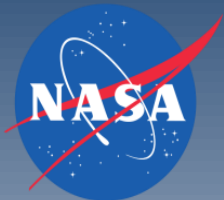


# Large Mission Concept Decadal Studies Second Pause and Learn (PAL)

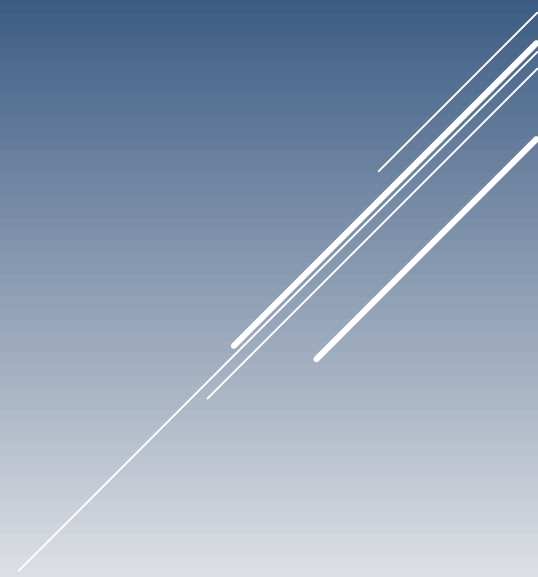
Karen Gelmis (Lynx Study Manager)  
Dr. Jessica A. Gaskin (Lynx Study Scientist)



Marshall Space  
Flight Center



Smithsonian



- ◆ Current Status
  - ◆ Science
  - ◆ Observatory (instrument, optics, spacecraft)
  - ◆ Roadmap Development
  - ◆ M4 Planning
- ◆ External Community Involvement
  - ◆ Webinars/Seminars/Conference Talks
  - ◆ Industry Involvement
  - ◆ International Involvement
- ◆ Lessons Learned & Path Forward
  - ◆ HQ/PCOS Support & Requested Guidance

# Lynx Concept Study Status

- The entire Lynx team consists of the STDT + various working groups and sub-teams
- At present, there are ~240 people across academia, industry, government, and non-US space agencies working on the Lynx Concept Study

- **Science Working Groups**

- 8 SWGs focusing on Lynx-specific science topics including:

Cycles of Baryons	1 <sup>st</sup> Accretion Light
Evolution of Structure	Physics of High Density Matter
Physics of Plasmas	Physics of Feedback
X-rays in the Multi-Wavelength	Stellar Lifecycles

- Currently working with the STDT to identify outstanding science questions and aid the STDT to produce a mission concept that best addresses these questions

STDT Face-to-Face held 6-7 April, 2017  
(Huntsville, AL)



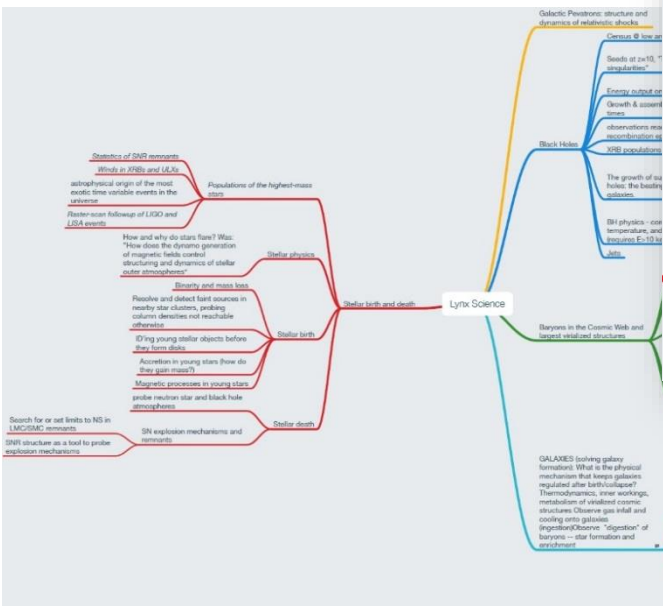
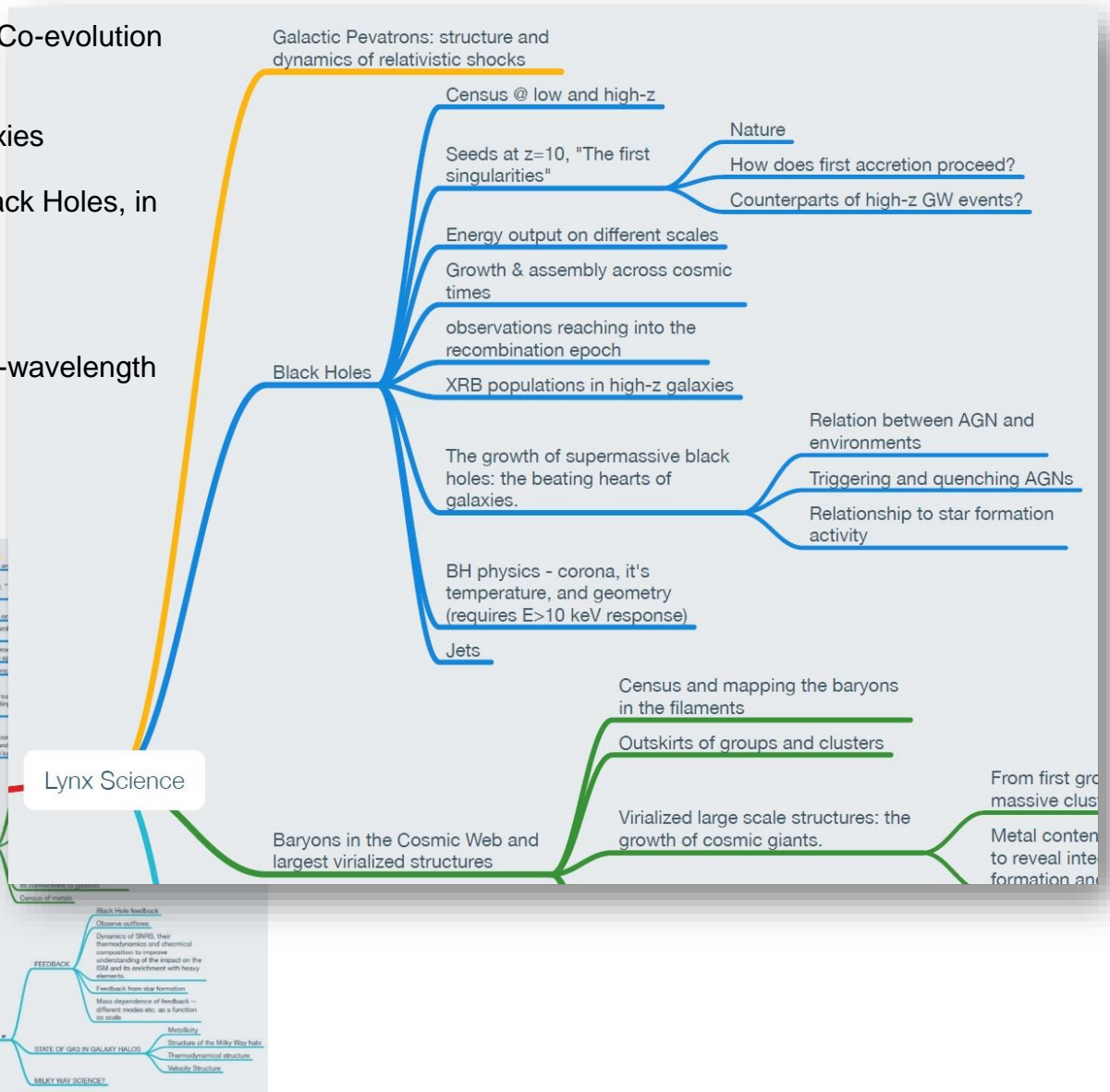
STDT Face-to-Face held 14-15 November, 2016  
(Washington, DC)



- Preliminary (first cut) science case was discussed at the 11/2016 F2F
- Science case was refined through telecons and through the generation of a Mind Map
- Science case was refined further at the 4/2017 F2F
- Key observations are being defined for the refined science case and related simulations are underway to determine observatory requirements by 06/14/2017
- Further discussion, augmentation and refinement of science case through final submission

# Science Status – Many Science Themes!

- First Black Holes in the Universe and their Co-evolution with Galaxies
- Cycles of (Hot) Baryons in and out of Galaxies
- Feedback from Stars, Supernovae, and Black Holes, in All Settings
- Stellar Lifecycles
- X-ray counterparts of GW events and multi-wavelength phenomena
- Physics of Accretion and Compact Objects



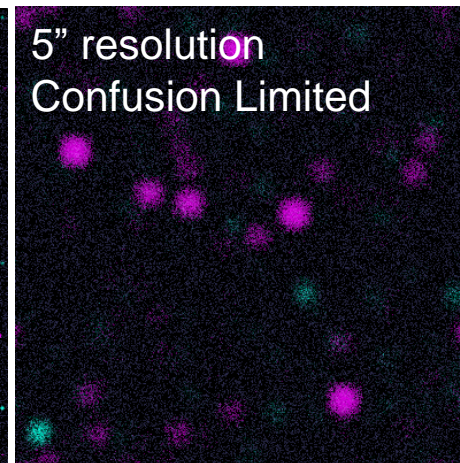
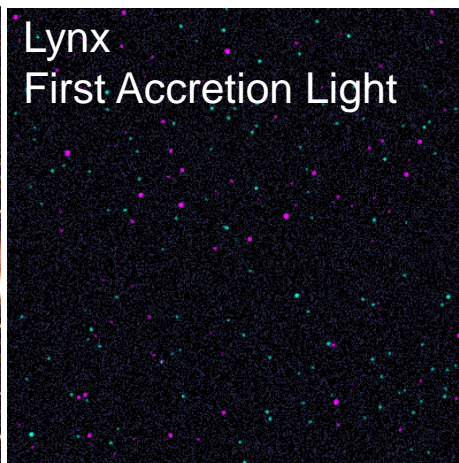
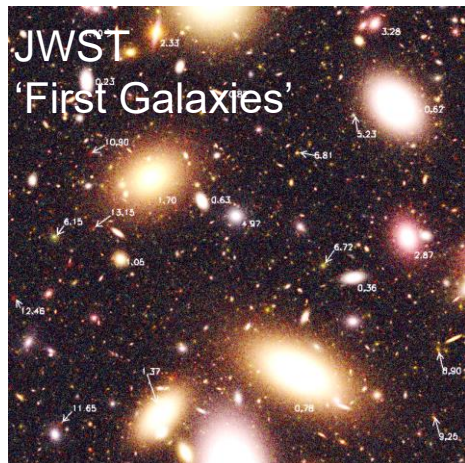
# Science Status – Unique Lynx Science

## Lynx will uniquely detect and characterize First Accretion Light

- Origin and growth of SMBH: Nature of the seeds and evolution of first accretion
- X-Ray Binary population in high-z galaxies
- Detect X-ray signals from the onset of recombination epoch via deep surveys
- Local studies of Super-Eddington accretion regime and relation to the growth of SMBH seeds

## Lynx will shed light on the hot gas that makes up most of the Baryons in the universe

- Detailed studies, including the velocity structure, of the Milky Way halo
- State of gas in galactic halos (Maps of thermodynamic profiles and metallicities)
- State of gas in Cosmic Web (Mapping the baryons in Cosmic Web filaments)
- Understand the energetics and mechanics of the galactic winds feedback
- Map the mass dependence of feedback, e.g. different modes as a function of galaxy mass etc.



JWST will detect  $\sim 2 \times 10^6$  gal/deg<sup>2</sup> at its sensitivity limit (Windhorst et al.). The 0.5'' angular resolution of Lynx will minimize source confusion while a 5'' beam will be confusion-limited

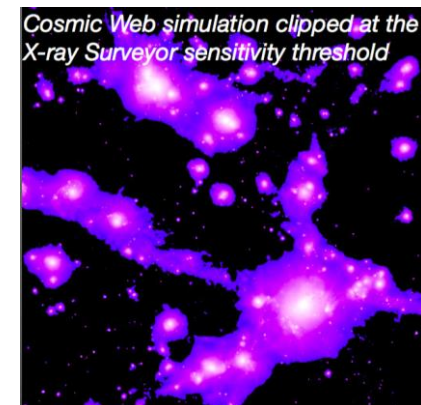
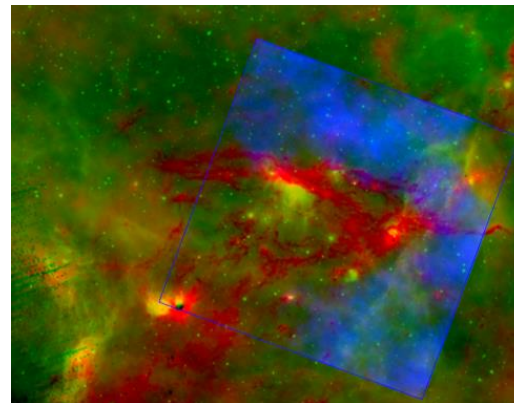
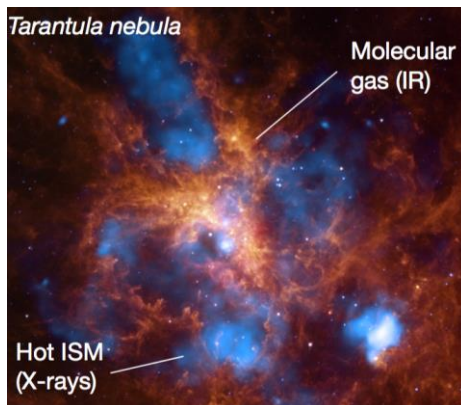
# Science Status – Unique Lynx Science

Lynx will make unique contributions to the physics of structure formation and evolution

- Census of metals in the Cosmic Web and galaxy groups to reveal integrated history of star formation and violent feedback
- Understand the energetics, triggering mechanism, and energy dissipation processes for Black Hole feedback
- Observe evolution of galaxy groups since  $z \sim 4-6$  to map the emergence of LSS

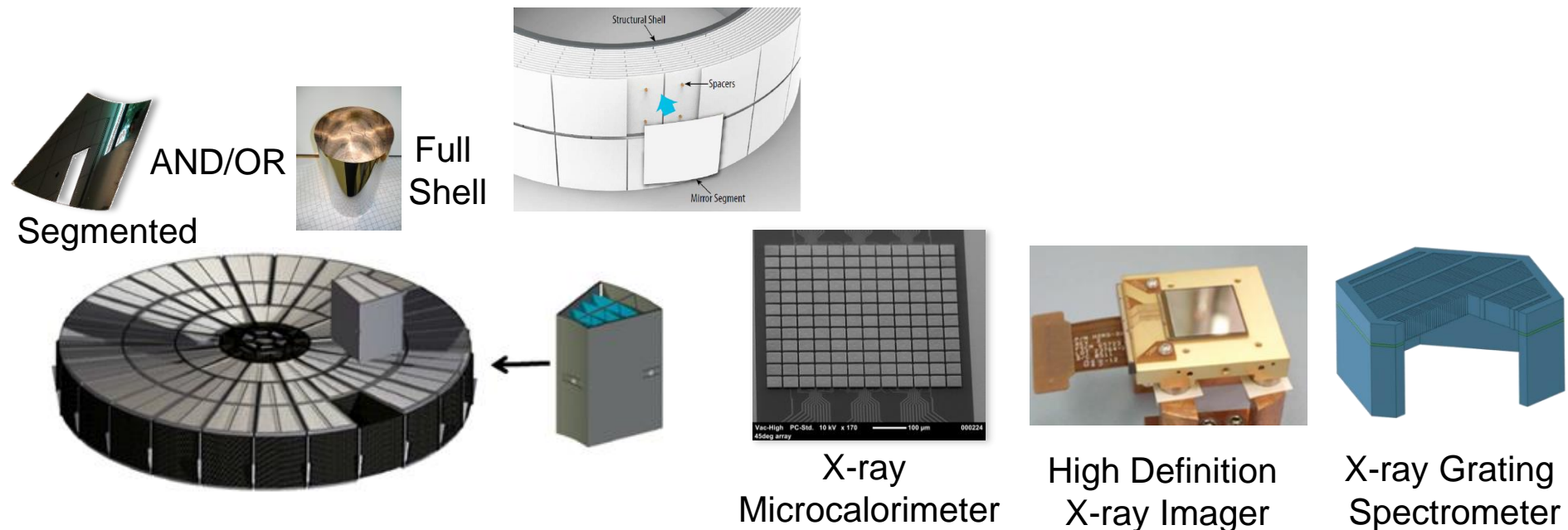
Lynx will significantly contribute to our understanding of Stellar Lifecycles and will uniquely constrain their local environments and provide insight into our own solar system

- Uniquely Observe and Characterize feedback from star formation using observations of the Milky Way and Local Group galaxies
- Use X-ray surveys of pre-main sequence stars to map instantaneous star formation in different environments
- Use Lynx data on SNR and stellar remnants to understand the SN explosion mechanism



# Observatory Requirements

- High sensitivity in the soft X-ray band. First Accretion Light science requires mirror effective area  $> \sim 2$  square meters at  $E < 2$  keV.
- High angular resolution (sub-arcsec) is key for nearly all *Lynx* science. Desire 0.5 arcsec or better resolution.
- Detectors should provide fine imaging, low internal background, and high resolution, spatially resolved spectroscopy.
- Very high spectral resolution ( $R > \sim 5000$ ) in the soft band.





- Instrument Working Group (IWG) has been working with individual SWGs to determine optimal requirements and define trades [06/14/2017]
  - Pixel size
  - Resolving Power
  - Effective Areas
  - Quantum Efficiencies
  - Array Sizes
  - Etc...
- Planned Instrument Design Labs [Near Term]
  - X-Ray Microcalorimeter (GSFC) – 06/2017
  - High Definition X-ray Imager (MSFC) – August (TBS)
  - X-Ray Grating Spectrometer (MSFC) – August (TBS)
  - Follow-up IDLs at GSFC for all instruments have been requested
- IWG will provide inputs into the PCOS & Aerospace TRL assessments and will begin discussions and input into Roadmap [Near Term]

# Observatory Status - Optics

## STDT

6/14/17

Provide initial optics system req'ts to OWG with acceptable  $\pm$  % bounds

- Optics Outer diameter
- Field of View
- Angular Resolution
- Effective Area
- Etc..

- Optics Working Group (OWG) has agreed on a path for determining a reference configuration for the optical assembly (for feasibility, cost and schedule.)
- OWG will provide inputs into the PCOS & Aerospace TRL assessments and will begin discussions and input into Roadmap [Near Term]

## OWG

5/17/17

Select Optics Concepts for Study

Si Passive Segments  
Kilaru-Pareschi

Passive Full Shell  
Zhang

Active Segments  
Reid

7/12/17

Develop Design based on State-Of-Art (SOA)

- Science requirements
- Mass allowance

Perform SOA error budget studies

Determine angular resolution error budget and delta of desired to SOA  
8/6/17

8/6/17 thru 4/1/18

Optimize and update error budget & analyses

5/17/17

Call for Point Design Decision Matrix contents

8/6/17

Populate Decision Matrix – first cut

1/31/18

Decide on 2 Point Designs for ACO follow-up

4/1/18

Fully populate Decision Matrix and assess analyses of the viable concepts within the STDT

6/1/18

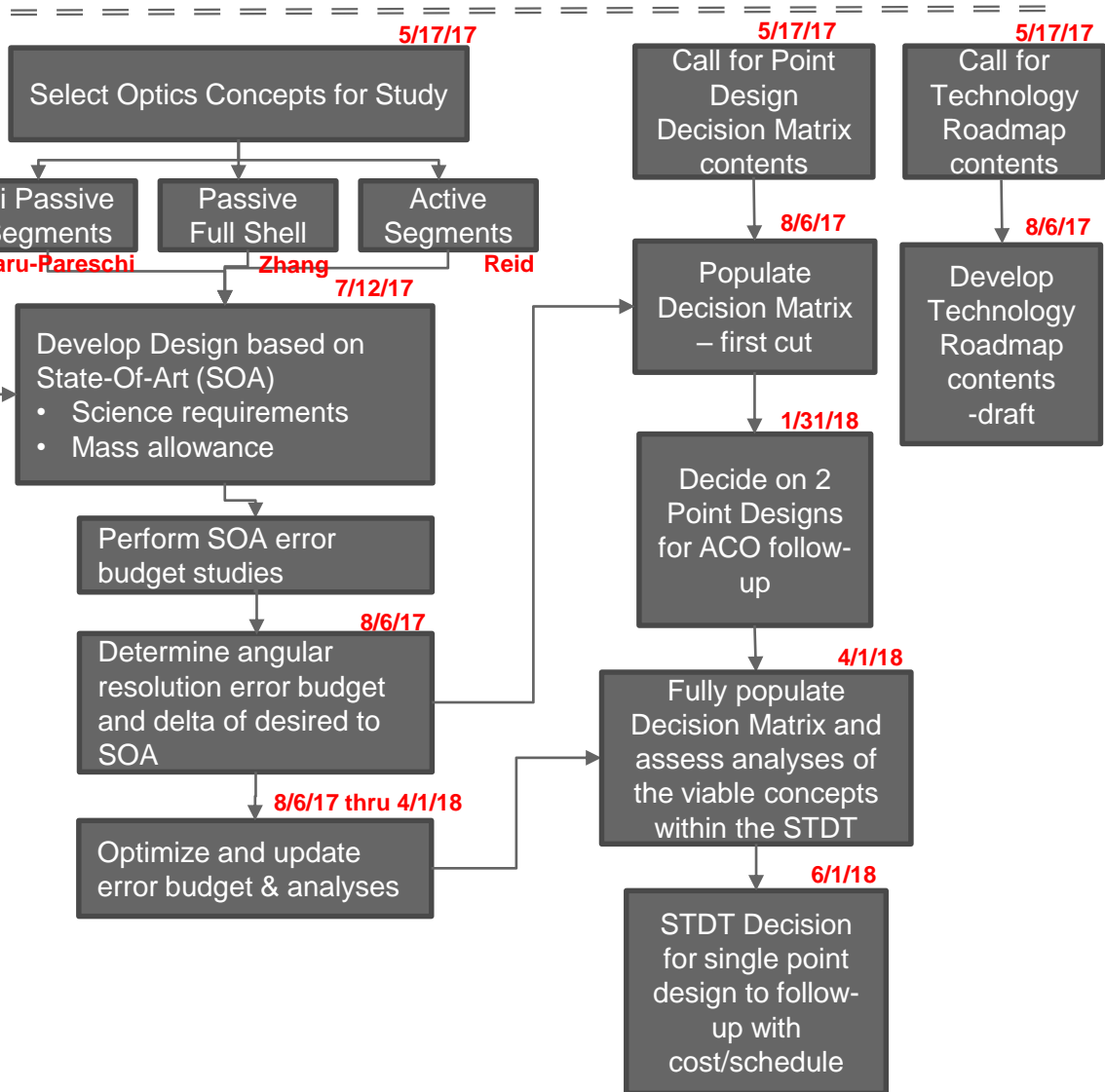
STDT Decision for single point design to follow-up with cost/schedule

5/17/17

Call for Technology Roadmap contents

8/6/17

Develop Technology Roadmap contents -draft



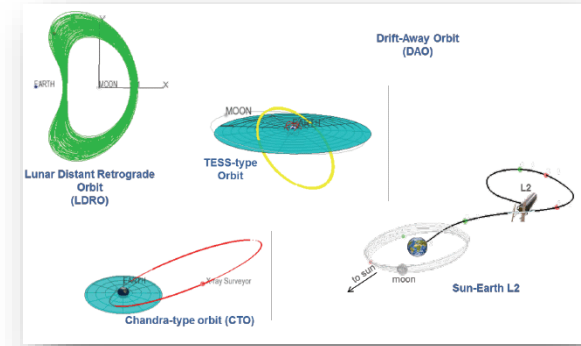
## **Optics Design Teams Must Provide Studies and Plans for ...(DRAFT)**

- Mirror manufacturing plan
- Metrology for all phases (manufacturing, assembly, alignment, etc)
- Coatings (reflectivity, micro-roughness, stress, stability, adhesion, etc)
- Mounting
- Stress (all environmental phases, residual stress, bonding, figure correction techniques, etc.)
- Alignment & Assembly
- Correctability (if applicable)
- Telescope resolution, mass and power budgets
- Technology roadmap, including TRL target dates (all relevant gates)
- Calibration plan

# Observatory Status - Spacecraft

- MSFC Advanced Concept Office (ACO) has continued non-payload specific studies

- Orbit trades (SEL2 and TESS Orbit are front runners)
- Slew rate trades
- Pointing stability/accuracy trades
- Launch vehicle trades
- Mechanism trades (movable optical assembly vs. Instrument table)

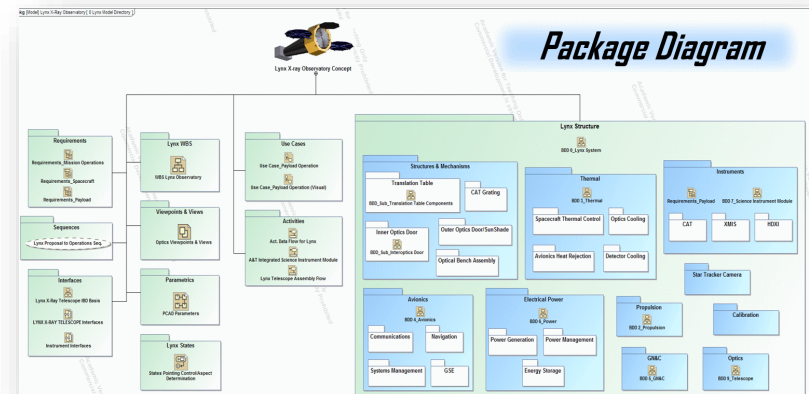


- MSFC ACO gearing up for HDXI and XGS IDLs (completed by 08/2017)

- Lynx Study Office met with Satellite Servicing Projects Division (GSFC). A follow-up will be planned once Lynx instrument/optics requirements are set. Lynx is participating in FASST telecons.

- MBSE approach to defining the Lynx Concept

- Lynx LSE: Andrew Schnell (MSFC)
- Instrument SE: Kevin McCarley (MSFC)
- Optics SE: Mark Freeman (SAO)





Aerospace Team is tasked using Lynx Project funds to support Roadmap strategy development and assessment

- Technology outline from the Optics and Instrument teams
  - *Incorporate results of TRL assessments already executed*
- Schedule & Milestones
- Establish tailored format for Lynx roadmap
- Develop roadmap strategy
- Set up working meeting to capture technology issues & assign action items

Aerospace Team provided an assessment of the 2015 X-Ray Surveyor concept to determine if the process for defining the concept with costing was reasonable.

- Several areas were highlighted as needing more discussion and/or clarification (fidelity, contingency, cost)
- No show stoppers!

Aerospace Team provided an independent assessment of the optics and instrument TRLs.

- Discussions are on-going

PCOS provided an independent assessment of the optics and instrument TRLs.

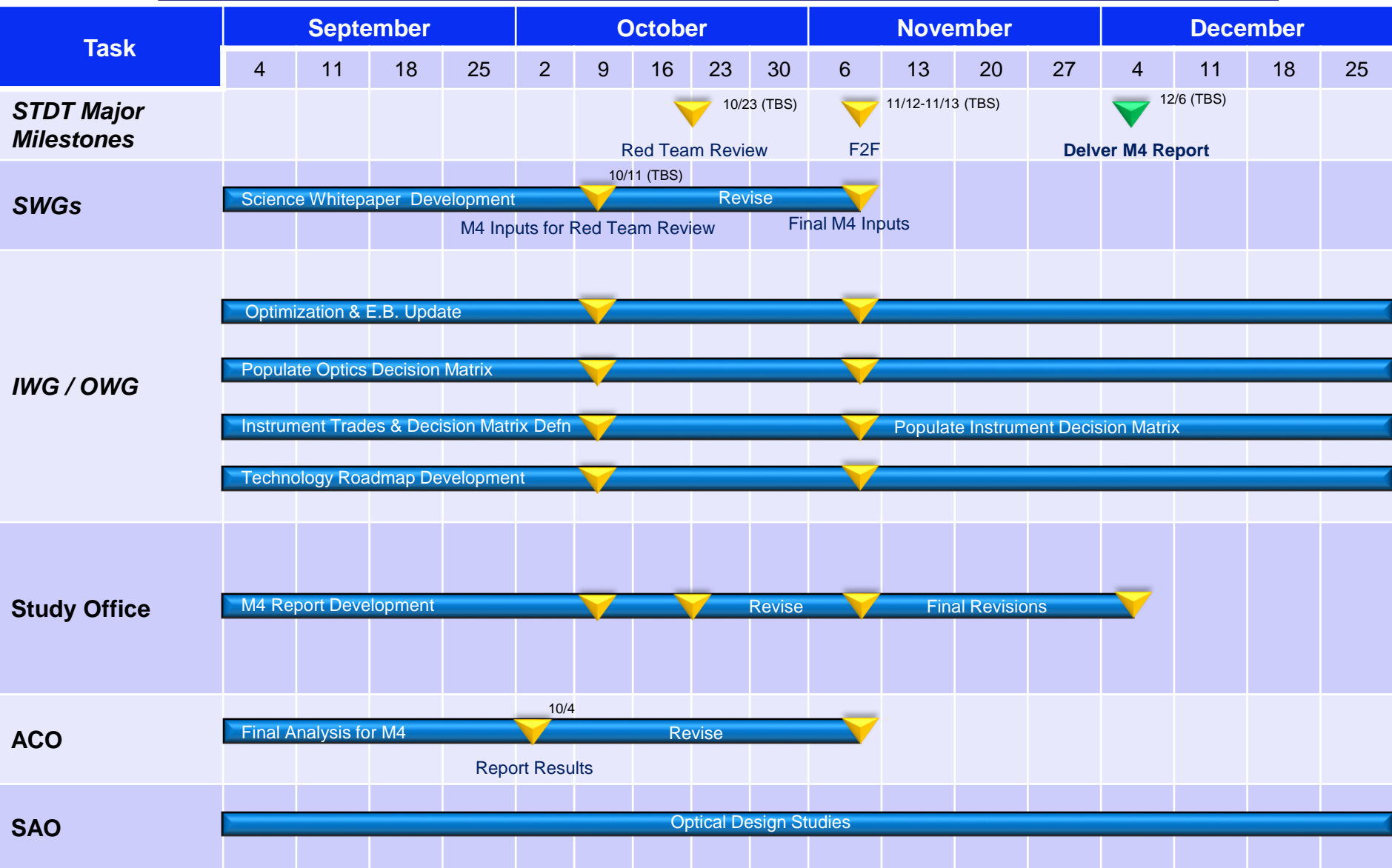
- Not entirely consistent with Aerospace assessment, but close.
- Feedback will be provided by June 30<sup>th</sup>, 2017
- Need further discussion to understand the discrepancies





# Lynx Concept Study

## Look Ahead Schedule, 2017





- Webinar/Seminar series on a wide range of topics to engage the astrophysics community
  - Towards understanding the inefficiency of star formation in galaxies (03/2017)
  - Active Galactic Nuclei and Large-Scale Structures (01/2017)
  - Observable Impacts of Exoplanets on Star Hosts from an X-ray Perspective (11/2016)
  - Quasar Microlensing (10/2016)
  - The physics and first observations of the Kinematic effect (09/2016)
  - The Role of Cosmic Rays in Stellar and Supermassive Black Hole Feedback (09/2016)
  - Cool Stellar Science with the X-ray Surveyor (09/2016)
- Participation in Conferences
  - 229<sup>th</sup> AAS (01/03/2017 – 01/07/2017)
  - Lynx-Chandra Meeting (08/08/2017-08/10/2017)



- SPIE Optics and Photonics Meeting (Lynx Technical Event) (08/08/2017)
- 16<sup>th</sup> HEAD Divisional Meeting (08/20/2017-08/24/2017)

# External Community Involvement

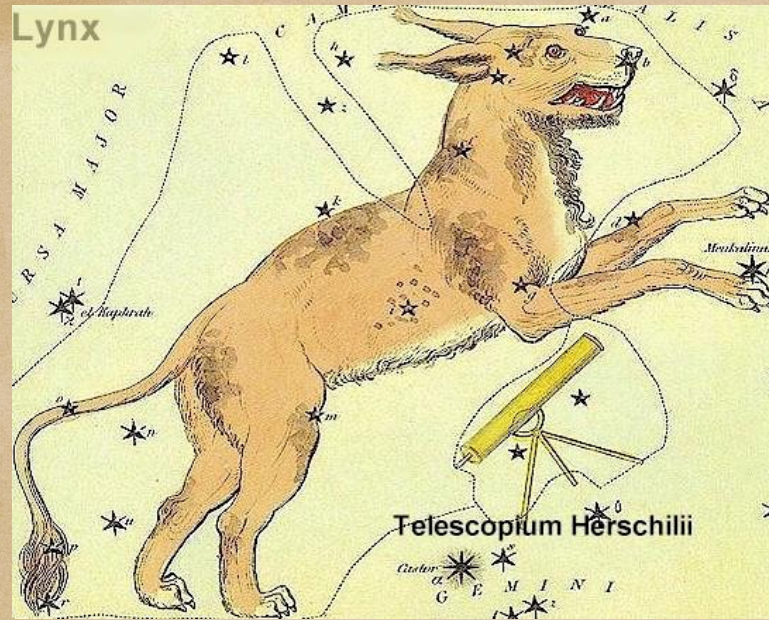
- Multiple Lynx Science Working Group Meetings
  - Lynx Synergy Workshop (Multiwavelength WG) (21-22 March, 2017)
  - Cycles of Baryons In and Out of Galaxies WG (17-18 April, 2017)
  - Stellar Lifecycle WG Lynx Workshop (July 2017 – Still being planned)
- Open F2F and weekly STDT Meetings
- Public Website (<https://wwwastro.msfc.nasa.gov/lynx/>)
- Communications Working Group (chaired by STDT members)
  - Planning for 231<sup>st</sup> AAS Winter Meeting
  - Organizing and running Webinar series
  - Considering a TEDx Huntsville talk (September, 2017)
  - Working on new logo and branding
  - New Name! Lynx!

L  
Y  
N  
X



Revealing  
the  
Invisible  
Universe

# Lynx - Acronym Free!



- ❖ A symbol of great insight
- ❖ Ability to see through rocks and trees to **reveal the true nature of things**



## DIALOGO DI GALILEO GALILEI LINCEO

MATEMATICO SOPRAORDINARIO  
DELLO STUDIO DI PISA.

*E Filosofo, e Matematico primario del  
SERENISSIMO*

GR. DVCA DI TOSCANA.

Due ne i congressi di quattro giornate si discorre  
sopra i due

MASSIMI SISTEMI DEL MONDO  
TOLEMAICO, E COPERNICANO;

*Proponendo indeterminatamente le ragioni Filosofiche, e Naturali:  
tanto per l'una, quanto per l'altra parte.*

CON PRI



VILEGI.

IN FIRENZA, Per Gio: Batista Landini MDCXXXII.

CON LICENZA DE' SUPERIORI.

The historic Accademia dei Lincei (Academy of the 'Lynx-eyed') based their name on this ability to perform incisive and penetrating investigations of the natural world.

Galileo himself was a proud member, and **the Academy of the Lynx coined the term telescope** for his marvelous device for peering into the cosmos.

*Much of the baryonic matter and the settings of the most active energy release in the Universe are visible primarily or exclusively in the X-rays, so...*

## Lynx-Industry Technical Interchange Meeting (5/22/17 – 5/23/17)

**65 Participants**  
**18 Companies**



National Space Science & Technology Center  
Huntsville AL

- Primary Outcomes for meeting:
  - Provide invited industry representatives background information on Lynx and the optics and instrument technologies involved
  - Discuss with invited industry representatives areas for partnership
  - Discuss the Technology Roadmap strategy and contents for use in the Decadal Survey report

# Lynx-Industry Technical Interchange Meeting

## Agenda, Day 1



Time	Topic	Presenter(s)
0800 – 0805	MSFC Center Director's Welcome	Todd May (MSFC Center Director)
0805 – 0810	Welcome / Meeting Logistics	Bautz / Schattenburg
0810 – 0835	Lynx Science Overview and Requirements	Gaskin
0835 – 0900	Mission Concept Overview	Mulqueen
0900 – 0930	IWG – Microcalorimeter Overview	Bandler
0930 – 1000	IWG – High Definition X-ray Imager Overview	Kraft
1000 – 1015	Morning Break	
1015 – 1045	IWG – Gratings Spectrometer Overview	McEntaffer / Heilmann
1045 – 1115	OWG – Segmented Shell Si Optics Overview	Zhang
1115 – 1145	OWG - Segmented Shell Glass Optics (Active) Overview	Reid
1145 – 1245	Lunch	
1245 – 1315	OWG – Full Shell Optics Background / MSFC	Kilaru
1315 – 1345	OWG – Thin Polished Glass Monolithic & Segmented Mirror Development	Basso
1345 – 1415	OWG – Preliminary T/S Aspects Based on Thin Glass Substrates	Civitani
1415 – 1445	OWG – Mirror Correction Overview	Chalifoux
1445 – 1500	Afternoon Break	
1500 – 1600	Technology Roadmap Strategy Discussion	Bukley
1600 - 1700	Technology Roadmap Development Discussion	Bukley
1700	Adjourn	

# Lynx-Industry Technical Interchange Meeting

## Agenda, Day 2



Time	Topic	Location*	Presenter(s)
0800 – 0810	Meeting Logistics	Conference Room 4078	Lynx / Bautz, Schattenburg
0810 – 0910	Consortium Presentation to Lynx Team	Conference Room 4078 (and dial in)	Ball, Northrop Grumman, Harris

Time	Spacecraft Q&A / CR 4078	Optics Q&A / CR 4065	Instrument Q&A / CR 4068
0910 - 0930	Quest Thermal	ADC	Create
0930 - 0950	Teledyne	Corning	Luxel
0950 - 1010	Moog	Lockheed Martin	Sarnoff
1010 - 1030	Morning Break		
1030 - 1050	Raytheon	Neptec	Raytheon
1050 – 1110		UTC Aerospace	
1110 - 1130	Orbital ATK	Viavi	Lockheed Martin – Palo Alto
1130 - 1150		QED	Instrument Interfaces Splinter Session with ACO
1150 - 1210			
1210 - 1250	Lunch		

Time	Topic	Location	Presenter(s)
1250 - 1350	Wrap Up / Path Forward	Conference Room 4078	Lynx / Bautz, Schattenburg

# Cooperative Agreement Notice (CAN)

- **CAN Release: June, 2017**
- **Short turn-around for proposals (~1 month)**
- **Hope to award and start studies in August**
- **Thank you to Julie Crooke for helping the Lynx Team better understand the process!**

The screenshot displays the FEDBIZOPPS.GOV website interface. At the top, there is a navigation bar with links for Home, Getting Started, General Info, Opportunities (highlighted), Agencies, and Privacy. Below the navigation bar, there are links for Buyers (Login | Register) and Vendors (Login | Register), along with an Accessibility icon. The main content area features the NASA logo and the title "Cooperative Agreement Notice for LYNX Mission Concept Study". Below the title, the solicitation number (NNM17626588R), agency (National Aeronautics and Space Administration), office (Marshall Space Flight Center), and location (Office of Procurement) are listed. There are three tabs: "Notice Details" (selected), "Packages", and "Interested Vendors List". To the right of the tabs are "Print" and "Link" icons. Below the tabs, there are three buttons: "Return To Opportunities List", "Watch This Opportunity", and "Add Me To Interested Vendors". The "Original Synopsis" section shows the date and time (May 16, 2017, 9:04 am). The "GENERAL INFORMATION" section on the right lists details such as Notice Type (Presolicitation), Posted Date (May 16, 2017), Response Date (-), Archiving Policy (Automatic, on specified date), Archive Date (July 1, 2017), Original Set Aside (N/A), Set Aside (N/A), Classification Code (A - Research & Development), and NAICS Code (541 - Professional, Scientific, and Technical Services/541712 - Research and Development in the Physical, Engineering, and Life Sciences (except Biotechnology)). At the bottom, there are links for "For Help: Federal Service Desk" and "Accessibility".

- Ex-officio members on the STDT and part of WGs
- Participation in international conferences
- Full-Shell Study Co-Lead is Giovanni Pareschi (INAF - Osservatorio Astronomico di Brera)
- Hope to involve potential foreign industry partners to assess optics and instrument capabilities



- Non-traditional industry partners may be critical to assembling a feasible path for Lynx
- Good communication and cross-talk among WGs is critical
- 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 Lynx visibility at meetings (F2F, AAS, APS, etc) is substantial
- Consistent participation in weekly STDT meetings is essential, however busy teaching schedules of some STDT members makes this impossible
- Archiving critical decisions and actions should be done on a regular basis

- Desire consistent and improved travel support for STDT face to face meetings
  - Overall, the support has been very helpful to the Lynx Team. However, still some cases of late responses and slow reimbursement
- Guidance is requested on the final submission deadline
  - Given the delay in schedule for the National Academies, Will the teams be able to deliver the final package later than March 2019? If not, will we be able to add material post-submission in March if we have critical new material to add?
- Guidance is requested on costing
  - Do we need to include pre-Phase A costing for technology maturation?
  - Request final, written guidance on Launch Vehicle cost (pass-through or other?)
- Somewhat concerned that there are 2 separate TRL assessments and no cross-talk. It is important to continue these discussions, to better understand any ambiguities and differences.
- Definition of M4 review