



PhysCOS Time-Domain and Multi-Messenger (TDAMM) Initiative and the Astrophysics Cross-Observatory Science Support (ACROSS) Pilot Project

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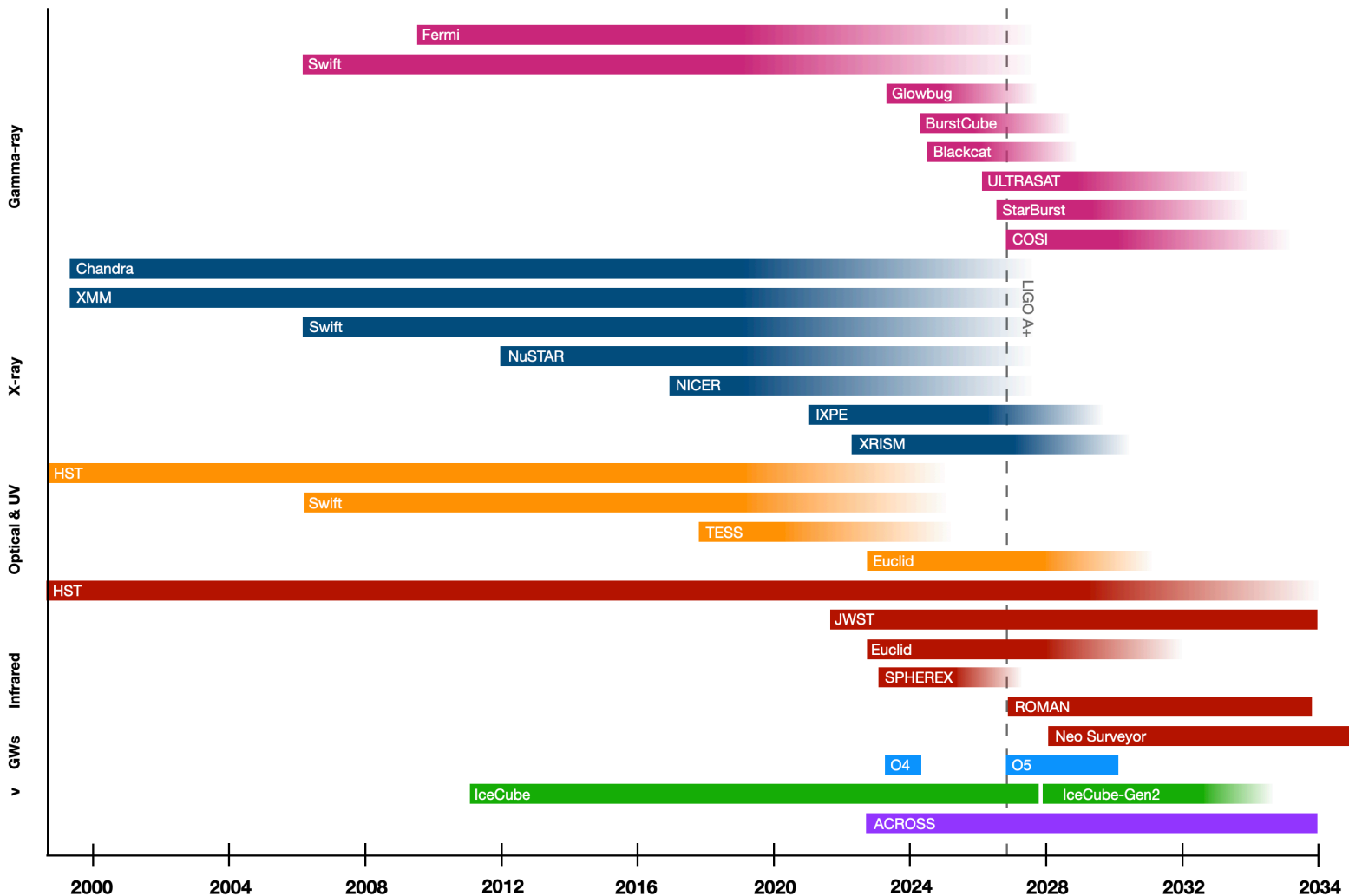
Background

- **The PhysCOS Time-Domain and Multi-Messenger (TDAMM) Initiative responds to a top-priority of the Astro2020 decadal report recommendation and has been tasked with:**
 1. Organizing a biennial **TDAMM** workshop,
 2. Conducting a three-year **TDAMM Study** investigating policy, processes and technical coordination mechanisms to enable TDAMM science,
 3. Recommending one or more potential implementations for a General Observer Facility for TDAMM science.
- **The Astrophysics Cross-Observatory Science Support (ACROSS) pilot project is an outcome of the first year of the TDAMM study, which identified needs for:**
 1. Software & data systems to facilitate TDAMM science workflows,
 2. TDAMM help desk to provide expertise & facilitate coordination, and
 3. TDAMM community grant program to incentivize scientific innovation.
- **The ACROSS core team members are from PhysCOS, Goddard, Marshall and Penn State.**

The objective of the pilot phase is to put ACROSS on a path to becoming a Center of Excellence for enabling TDAMM science.



NASA Fleet with Highlighted Multi-Messenger Facilities Timeline





Barriers to Effective and Efficient TDAMM Science Outcomes

- **TDAMM science outcomes are affected by many NASA mission design factors for operating missions; most are difficult or impossible to alter once in operations**
 - Instrument sensitivity, field-of-view and onboard science algorithms,
 - Mission orbit and spacecraft slewing rate,
 - On-board autonomy capabilities and data-handling flexibility,
 - Space communications architecture and service access timeliness,
 - Ground science data processing pipelines, among other factors.
- **Improvements to TDAMM science outcomes require broad and specific understanding of end-to-end operational workflows**
 - Easy access to NASA mission observing plans is hampered by heterogeneous formatting and availability (i.e. every mission is different).
 - There is no timely or reliable way to know if a TDAMM event was observed serendipitously by one or more missions.
 - Events (or candidate events) detected by other observatories may be “sub-threshold data” and at risk of loss unless reprioritized for downlink, so rapid response is essential.
 - Determining the observing feasibility and most scientifically effective course of action for multiple observatories is extremely complex for technical, procedural and social reasons.

The ACROSS pilot is prototyping and demonstrating ways to improve access to information and operational workflows where possible to enable more effective use of NASA's fleet for TDAMM science.



ACROSS Pilot Technical Infrastructure Development Areas



- **Observatory Workflow Status Data Feeds**
 - Provides a live data feed of public NASA observatory status parameters relevant for TDAMM science planning & execution (e.g. observing plans).
 - Can be accessed via the internet and directly incorporated into local General Observer and Science Operations Team planning & execution tools & workflows.
- **TDAMM Toolkit**
 - A collection of generalized, modular, open-source software products that can be instantiated to streamline, standardize, and automate TDAMM workflows.
 - Deployed locally by General Observers and Science Operations Teams, with or without support from ACROSS SMEs.
 - Future TDAMM grant program will incentivize community contributions to the toolkit.
- **TDAMM Web Services**
 - Accessed through our portal (potential future URL: multimessenger.nasa.gov).
 - Organizes and deploys status data feeds and TDAMM Toolkit products into value-added TDAMM science planning and execution web services.
 - Services are cloud-hosted, with human and machine interfaces, and provide:
 1. Science Situational Awareness – dashboards for understanding the current, near-future & recent-past status of observatory workflows and data products associated with a TDAMM event.
 2. Multi-observatory follow-up planning & feasibility analysis tools.
 3. Follow-up hub for observatory tasking request specification & submission (e.g., ToO requests).
 4. Follow-up course-of-action decision support & recommendations.



Highlighted Recent Accomplishments

- **Pre-coordinated gravitational-wave follow-up plans among current NASA X-Ray missions and XMM-Newton during the LVK O-4 observing runs.**
 - Each mission provided an overview of its approved general observing programs.
 - Discussed courses-of-action to ensure effective and efficient follow-ups.
 - Established an O4-follow-up Slack channel for rapid science team coordination.
 - Demonstrates a value-added function provided by an ACROSS TDAMM Help Desk.
- **Delivered a Minimum Viable Product TDAMM web service for BurstCube**
 - Allows BurstCube Science Team to rapidly identify serendipitously observed TDAMM science events detected by others (e.g. LVK).
 - Supports reprioritization and downlinking of priority science event data.
 - Serves as a pathfinder for how ACROSS manages and implements value-added interfaces with in-development mission science teams and systems.
- **Established interfaces to receive NuSTAR near-future/recent-past observing plans**
 - Fills a gap in science situational awareness for both observers and science teams.
 - Serves as a pathfinder for how ACROSS manages and implements value-added interfaces with current NASA mission science teams and systems.
 - Informs the design of potential future interfaces with ground-based and international observatory science teams and systems.



Study Year 2: Coordinating with U.S. Ground Assets



■ Objectives:

1. Assess the landscape of infrastructure efforts among the ground-based community.
2. Understand what information from the NASA fleet needs to be exposed to the ground-based community and vice versa.
3. Discuss what tools, platforms, or services can be shared or co-developed between NASA and the ground-based community.

■ Tasks & Status:

- Participated in the NOIRLab-hosted [Windows on the Universe: Establishing the Infrastructure for a Collaborative Multi-messenger Ecosystem](#) workshop and white paper.
 - Using the [white paper](#) recommendations to inform the TDAMM GO Program design.
- Meeting with developers of widely used ground observatory software infrastructure tools (TOM Toolkit, SkyPortal, YSE PSE, AEON) to understand workflows, options for interfacing ACROSS data streams and web services.
- Meeting with observers to survey user experience of coordinating observing campaigns between ground and space assets.
- Holding monthly meetings with the ACROSS Advisory Group to provide status and receive feedback.



TDAMM Community Grant Program & Current Status



- **Subject to funding availability and suitable mechanism, Phase I study identified opportunities for community grants in 3 areas,**
 1. Development of tools and observing modes that enable new TDAMM science cases.
 2. Funding Director's Discretionary Time (DDT) observations made by smaller missions (analogous to flagship DDT opportunities).
 3. An overarching TDAMM science call for proposals designed to streamline or fill the gaps between existing joint observing calls, remove the risk of double jeopardy, and explicitly support observing programs which require coordination between two or more observatories.

- **National Science Foundation's recent Windows on the Universe Workshop and White Paper validated our Phase I study findings**
 - NSF recently released an infrastructure grant program "Multi-Messenger Coordination for Windows on the Universe."
 - \$7.5M in total award value, with an expected 3-5 number of awards.
 - Will coordinate our community grant area #1 (development of tools) with this program.



TDAMM Community Grant Program Open Questions & Next Steps



- **What is the most effective role a TDAMM Community Grant program can play in a financially constrained budget environment?**
- **TDAMM community grant program areas identified by Phase I study**
 1. Tools: What scope of award is useful to the community? Should we emphasize prototyping of new tools or sustainment of established tools? Would it be appropriate for ACROSS to adopt/institutionalize tools that become core pieces of the community infrastructure?
 2. DDT funding: what criteria to use to determine who receives funds? What scope of award is appropriate?
 3. Observing time: need to scope the program to *complement* existing joint programs.
- **We will continue definition and refinement of the grant program design, in consultation with stakeholders, Missions and Program Scientists for other NASA Grant programs.**



Summary and Next Steps

- **ACROSS was developed as a result of the 1st year of the TDAMM study.**
- **ACROSS seeks to develop what will become a Center of Excellence for TDAMM Science.**
- **ACROSS will develop expertise, tools and a grant program, subject to funding availability, to maximize the TDAMM science return of NASA missions and beyond.**
- **We have engaged with several operating missions to develop relationships between them and ACROSS.**
- **We will engage with missions currently in development.**
- **We will work on engaging with flagship and probe-class missions.**
- **Engaging with the community to develop a diverse set of early adopters to evaluate tools.**
- **Engaging outside of NASA to US-based and foreign observatories.**

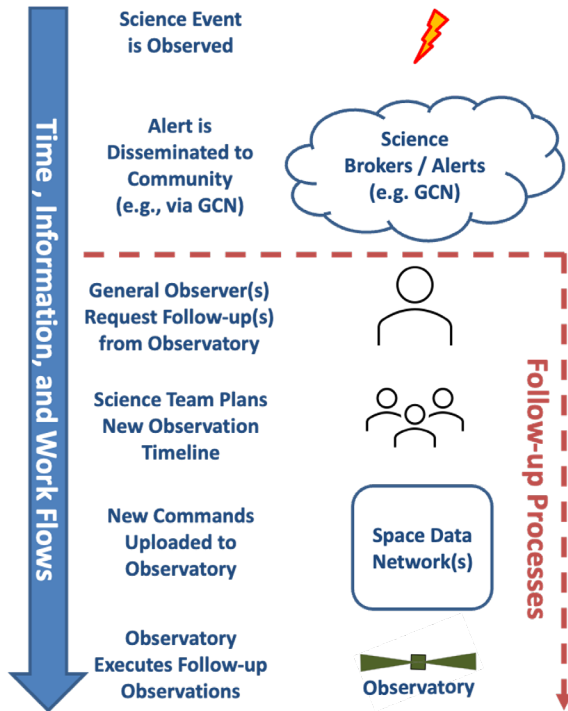


Backups

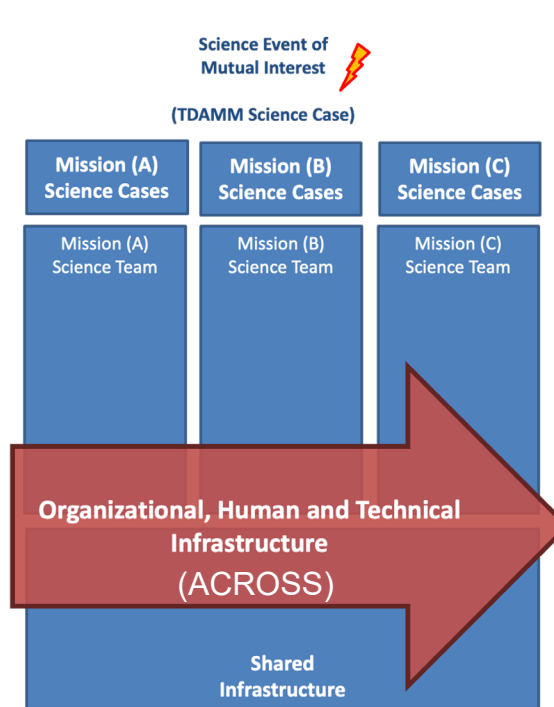


Where does ACROSS fit?

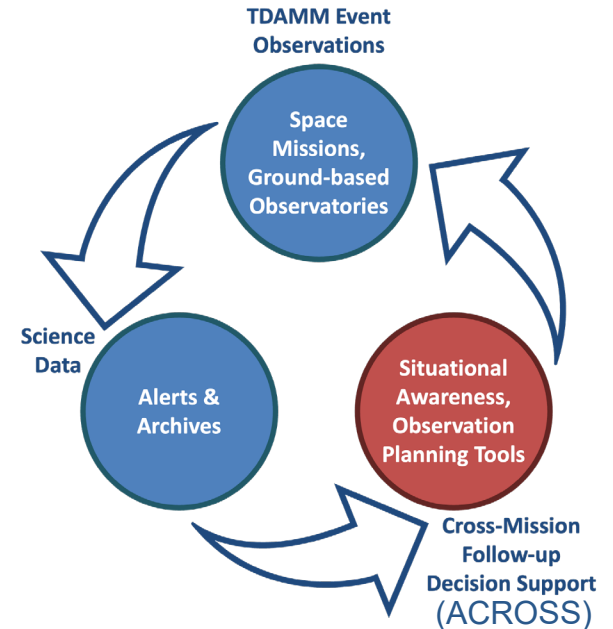
Year 1 of the TDAMM study examined NASA mission workflows, and...



...recommended infrastructure to enable the fleet to operate as a cohesive TDAMM observing system.



The ACROSS Pilot Project was initiated in October 2023 to prototype, demonstrate, and validate means for achieving effective and efficient TDAMM science outcomes.



ACROSS incentivizes and enables TDAMM science for general observers and lessens the coordination burden on observatory science operations teams.



ACROSS Top-Level Organizational Requirements (1/2)



1. **ACROSS shall be a Center-of-Excellence for enabling cross-observatory science observation planning and execution workflows in support of TDAMM science cases.**
 - a) ACROSS shall provide NASA mission and infrastructure expertise to assist general observers plan and execute TDAMM science cases.
 - b) ACROSS shall provide NASA mission and infrastructure expertise to assist observatory (mission) science teams plan and execute TDAMM science cases.
 - c) ACROSS shall procure services, develop, operate, maintain and sustain infrastructure systems, tools, or other technologies to support planning and execution of TDAMM science cases, as necessary.
 - d) ACROSS shall employ, broker or establish agreements among astrophysical observatories to support planning and execution of TDAMM science cases.
 - e) ACROSS shall establish and sustain an Advisory Group, comprised of TDAMM general observer and observatory (mission) science team representatives, to advise on capability development and operations priorities.



ACROSS Top-Level Organizational Requirements (2/2)

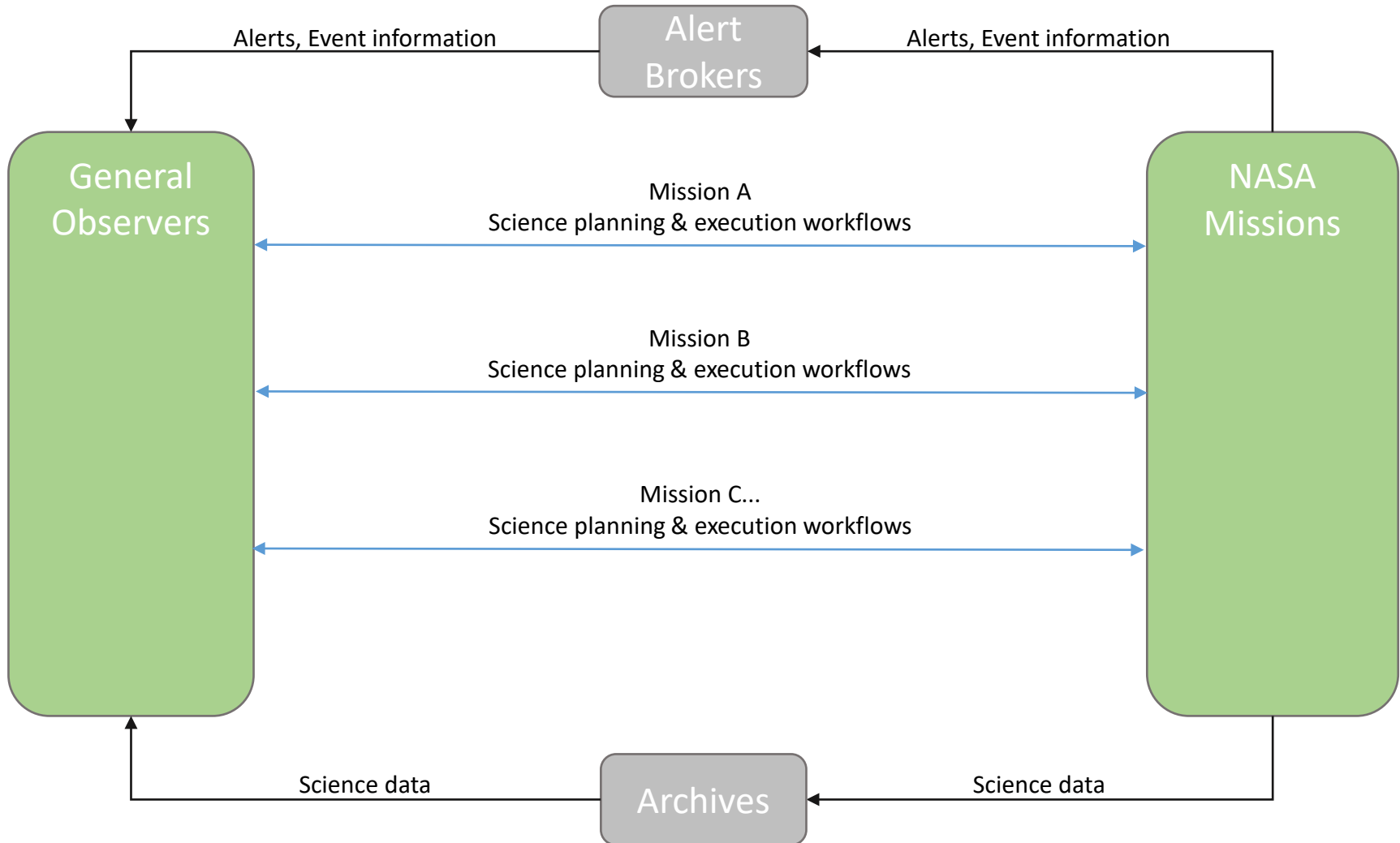


2. **ACROSS shall promote open and equitable access to its resources and infrastructure.**
 - a) ACROSS shall host a science workshop at a regular interval.
 - b) ACROSS shall provide training for general observers, for example proposal development and software examples and tutorials.
 - c) ACROSS shall provide opportunities for workforce development, for example through internships, post-doctoral programs, or rotational assignments.
 - d) ACROSS shall facilitate the development and dissemination of open-source software.

3. **ACROSS shall implement a competitive community grant program to enable and incentivize TDAMM science.**
 - a) ACROSS shall define an announcement of opportunity.
 - b) ACROSS shall manage an end-to-end proposal review process.
 - c) ACROSS shall administer grants, monitor work progress, and manage close-outs and no-cost extensions.
 - d) ACROSS shall maintain an online database of awards accessible to the public.
 - e) ACROSS shall ensure the datasets and work products associated with its grant programs are archived and publicly accessible.

High-Level Architecture: Current State Context Diagram

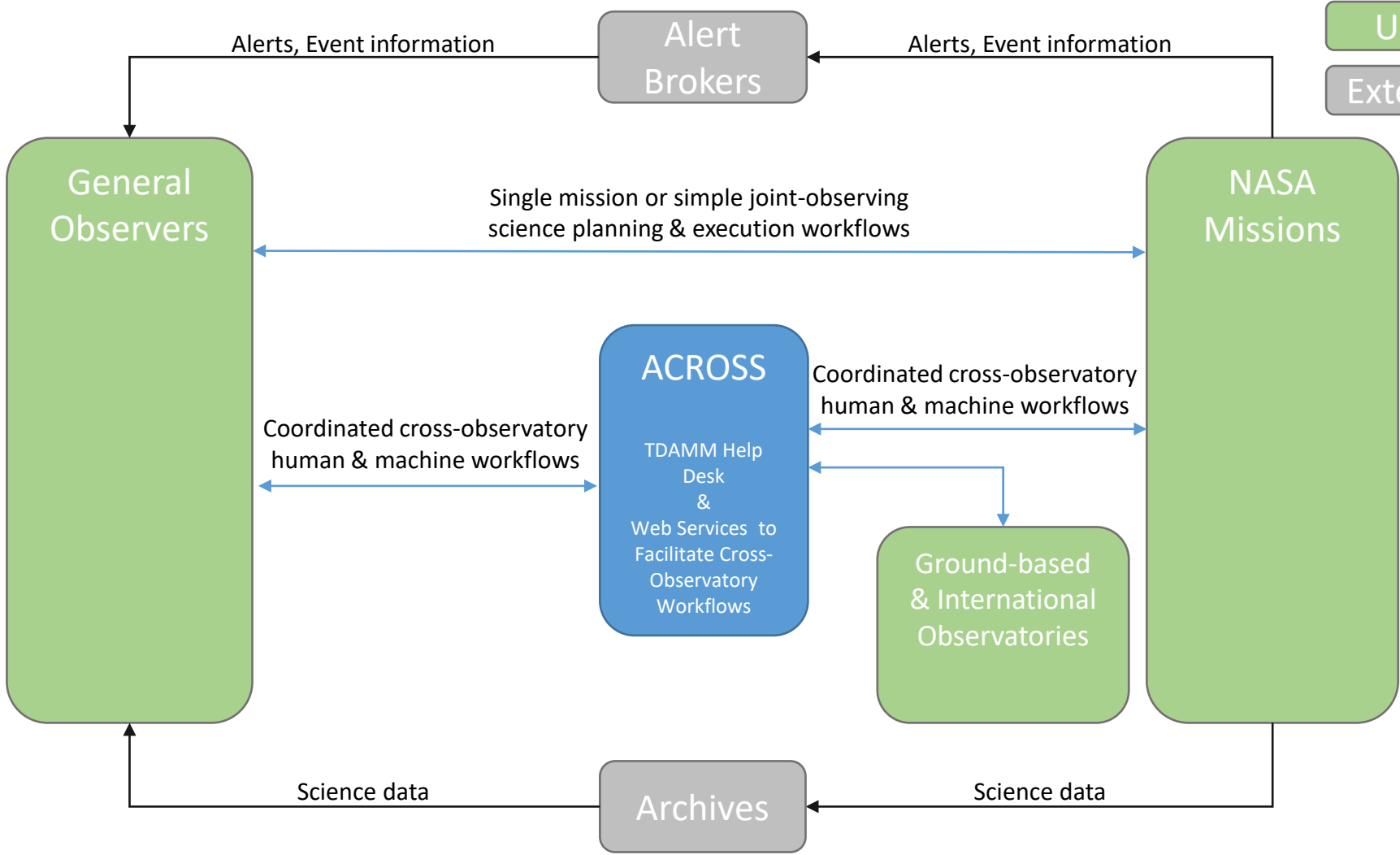
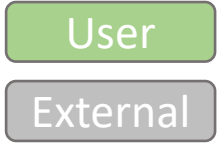
Science Support Infrastructure



High-Level Architecture: Future State Context Diagram

Science Support Infrastructure

Key:





ACROSS General Observer Use Cases

1. GO researches near-term (*minutes-weeks, TBR*) observatory workflow status associated with a TDAMM event.

Workflow status parameters for each mission may include: Orbit and pointing, Observing request created, submitted, rejected, approved; Observation scheduled, failed, completed; Data: in-queue (onboard), in-processing, available for analysis or at archive.

2. GO plans and analyzes near-term (*minutes-weeks, TBR*) observing feasibility of a TDAMM event.

Observing feasibility calculations can be for serendipitously observed sources in the recent past or for near-future new observations of the source. This use case emphasizes rapid, “first-order” screening for observing feasibility with multiple missions/instruments, including “schedulability” considerations; These calculations may not be suitable for fully specifying observing parameters for a requested observation or other tasking. If a calculation is feasible, ACROSS contact scientists may be engaged to facilitate more detailed interactions with mission subject matter experts. Recommendation functions also aid in complex planning and tasking decision making.

3. GO plans and specifies observing or other parameters for requested tasking to alter an observatory workflow.

Typically, a tasking request is for pointing to observe a “Target of Opportunity,” however, serendipitously observed sources may need tasking other parts of their workflows (e.g., priority downlink, processing, etc.). Mission-provided APIs or external/specialty tools may be required to fully specify observing parameters for specific instruments. Recommendation functions also aid in complex planning and tasking decision making.

4. GO submits a tasking request to change an observatory workflow to one or more science teams.

Tasking requests are associated with a TDAMM event record to enhance global situational awareness and inform future tasking sequences. A tasking request may be associated with a pre-approved GO Program (based on activation criteria in the proposal) or be unanticipated (DDT).

5. GO conceives, proposes and obtains funding to execute development of TDAMM tools.

GO interacts with ACROSS subject matter experts, submits proposals to ACROSS research grant program and obtains funding & administrative support services from ACROSS to execute the grant deliverables.

6. GO conceives, proposes and obtains funding and observing time to execute TDAMM science cases.

GO interacts with ACROSS subject matter experts, uses portal information content and applications, submits proposals to ACROSS research grant program and obtains funding & administrative services from ACROSS to execute the grant deliverables.

7. GO researches or obtains TDAMM training resources or other career opportunities.

GO interacts with ACROSS subject matter experts, uses portal information content and web applications, attends workshops, participates in internships, post-docs or other mentoring activities hosted by ACROSS.



ACROSS Science Team Use Cases

1. Science team provides timely near-term status parameters of their science planning and execution workflows.

Submit parameters through the science team user interface.

2. Science team provides access to science planning and execution tools through a web interface.

TDAMM General Observers access high-fidelity mission team tools and tasking pages through ACROSS web interface or other community Target and Observation Manager platforms.

3. Science team obtains situational awareness of a TDAMM event to inform their planning and execution activities.

Access ACROSS situational awareness functions through the GO user interface.

4. Science team receives decision support and course-of-action recommendations for efficient and effective TDAMM science execution.

Current optimized recommendations for cross-observatory localization and follow-up strategies, flagging potentially duplicative observing requests or unintentionally redundant observations

5. Science team provides requirements, evaluates solutions, uses web applications or tailors reference software implementations that facilitate TDAMM science planning and execution workflows.

6. Science team coordinates periodically to enhance timely, efficient and effective TDAMM science operations.

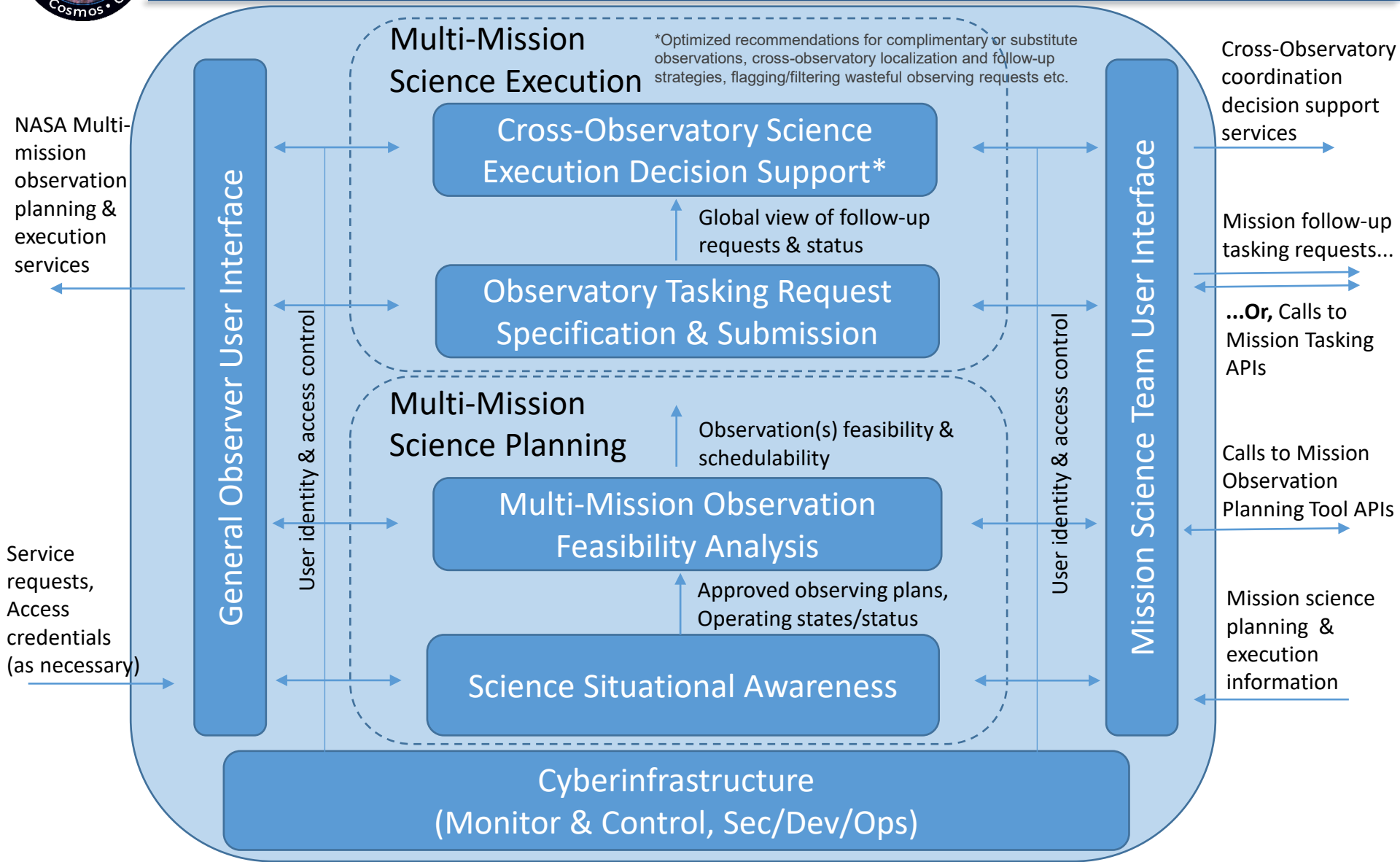
ACROSS contact scientists convene awareness and course-of-action pre-planning discussions about approved mission GO Programs that involve TDAMM source discovery or follow-ups. ACROSS contact scientists provide facilitate real-time communications among science teams during rare or community-defined high-priority TDAMM science events. ACROSS contact scientists filter and broker interactions with TDAMM General Observers, as requested by mission science teams.

7. Science team participates in evaluations of TDAMM community research proposals.

8. Science teams researches, obtains access to or contributes to TDAMM training resources and workshops.



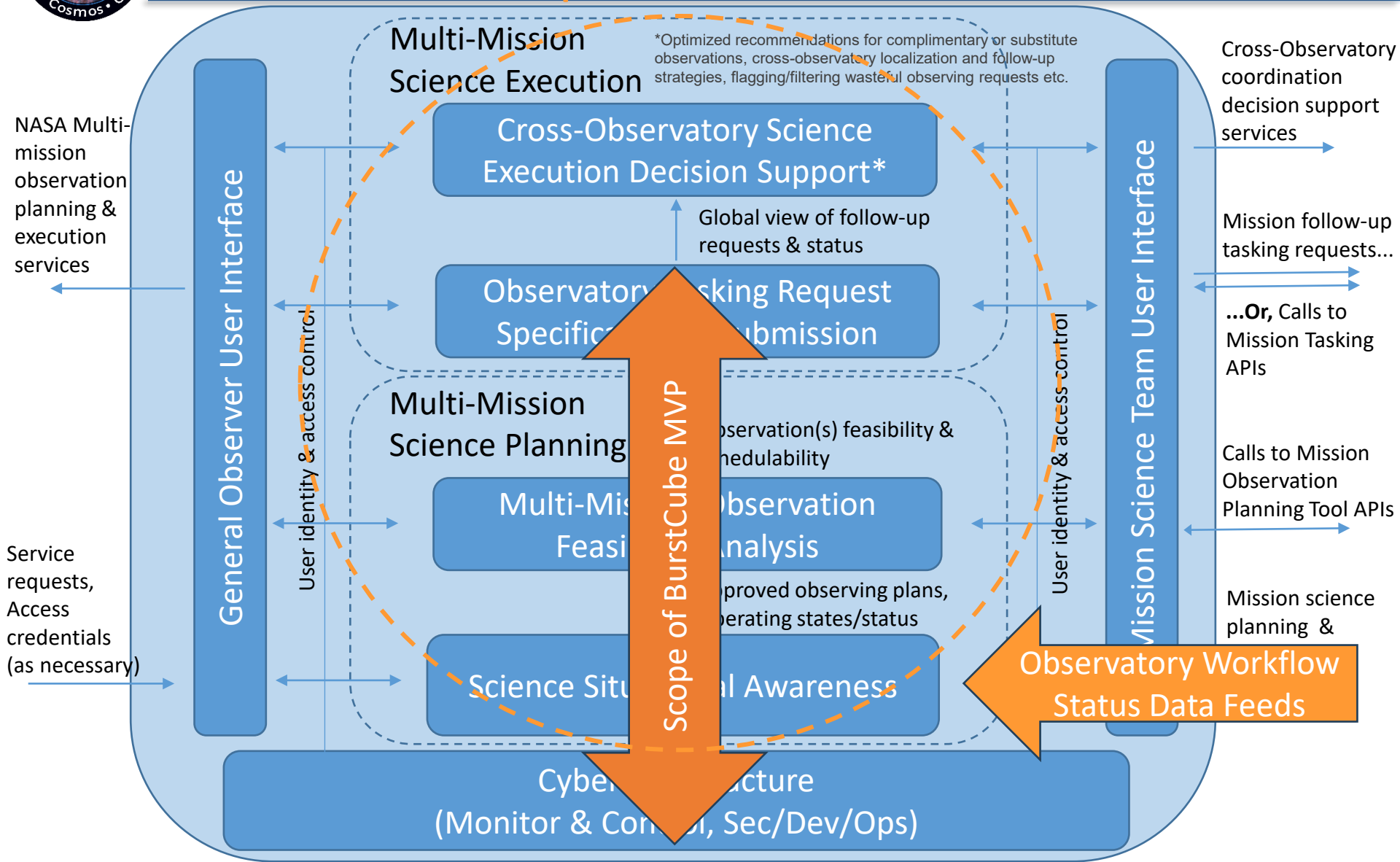
ACROSS Architecture: Web Services Internal Diagram





ACROSS Architecture: Web Services Internal Diagram

Scope of TDAMM Toolkit





PhysCOS TDAMM Initiative Schedule

Activity	FY24				FY25				FY26				FY27				FY28				FY29				FY30							
	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q				
Community Support & Engagement																																
Support to TDAMM SIG & Relevant SAGs																																
Engagement at Relevant Conferences & Events																																
NASA Funded TDAMM Workshop				▲								▲								▲												▲
TDAMM Grant Program (subject to funding availability)												▲				▲				▲				▲								▲
TDAMM Study																																
Phase 1 (NASA Assets) – Completed																																
Phase 2 (Other US Gov. Assets)	▲	—	—	▲																												
Phase 3 (International Assets)					▲	—	—	▲																								
ACROSS Project																																
Pilot Phase (Prototype-Use-Learn)	▲	—	—	—	—	—	—	▲																								
Sustainment & Continuous Improvement									▲	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—		
TDAMM Help Desk									▲	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—		

- **Community Support & Engagement**
 - Support to TDAMM SIG & SAGs (e.g. current participation in the Space Communications SAG)
 - Engagement at Conferences (e.g., recent presentations/posters at GRB50, NSF WoU, AAS Winter Meeting, APS, HEAD)
 - TDAMM Grant Program is in formulation, envisioned annual call starting FY26

- **TDAMM Study**
 - Study findings inform phasing of ACROSS capability requirements & TDAMM grant program design

- **ACROSS Project**
 - Pilot phase emphasizes improving TDAMM workflows, using agile software development process to drive use-learn-improve cycles towards a mature operational system that enriches the global multi-messenger ecosystem.
 - Initial Operating Capability synchronized with end of TDAMM Study and before start of TDAMM grant program.
 - Help desk provides support to TDAMM general observers and facilitates coordination among science teams.