

Lessons Learned through Operations with a Federated Ground Station Network

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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

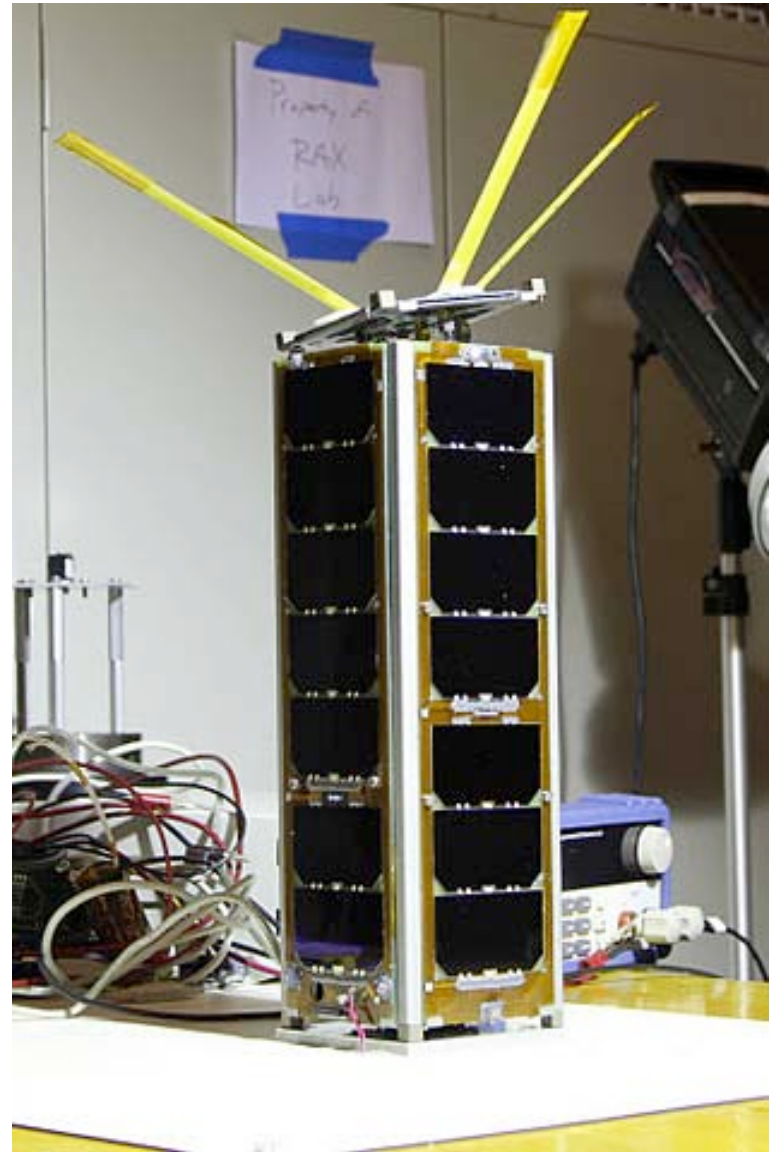
Are we tapping the full potential of the global network?



http://gs.engine.umich.edu/g_s_survey/

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.



We were helped by some fantastic, global trackers.



Alan Creswell,
ZL2BX



Mike Rupprecht, DK3WN



Colin Hurst, VK5HI



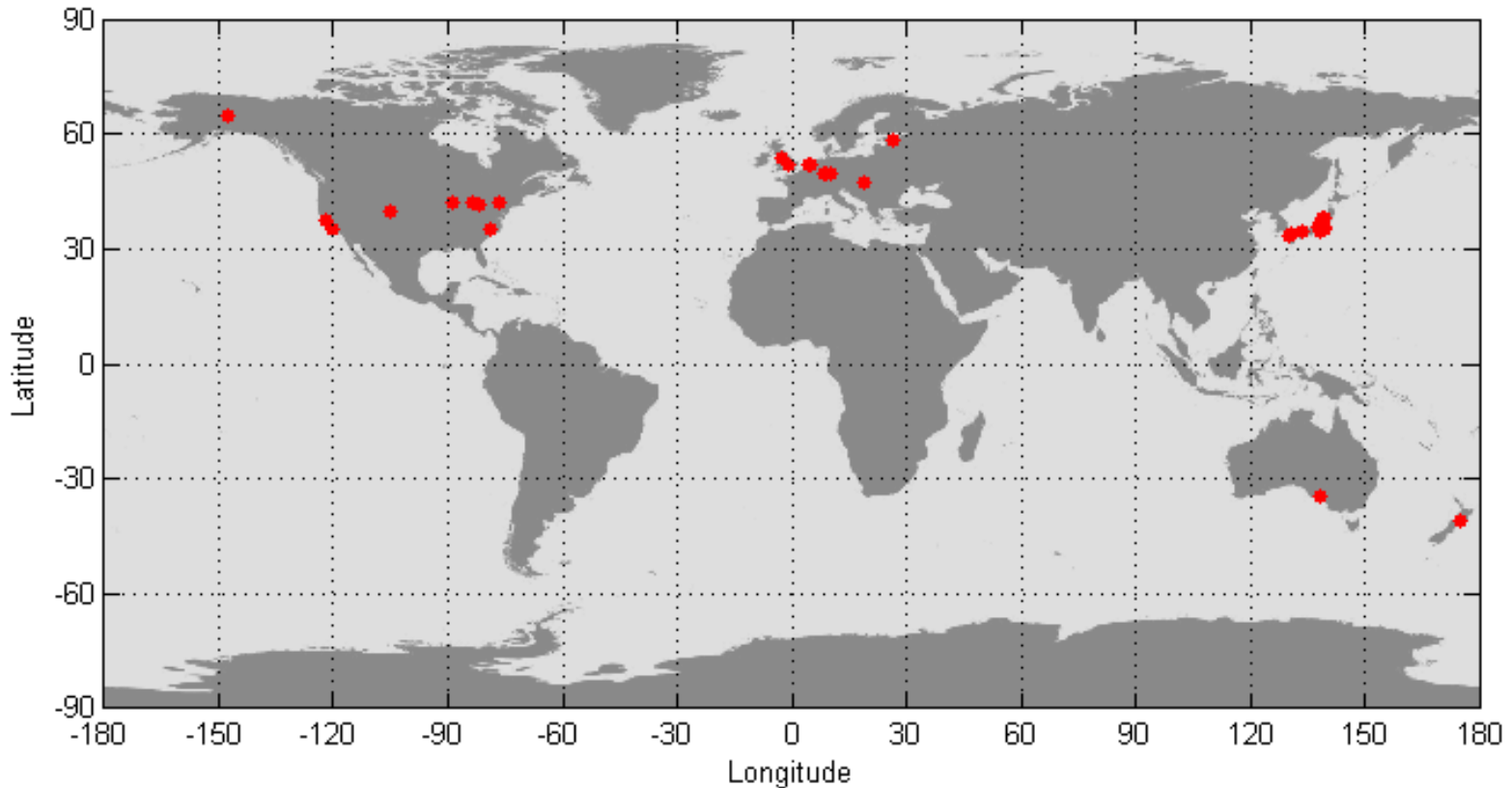
Tetsurou Satou,
JA0CAW,



Mark Hammond, N8MH

The network supporting RAX is global, and growing.

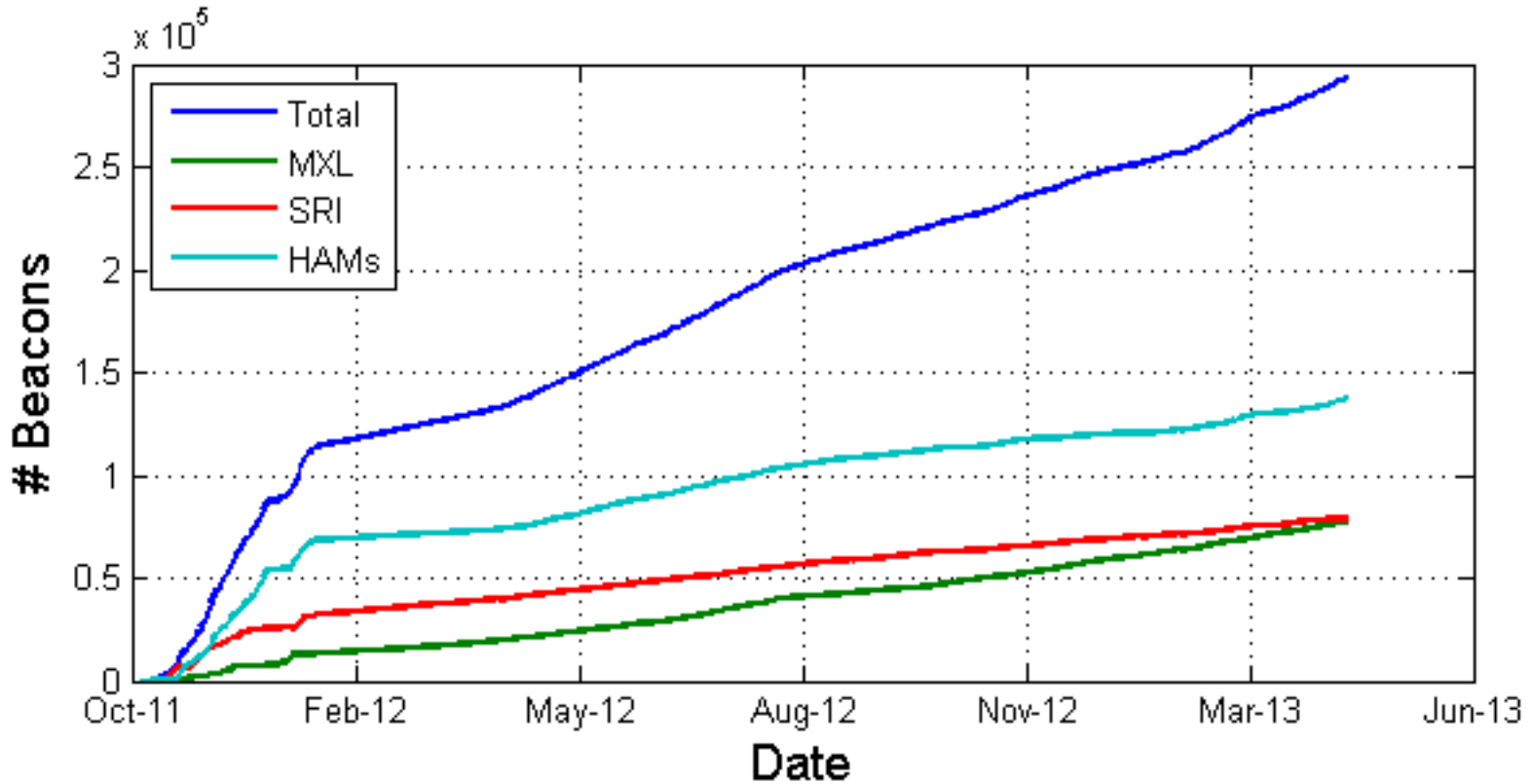
Map of all stations that have received RAX data with our client:



Recent additions of England, Estonia, Cornell University

The network enabled dramatically improved downloads.

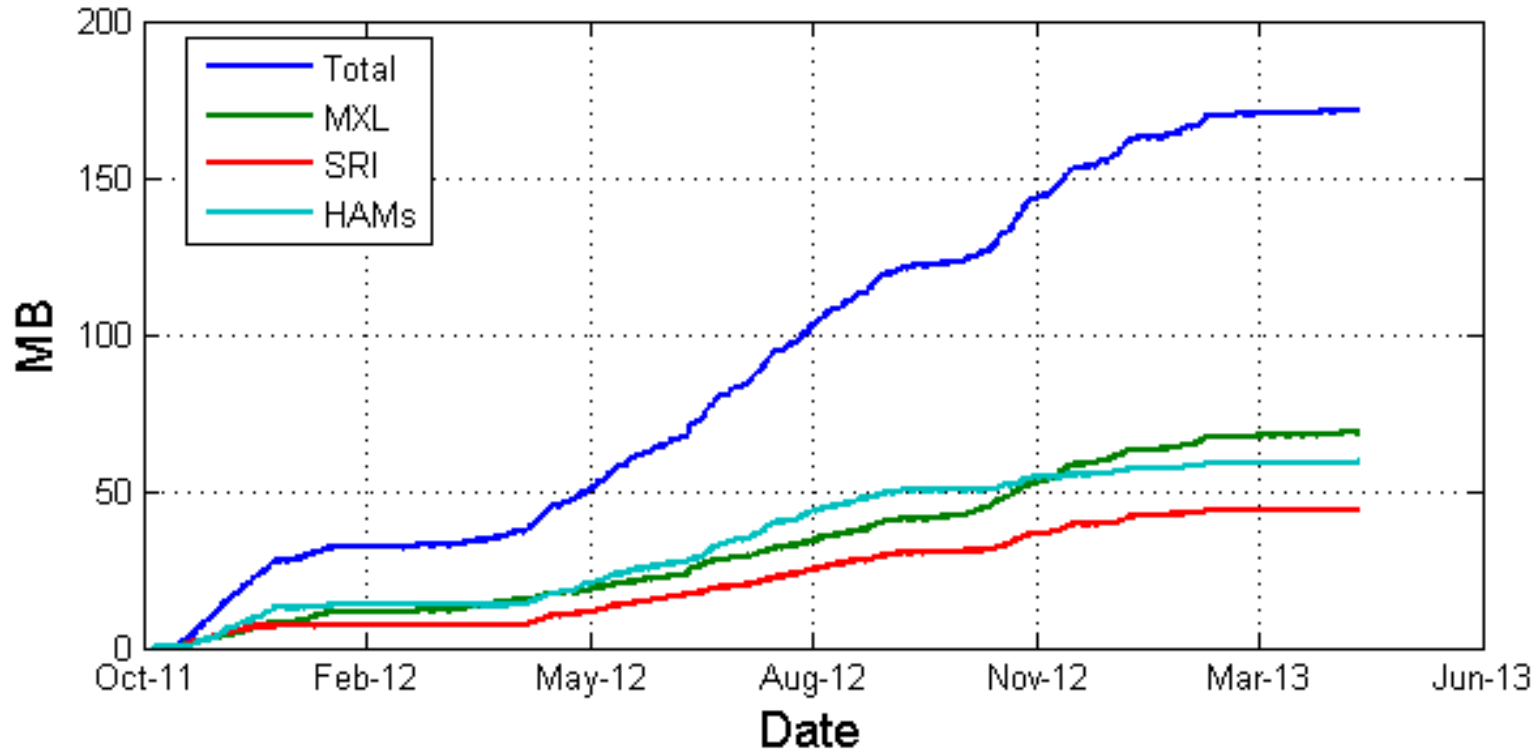
Cumulative Beacons received over time:



293,344 total beacons

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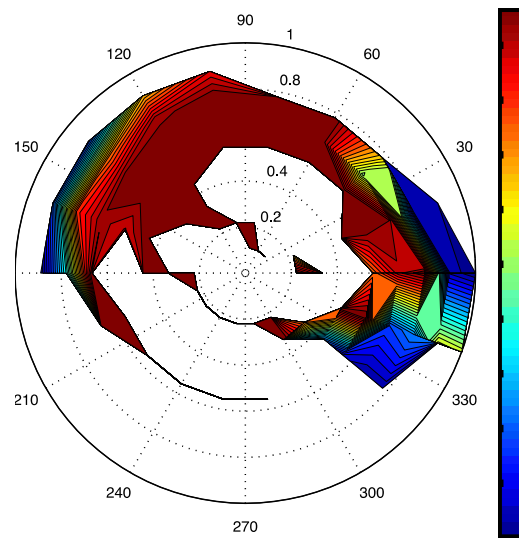
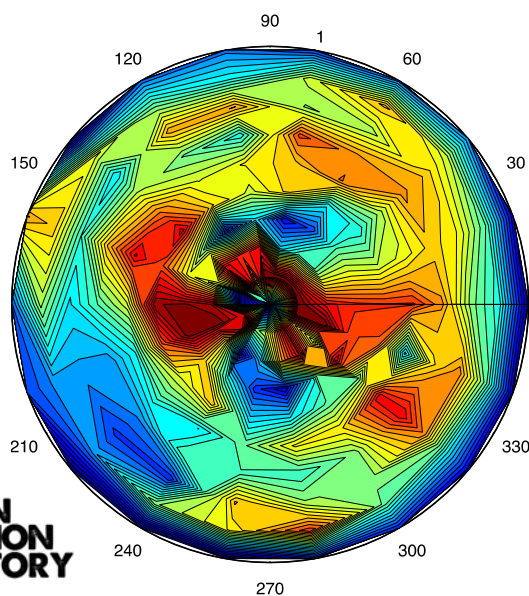
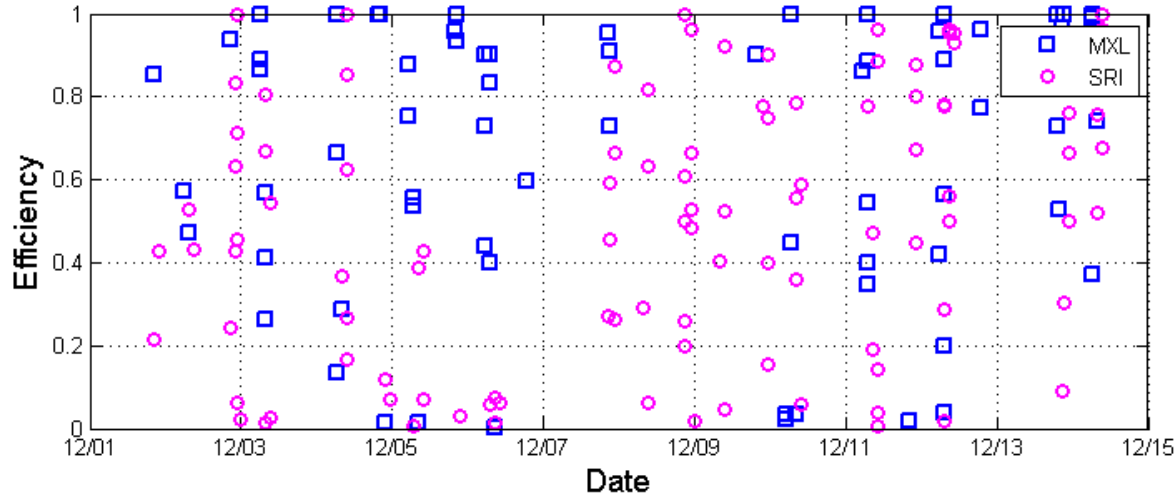
Cumulative data received over time:



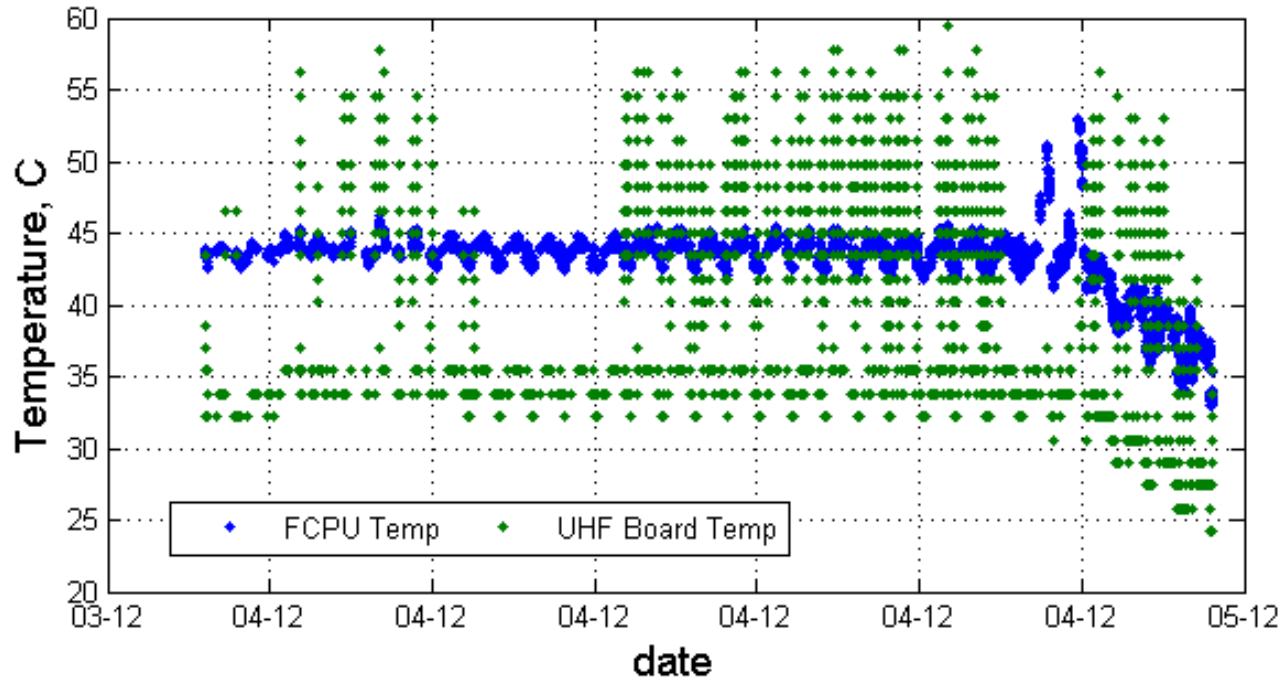
172 MB total on 9.6 kbps link

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

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



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



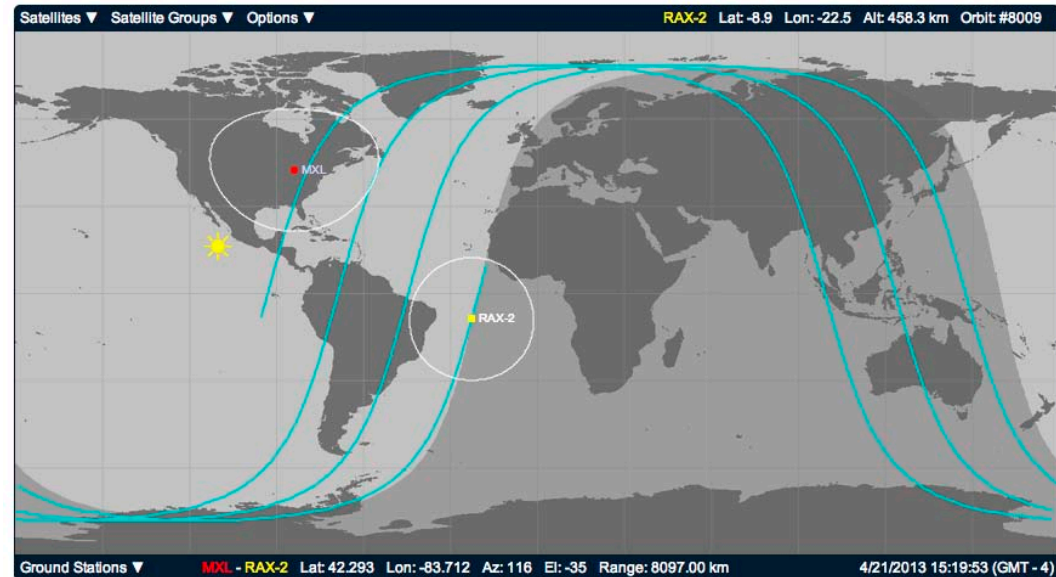
- Command queue length limited by on board RAM – failed SD card prevents arbitrary lengths.
- Reduces stored commands on orbit and alters download profiles.

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.

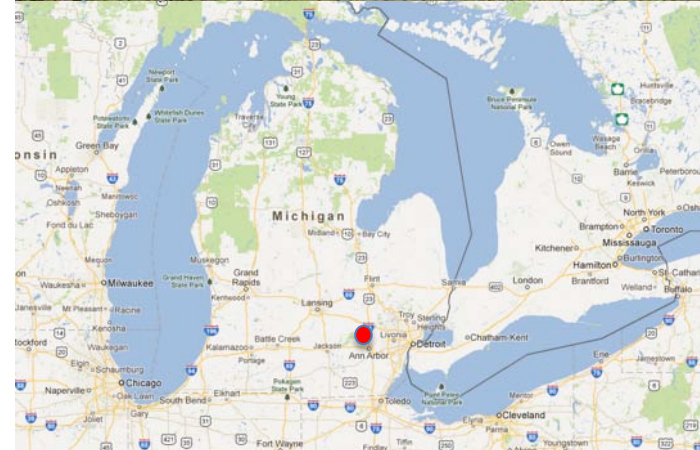


Recommended community next step – *develop minimum standards with room to grow.*

- 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.



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?

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