

### U.S. Contributions to the X-ray Integral Field Unit Instrument

- Important X-IFU consortium activities
- LPA2.5a+: way forward to EM
- TRL development & review



#### Simon Bandler NASA/GSFC

- On behalf of the U.S. contribution to the X-IFU
- NAST Meeting, July 14<sup>th</sup>, 2020

## X-IFU Movie





## **The Athena X-IFU**



For an introduction to the Athena X-Ray Integral Field Unit Instrument, please see the following 2-minute video: <a href="https://youtu.be/\_WvV6tLDNF8">https://youtu.be/\_WvV6tLDNF8</a>





The X-IFU 50 mK focal plane assembly (FPA)



- Baseline detector array for DC bias referred to as 'LPA2.5a'.
- Currently assumed there will be 96 channels of TDM read-out, each reading out 34 TESs.
- In each channel, 33 detector pixels, and 1 TES "dummy" for read-out drift corrections.
- Small design iterations being investigated to slow pixels down, to make read-out easier.

# **Important X-IFU Consortium activities**



#### **Read-out**

- Baseline readout switched from Frequency Domain Multiplexing (FDM) to Time Domain Multiplexing (TDM)
  - SRON keeps system responsibility of the focal plane assembly
- Larger US contribution in providing, in addition to the focal plane array:
  - 1) The first stage multiplexing SQUIDs (NIST)
  - 2) Support to the TDM implementation (NIST & GSFC)
- No performance degradation assumed for the red book/MAR

#### Cryostat

- Cryostat demonstration model "DCS" CDR unsuccessful; DCS will not be in time for the MAR.
  - Unanticipated technical and funding issues related to the system complexity.
- Risk that similar /larger difficulties are faced for EM and FM cryostats deemed unacceptable by X-IFU PM/PI and ESA
  - Major risk raised during MFR (team heritage, team size, need for industrial support).
- Hence it has been decided that ESA will procure the cryostat through an industrial contract.
- Both potential spacecraft industrial partners now also bidding to provide the X-IFU cryostat as well (Thales & Airbus).
- Draft of interface requirements document (IRD) has already been provided by X-IFU consortium to these partners, update to these requirements expect by ~ September in order to fix them allow design phase to begin.

Overall impact on schedule of these two major changes, as well as COVID-19 not yet known, FPA sub-system currently assuming a 9-month delay



### DC-biased TES baselined, LPA2.5a is reference design







## Excellent energy resolution and uniformity demonstrated



NAST meeting, 7/14/20



# **Broad-band performance**







## Developing"Athena" scale arrays & test set-ups







- Two platforms planned at GSFC for full-scale array testing.
- Testing has started on Athena-3b arrays.
- 3,840 sensors on 265 µm pitch.
- 960 pixels connected to bond pads currently.





NAST meeting, 7/14/20

# Technical Readiness Level (TRL) assessments, and budget/schedule planning reviews



- NASA Headquarters requested a TRL assessment and review of program budgets and schedules for all critical Athena contributions.
- X-IFU X-ray microcalorimeter (detector) review: Thursday July 16<sup>th</sup>.
- X-IFU TDM read-out review: Monday July 20<sup>th</sup>.



# Performance Parameters/Technical Targets for TRL-5, demonstrating performance with full-size arrays



#### Working towards 13 milestones:

- 1. Sub-set of at least 100 pixels demonstrate an average energy resolution of individual pixels of < 2.1 eV at 7 keV. Pixel characteristics meet X-IFU count-rate & throughput requirements. Demonstrations should be with array size > 3000 pixels.
- 2. Pixels meet requirements on sensitivity to environment, including electromagnetic compatibility (EMC)
- 3. Pixel yield has a credible path to 99% yield.
- 4. Quantum efficiency of pixels tested meets QE requirements
- 5. Reflectivity of absorbers is > 40% above for radiation above 1  $\mu$ m.
- 6. Pixels meet thermal cross-talk requirements.
- 7. Array meets electrical cross-talk requirements.
- 8. Thermal design of array meets thermal background requirements due to cosmic rays
- 9. Supporting tests & analysis demonstrates robustness of mechanical design to launch vibrations.
- 10. Supporting tests & analysis demonstrates robustness of design to L2 space radiation environment.
- 11. For a sub-set of 100 pixels, demonstrate that energy scale can be calibrated with an uncertainty of ± 0.4 eV from 1.5–7 keV
- 12. Must demonstrate that the baseline X-IFU interface/packaging between the detector & read-out is feasible.

13. Must determine that when stored and operated according to X-IFU requirements there is no loss of performance over the specified timescales.

Milestones consistent with TRL-5, scaling up requires reading out more pixels, greater yield etc., but no new technology development.





# **Schedule summary**



Status Period Ending: 7/10/2020

X-Ray Integral Field Unit (X-IFU) Detector	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
Athena Mission Reviews & Milestones	MFR $\blacklozenge$	MFR ◆ 6/15 6/29								401020304	101020304	IQIQZQ3Q4	UIU2U3U4	Launch	QIQZQ
X-IFU Instrument Reviews	11/1 MFR 11/1		SRR 9/15	PDI 11/21 (	۲ ۲		CDR △ 8/18			Q  12,	R iA \ /5	AR △ 1/1		8/4	
X-IFU Detector Development Phases	PI	nase B1 <mark>7</mark>	PI	hase B2 🗾		ZZZ Phase C	<u>, , , , , , , , , , , , , , , , , , , </u>	1 🛛	Pł	nase D	m	ZZZ To La	unch 📶		
X-IFU Hardware Deliveries		DM FPA				PFM1 △/		/12							
Detector	1b 3	6 7	31 9/1	11/4		11// 1/	23 8/0								
TRL-5 Development Milestones	1a2	▲ △ 5 8	∆ ∆ 9	,10,11,12,1	3 Margin										
Athena-1 Optimize Pixels			9/1 2	2/15					TRI	- 5 Requir	ements:				
Athena-1k		1/13							🔺 Suk	set of +10	00 Pixels [	Demo avg	energy re	s.	
Athena-1l			🛛 3/25						Pix	el Chars M	leet X-IFU	l Count-ra	te & Thru	put	
Athena-1m (DC Bias)			<b>ZZ</b> 5/12						Pix	els meet r	qmts on s	enstvty to	env		
TRL-5/Athena-3 (Demonstration of Athena-scale Array Performance)									Pix	el yield ha	s credible	e path >99	% Taatad <b>N</b> A	+ - 05	
Athena-3b - LPA 2.5a		1	.1/3						4-	Quantum Pofloctivit	Efficiency	/ OF PIXEIS	Tested IVI	eets QE	
Athena-3c - Suspended										Pivels mee	of Therm	Cross-talk	<b>'0</b>		
Athena-3d			2/18						$\overline{\Lambda}_{7}$	Pixels mee	et Elec Cro	oss Talk			
Athena-3e	2/2								8 - Thermal Design of Array Meets Bkgrnd						
X - IFU Engineering Model (EM)									Δ 9-	Mechanic	al Robstn	s Demo to	Launch V	'ib	
EM Design	EM Design Release								△ 10	- Radiatior	n Robstns	Demo thr	u suportr	ng tests 8	ż 🛛
EM Fab & Array Test Batch #1		#1 222222 1/23							<ul> <li>11 - Demo Energy Scale Calibration</li> <li>12 - Demo bsln X-IFU interface/pkg between Detect</li> </ul>						
EM Fab & Array Test Batch #2	_	#2 6/9													
ENI Detector Prep & Snip	-		Petector D	elivery 🛇	11/4				△ 13	- Lifetime	& Storage	e plan - 5 ľ		S	-
A - IFO Qualification/Flight/Flight Spare Models					#1 277		1/22		- Di	enio Brass	board me	eting all 1	KL-5 WIIIE	stones	
Fab & Array Test Batch 2					#1 #2		J/22 7 3/1/								
Fab & Array Test Batch 3					#2	#3	ZZZ 8/14	1							
Fab & Array Test Batch 4						#4 🖂	innin	1/6							
Fab & Array Test Batch 5						#5		6/9							
Fab & Array Test Batch 6							#6 2222	1////	10/27						
QM Detector Prep & Ship				QM I	Detector D	Delivery 🛇	11/7								
FM Detector Prep & Ship					FM De	etector Deliv	very 🛇 8/6								
FS Detector Prep & Ship	FS Detector Delivery 🛇														
Infra-structure Build-up															
Carrier Chips		2nd Set	Complete												
HPD 1	s s	ystem Be	ing Tuned	d Up											
HPD 2		<b>0</b> 1	nline Test	Complete											
HPD 3			m	Online Test	Complete	2									

- See back-up file for more detailed schedule