RAX Communication Reflections

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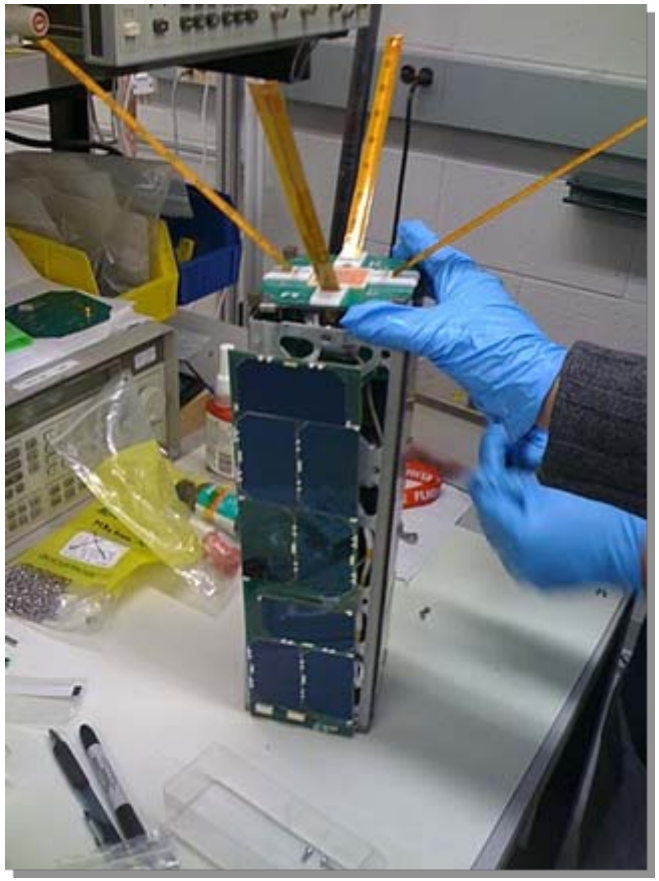
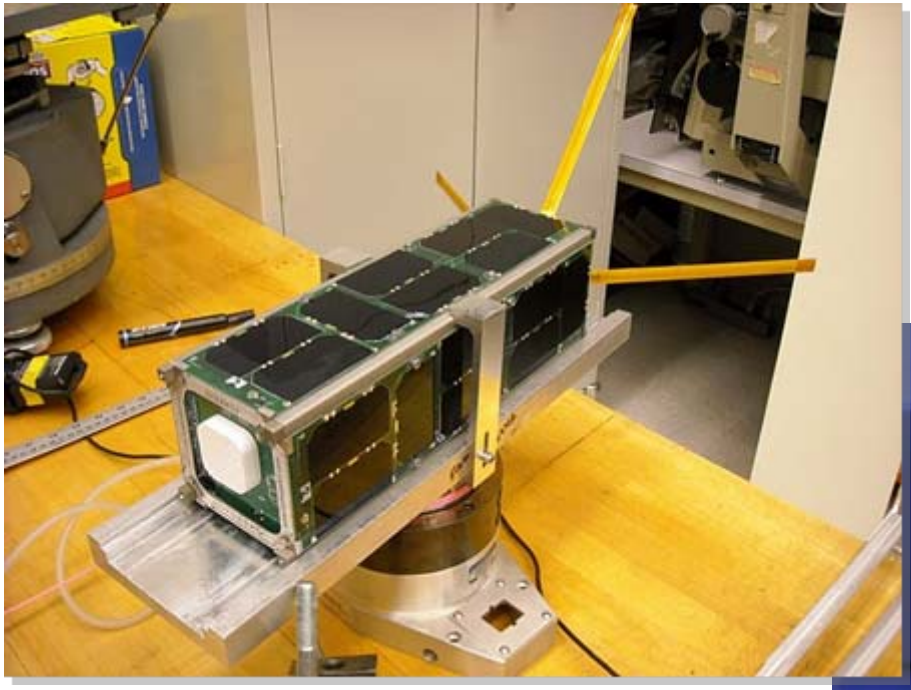
University of Michigan and SRI

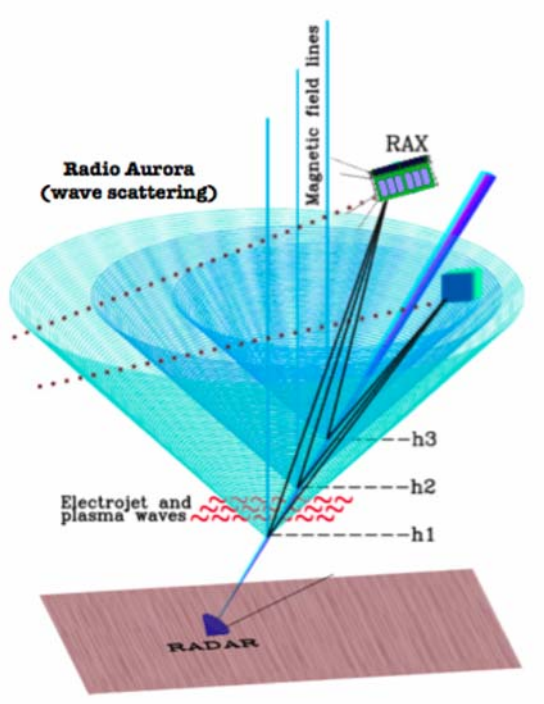
RAX EDU Ready for Shake Test



Example Integration Testing



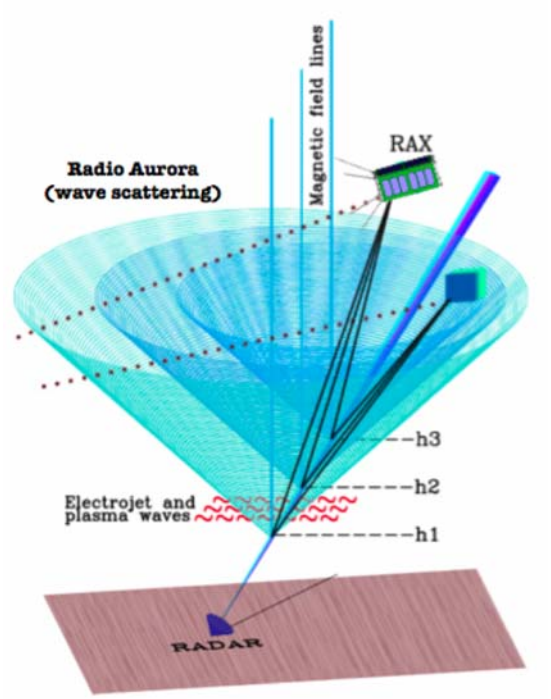
RAX Communication Requirements



Baseline Requirement

- 1 Experiment per day.
- 1.2 GB of data per experiment

RAX Communication Requirements



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Downlink time

- @ 10kbps = ~270 hours
- @ 1Mbps = ~ 2.7 hours

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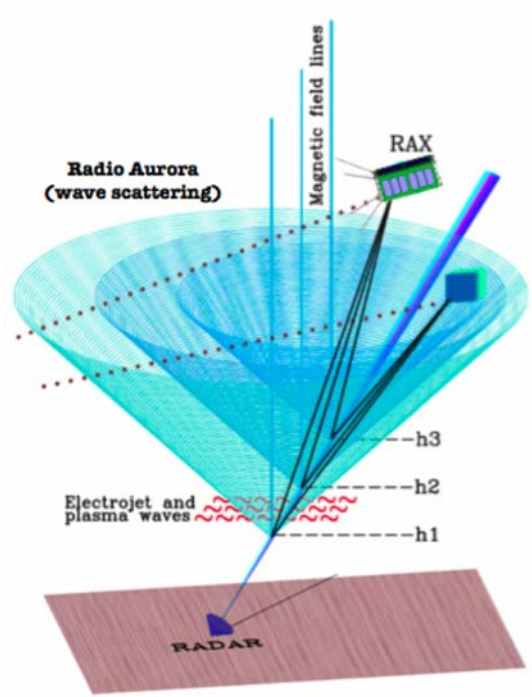

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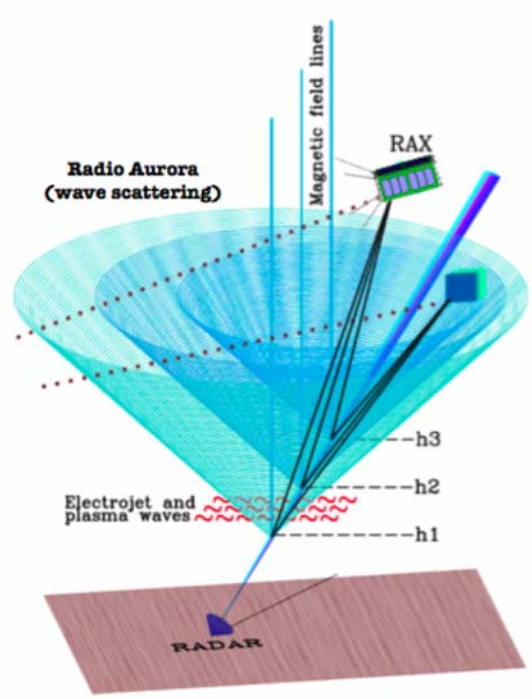

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Assessment: Communication is a bottleneck…
Optimal designs needed for resource constrained Cubesats.

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  - GPS or radar encoded
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Post processing Step 2

- **Radar pulse processing code**
- **Reduces data to 1MB's**

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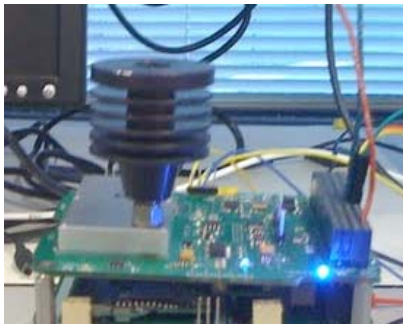
Post processing Step 2

- Radar pulse processing code
- Reduces data to 1MB's

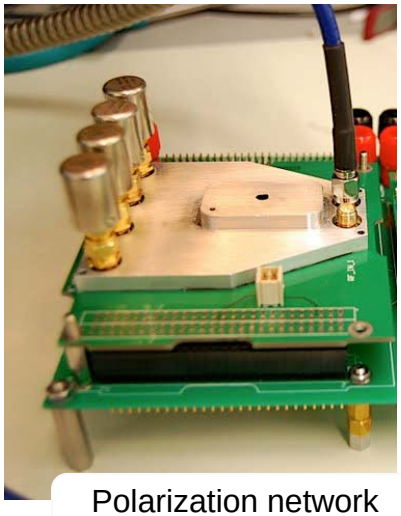
Requires system optimization especially with respect to power.

RAX Communication Architecture

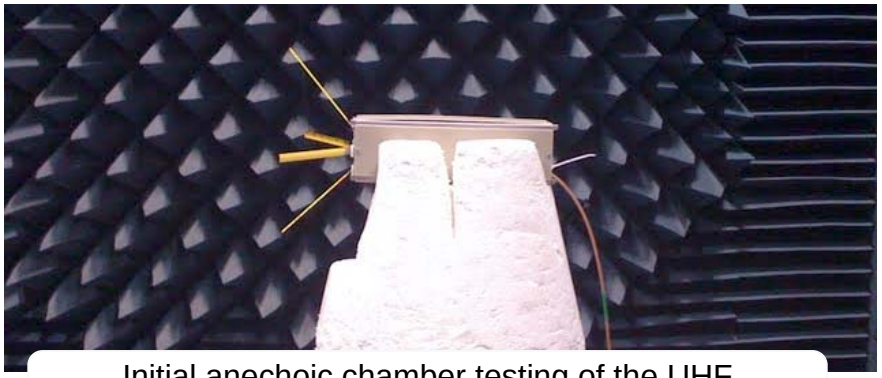
- Primary Radio
  - UHF < 100kpbs
  - Lithium-1 from AstroDev
  - In House antenna
  - Polarization network and switch from AstroDev.
  - HAM band
- Secondary Radio
  - MHX2400
  - Will fly a better option if available



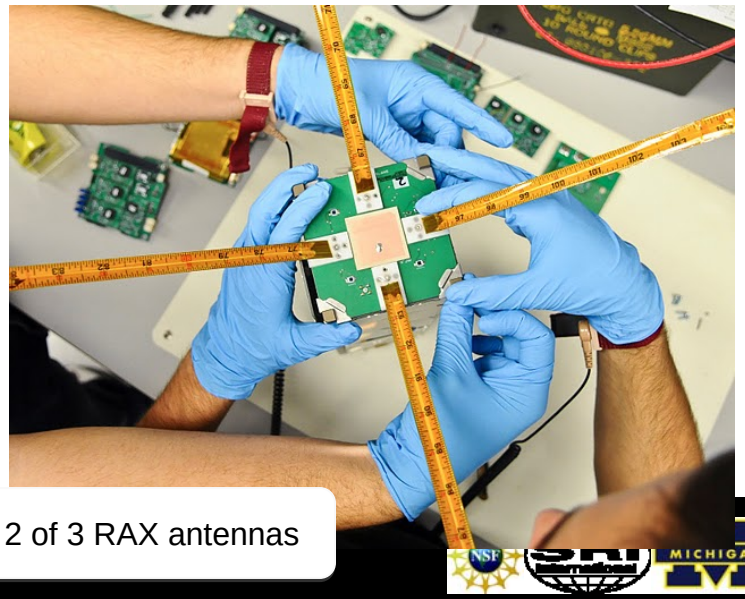
Lithium integrated on our UHF and Watch Dog board



Polarization network and antenna switch



Initial anechoic chamber testing of the UHF antennas.



2 of 3 RAX antennas

Forward Thinking

NSF community needs a system-wide, “holistic” approach.

- What bands can we operate on?
- What radios (space and ground) can we use?
- How do we harness global, heterogeneous ground stations?
- How do we identify satellite communication requirements during design and on orbit?
- How do we optimize system-wide scheduling?

For Example…Network Capacity Model

Amount of Data Exchanged per Period

Network Capacity of m ground stations:

$$C_N = \sum_{j=1}^{j=m} C_j,$$

From a ground station (j) perspective:

$$C_j = \sum_{i=1}^{i=n} \int_{t=0}^{t=T} a_{ij}(t) r_{ij}(t) l_{ij}(t) \eta_j(t) dt$$

With respect to satellite i
T = Period (1 day)

- *a:* Availability
- Average rate of data exchange
- *r:*Data rate
- *l:* Link feasibility
- *η:* GS Efficiency

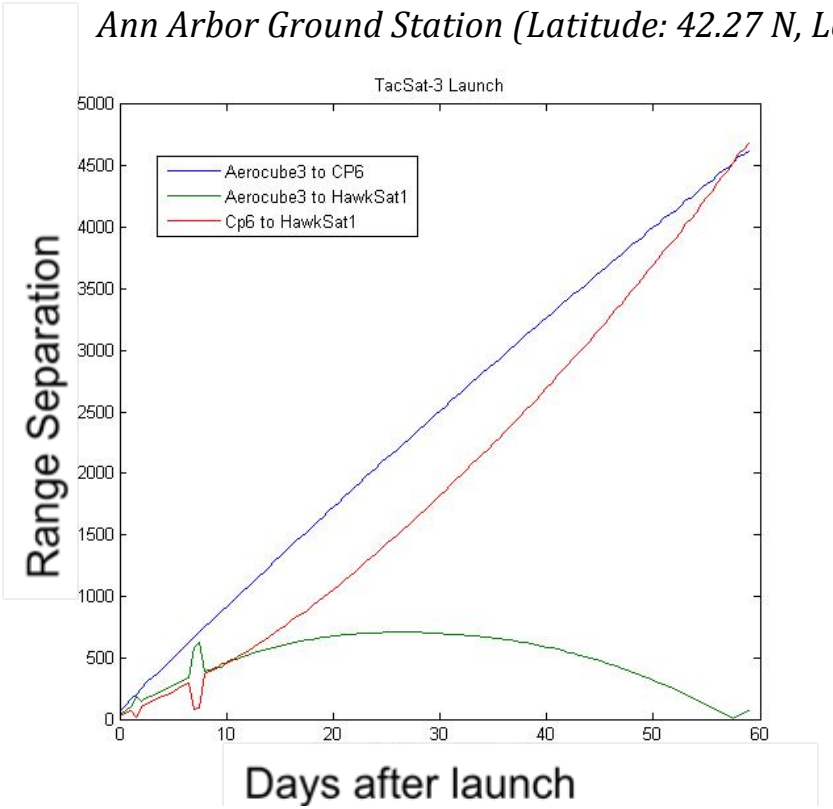
Capacity Simulations

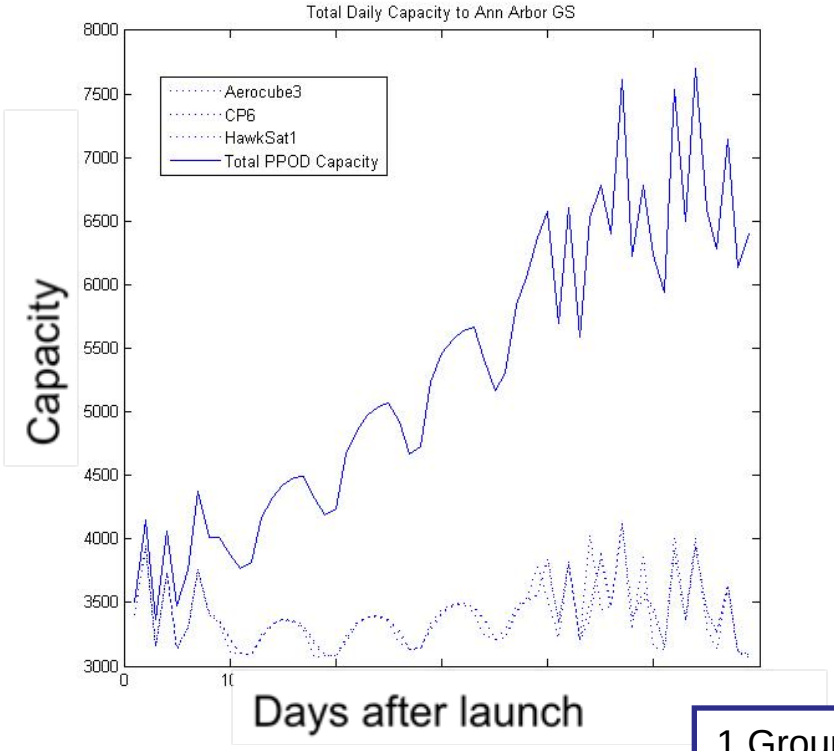
Orbital Parameters

Satellite	TacSat3 Launch
Inclination (i)	40.5°
Eccentricity (e_{avg})	0.003
Mean Motion (n)	15.4 rev/day
Semi-major axis (a)	6.83km

Network Capacity (Scheduled Model)

3 satellites in P-POD TacSat3 launch to
Ann Arbor Ground Station (Latitude: 42.27 N, Longitude: 83.74 W)

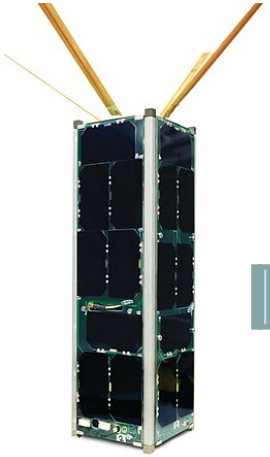




1 Ground Station
3 Satellites

For Example…Satellite Needs

Data Flow Model

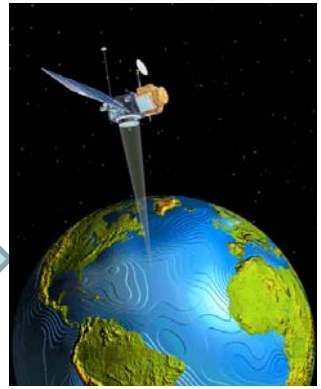


1. Data Generation

2. Filtering

3. Compression

4. Data Storage

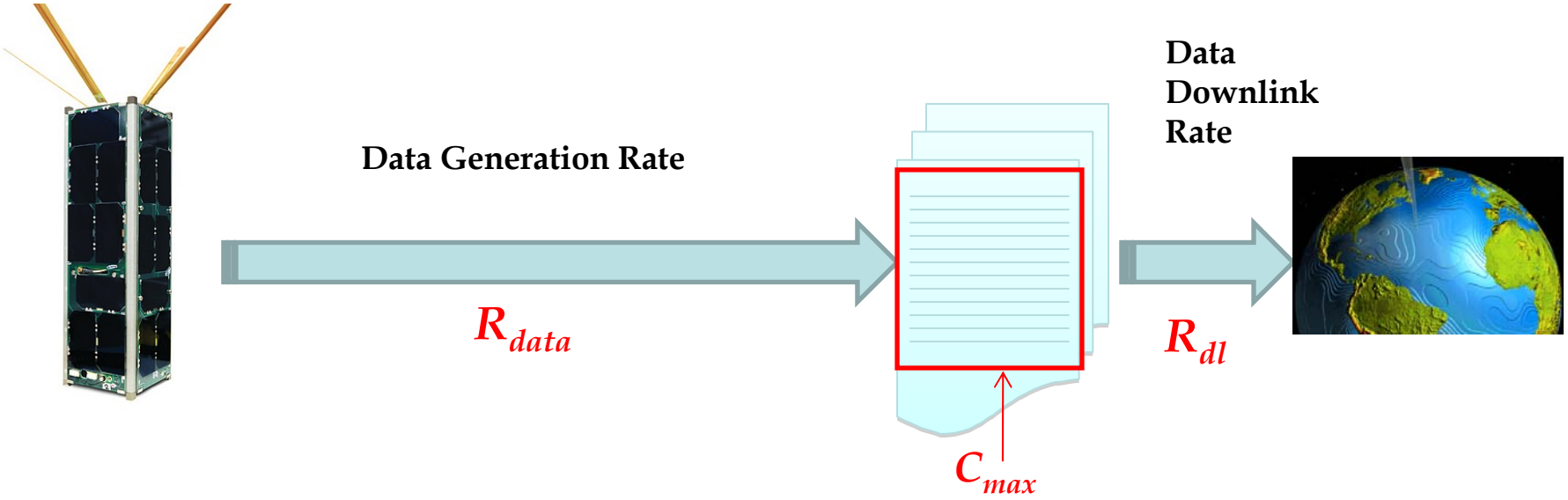


5. Download

Data flows from left to right in satellite operations.

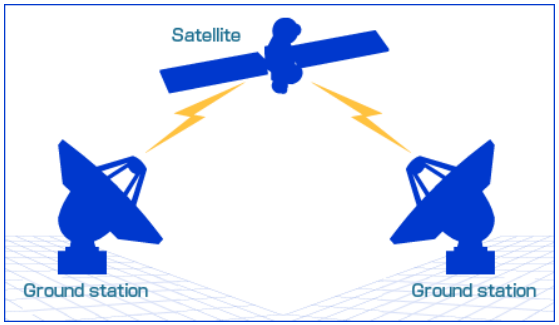
Image Credit: Tmackinnon Website

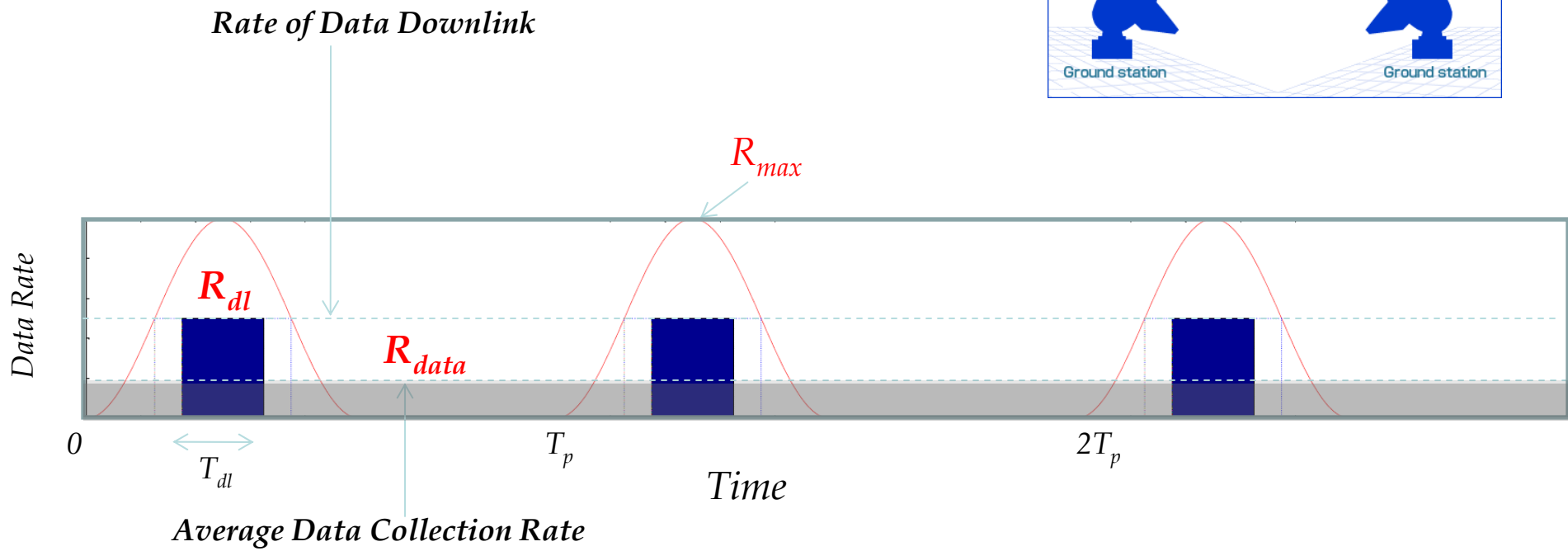
Data Flow Rates



- If $R_{data} > R_{dl}$, data stored in onboard memory.
- If storage capacity exceeded (C_{max}), old data deleted or new data lost.

Data Exchange





R_{data}: Data Collection Rate
R_{dl}: Downlink Data Rate
T_{dl} : Downlink Time
T_p: Period between Downlinks

- If $R_{data}T_p > R_{dl}T_{dl}$, data stored in onboard memory.

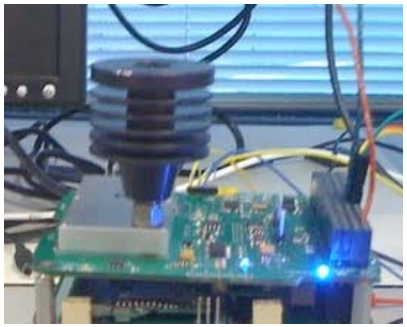
Our Next Steps

- Continue GS survey
- Develop model/survey for assessing *satellite communication needs*
- *Global optimization* of satellite contacts and operations in a dynamic community.

More Details

UHF Solution

- Built our “own” UHF radio
  - Founded AstroDev with Kevin Brown while at Stanford.
  - Government funding to develop low-cost radios.
- Lithium-1 radio
  - ~140MHz – 600MHz.
  - Select 20MHz band at build time.
  - AX.25 packetization.
  - Configured for single band (dual possible).
  - Up to 40kbps like past AMSATs (though > 100kbps possible).
  - Independent of “bus” system architecture
- In House Antenna design
  - Turn stile with optimal orientation for radar signal reception.
- Polarization and antenna switch
  - Partnered with AstroDev to develop.
  - Polarization control: LHCP or RHCP
  - Antennas shared by both payload and transceiver.



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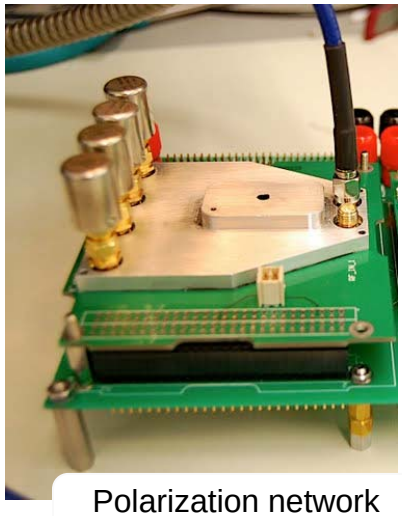

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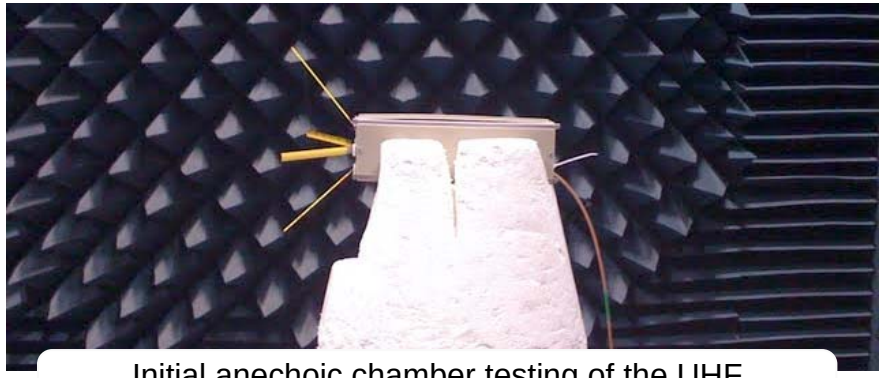

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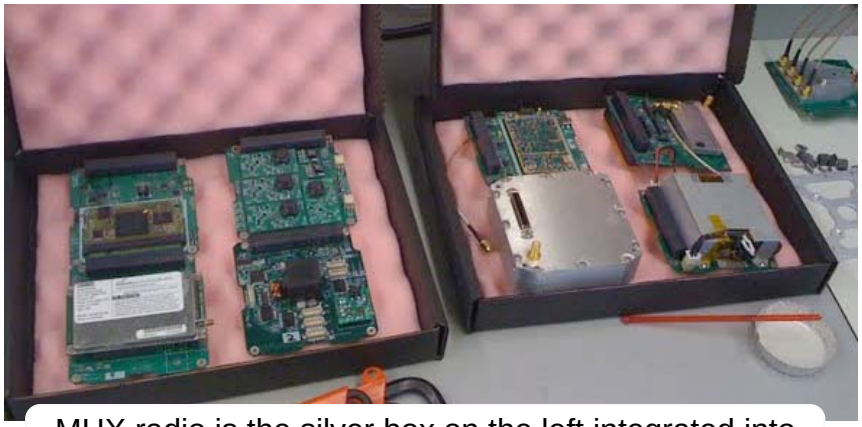
Disclaimer: Cutler has a vested interest in AstroDev.

S-Band "Solution"

- Not a real solution, but a temporary hack.
- Microhard MHX2400
  - Pros
    - It has flown several times.
    - It has sort of worked (low rates).
  - Cons
    - It has only sort of worked
    - Closed protocol.
    - Requires two MHX's one each end.
  - Note, we are not flying the MHX2420, it is power hungry.
- In House antenna design.
  - Low profile circularly polarized patch.
  - Needed because COTS solutions would not fit in structure constraints and Cubesat standard.
- Other radios?
  - The UTIAS S-band is nice but expensive.
  - Surrey, Spacequest, AeroAstro—inefficient and expensive.
- RAX is modular
  - Can "easily" except a new radio if one is available soon.
  - DII effort from NRO looking for a radio solution.



MHX radio is the silver box on the left integrated into our UMich FCPU.