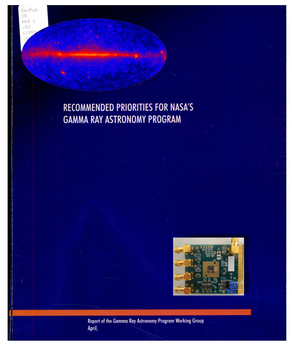
- Advocate with your own funding agency (NSF, DoE, ASI, CNES, …) for the need for a Gamma-ray Roadmap and a new Gamma-ray Observatory.

- Talk to your colleagues. Mention this in talks/posters/ publications. If we don't push as a community, there's no guarantee we will have a gamma-ray mission after Fermi, Swift, and COSI.

Help develop the Roadmap

- We plan on creating a ‘Science Analysis Group (SAG)’ to develop the roadmap.
- We need the full gamma-ray community (NASA, NSF, DoE, ASI, CNES,…) to work on this. This will be our plan.

Future Gamma-ray Roadmap Science Analysis Group



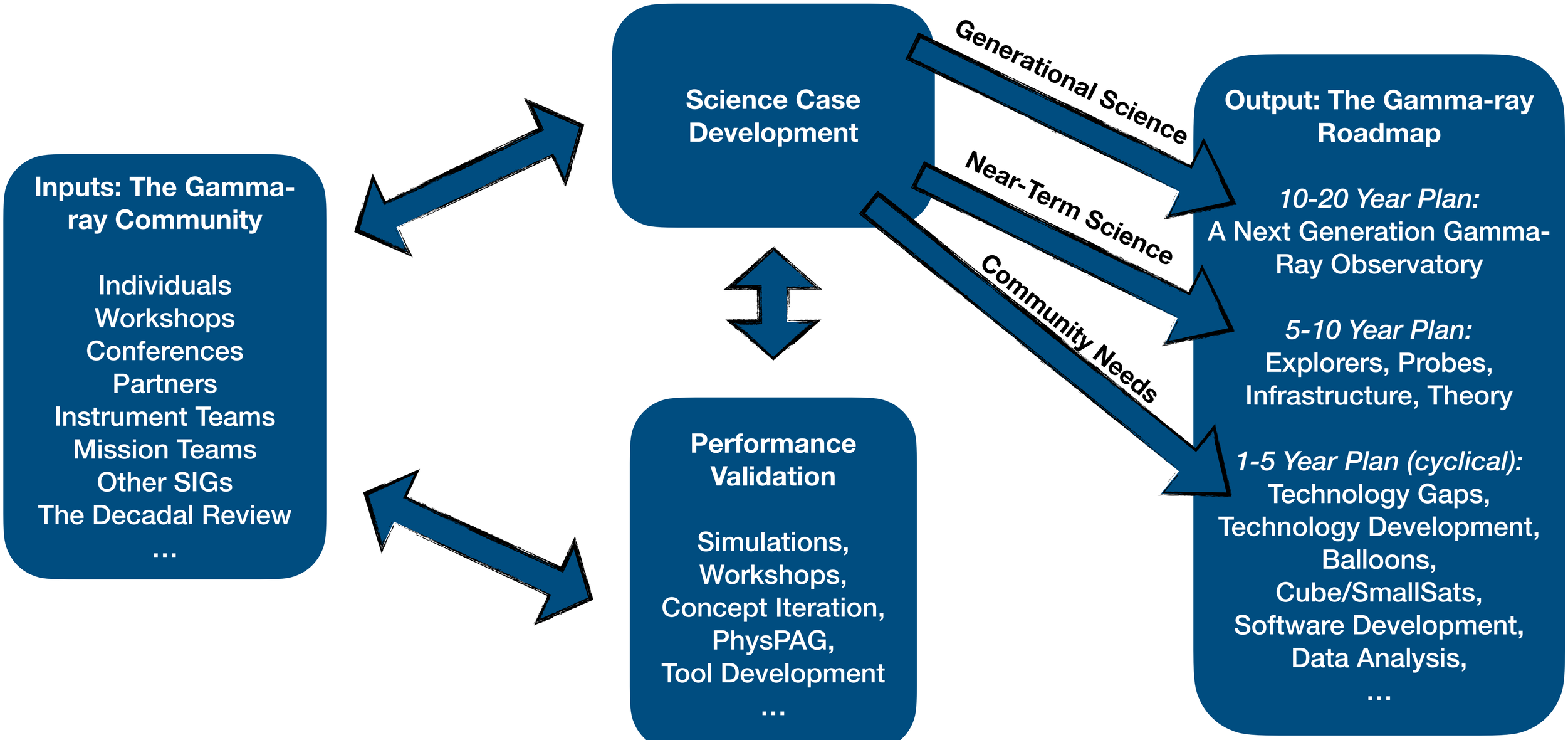
NASA Astrophysics Advisory Committee (APAC)

NASA Astrophysics Division Director (Mark Clampin)

A report for 2023

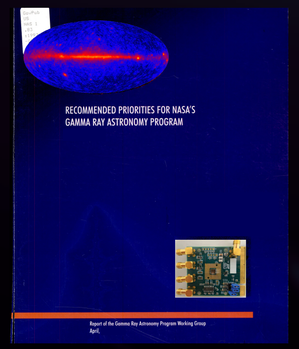
- Of course, the ’97 roadmap led to new questions as well. Some I’ve highlighted already but I think there are three key ones that we should think about including:
  - The report only mentioned Dark Matter in two places and it wasn’t one of the big science questions.
  - The report recommended an MeV continuum mission but that did not materialize.
  - Multimessenger Astronomy is (of course) not mentioned. One could argue that this report directly led to the advent of MMA since Fermi and Swift are a critical part of that field.
  - Inclusion, Diversity, and Equity are not mentioned. This should be a critical aspect in everything we do.

Gamma-ray Roadmap SAG



- There are new questions that need to be answered since the ’97 report.
  - Many of these questions can only be addressed in the gamma-ray regime.
- Other fields (Neutrinos, Gravitational Waves, …) depend on the existence of a gamma-ray mission.
- We can’t wait until NSF, NASA, or DoE ask for something. We as a community should lay out the science questions we think we should answer over the next decades.
- *There’s no guarantee of a future gamma-ray mission. We need to work on a plan now.*

Future Gamma-ray Roadmap Science Analysis Group



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