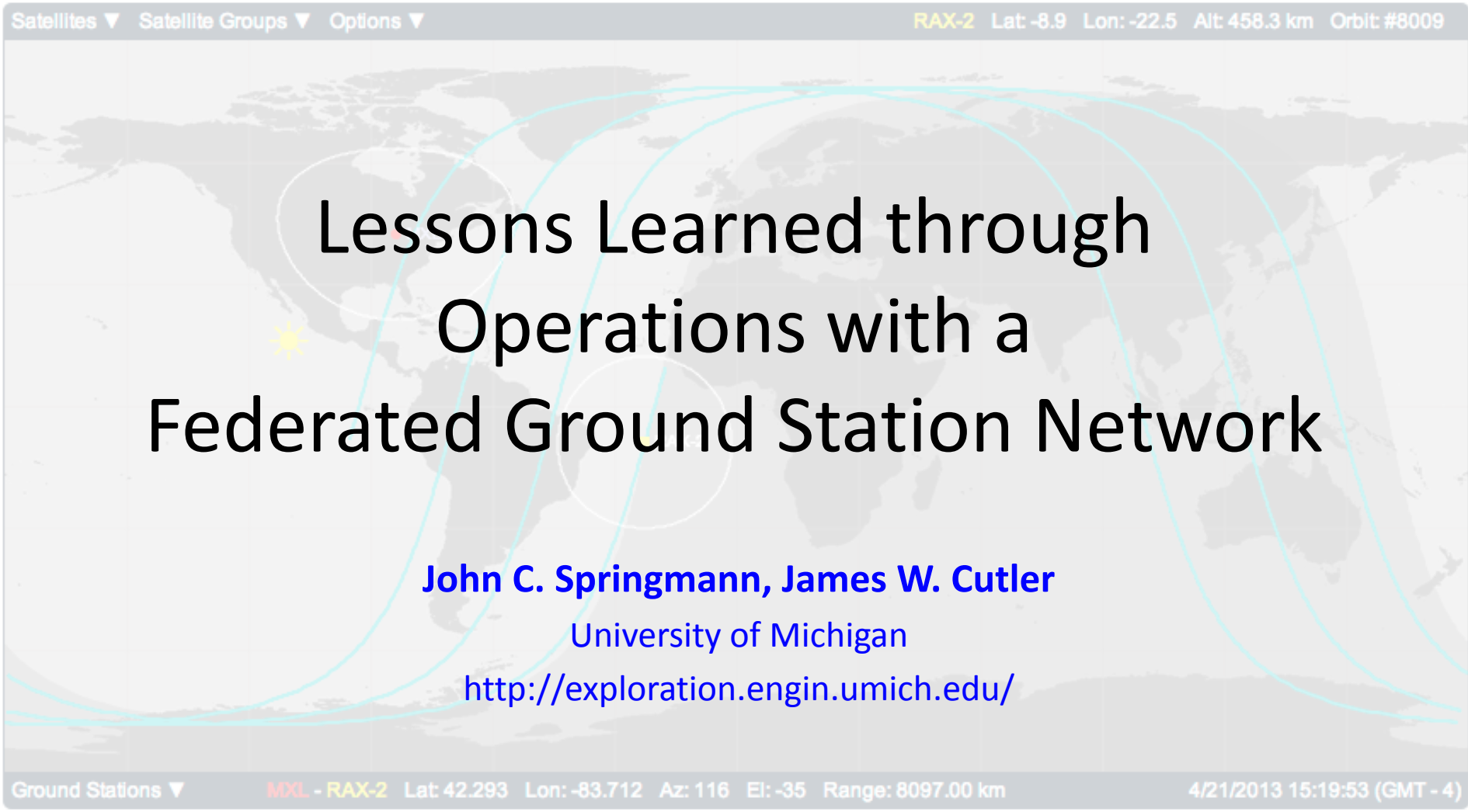

Lessons Learned through Operations with a Federated Ground Station Network

John C. Springmann, James W. Cutler

University of Michigan

http://exploration.engin.umich.edu/

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Federated networks – a *loose* connection of *independent* stations.

- 1990's – Federation enabled by the Internet.
  - Most software focused on single station operation.
- Late 90's – Mercury created to provide remote, Internet-enabled operations
  - Prototype, open source, complex
  - Small number of nodes to support QuakeSat and Opal.
- Early 2000's – GENSO created with Mercury lessons learned.
  - ESA led/controlled effort.
  - Closed source, ??? nodes.
- Commercial/private networks exist but no extended partnerships.
  - AFSCN, NASA, USN, Surrey network, NASA Ames/SCU network

Are we tapping the full potential of the global network?

http://gs.engin.umich.edu/gs_survey/

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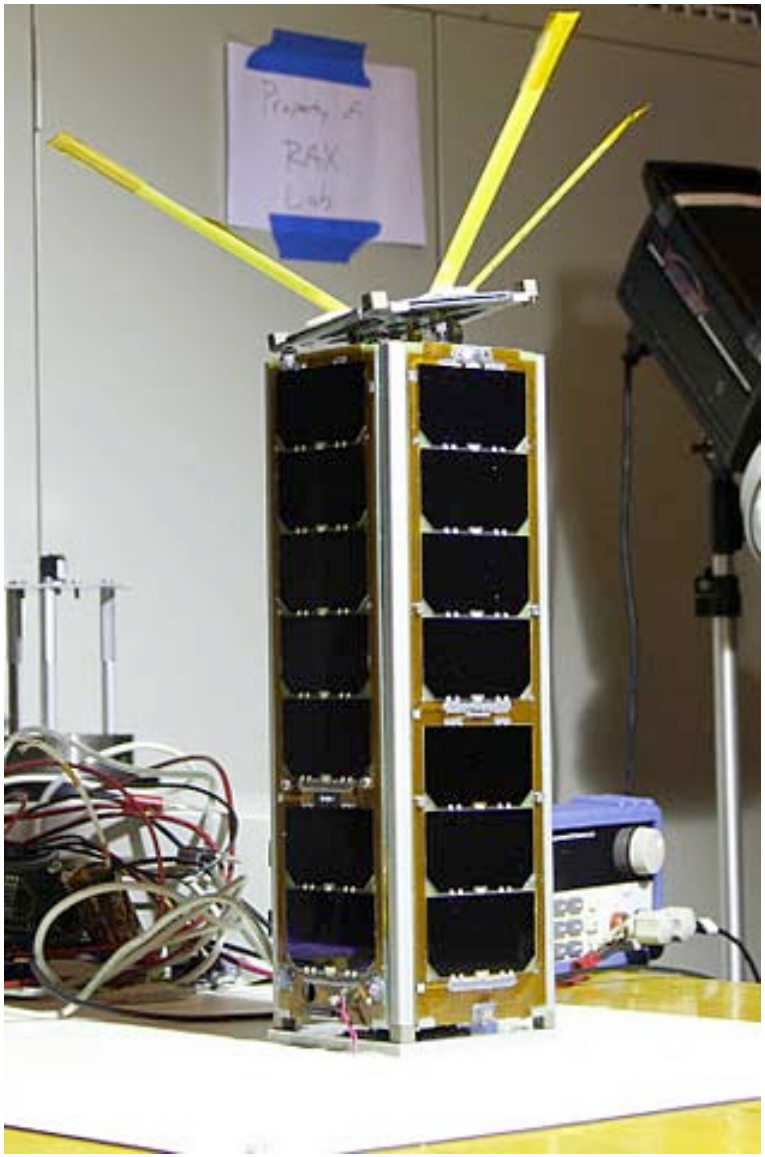
S. Spangelo, J.W. Cutler, A. Klesh, and D. Boone**, "Models and Tools to Evaluate Space Communication Network Capacity**", IEEE Transactions on Aerospace and Electronic Systems, Volume 48 , Issue 3, July 2012, pages 2387 – 2404, 10.1109/TAES.2012.6237598.

When we launched RAX-1 and RAX-2, there was no available "network".

- Launches:
  - 19 November 2010
  - 28 October 2011
- Communication summary
  - UHF half duplex
  - 9600 bps, GMSK
  - AX.25.
- Great collections of HAMs with ad hoc tracking.
- GENSO didn't have the capabilities or the tools.



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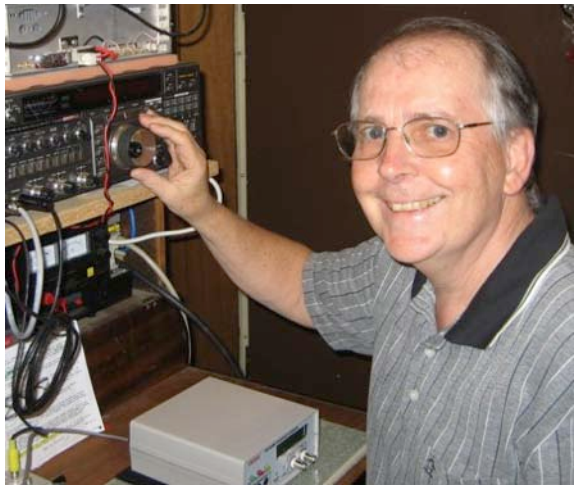
We were helped by some fantastic, global trackers.

Alan Creswell, ZL2BX

Mike Rupprecht, DK3WN



Colin Hurst, VK5HI

Tetsurou Satou, JA0CAW,

Mark Hammond, N8MH

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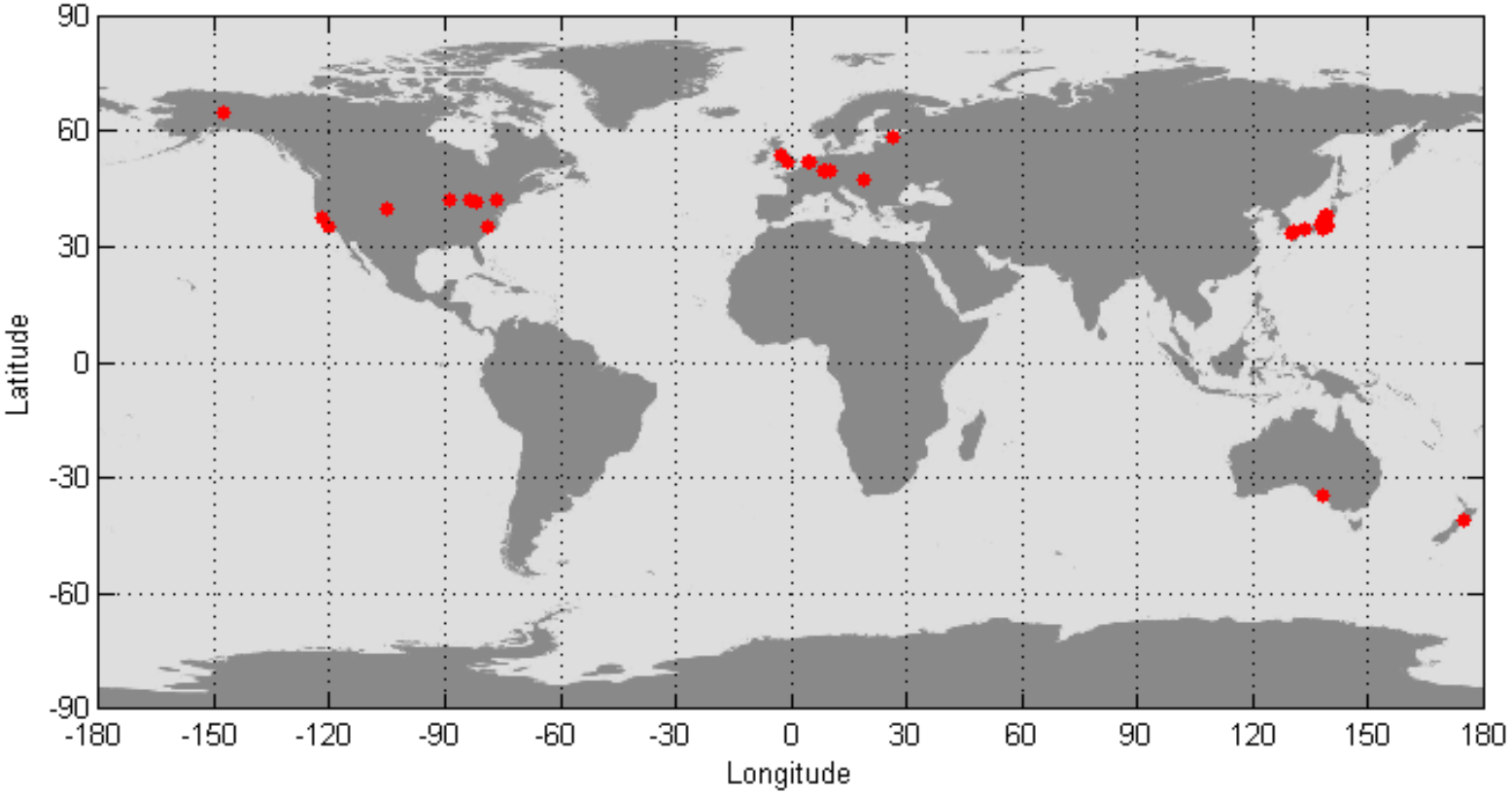
The network supporting RAX is global, and growing.

Map of all stations that have received RAX data with our client:



Recent additions of England, Estonia, Cornell University

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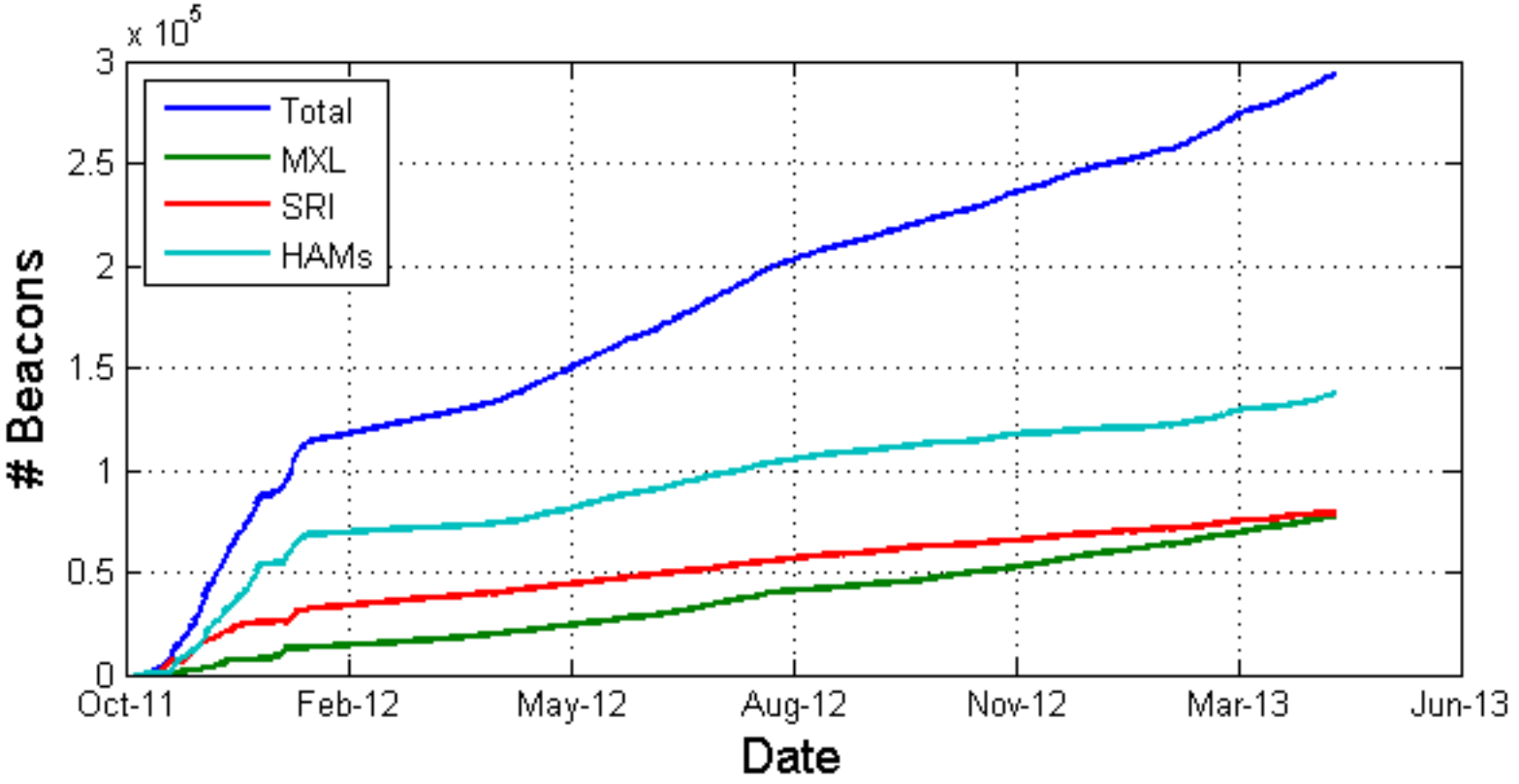
The network enabled dramatically improved downloads.

Cumulative beacons received over time:



293,344 total beacons

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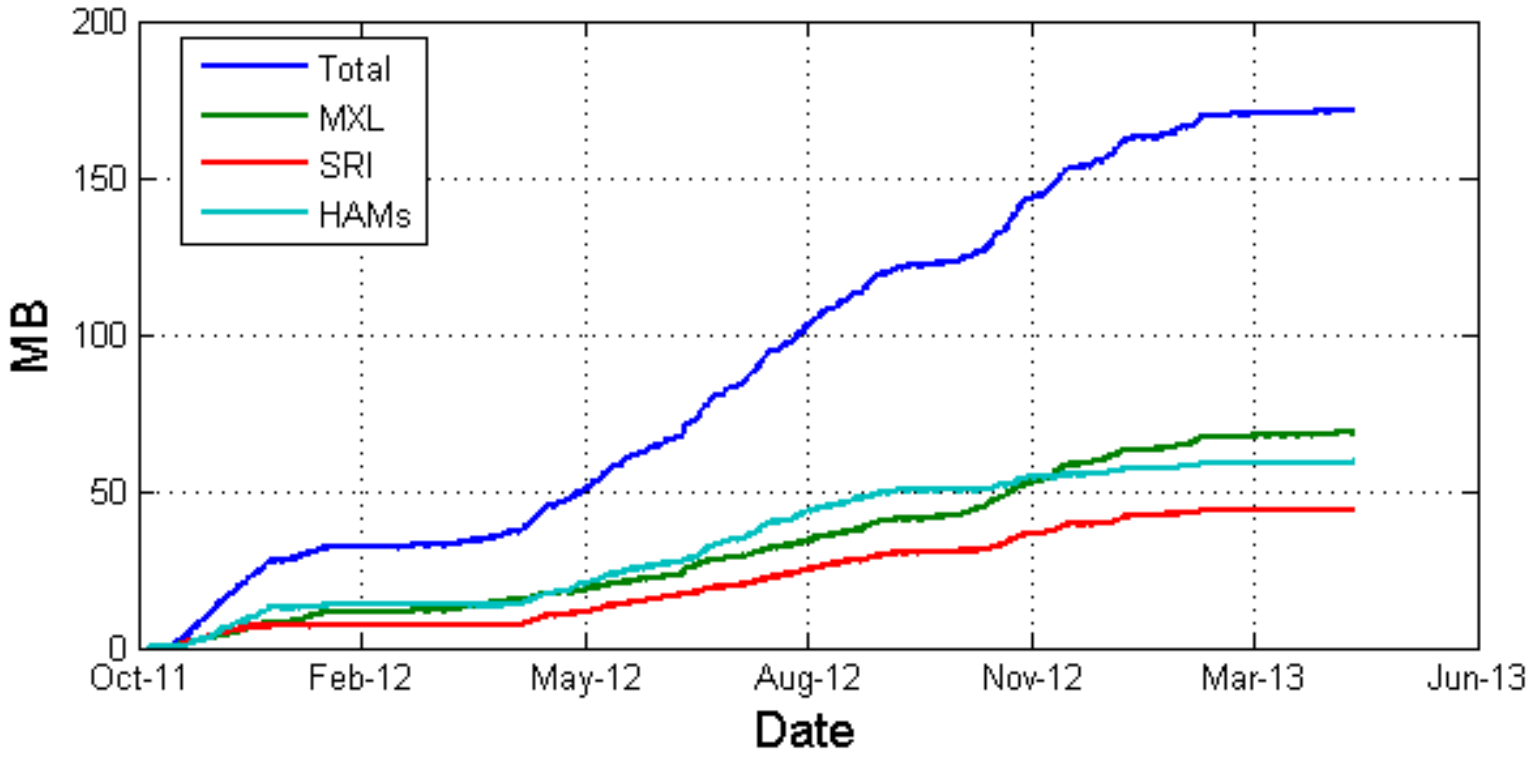
The network enabled dramatically improved downloads.

Cumulative data received over time:



172 MB total on 9.6 kbps link

(amount also limited by temperatures and command queue on RAX-2)

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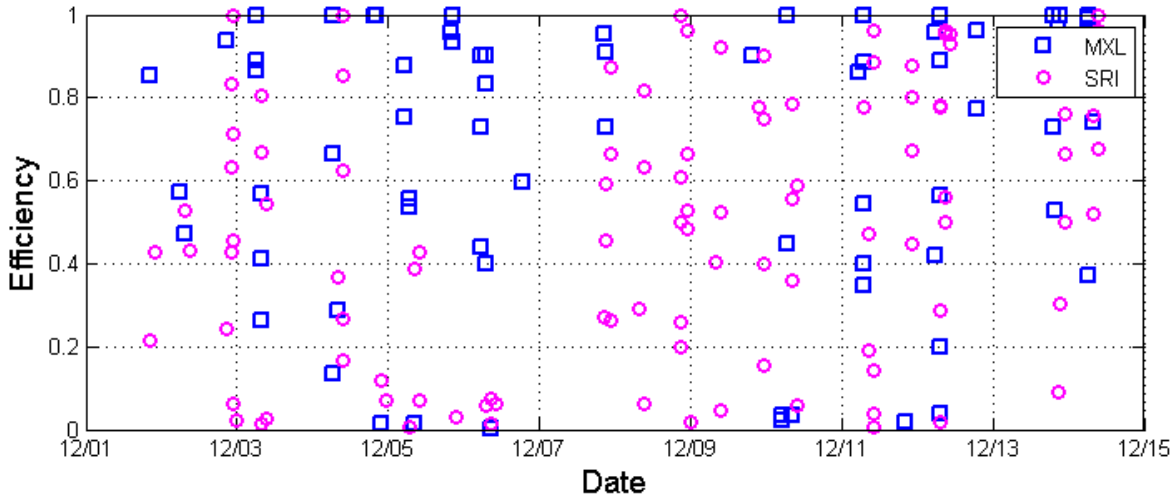
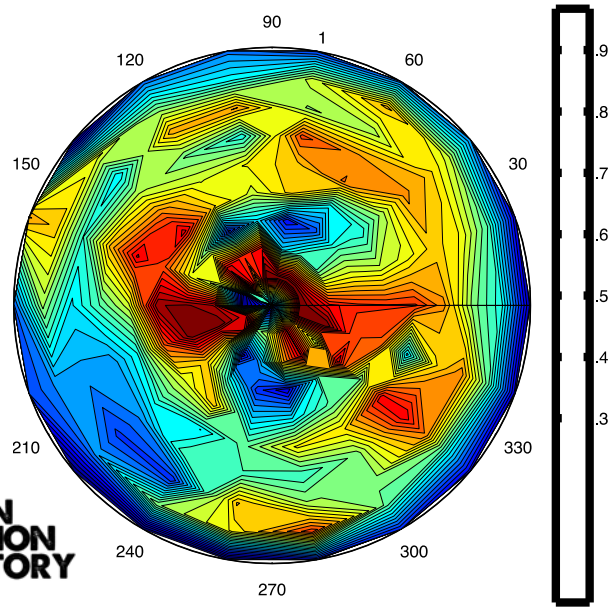
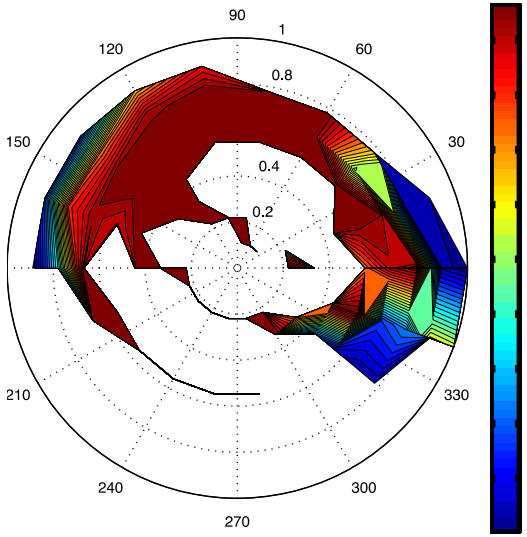
We monitor station performance and schedule according to recent reception and local plans.







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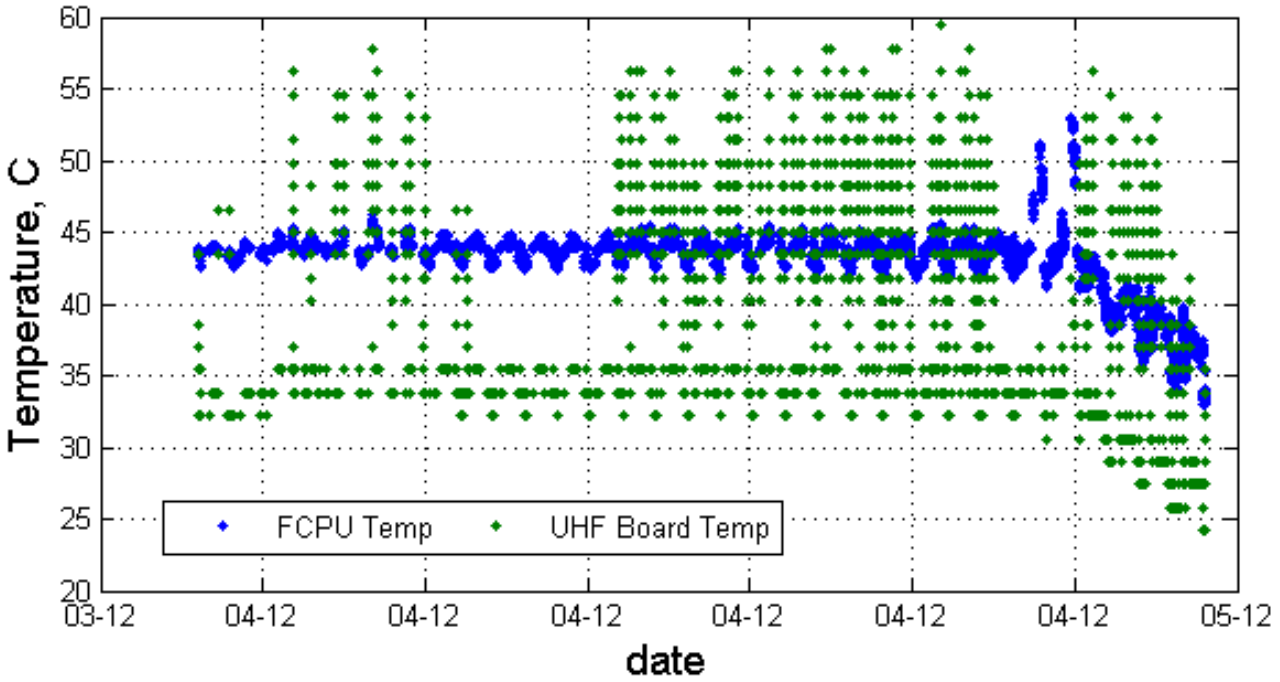
Downlinking scheduling based on priorities and satellite limitations (power and command queue).



- Command queue length limited by on board RAM – failed SD card prevents arbitrary lengths.

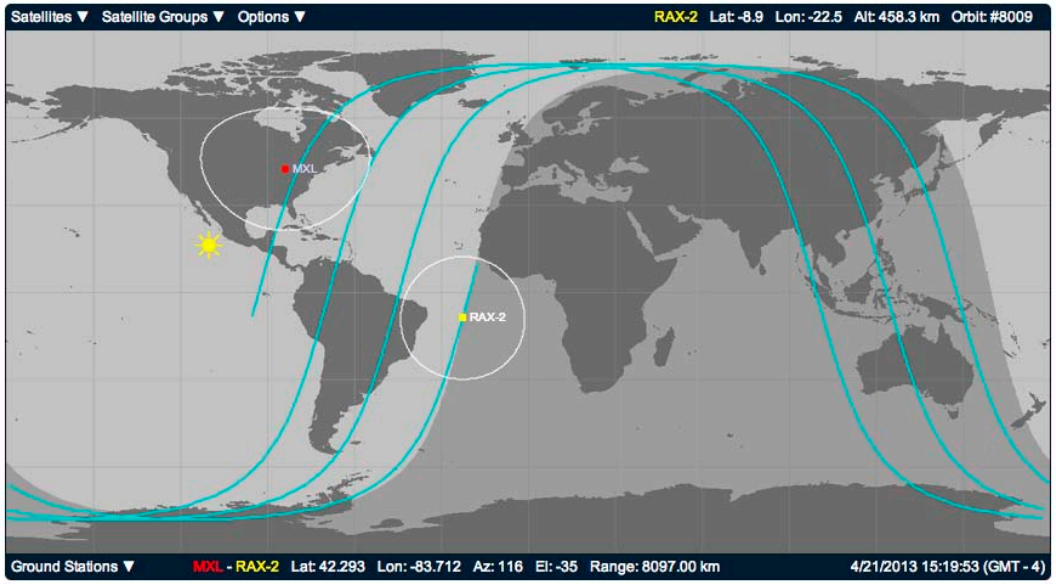
- Reduces stored commands on orbit and alters download profiles.

The network has enabled more data than expected, and we have learned a few things.

- HAMs are great…there is strong interest from all types to help.
- Make the software simple and easy.
  - RAX software is easy enough, but could be better.
- Use a NACK based protocol.
- Use what is already out there, but plan for the new.

Our next steps to federation—simpler code.

- Client code is moving from java to web application.
  - No install, “instant” upgrades and patches.
- *fetchTLE* – an open source web app for TLE fetching
  - Database-backed, time history
- *retroTrack* – simple, online tracking view tool
- *Mercury 2* – next gen. ground station system with global networking services. August 2013.



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Recommended community next step – *develop minimum standards with room to grow.*

- At what protocol levels do we attempt standardization?
  - Physical, link, network, application?

- Side step the complexity and look for a common denominator.
  - Standard for scheduling and describing GS capabilities.
  - Standard for "software defined ground stations".
    - We're all moving to SDRs (USRP, FunCube, etc, etc, etc).
    - Create a mechanism for running software – a virtual machine with the code.

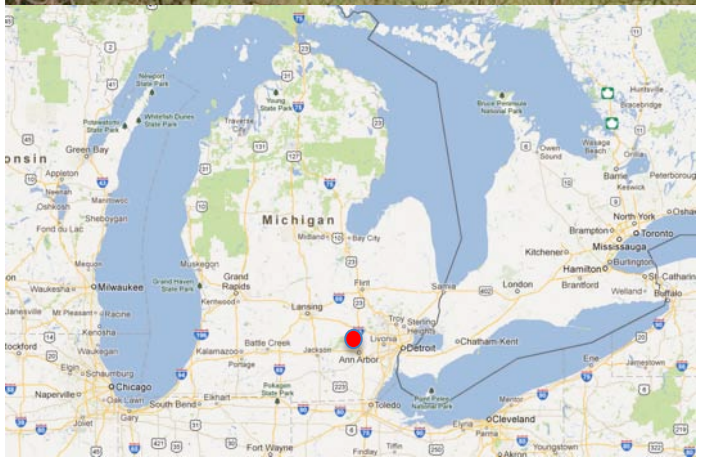
- This will future-proof upgrades and enable standardization to occur immediately and organically.

Also, at Michigan, we're working on high gain systems.

- Our satellite will continue to be resource constrained, let's leverage the ground.

- Upgrade Peach Mountain
  - 26 m radio telescope
  - Deep space and "slow" targets

- Site for future testing and collaborations
  - 5-12 m dish site
  - Laser communication
  - Available to the community.



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Thanks for your time…

Most teams don't think about ops until post launch…but with CubeSats, launch is a constant activity. Let's solve some of the ops challenges.

Any questions?

http://exploration.umich.edu/

http://gs.engin.umich.edu/