NASA X-RAY CONCEPTS STUDY, REPORT FROM THE DECEMBER WORKSHOP, AND THE X-RAY MISSION LANDSCAPE

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Outline

- **Near-term Landscape**
- **Background for Study**
- **X- ray Study**
  - Objectives, Process, Participants, Schedule
  - Workshop
  - Next Steps

Near Term X-ray Landscape

- **Current missions**
  - Chandra (1998-) Unprecedented imaging and (limited) high resolution spectroscopy
  - XMM-Newton (1999-) Wide field, good angular resolution, large area
  - Suzaku (2005-) Very broad-band, low surface brightness spectroscopy
  - Swift (2004-) Rapid response to transients, deep 10+ keV survey
  - ~~RXTE (1996-2012)~~
- **Upcoming missions**
  - NuSTAR (2012) Hard X-ray imaging (6-80 keV)
  - Astro-H (2014) Spatially resolved high res spectroscopy + broad band
  - GEMS (2014) Sensitive X-ray polarimetry
  - Astrosat (2013?) Large area timing
  - SRG (eROSITA, ART) (2013) 0.3-15 keV all sky survey
- **No guaranteed mission after 2017 – "golden age" will end abruptly**
- **What's missing is a new strategic mission**

Background for concepts study (1 of 3)

- **Constellation-X was NASA's strategic X-ray mission concept (1996-2008)**
  - High resolution spectroscopy with large effective area
  - Four mirrors (~3m^2 @ 1 keV) with calorimeter and gratings, plus HXT
  - Ranked 2nd among large missions in 2000 decadal survey
  - Substantial technology development – mirrors, calorimeters, gratings
- **X-ray Evolving Universe Spectrometer mission (XEUS) was European counterpart (2000-2008)**
  - Very large collecting area with wide field imaging plus high resolution spectroscopy, high time resolution and polarimetry
  - One of three L-class mission candidates selected in 2006 for ESA's Cosmic Visions
- **In 2008, the missions were merged to form the International X-ray Observatory (IXO)**
  - Submitted to both US Decadal Survey and ESA Cosmic Visions

Background for concepts study (2 of 3)

- **In 2010 IXO was ranked fourth among large missions in *New Worlds New Horizons***
  - Science was very well received but projected cost thought to be too high ($3.3B-$4.8B)
  - Key IXO science is high resolution spectroscopy
  - IXO should cost no more than $2B; 10 arcsec resolution acceptable
  - Strong recommendation to develop optics and other enabling technology to higher readiness level (~$200M over decade)
- **In March 2011, ESA decided to redefine all three L candidates**
  - Due to JWST costs and budget realities, ESA was no longer confident that NASA could contribute its share, about half the cost of each mission
  - ESA component of mission to be less than ~€800M
  - US participation possible at ≤$150M level
  - Downselect decision postponed until February 2012 (now June)
- **ESA decision meant the termination of IXO (and LISA)**
- **ESA has subsequently developed Athena concept**
  - Two mirrors, focusing onto WFI and microcalorimeter (N. White talk)

The Decadal View of IXO

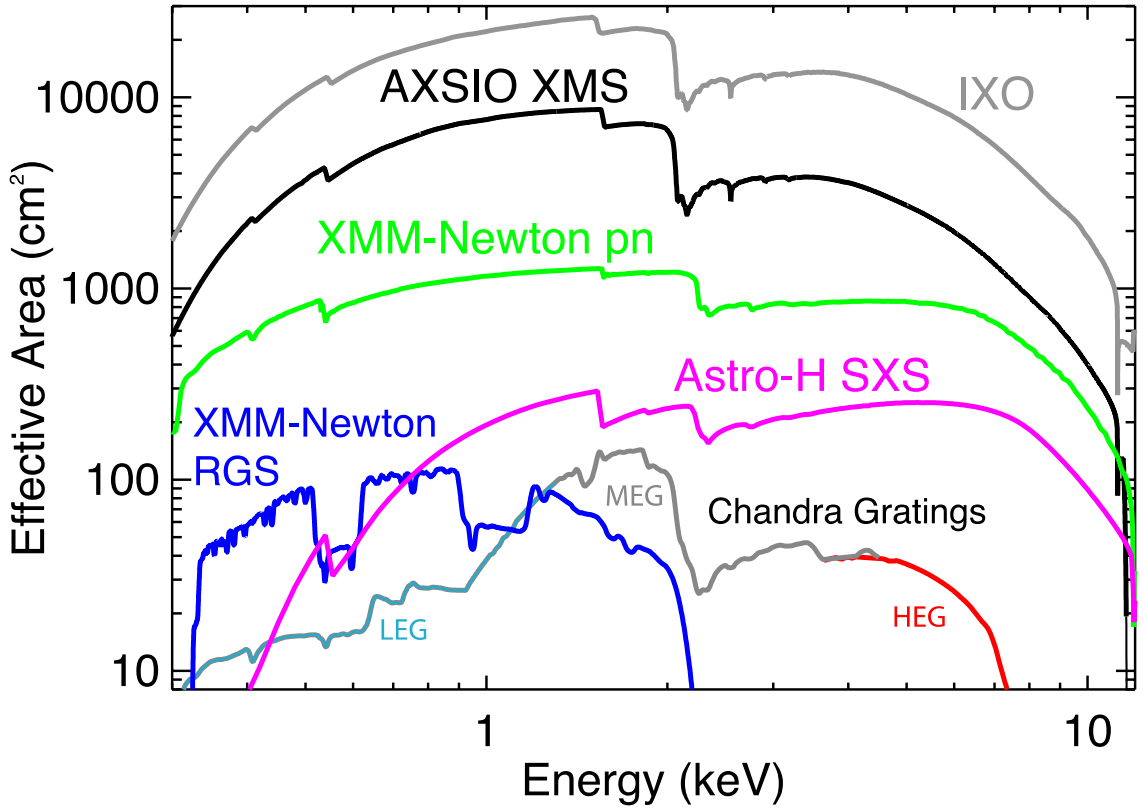
- **"IXO is a versatile, large-area, high-spectral-resolution X-ray telescope that will make great advances on broad fronts ranging from the *characterization of black holes* to *elucidation of cosmology* and the *life cycles of matter and energy in the cosmos*. Central to many of the science questions identified by this survey, IXO will revolutionize high-energy astrophysics with more than an order-of-magnitude improvement in capabilities." (p19, emphasis. added)**

Background for concepts study (3 of 3)

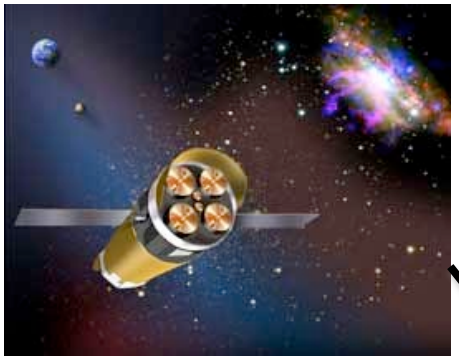
- **IXO study activities in US were terminated in fall 2011**
  - Prior to termination:
    - Produced mirror development plan consistent with NWNH recommendation
    - Developed AXSIO concept (IXO redesigned to meet decadal constraints – next slide)
- **X-ray study activities and technology development moved under PCOS**
  - SAT plus directed support for technology in 2012 and beyond
- **In September 2011, NASA HQ directed PCOS office to perform a concept study to identify more cost effective ways to perform IXO and LISA science**

AXSIO: The Advanced X-ray Spectroscopic Imaging Observatory

Designed to meet NWNH recommendations (<$2B)
Optics: 0.9m^2 at 1.25 keV; 0.2m^2 at 6 keV: 10" resolution (5" goal)
Calorimeter 40X40 array with < 3 eV resolution
Grating $\lambda/\Delta\lambda$ >3000; ~1000cm^2 (0.3-1.0 keV)

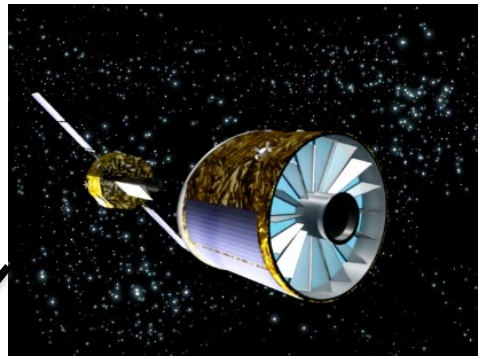


The road to the next strategic X-ray observatory



Constellation-X
(1996-2008)

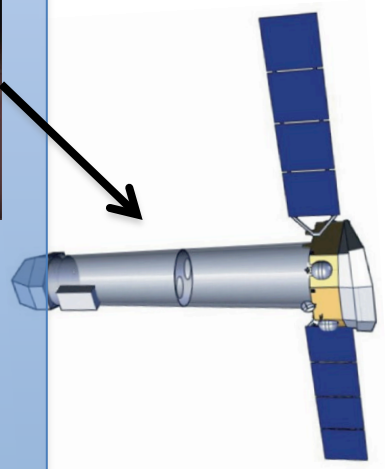
IXO
(2008-2011)



XEUS
(2000-2008)

- **Tech. development plan (2011-2012)**
- **Mission architecture assessment, with and without US contribution to Athena (2011-2012)**
- **Mission concept(s) definition (>2012)***

*** Purview of the CAA and NASA HQ**



Athena
(2011-??)

NASA ***ESA***

X-ray Concepts Study

- **Objectives**
  - Determine the range of science objectives of IXO that can be achieved at a variety of lower cost points
  - Explore mission architectures and technical solutions that are fundamentally different from the heritage designs
  - Fully engage the community and ensure that all voices are heard, all perspectives considered
  - Create data for a report to the CAA that describes options for science return at multiple cost points for X-ray astronomy
- **Deliver final report to NASA HQ that:**
  - Describes and analyzes trade space of science return vs. mission cost
  - Summarizes the mission concepts developed during the study and how they relate to the trade space and other mission concepts that were not developed in a design lab
  - Summarizes the RFI responses and the workshop and describes how they were folded into the whole study

Study Phases

- ✓ **Request for Information (RFI)**: solicit ideas for missions and enabling technology. **29 responses received.**
- ✓ **Community Science Team (CST)**: 10 members of the community selected by NASA HQ to serve as the study science team.
- ✓ **Workshop**: provide the community a forum to comment on concepts and technology and identify concepts for further study.
- ✓ **Notional Mission Selection**: Define up to three mission concepts at different cost points.
- – **Design Labs**: Study team develops concepts through mission design lab runs. Focus is on identifying the technical and cost drivers of each concept.
- – **Final Report:** Summarizes study activities and results for HQ and CAA. **Due to NASA HQ on June 7, 2012**

Study Boundary Conditions

- The basis for discussion and selection of concepts for further study is the degree of compliance with IXO science objectives, as endorsed by NWNH.
- We are **NOT** revisiting decadal survey decisions regarding science questions or mission priorities.
- We are studying *representative* missions for the various cost classes. The goal is to assess the fraction of IXO science that can be performed vs. mission cost. There are no winning or losing concepts. It is unlikely that any submitted concept will be taken to the design lab "as is."
- No recommendation for a specific mission or a preferred cost class will be given in the final report. This is the CAA's responsibility.
- External constraints (e.g., Athena) will need to be taken into consideration.

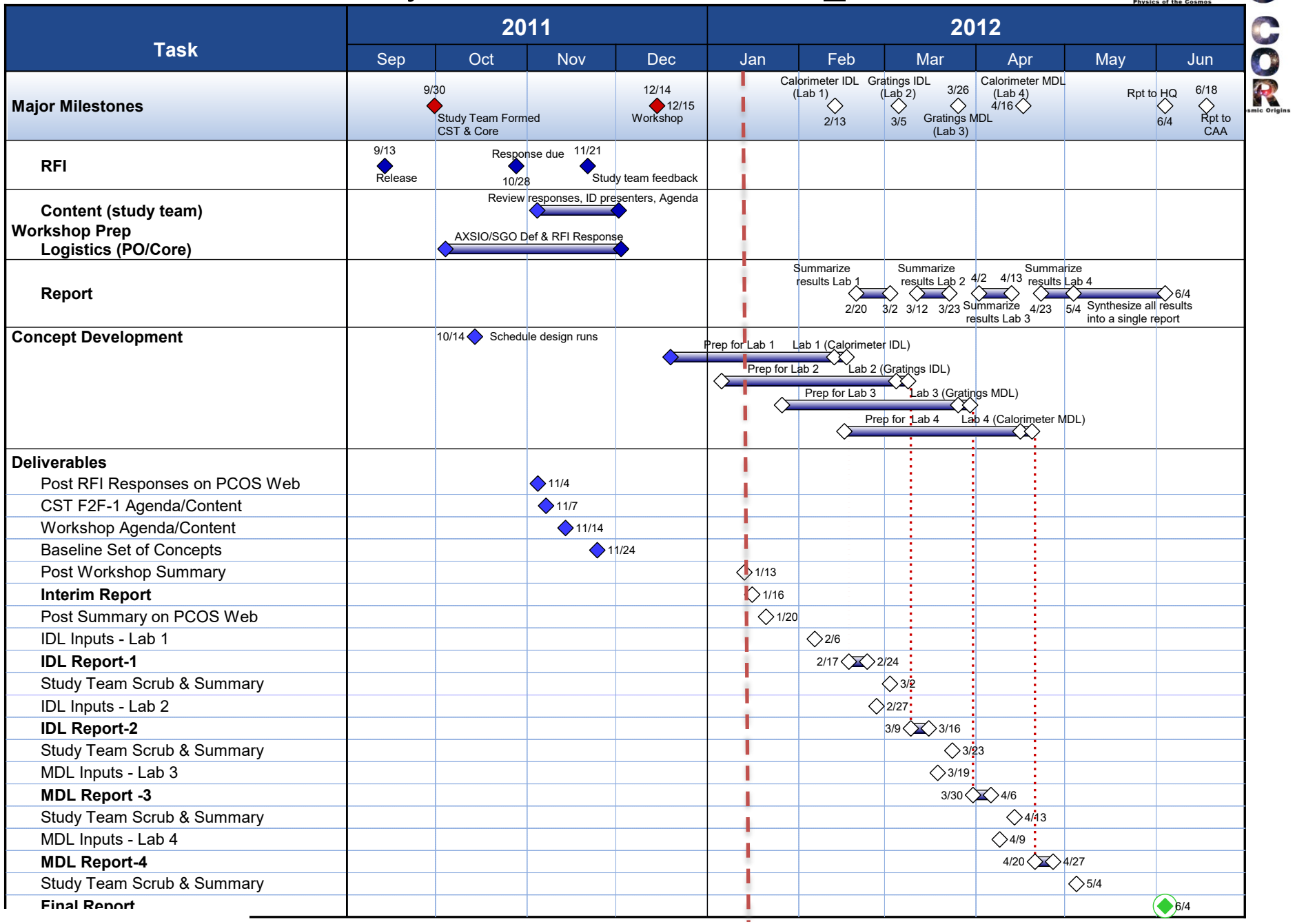
Study Team Membership

- **Study Manager –** Gerry Daelemans (GSFC)
- **Study Scientist** – Rob Petre (GSFC)
- **Community Science Team** – 10 members selected by NASA HQ (next slide)
- **Science Support Team** – Andy Ptak (GSFC), Jay Bookbinder, Randall Smith, Mike Garcia (SAO)
- **Engineering Support Team** – Tony Nicoletti, Gabe Karpati (GSFC), Mark Freeman, Paul Reid (SAO), discipline engineers
- **Support & oversight from:**
  - PCOS Program Office (GSFC)
    - Ann Hornschemeier (Chief Scientist)
    - Jackie Townsend
  - NASA HQ
    - Rita Sambruna (PCOS Program Scientist), Richard Griffiths, Wilt Sanders
    - Jaya Bajpayee (PCOS Program Executive)

Community Science Team Members

- Joel Bregman (Michigan) - chair
- Mark Bautz (MIT)
- David Burrows (Penn State)
- Webster Cash (Colorado)
- Christine Jones-Forman (CfA)
- Steve Murray (Johns Hopkins)
- Paul Plucinsky (CfA)
- Brian Ramsey (NASA / MSFC)
- Ron Remillard (MIT)
- Colleen Wilson-Hodge (NASA / MSFC)

X-ray schedule w/deliverables_1-5-12



RFI responses

- **29 received: 16 mission concepts, 13 enabling technology**
  - In the aggregate, the notional missions should probe various points of the science return vs. mission cost trade space.
  - Variety of concepts in nominal "cost bins":
    - 4 ≤ $0.6B (small)
    - 6 ~ $1.0B (medium)
    - 4 ≥ $2B (large)
  - Degree of fulfillment of IXO science goals scaled with concept cost
  - Small missions skirted edges
  - Medium, large addressed one or more topics directly
- **Technology responses addressed wide range of technology: optics, gratings, calorimeters and other detectors, structures**
- **All responses posted on PCOS website**

Broad Range of Mission Concepts submitted as RFI responses

- The Warm-Hot Intergalactic Medium Explorer
- The Advanced X-ray Timing Array
- The High Energy X-ray Probe
- The Black Hole Evolution and Space Time Observatory
- SuperMon & Black Hole Tracker
- An Astrophysics Experiment for Grating and Imaging Spectroscopy
- The Extreme Physics Explorer
- Spectral Analysis with High Angular Resolution Astronomy
- Orbiting Wide Field X-ray Imaging Spectrometer
- Wide Field X-ray Telescope Mission
- Epoch of Reionization Energetic X-ray Survey
- Xenia: A Probe of Cosmic Chemical Evolution
- The Advanced X-ray Spectroscopic Imaging Observatory
- Square-Meter Arcsecond Resolution X-ray Telescope

Analysis of RFI responses (concepts only)

- **Analysis by science support team + CST**
  - Brief summary of each concept
  - Comparison of objectives to those of IXO
  - Set of questions created for each concept and sent to respondent
  - Responses to questions are being posted
- **Analysis by engineering support team**
  - Responses assessed for “completeness” (sufficient information for DL run?)
  - Cost assessed based on information provided (for binning purposes)

Workshop Objectives

- **Provide the community an opportunity to comment on the study and shape the missions that will be developed in design labs.**
- **Provide a forum for discussion and exchanging information between the study team and the community.**

Workshop Outcome

- **Over 100 participants; more would have attended if timing had been better**
- **Every respondent to RFI was given an opportunity to present**
- **General support by community for the current limited study**
  - Unclear whether a real opportunity exists, but we need to be ready to take advantage
- **Recognition of small number of key technology areas**
  - Mirrors (7 concepts used segmented glass)
  - Microcalorimeters (and coolers) (6 concepts)
  - Grating spectrometers (3 concepts)
- **Genuine concern about longer term future of X-ray astronomy**
  - Competitive strategic mission for 2020 decadal survey
  - Technology funding is marginal at best (APRA, SAT)
    - Is ~$200M recommended in NWNH going to materialize?
  - Should follow this effort with broader study of future of field (1995 XAPWG)

Notional Missions Selected by CST

- **Two mission concepts selected thus far, one for each Cosmic Visions outcome**
  - Case I: Athena selected: modest gratings only mission
    - Goal is to keep cost < $500M
    - ≥500 cm^2 (0.2-1.0 keV) with R~3000
  - Case II: Athena not selected: medium calorimeter only mission
    - Goal is to keep cost < $1.0B
    - 5000 cm^2 at 1 keV; 2000 cm^2 at 6 keV, 4 arcmin FoV, <10 arcsec angular resolution
- **For both concepts, understand how capability scales with cost**
- **Committee reserving option for studying third concept**
- **AXSIO serves as the representative $2B mission**

Enabling Technology

- **RFI solicited responses regarding enabling technology**
- **Technology responses will be used to:**
  - Inform discussion about notional missions
  - Provide input to NASA about key areas to be addressed through APRA and PCOS funding
  - Identify in study report critical and enhancing technology areas where support needed for short and long term needs

Next Steps

- **Interim Study Report**
  - Summarize RFI responses and analysis
  - Summarize Workshop Outcome
  - Summarize concepts selected for further study
- **For the selected concepts:**
  - Study team is collecting data needed for design lab and defining trades (ongoing)
  - Design lab runs will be performed and results analyzed (February – April)
- **Results from design runs plus external trades incorporated into study report**

Involvement of the broader community

- **Workshop**
- **Mostly through the PCOS web site**
  - RFI responses and study team summaries
  - Workshop presentations
  - Regular status reports
  - Community “bulletin board” for comments
  - Study report
- **Presentations to PhysPAG (Austin and beyond)**
- **Informal “town hall” at Austin AAS meeting (Tuesday evening)**
- **Regular progress reports distributed through PCOS, HEAD newsletters**
- **Final study report will be summarized at SPIE, elsewhere**