TDAMM Comm SAG

- Why TDAMM? - Rapidly time-variable and transient phenomena motivate the most stringent requirements on communications.
- SAG membership recruited by invitation for current missions and missions in development, communications experts, and open community call (~30 participants).
- Defined TOR, and met monthly from July 2023 - March 2024 to discuss each Topic in TOR.
- Compiled report with case studies and findings.
- Provide report to APAC who make recommendations to NASA regarding communications to enable the science of TDAMM.
Current NASA Communications Services

- **Near Space Network**
  - Supporting missions <1M miles from Earth
  - Space Relay (TDRS)
    - Spacecraft initiated demand access
    - Low-latency commanding
    - High data rate, high coverage
    - Example usage: Hubble, Fermi, Swift, ISS
  - Direct to Earth (DTE) ground stations
  - Commercial Stations Supporting NSN

- **Deep Space Network (DSN)**
  - Supporting missions typically >1M miles from Earth
  - Example usage: TESS, JWST, Chandra, planetary missions

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Future Challenges with NASA Communications Services

Space Relay - TDRS

- NASA is not planning to replace TDRS satellites, but continuing to operate fleet into the 2030’s
  - Last TDRS launch in 2017 (TDRS-13)
  - Services are already degraded - TDRS-9 decommissioned January 2023
  - Guam ground station damaged after Typhoon in May 2023, service to TDRS-275 restored in June 2024
    - Caused ~10 minute gap in continuous coverage for >1 year
  - Only missions in development (COSI, StarBurst) allowed to use TDRS, but only guaranteed in prime mission
  - Hubble and ISS are the major users - future of TDRS uncertain beyond their operation

Ground Network - DTE & DSN

- DTE provides access to NASA and some commercial ground stations
  - Limited access to Ka-band stations
  - Adopting use of additional commercial ground stations will help alleviate congestion
  - On-the-fly comms requires modernization of scheduling interfaces
- DSN utilizes 3 capable antennas
  - Oversubscription is limiting utilization by missions
  - Advance scheduling makes it not ideal for TDAMM
Communications Services Project (CSP)

- Study of commercial space relay replacements for the TDRS system
- Six Funded Space Act Agreements (FSAA) to commercial industry partners with the objective of demonstrating end-to-end services to meet multiple NASA mission use case
- Developing portfolio of validated commercial services that will be ready for adoption and acquisition by NASA missions no later than 2030
- Ultimately RfP process open to all commercial service providers
- TDAMM Comm SAG co-chairs participating in Commercial Services Users Group (CSUG)

<table>
<thead>
<tr>
<th>FSAA Partner</th>
<th>Architecture</th>
<th>Mission Partners</th>
<th>Demo Complete</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amazon project kuiper</td>
<td>Optical LEO Network</td>
<td>Amazon mission &amp; Blue Canyon</td>
<td>Q3 FY25 Q1 FY26</td>
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<tr>
<td>SpaceX</td>
<td>Optical LEO Network</td>
<td>Commercial Crew</td>
<td>Q1 FY26</td>
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<td>Viasat</td>
<td>GEO commercial Ka-band</td>
<td>Maxwell &amp; Loft Orbital</td>
<td>Q1 FY26 Q2 FY26</td>
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<td>Inmarsat</td>
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<td>GEO C-band and MEO commercial Ka-band</td>
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<td>Telesat</td>
<td>GEO C-band and LEO commercial Ka-band</td>
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<td>Q1 FY27</td>
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</table>

https://www.nasa.gov/directorates/somd/space-communications-navigation-program/communications-services-project/
Other Future Capabilities

- Commercial ground stations
  - Commercial providers such as KSAT, AWS, and Azure offer Ground Stations as a Service (GSaaS)
  - Growing capability

- Laser Comms
  - Laser Communications Relay Demonstration (LCRD)
  - Deep Space Optical Communications (DSOC) - used for Psyche mission.
  - Commercial Laser Comms - e.g. Starlink Space-to-Space comms.

- Lunar Relay
  - Direct-to earth communication and navigation services for missions operating from 36,000 km in the GEO to cis Lunar and other orbits out to 2 Million km
  - S-band, X-band, Ka-band
  - Program in development

https://spacenews.com/aws-completes-six-ground-stations-changes-rollout-strategy/


**TDAMM Driven Communications Capabilities**

- A broad range of comms capabilities are needed at both predictable and unpredictable times.
- While existing NASA resources can meet these needs, they do not necessarily provide adequate flexibility, availability, and cost effectiveness.
- Upcoming replacement commercial services should improve upon current capabilities and maximize the science potential of NASA’s future fleet.

<table>
<thead>
<tr>
<th>Communication Capability</th>
<th>Usage</th>
<th>Technical Challenges</th>
<th>Examples</th>
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</thead>
<tbody>
<tr>
<td>Continuous Contact</td>
<td>Forward - commanding</td>
<td>Spacecraft Power</td>
<td>Space-to-Space Laser Comms Scheduling frequent passes on TDRS-MA, DTE, or commercial systems</td>
</tr>
<tr>
<td></td>
<td>Return - alerts</td>
<td>Availability, Geographical Coverage, Network Congestion, Complexity (pointing, handovers, etc.)</td>
<td></td>
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<tr>
<td>Demand Access</td>
<td>Return - small alerts (e.g. GRB notice). Spacecraft initiated contact.</td>
<td>Availability, Geographical Coverage, Complexity, Additional Hardware</td>
<td>TDRS-DAS, Commercial space communications</td>
</tr>
<tr>
<td>Low-Latency Data Downlinking</td>
<td>Frequent pre-scheduled passes. On-the-Fly scheduling of passes with low latency</td>
<td>Availability, Geographical Coverage, Automation. Flexibility.</td>
<td>KSAT-lite and other GSaaS providers.</td>
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<tr>
<td>High-Latency Data Downlinking</td>
<td>Download bulk data</td>
<td>Latency</td>
<td>DSN, DTE, TDRS-SA</td>
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</table>
Science Drivers

Science Topics defined by 2022 NASA-NSF TDAMM Workshop White Paper

- TDAMM science cases drive latency and data volume
- TDAMM drives the need for
  - Rapid alerting
  - Rapid commanding
  - Rapid downlinking for ground searches

<table>
<thead>
<tr>
<th>Capability</th>
<th>Science Examples</th>
<th>Onboard Alert Latency</th>
<th>Ground Search Latency</th>
<th>Follow-up Latency</th>
<th>Data Volume</th>
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<tr>
<td>Rapid Discovery and Reporting</td>
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<td></td>
<td>SGRs</td>
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<td>Supergiant Fast X-ray Transients</td>
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<td>Rapid Follow Up</td>
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<td></td>
<td>Neutron Star Merger (GW trigger)</td>
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<td>Nearby CCSNe (ν trigger)</td>
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<td>Fast Optical Transients</td>
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<td>Kilonova</td>
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<td>Novae</td>
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<td></td>
<td>CCSNe (γ-ray lines)</td>
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<td>Ground Searches of Large Datasets</td>
<td>X-ray binaries</td>
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<td>Orphan GRB Afterglows</td>
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<td>Variable Sources in Outburst</td>
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Non-LEO Orbits Offer Advantages to TDAMM Missions

Finding #1: Developing services to provide high-bandwidth, low-latency communications to non-LEO orbits is essential to enable future TDAMM missions.

Finding #2: Investment in developing new technologies that can provide spacecraft initiated demand access service or continuous communication links to non-LEO orbits is essential to enable future TDAMM missions.

Bandwidth, Latency, and Coverage
Limit TDAMM ConOps

Finding #3: To support TDAMM Science, future communications solutions should look to ensure that low latency, high bandwidth and high coverage is available for all missions profiles.

Finding #4: The flexibility of TDRS has enabled TDAMM science, therefore access to similar solutions with commercial services in the future will be crucial.

Finding #5: Due to the limitations of onboard computing, some missions require rapid or high cadence downlinks of large datasets to detect and characterize transients - a function that is not currently possible.
Availability and Scheduling Flexibility are Needed to Enable TDAMM Observations

Finding #6: High availability of communication networks on short notice is essential for TDAMM missions to rapidly schedule communications assets to both respond to target of opportunity (ToOs) follow-up observations and prioritize downlinking of data around events of interest.

Finding #7: The use of efficient modern commercial scheduling interfaces (e.g. APIs) will enable TDAMM observations, and are more efficient than existing SCaN interfaces. APIs provide realtime view of availability and eliminate back and forward interactions with human schedulers.

Deep Space Network Mid-Range Scheduling Process

https://aws.amazon.com/ground-station/
High Comms Cost Disadvantages TDAMM Proposals

**Finding #8:** In order to ensure that reliable and timely cost estimation by proposal teams is possible, teams need easy access to up-to-date documentation or tools to allow an accurate self assessment of projected communications costs.

**Finding #9:** Pursuing direct relationships with commercial communications providers allows proposal teams to realize potential cost savings.

**Finding #10:** Removing communications costs from PI Managed Mission Costs would ensure TDAMM missions are not disadvantaged compared to other missions with less burdensome communications requirements, and ensure communications needs are scientifically motivated, rather than cost-driven.
Lack of Transition Planning and AO Consistency Threatens Future TDAMM Capabilities

Finding #11: A smooth transition between communications services in the future ensures that AOs do not disadvantage missions whose science case depends on a service which is in transition.

Finding #12: Consistent communications requirements and costing across all NASA SMD AOs would ensure more accurate proposal development and evaluation.

Finding #13: Access to multiple providers through a common interface has potential to provide affordability and long-term stability to missions via bulk investment by SCaN.
Conclusions

- Commercial providers have great potential to enable TDAMM missions in Earth orbit, if implemented correctly (e.g. allow GSaaS scheduling APIs, transition planning and affordability).
- Non-LEO orbit solutions, which lack commercial development, provide an opportunity for NASA to invest in the future.
- Removing comms costs from AOs would ensure TDAMM Missions can compete on a level playing field with other mission types.
- We hope that APAC will endorse our report and the findings.