

Large Mission Concept Decadal Studies Pause and Learn (PAL)

Dr. Jessica A. Gaskin (X-Ray Surveyor Study Scientist)



Marshall Space
Flight Center



Smithsonian Astrophysical Observatory





- ◆ X-Ray Surveyor Success Criteria
- ◆ Study Team Organization
- ◆ Study Planning & Communications
- ◆ Near-term Analysis Planning
- ◆ Engagement with Other Organizations
- ◆ Lessons Learned



NASA Astrophysics Division Decadal Success Criteria:

"full success" is the delivery to the Decadal Survey Committee of **compelling** and **executable concepts** for all four large missions so that **science can be adequately prioritized by the Decadal Committee.**

Executable is defined as *feasible* with respect to technical, cost, and risk resources outlined in the Study Report

X-Ray Surveyor Success Criteria



The delivery to the Decadal Survey Committee of a **compelling** and **executable concept** for the X-Ray Surveyor mission.

1. Define a strong science case that has support from the entire community

- Must result in a payload that is executable (strong risk/cost assessment)
- Must be significantly improved/different from Chandra, Athena & Others

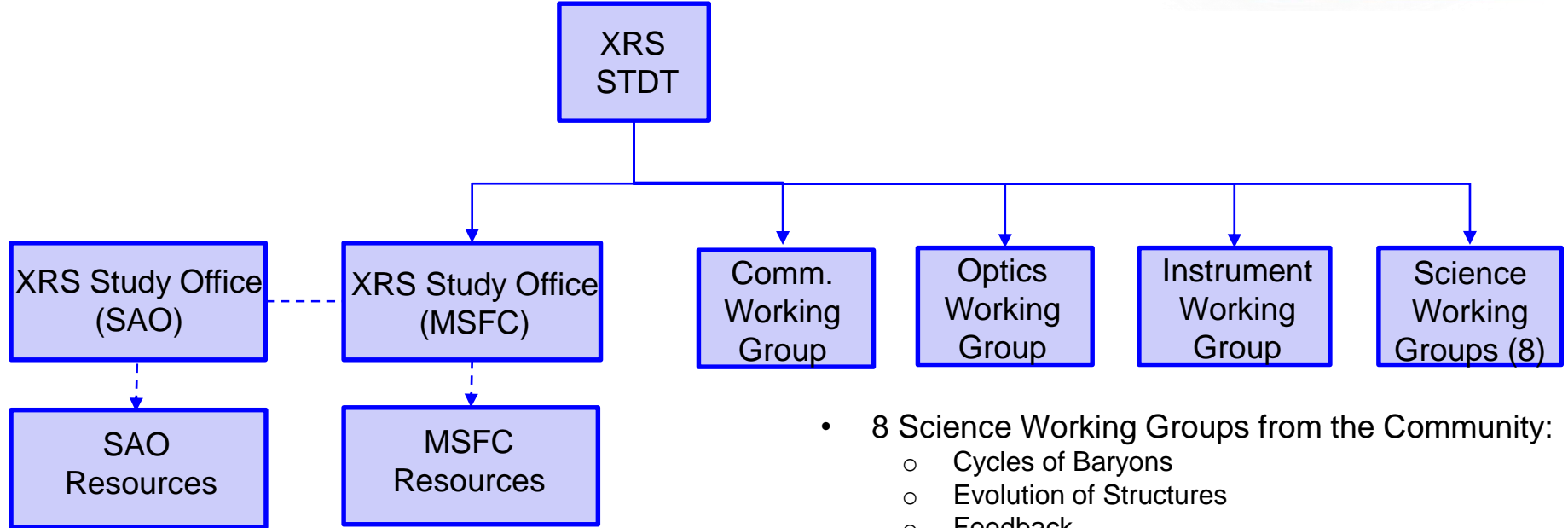
2. Define a solid path towards achieving the required optics

- This must include the optics *and* all tasks that support or relate to the optics

3. Define a solid path towards achieving the science instruments

- Must relate each closely to the science requirements and optics performance

Study Team Organization



- Study Office
 - Partnership with SAO and MSFC for technical and strategic planning
- MSFC Resources
 - ACO (mission concept engineering)
 - Office of Strategic Analysis & Communications (strategic development, external relations, engineering cost assessment, graphics, technical writing)
- SAO Resources
 - Optics engineering support
 - Concept support
 - Organizational support
- 8 Science Working Groups from the Community:
 - Cycles of Baryons
 - Evolution of Structures
 - Feedback
 - 1st Accretion Light
 - High Density
 - Multi-Wavelength
 - Physics of Plasmas
 - Stellar Lifecycles
- OWG and IWG from Science Community and Industry – define optics design and instruments
- Communications Working Group – strategic communications



- ◆ All WGs have well-defined charters
 - ◆ How do we behave?
 - ◆ What are we doing?
 - ◆ How are we governed?
 - ◆ Role of the Study Office?

- ◆ Regular WG status at STDT bi-weekly meetings

- ◆ All WG tie-in info is readily available to every STDT member

- ◆ All WGs are chaired by at least 1 STDT member

- ◆ Some members are on multiple WGs

- ◆ STDT Chairs and Study Office members tie-in to multiple WG meetings

**STRONG INTERNAL CROSS-COMMUNICATION ENSURES BROAD DISCUSSION AND INTEGRATION
THROUGHOUT THE STUDY TEAM AND COMMUNITY**

◆ Smithsonian Astrophysical Observatory (SAO)

- ◆ Both MSFC and SAO contribute significant funding and FTE/WYE towards the XRS concept development
- ◆ SAO contributed efforts:
 - Participation in several of the Working Groups, including the Optics WG and the Instruments WG
 - Assistance in the development of the Request For Information (RFI) about the candidate optical designs
 - Provision of detailed analyses for a segmented design and study of key parameters (focal length, aperture, vignetting, mass) as per the RFI
 - Support of STDT face-to-face meetings, as well as ancillary meetings such as the Aerospace Corporation meeting on 9/21
 - Module-level and assembly-level concept studies
 - Mission level concept studies
 - Interdisciplinary scientist whose primary deliverable will be an “XRS simulation toolkit” that will be made available to the science community
- ◆ SAO contract initiated in June, 2016
 - Scope of work includes tasks necessary for the STDT to deliver the required elements of the final report to the 2020 Decadal Committee
 - Tasks include:
 - Science Support (organizing workshops/conferences, interdisciplinary studies)
 - Support High Fidelity Concept Studies
 - Technology Tasks (technology assessments, optics engineering design support)

◆ MSFC's Advanced Concepts Office (ACO)

- ◆ ACO is an office in the MSFC engineering directorate providing detailed early concept analyses
- ◆ Capabilities within ACO include mission, configuration, propulsion, power, avionics, GN&C, thermal, structural, mechanism, environments and cost analysis
- ◆ Each concept study has a Study Lead (Andrew Schnell) who coordinates a team of engineers to work with Scientists to carry out the study. Needed engineering resources are Study dependent. Advanced planning is necessary.
- ◆ ACO is familiar with XRS and understands the context of the study
- ◆ XRS Study Office has been working with ACO to plan activities following mission science definition by the STDT

TO OPTIMIZE RESOURCES AND TIME, ACO HAS INITIATED SEVERAL NON-PAYLOAD SPECIFIC STUDIES THAT COULD HAVE APPLICABILITY ACROSS ALL MISSION CONCEPTS

◆ Aerospace Corporation

- ◆ Received 8/1/16 guidance on engaging with Aerospace
- ◆ Met face to face on 9/21/16 to discuss specifics of XRS study
- ◆ Key questions included Aerospace scope, overall involvement, frequency of involvement, specific milestones, etc.
- ◆ Apparent from discussion that more clarity is needed on both sides before technical engagement can commence



◆ Near term planning:

◆ Technical:

- Next STDT Face-to-Face (11/14 – 11/15):
 - Receive inputs from SWGs on Science Case and Performance Drivers
 - Define preliminary Science Case
- Preliminary Payload Architecture(s) Definition (12/16 – 01/17)
- Advanced Concepts Office (ACO) Concept Definition Study (01/17 – 06/17):
 - With the Science Case(s) as input, ACO will provide overall mission analysis, observatory configuration development support, identify mission drivers, technologies for development, and cost estimate

◆ Near term planning:

◆ Strategic:

- Regular seminar series on a wide range of topics to engage the astrophysics community
 - Quasar Microlensing (10/19)
 - AGN Feedback in Galaxy Clusters (11/2)
 - X-rays from Comets and Planets (11/30)
 - AGN and Large Scale Structures (01/11)
- Participation in Conferences and other Seminars
 - CoPAG Seminar (10/10)
 - GSFC Tech Days (10/31 – 11/04)
 - 229th AAS (01/03 – 01/07)
 - The STDT is populating a database of out-year conferences and seminars

◆ Internal:

- Community Calendar
- Near-term Look-ahead
- Study Schedule



Home

Sign up for News & Announcements

Working Groups

Study News & Meetings:

- Bi-Weekly STDT Meeting
- Seminar Series
- 25-26 Jul 2016 STDT Face-to-Face Meeting

Documents

Presentations

Seminar Series presented by the X-ray Surveyor STDT

(all times 12:30-1:30 pm Eastern unless otherwise noted; schedule subject to change)

- 19 Oct 2016: **Dave Pooley** (Trinity University)
Title: Quasar Microlensing
([Watch Online](#))
- 02 Nov 2016: **Chris Reynolds** (University of Maryland)
Title: AGN Feedback in Galaxy Clusters
- **14-15 Nov 2016: STDT Face-to-Face Meeting, Washington, DC**
- 30 Nov 2016: **Scott Wolk** (CfA)
Title: X-rays from Comets and Planets
- 11 Jan 2017: **Ryan Hickox** (Dartmouth University)
Title: AGN and Large-Scale Structures
- 08 Mar 2017: **Juna Kollmeier** (Carnegie Institution for Science)
Title: X-ray Surveyor and the Baryon Cycle

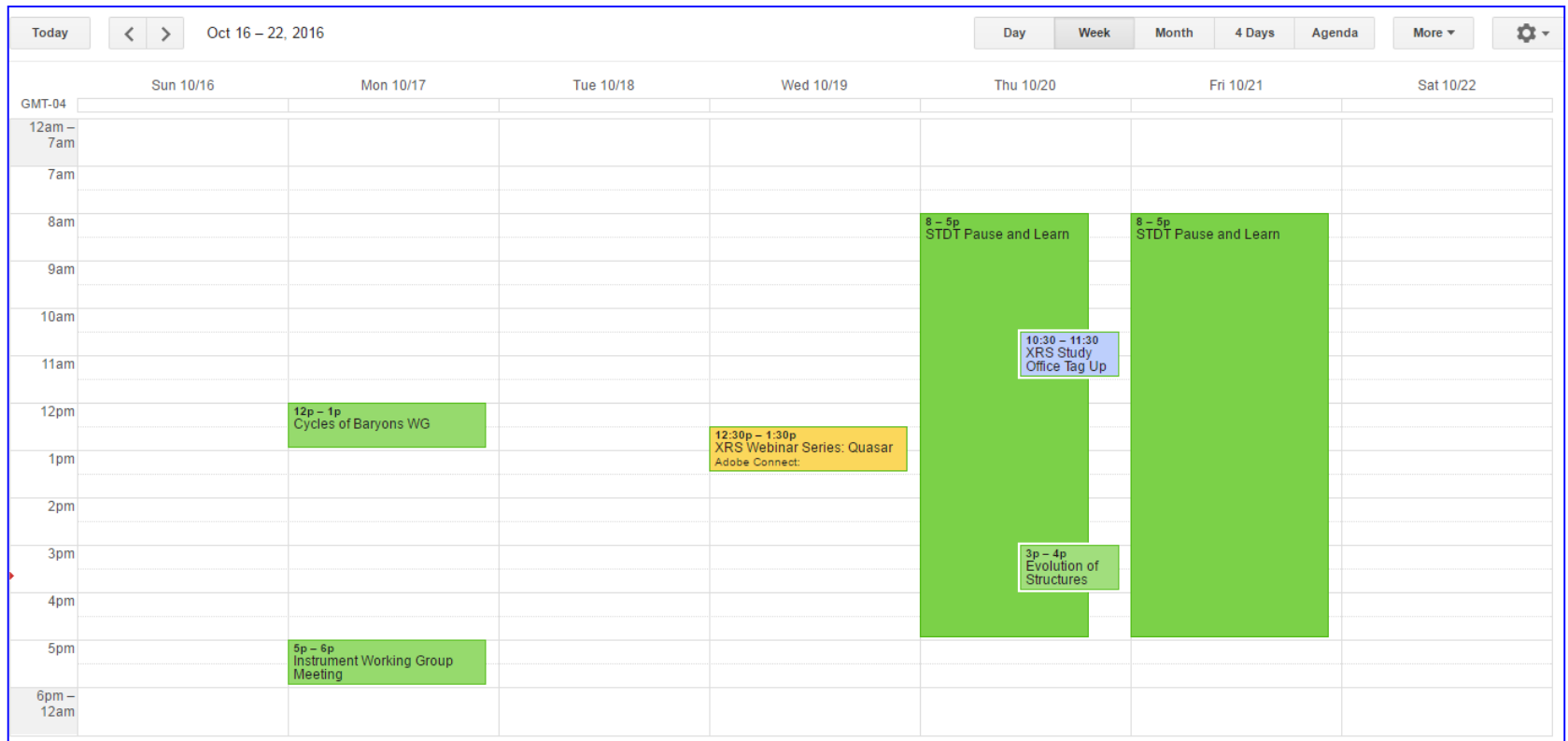
Archive of past Seminar Series presentations

- 28 Sep 2016: **Rashid Sunyaev** (Max Planck Institute for Astrophysics)
The physics and first observations of the Kinematic effect (kSZ): A way to measure peculiar velocities of gas in distant clusters of galaxies and during the epoch of reionization ([Watch Recording](#))
- 21 Sep 2016: **Mateusz Ruszkowski** (University of Michigan)
The Role of Cosmic Rays in Stellar and Supermassive Black Hole Feedback ([Abstract](#)) ([Watch Recording](#))
- 14 Sep 2016: **Rachel Osten** (Space Telescope Science Institute)
Cool Stellar Science with the X-ray Surveyor ([Watch Recording](#))

XRS Community Calendar



- ◆ We have created a community calendar (via Google) with public and internal meetings and activity information
 - ◆ Includes STDT meetings, SWG meetings, Seminars, etc
 - ◆ All activities include tie-in information for “one click” access



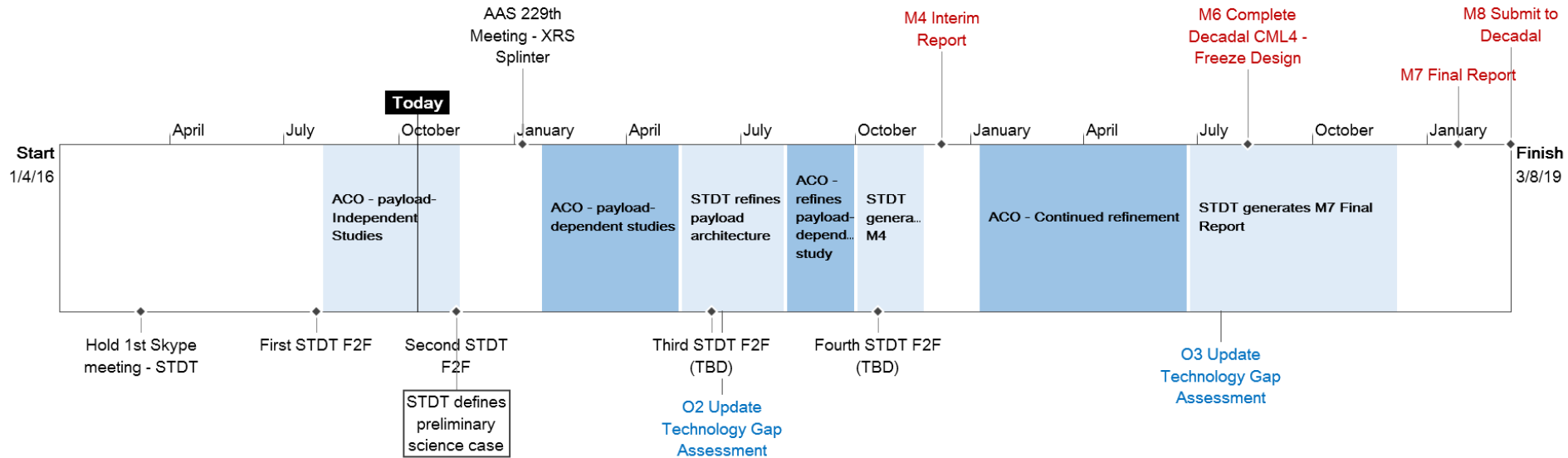
XRS STDT: 6 Month Look-Ahead

(revised 10-17-16)



Organization		October					November				December				January					February			
		3	10	17	24	31	7	14	21	28	5	12	19	26	2	9	16	23	30	6	13	20	27
DSMT				☐ Pause and Learn (10/20 – 10/21)																			
STDT								☐ Fall F2F (11/14 – 11/15)						☐ 229 th AAS (1/3 – 1/7)									
Working Groups	Science		☐ CoPAG Seminar (10/10)		☐ Quasar Microlensing (10/19)		☐ AGN Feedback in Galaxy Clusters 11/2)		☐ Fall F2F (11/14 – 11/15)														
							☐ Define Preliminary Science Case (11/14)																
	Optics		☐ Optics Point Design RFI inputs due (10/14)		☐ GSFC Tech Days (10/31 – 11/4)				☐ Fall F2F (11/14 – 11/15)														
	Instrument								☐ Fall F2F (11/14 – 11/15)														
	Comm.								☐ Fall F2F (11/14 – 11/15)														
Study Office				☐ Pause and Learn (10/20 – 10/21)					☐ Fall F2F (11/14 – 11/15)														
Other	ACO																						
	Aero Corp																						
	Other Resources																						

Schedule Summary – Timeline



- ◆ Comprehensive Project schedule is developed to manage the study, actions and milestones
- ◆ MSFC Advanced Concept Office interaction will be an iterative process.
- ◆ F2F Meetings will be strategically planned prior to M4, M6, M7 deliverables.

- ◆ Optics Point Design Request for Information (RFI):
 - ◆ Serves as input for analysis of various mirror optical designs to better understand mirror assembly, mass, envelope, thermal control power requirements, performance sensitivities, etc.
 - ◆ Includes technical performance characteristics of various telescope point designs to inform the work of all XRS Science Working Groups
 - ◆ Document released to various optics technology developers on 9/20/16 and responses were due on 10/14/16
 - ◆ Results will be presented at 10/19/16 STDT meeting.
- ◆ Segmented Mirror Parametric Analysis:
 - ◆ On-going work to define several segmented systems with varying focal length and diameter
 - ◆ Study expected to end by 12/16
- ◆ Full Shell Point Design Parametric Analysis:
 - ◆ Draft RFI for analysis completed
 - ◆ Study expected to end by 2nd quarter CY17

Mirror Assembly Constraints:

- Outside diameter of largest optical surface: 3.0 meters (to start)
- Focal lengths (1 point design for each of the four focal lengths): 5 meters, 10 meters, 15 meters, 20 meters
- Field-of-View: 10 arc min radius at 1 keV, with less than a 20% drop in geometric area due to vignetting
- Point Spread Function (PSF)
- On-axis: at least 0.5 arc sec HPD on-axis
- Off-axis: at least 0.7 arc sec HPD out to a radius of 5 arc min

Design Input Data:

The information provided should minimally include:

- Type of optical prescription (e.g., Wolter I or Wolter-Schwartzchild)
- Flat or curved focal plane array
- Mirror substrate material and properties (CTE, rigidity, etc.)
- Mirror thickness (which may vary as a function of mirror shell radius)
- Support material and mounting
- Gap between primary (P) and secondary (S) mirrors
- Mirror coatings, including composition, source of optical constants (e.g., Center for X-ray Optics databases or IMD modeling code)

Additionally, please provide the specific information for either

Segmented-shell designs:

- segment dimensions, including axial (shell length) and azimuthal (shell “width”) , both of which may vary as a function of mirror shell radius
- axial offset from a common P/S intersection plane if the P/S intersection is not constant for each mirror pair (P/S) Assembly schemes: for example, the segments assembled into “blocks” which in turn are aligned together; or the segments are assembled in one, monolithic structure; the amount of geometric areasacrificed to mount the segments and/or blocks.

Integral- or full-shell designs :

- construction type (monolithic primary & secondary, or discrete primary and secondary)
- shell length



X-Ray Vision Workshop

October 6-8, 2015 Washington DC

DETAILS



Simulation Tools

The package contains response matrices and effective area files for the 3 notional X-ray Surveyor science instruments:

- High Definition X-ray Imager ("hdx")
- The microcalorimeter spectrometer ("calorimeter")
- The CAT implementation of the X-ray grating spectrometer ("cat")

The package also contains background files for the hdx and calorimeter instruments. To properly use the backgrounds in XSPEC simulations, they first need to be rescaled to the appropriate source extraction area. This is done with the script `scale_xrs_bg` also included in the package. `scale_xrs_bg` needs FTOOLS.

Usage:

```
./scale_xrs_bg xrs_hdx_bg.pha area outputbg.pha
```

Where area is your source extraction area in square arcsec.

After you've created the scaled background, it can be used with XSPEC's fakeit command as:

```
fakeit outputbg.pha
```

Then proceed with the fakeit command as usual, but please make sure that you set correct exposure time for your source.

The simulated faint source spectra are likely to have few photons in some channels, which breaks the χ^2 statistics. Please either group the simulated spectra (e.g., using `grppha`) or use `cstat / lstat` statistics in XSPEC

Response Data
Click to download:
[xrs_resp.tar.gz](#)



ACO Current & Near Term Activities



- ◆ The Advanced Concepts Office (ACO) has been conducting several directed non-payload specific trades in preparation for the conceptual design study in 2017.
 - ◆ A progress report will be delivered at the November face to face

- ◆ ACO will present study input questions regarding the requirements for the 2017 design study at the November STDT face to face.



ACO Schedule – Planning Snapshot



	July				August				September					October				November			
	7/7	7/14	7/21	7/28	8/4	8/11	8/18	8/25	9/1	9/8	9/15	9/22	9/29	10/6	10/13	10/20	10/27	11/3	11/10	11/17	11/24
Kickoff	●																				
Define Tasks	█																				
Cost Review	█																				
Discipline Updates		█																			
Non-payload Specific Tasks		█																			
STDT Meeting with Aerospace											●										
Pause and Learn																●					
Documentation																		█			
Manager Review																					●
STDT Face to Face																					●
Customer Review																					●

- Discipline Needs are specified and planned
- Funding is incremental (Green Bar)
- Weekly internal ACO Meetings and Status reports to Study Scientist
- Status to STDT at Face to Face meetings
- **More frequent reporting to the STDT is expected once concept design begins (January/February 2017)**



Methodology for 2017 study



- ◆ ACO will work with the STDT on a set of requirements for the conceptual design
 - ◆ It is very important that the requirements be provided at the start of the design study
- ◆ ACO meets weekly to provide status updates, ask questions, and work on the design
- ◆ Each ACO team member will develop a mass and power estimate for their discipline
- ◆ The ACO team will iterate as necessary to accommodate changes in the design and requirements
- ◆ Once the mass and power estimates are complete, a cost estimate will be developed
- ◆ Final products will include drawings of the conceptual design, mass, power, and cost estimates, and a chart deck summarizing the work completed, requirements, assumptions, and future work



List of Non-Payload Specific Tasks



Mission design topics independent of payload might include:

1. Orbit trades

Consider nominal orbits at L2, a nominal high earth orbit (e.g., Chandra-like), and lunar resonant orbits. Can a sun-trailing orbit be dismissed? Considerations should include the following:

- (a) **Trajectory and time to final orbit.** Launch window opportunities. What are re-entry or disposal requirements, if any?
- (b) **Radiation environment.** Evaluate the lifetime of critical electronics and systems and shielding requirement assumptions
- (c) **Define the mass that can be placed in such orbit,** and possible launch vehicles to deliver to orbit
- (d) **Expendables required** to maintain the orbit, and the orbit lifetime and evolution
- (e) **Telemetry rates available vs. power** required for uplink/downlink in the orbit. Consider the average ground station availability, maximum outage times, telemetry rates as a function of orbital phase if relevant
- (f) **Thermal environment** including eclipses
- (g) **Micro-meteoroid environment**

2. Thermal insulation and thermal control

- (a) Define one or more **thermal control concepts** applicable to the optics, focal plane, and spacecraft
E.g., cold bias, isolation philosophy, hardware feedback from sensors vs. software control
- (b) **Consider insulator materials,** thermal blanket requirements, etc.
- (c) **Thermal isolation for the mirror, reduction of radiation to space**
- (e) Total **thermal control power requirements**

3. Rapid Response Constraints

4. Attitude Control

5. Avionics Studies

6. Optical Bench Materials



Orbit Trades - Example



- ◆ Several candidate orbits are included in the trade space
 - ◆ SE-L2
 - ◆ LDRO
 - ◆ Chandra-type
 - ◆ Drift-away (Earth-trailing)

- ◆ Diagram, delta-v budget, and launch vehicle performance to each transfer orbit are provided in the charts below
 - ◆ Timelines for each option are currently being generated

- ◆ Orbit considerations include:
 - ◆ Delta-V requirements
 - ◆ Thermal and dynamic stability
 - ◆ Distance over time and the effect on communications
 - ◆ *Assuming all options can fulfill the sky observing requirements*
 - so no sky coverage analysis is included in these results



Figures of Merit (FOMs)



◆ Subjective ranking of the different options

◆ Use the “graduate student” grading scale

- A = Meets requirement
- B = Does not fully meet requirement
- C = Does not meet requirement

Grade scale	Multiplier
A	1.00
B	0.75
C	0.50

	Total Score	Launch Vehicle	Delta-V	Duration	Thermal	Comm	Environment
Max Points -->	100	10	15	20	20	20	15
SE-L2	91	A	A	A	A	B	B
Drift-away	76	A	A	C	A	C	B
LDRO	84	A	C	A	B	A	B
CTO	76	B	B	A	C	A	C
LEO	68	A	C	B	C	C	A

WINNER: SE-L2



FOM Rationale



	Launch Vehicle	Delta-V	Duration	Thermal	Comm	Environ-ment
	How large of a launch vehicle is required?	Smaller budget is better. Note that disposal is a major issue for the CTO.	Will the observatory remain close enough to allow reasonable comm?	How stable is the thermal environment?	How large must the comm system be to provide the science data downlink?	How bad is the radiation and meteoroid environment in this orbit?
SE-L2	SE-L2, Drift-away, and LDRO are roughly similar in LV requirements	Budget is not bad, but the orbit maintenance adds up over 20+ years.	Stays within 0.1 AU from Earth.	Very stable.	30 times further than LDRO, making high data rates challenging.	Ionizing radiation: no geomagnetic shielding from solar particle events which drive total dose. Galactic cosmic rays drive single event effects. Meteoroids are same as interplanetary space.
Drift-away	SE-L2, Drift-away, and LDRO are roughly similar in LV requirements	No orbit maintenance or correction maneuvers results in the lowest DV budget.	Reaches 0.3+ AU after a few years.	Very stable.	System would lose performance with distance.	Ionizing radiation: no geomagnetic shielding from solar particle events which drive total dose. Galactic cosmic rays drive single event effects. Meteoroids are same as interplanetary space.
LDRO	SE-L2, Drift-away, and LDRO are roughly similar in LV requirements	Low orbit maintenance, but transfer trajectory does require some maneuvers.	Always less than 500,000 km from Earth.	Fairly stable, though there could be some shadowing during the mission.	LDRO and CTO would be similar systems being same order of distance.	Ionizing radiation: no geomagnetic shielding from solar particle events which drive total dose. Galactic cosmic rays drive single event effects. Meteoroids are same as interplanetary space.
CTO	CTO requires more performance (i.e., 1 or 2 more SRBs).	While Chandra has required little orbit maintenance, the new orbital debris standards may require a disposal maneuver at the end of any new missions planned for this orbit.	Always less than 200,000 km from Earth.	Least stable of the options since the satellite passes within 16,000 km of Earth every orbit.	Available DSN link may be intermittent at times, restricting specific link times.	Ionizing radiation environment is same as other candidates PLUS the passage through the radiation belts which contributes significant total dose and single event effects. Meteoroid environment is similar to others but with mild enhancement at perigee due to gravitational focusing (speeds up slower meteoroids), however spacecraft spends little time that low and apogee is same interplanetary environment.
LEO	Greatest launch vehicle performance is to LEO.	Controlled reentry required. Orbit maintenance required to avoid reentry during lifetime, which can get expensive for long missions.	Duration is completely dependent on station-keeping and orbit maintenance.	Lots of thermal cycling, reflected heat from Earth.	In LEO, the NEN will be used for comm. S-band is limited to 5Mbps per customer, and X-band is limited to 10Mbps.	In LEO, the observatory is shielded from solar particle events.



◆ Engagement with other STDTs:

- ◆ XRS STDT member D. Stern is also on the HabEx STDT
- ◆ XRS Multiwavelength WG has reached out to D. Leisawitz on the Far-IR Surveyor, and identified connections there with XRS on AGN and young stellar objects, with a few cross-disciplinary questions identified already; Chien-Ting Chen is on both the XRS AGN-SWG panel and involved with the Far-IR as well.
- ◆ XRS Multiwavelength WG has not yet made connections to LUVOIR or HabEx, but plan to as the concept progresses.

◆ Engagement with other Study Teams to date

- ◆ Participated in Telescope TIM at JPL
- ◆ Will Participate in Mirror Technology Days (Nov 1st)
- ◆ Decision Making Process Talk given by Gary Blackwood – *Thank you Gary for an informative talk!*
- ◆ Seminar Series (operation & posting) – *Thank you to Ravi Kopparapu for your help!*



- ◆ Working Groups members are from the broader community
 - ◆ 8 Science WGs, Instrument WG, Optics WG
- ◆ AAS Splinter Meeting is Scheduled
- ◆ Planning a Spring Conference for FY17 (Date TBD)
- ◆ Planning a focused X-Ray Astronomy Workshop in the Summer (2017)
- ◆ Open F2F and bi-weekly STDT Meetings
- ◆ Public Website (<http://wwwastro.msfc.nasa.gov/xrs/>)
- ◆ Webinar/Seminar Series



◆ Science & Technology Talks/Presentations (Sample)

- ◆ R. Osten, “Cool Science with the X-ray Surveyor,” HEAD webinar, Sept. 14th, 2016
- ◆ C. Reynolds, “X-Ray Surveyor and Cosmic Origins,” COPAG Seminar, October 10, 2016
- ◆ M. Pivovarov, “Science drivers for the X-ray Surveyor (XRS) telescope,” Telescope TIM, June16-17, 2016, JPL
- ◆ M. Pivovarov, “The X-ray Surveyor (XRS) Mission: Strategy for Achieving High-Resolution, Large-Area Optics,” 2016 SPIE Astronomical Telescopes + Instrumentation, 29 June, 2016, Edinburgh, UK
- ◆ L. Cohen, “X-ray Surveyor (XRS) Assembly, Alignment & Structural Considerations for the Mirror Assembly. Looking Forward to The Decadal Review Inputs,” Telescope TIM, June16-17, 2016, JPL
- ◆ A. Falcone, “The High Definition X-ray Imager Instrument Concept on the X-ray Surveyor Mission,” SPIE Mtg. 2016 (June 2016, Edinburgh)
- ◆ P. Reid, “Development Status of Adjustable X-ray Optics with 0.5 Arcsec Imaging for the X-ray Surveyor Mission Concept,” HEAD, April 2016.
- ◆ H. Günther, “Ray-tracing critical-angle transmission gratings for the X-ray Surveyor and Explorer-size missions,” SPIE Mtng 2016, Edinburgh, UK
- ◆ S. Bandler, “Development of x-ray microcalorimeter imaging spectrometers for the X-ray Surveyor mission concept,” SPIE Mtng 2016, Edinburgh, UK
- ◆ J. Arenberg, “A performance budget for the x-ray surveyor telescope,” SPIE Mtng 2016, Edinburgh, UK
- ◆ G. Pareschi, “Beyond Chandra (towards the X-ray Surveyor mission): possible solutions for the implementation of very high angular resolution X-ray telescopes in the new millennium based on fused silica segments,” SPIE Mtng 2016, Edinburgh, UK

MANY MORE TALKS ARE SCHEDULED FOR THE NEAR-FUTURE. IN ADDITION, STDT MEMBERS AND WG MEMBERS ARE INCORPORATING XRS INTO THEIR TALKS. AS THE CONCEPT MATURES, WE EXPECT THIS ACTIVITY TO INCREASE.



- ◆ Formal engagement plan is being developed
 - ◆ Communications Working Group (chaired by STDT members)
 - ◆ MSFC Office of Strategic Analysis and Communications (OSAC)
 - ◆ Other Study Office Resources (Outreach Office)
 - ◆ Approval by STDT

- ◆ International Involvement
 - ◆ Ex-officio members on the STDT and part of WGs
 - ◆ Participation in international conferences



- ◆ Identify common needs (e.g., x-ray testing facilities, thin-film deposition capabilities, HPC-based FEA) and have this peer-reviewed by friendly but independent teams

- ◆ Engage industry (RFI, TIMs, other?)
 - ◆ Optics RFI should be sent to aerospace industry, semiconductor industry (silicon processing, metrology firms for robotic handling and high throughput screening), robotics firms, etc...
 - ◆ 2- or 3-day TIM would include as many of these firms as possible, and solicit their input for Technology Roadmap development

- ◆ Engage Optics Community
 - ◆ RFI to optics community for input into Optics Point Designs has been initiated. Responses will be fed back to the SWGs to support simulations and science definition.

- ◆ Look for help from adjacent fields: adaptive optics, DOE x-ray light source facilities, additive manufacturing, robotic-enabled, serial production

How can XRS use non-traditional partners from industry, academia and other institutions?



SPIE talk
M. Pivovarov

◆ Segmented silicon

◆ X-ray mirrors

- Production of silicon “blanks”
- Semiconductor production: silicon etch, metrology and potentially even coating

◆ Assembly

- Robotic manufacturing

◆ Segmented, actuated glass

◆ X-ray mirrors

- Semiconductor production: piezo application, implantation?

◆ Assembly

- Robotic manufacturing

◆ Full-shell approaches

◆ X-ray mirrors

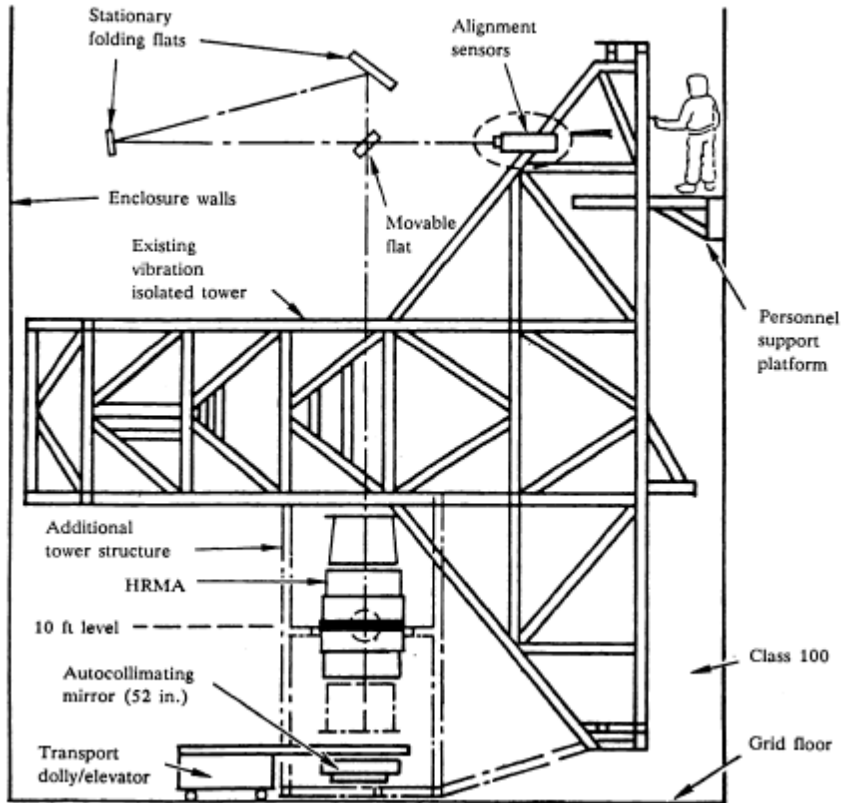
- Advanced manufacturing techniques

Teams must answer this question, but there is likely untapped potential

Ecosystem: examples of industry infrastructure available today



Old school



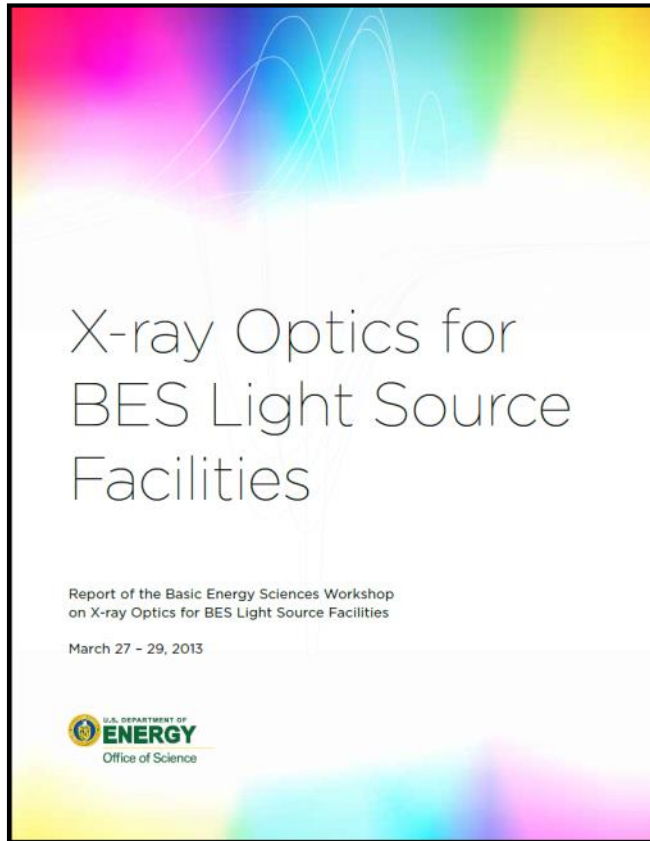
The core of this facility still exists. Some of the AXAF engineers are still active in industry; Figure 9 from Spina, *SPIE*, 1113:2 (1989)

Disruptive



Robotic manufacturing at Raytheon/Tucson (Apr 2016)
<http://www.popularmechanics.com/military/research/a20456/raytheon-factory-robots-make-missiles/>

DOE has recently studied optics needs for U.S. x-ray light sources



Technology needs identified and review

1. Grating Optics
2. X-ray Mirrors
3. Optical & X-ray Metrology
4. Simulation & Modeling
5. Nanodiffractive Optics
6. Crystal Optics
7. Thin Film Optics
8. Adaptive X-ray Optics
9. Refractive Optics

- Of these nine technologies, there are potentially **six** where DOE/SC/BES needs match those of XRS
- Technologies exist across the DOE complex at: Lawrence Berkeley, Argonne, Brookhaven, SLAC and Lawrence Livermore
- Thin-film, Metrology, Mod & Sim and Adaptive X-ray Optics are the most promising areas for collaboration

http://science.energy.gov/~media/bes/pdf/reports/files/BES_XRay_Optics_rpt.pdf

- ◆ Good communication and cross-talk among WGs is critical
 - IWG and OWG support STDT meetings and SWGs and participate in the F2F meetings
 - Critical to involve the instrumentation and optics expertise in the process from the beginning

- ◆ Good communication between Study Office and STDT is critical
 - Clarity of roles, responsibilities and decision making authority between Study Office and STDT co-chairs is essential

- ◆ Good communication between the Study Office, HQ and PCOS is critical
 - Informal/formal lines of communication between STDT chairs, Study Office personnel, and HQ & Project Office officials has worked well
 - HQ & PO support for XRS visibility at meetings (F2F, AAS, APS, etc) substantial

- ◆ Consistent participation in bi-weekly STDT meetings is essential, however busy teaching schedules of some STDT members makes this impossible

- ◆ Archiving of critical decisions and actions should be done on a regular basis



- ◆ Request clarity from HQ on engagement of Aerospace Corporation (roles, scope, deliverables, SOW, etc.)

- ◆ Desire consistent and improved travel support for STDT face to face meetings
 - ◆ What, if any, FY16 funds remain from NRESS line item can be used for FY17?

- ◆ Need clarification on funding for FY17
 - ◆ When will FY17 funds be released for use?

- ◆ Independent TRL & CML assessments as the concept matures, provided by HQ/PO, would be welcome

◆ Joint Technical Information Meeting

- ◆ Could be beneficial. Suggest that Such a TIM be formulated with Study Team participation to maximize benefit to all teams.

◆ 2 to 3 Day Industry XRS-Focused Workshop/Conference

- ◆ Need clarification from HQ on how to engage with industry without compromising potential future procurement competitions

BACK-UP SLIDES

1. Orbit trades

Consider nominal orbits at L2, a nominal high earth orbit (e.g., Chandra-like), and lunar resonant orbits. Can a sun-trailing orbit be dismissed? Considerations should include the following:

- (a) Trajectory and time to final orbit. Launch window opportunities. What are re-entry or disposal requirements, if any?
- (b) Radiation environment.
Evaluate the lifetime of critical electronics and systems. Define shielding requirement assumptions. Evaluate the implications for thermal insulation. Consider possible implications for observing efficiency. Assume the known radiation environments, and the possibility of 2 (TBR) “largest solar CME” per solar cycle.
- (c) Define the mass that can be placed in such orbit, and possible launch vehicles to deliver to orbit.
- (d) Consider the expendables required to maintain the orbit, and the orbit lifetime and evolution.
- (e) Consider the telemetry rates available vs. power required for uplink/downlink in the orbit. Consider the average ground station availability, maximum outage times, telemetry rates as a function of orbital phase if relevant.
- (f) Thermal environment including eclipses.
- (g) Micro-meteoroid environment.

2. Thermal insulation and thermal control

Note that a 3 m diameter mirror at 22° C will radiate 3000 watts to space.

- (a) Define one or more thermal control concepts applicable to the optics, focal plane, and spacecraft.
E.g., cold bias, isolation philosophy, hardwire feedback from sensors vs. software control.
- (b) Consider insulator materials, thermal blanket requirements, etc.
- (c) Thermal isolation for the mirror, reduction of radiation to space.
- (d) Numbers of thermistors, requirements for proximity to heaters, redundancy requirements.
- (e) Total thermal control power requirements.

3. Rapid response capability.

Attempt to define the break points in terms of response time for the following system elements. Distinguish between hard requirements to respond in a given time, vs. a state-dependent capability to meet the response time requirement, say, half (TBR) the time on average.

(a) Ability to slew the observatory.

Capability of the reaction wheels, necessary settling time for celestial location and image stability, use of expendables.

(b) Ability to communicate with the observatory.

Ground station line of sight, scheduling availability. Necessary uplink/downlink bandwidths.

(c) Ability to generate necessary observatory commands.

Fidelity of the scheduling and command generation software. Necessity for human verification of subsystem commanding.

(d) Implications of allowing autonomous Observatory re-orientation.



4. Define attitude control equipment.

(a) Reaction wheels.

Consider size, mass, torquing capability, momentum storage capability, redundancy and single failure capabilities, and isolation requirements.

(b) Momentum unloading capability.

Method, expendable requirements for 10yr (TBR) life.

(c) Consider disturbance torques in possible orbits.

Gravity gradient, solar pressure.

(d) Study the pointing control system as a function of pointing accuracy, both relative and absolute.

5. Avionics Studies

- (a) Develop possible architecture(s) to provide communication, data storage, and subsystem control and monitoring.
- (b) Identify what are the interfaces which will need to be documented and controlled. Outline requirements and protocols.
- (c) Define safe modes, redundancy switching management.
- (d) Study Laser Based Communication systems, trade with radio frequency communications.
- (e) Power requirements. Battery requirements. Harnesses. Trade impacts of different solar panel design. Consider articulation versus body mounting schemes.

6. Optical Bench Studies

A notional mirror focal length has been 10 m. The optical bench studies might include assessment of the implications of shorter or longer focal lengths.

- (a) Materials, finite element analysis to meet loads, allowing for low CTE, and light weight.
- (b) Identify what are the interfaces
E.g., to the mirror, science instrument compartment, gratings, magnetic brooms, mechanisms, spacecraft bus.
- (c) Identify thermal control approaches, active control requirements.