University Amateur Radio Success
PSAT Mission Review and Lessons from 18 mos in Space

16 years

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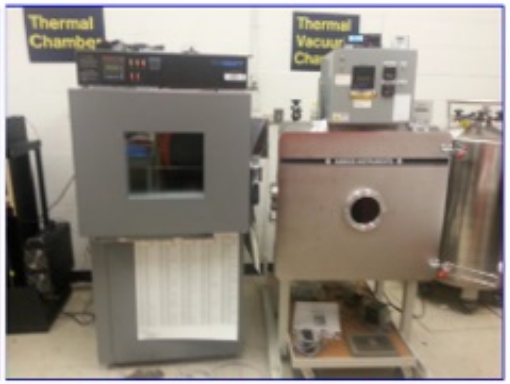
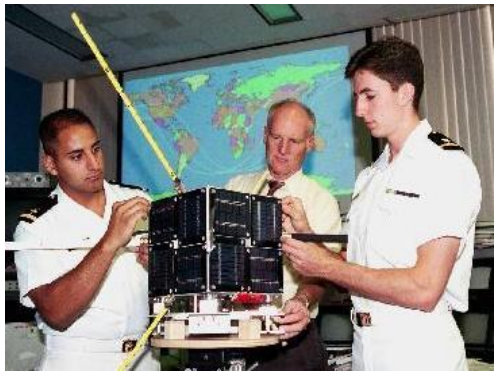
Shaker



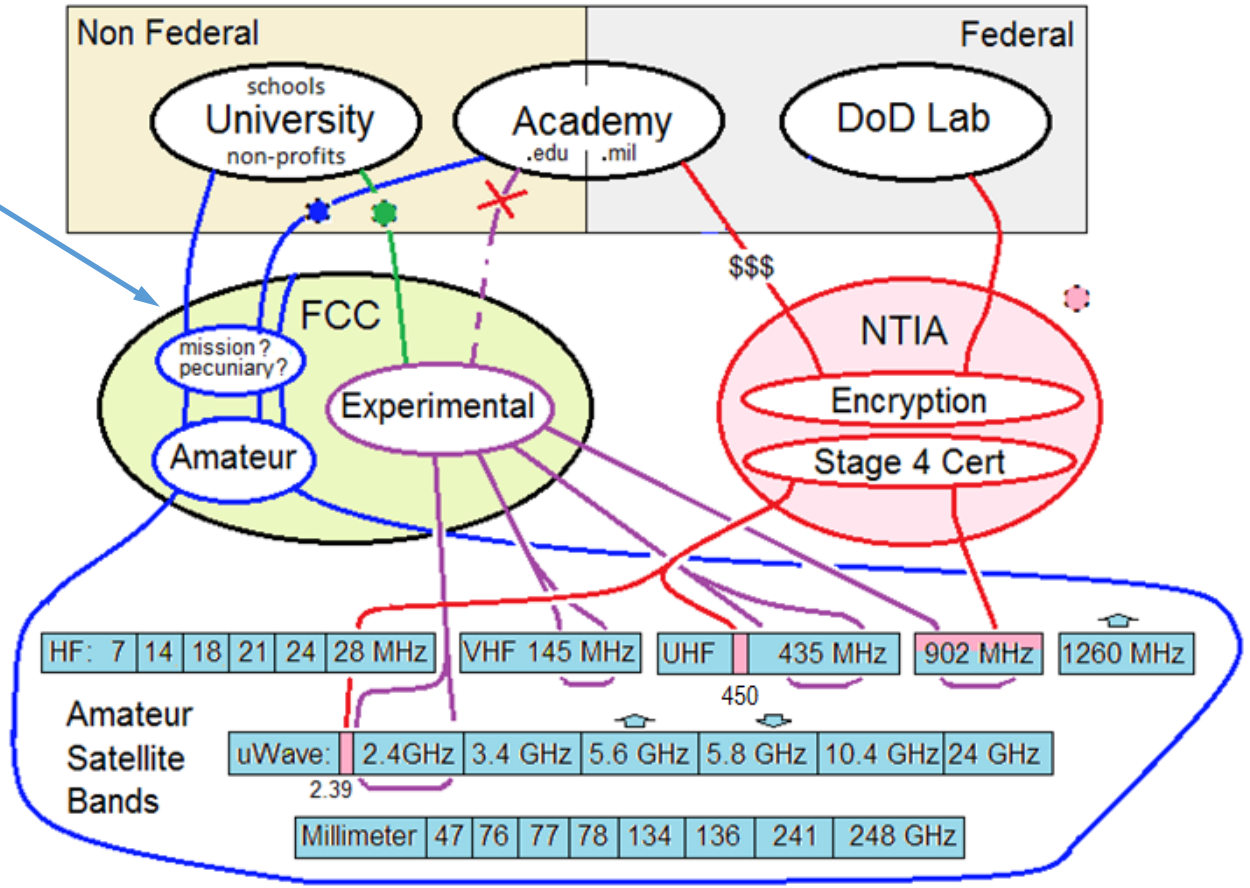
Thermal and Thermal Vacuum Chambers

Solar Simulator



Licensing in a Nutshell

Anyone can build Amateur
As long as they meet requirements

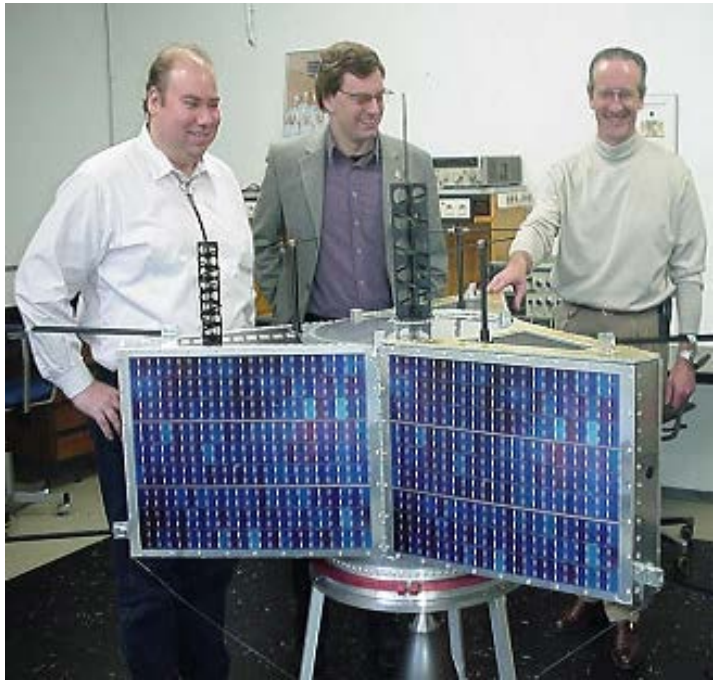


23 Bands

- 2013 FCC clarification of Experimental Licenses
- Naval Academy Student Amateur Satellite missions
- Experimental is not possible for Federal Academies or Labs
- NTIA has no comparable Experimental license class

What is an Amateur Satellite?

(>200+? in 55 years since 1961)



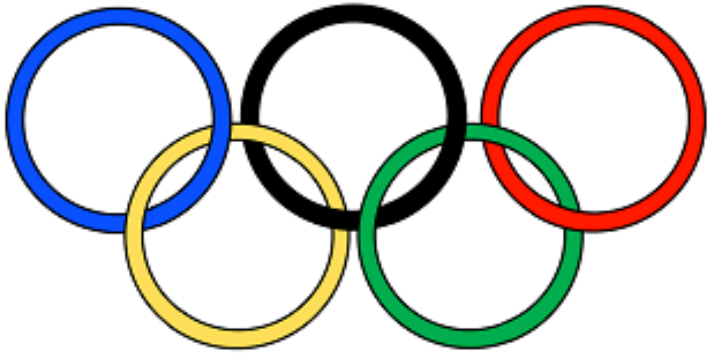
Any size…

built by anyone…

But Operated: (individual education)

- with a (non pecuniary) interest in the Satellite Art "amateur"
- And serving an Amateur Radio Mission (& users)

What is an Amateur Radio Satellite? (>200+? in 55 years since 1961)



amateur

The main thing "amateur" about the Amateur Satellite Service is the non-pecuniary interest requirement. (*kinda like the Olympics*)

Many hands-on communications professionals also have amateur licenses to allow them direct access to frequencies throughout the Electromagnetic Spectrum for personal experience in the radio art.

The Amateur Frequencies provide parts of the EM spectrum for the public, protected from commercial/government exploitation; like the National Parks protect the wilderness and the land for public use. Just get a license or permit And follow the rules.

50% of Astronauts on the ISS have Amateur Licenses

They are paid government employees

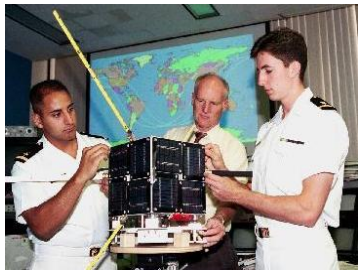
They use them to bring value to the radio art (and students)

Senior Engineering Student Capstone Projects

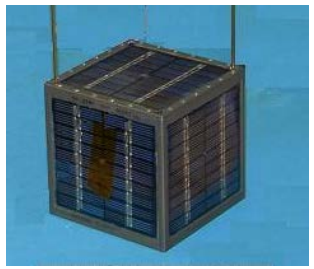
Accredited Engineering now requires hands-on Design-Build-Fly type projects – All majors

Project Based Learning

Ten Astro Student Amateur Satellites over 16 years

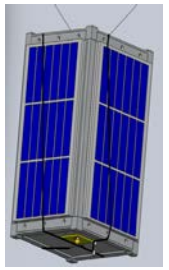


PCSAT (2001)

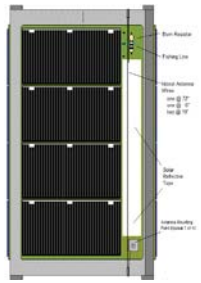


RAFT(2006)

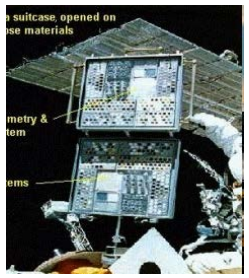
ARISS on ISS



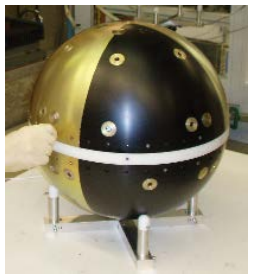
PSAT(2015)



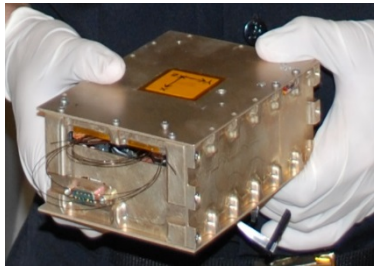
PSAT-2(2017)



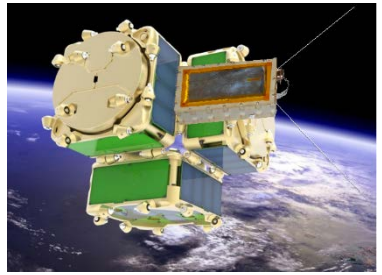
PCSAT2(2006)



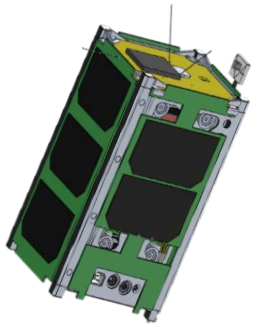
ANDE(2006)



QIKCOM-1 on ISS



QIKCOM-2 (Sep 2017)



BRICSAT2 (2017)

KEY: Still Alive, De-orbited, Manifest, Immediate

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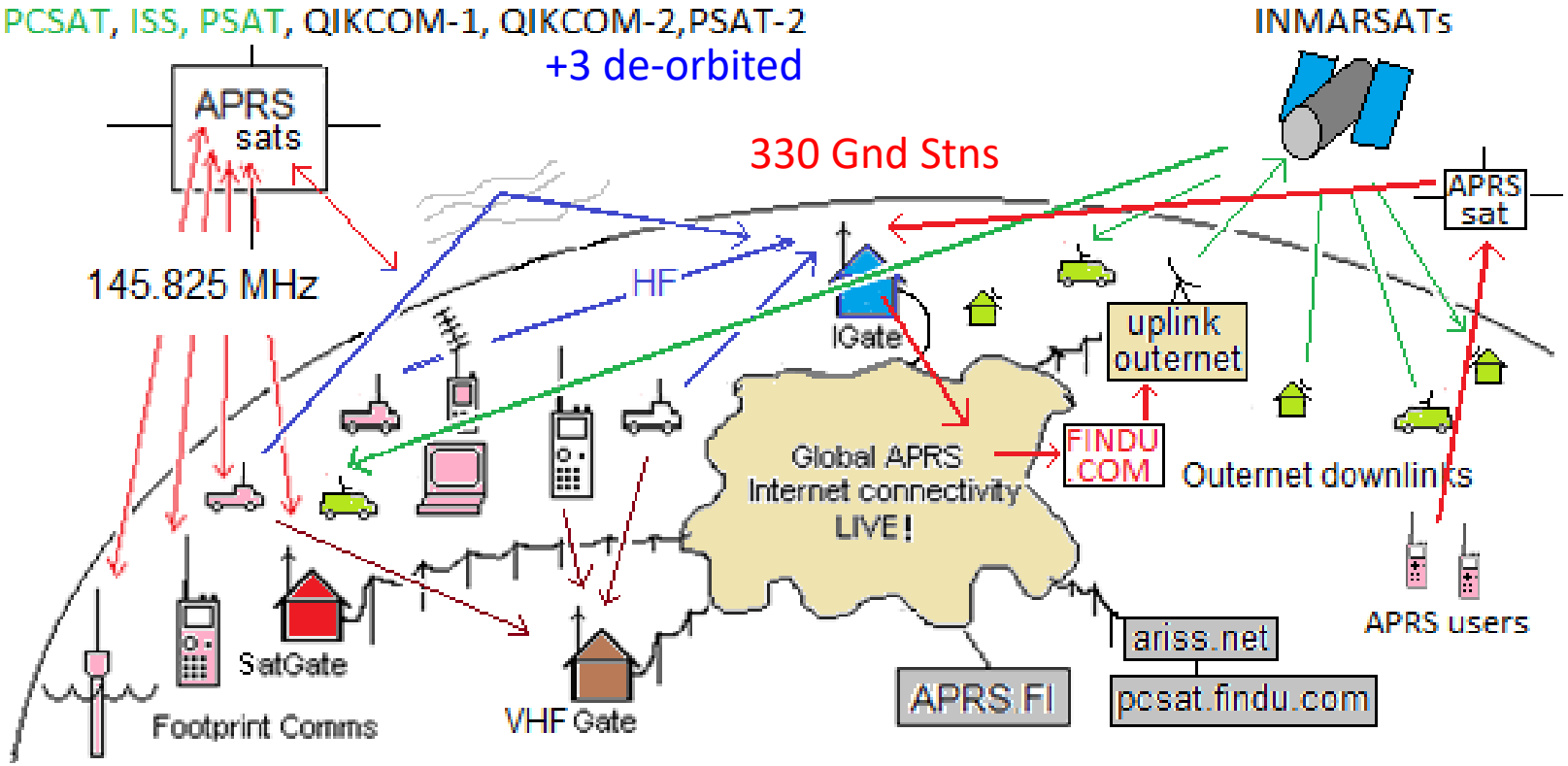
A Mission & Global Internet linked Data Network

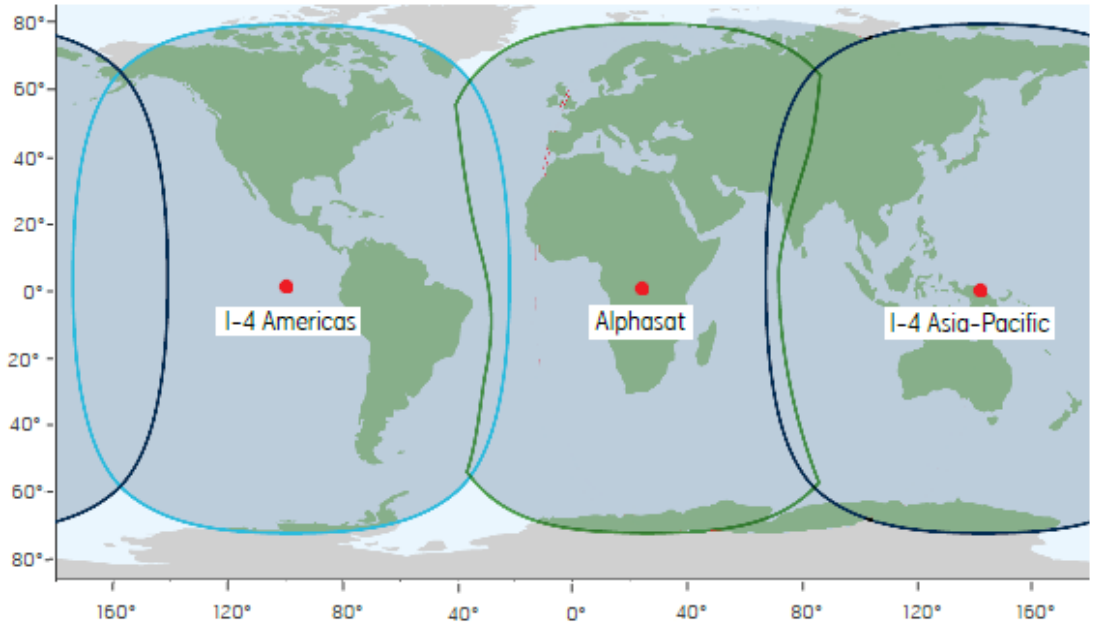


APRS Global Packet Radio Network

Internet Linked for live Communications

Automatic Packet Reporting System

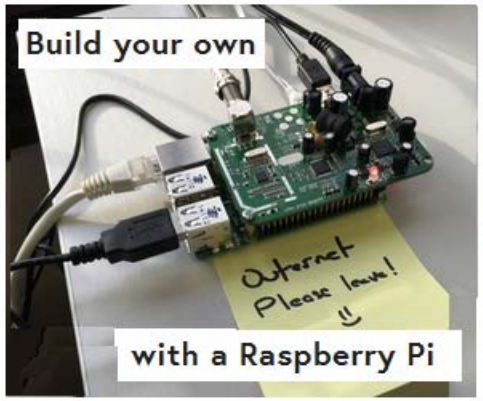
Includes channels on Three Geostationary Satellites



APRS Worldwide Coverage via OUTERNET on Inmarsat

OUTERNET

Simple Ground Station:



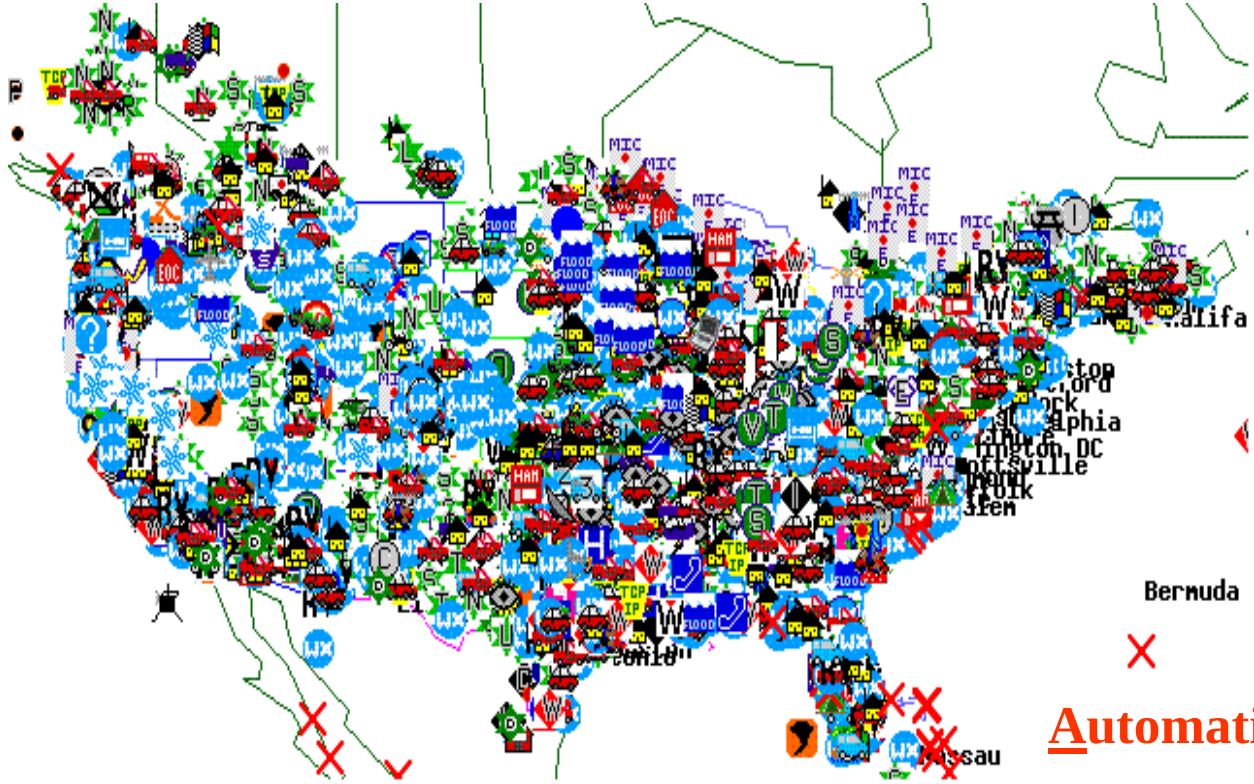
& SDR USB dongle

USNA Satellites and Global Ground Station Network

These are daily amateur satellite ground stations, users, experimenters using USNA satellites

Amateur Packet Radio (APRS) is Everywhere *

- Supports over 40,000+ terrestrial users and experimenters.

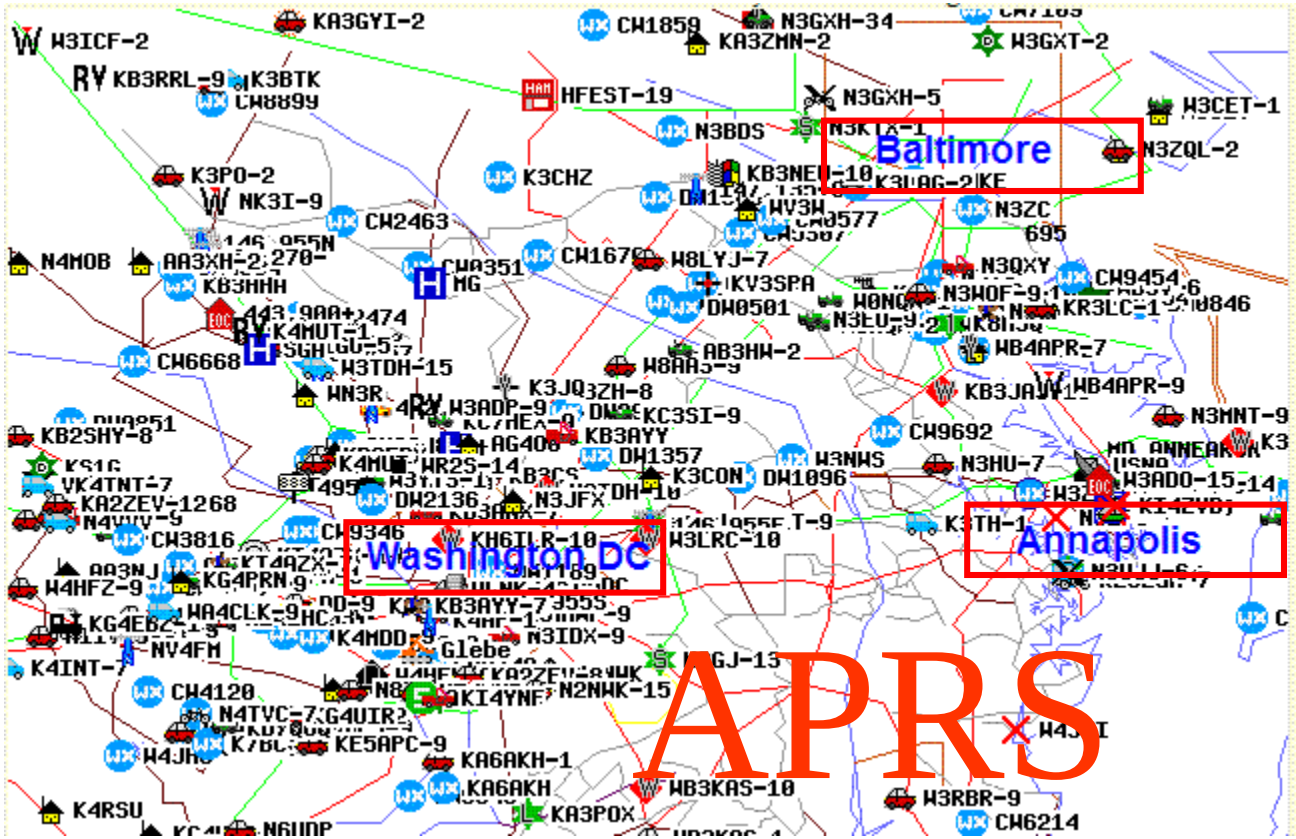


* APRS Pioneered at USNA

Automatic Packet Reporting System

* But stops at the shoreline and has huge holes in the wilderness

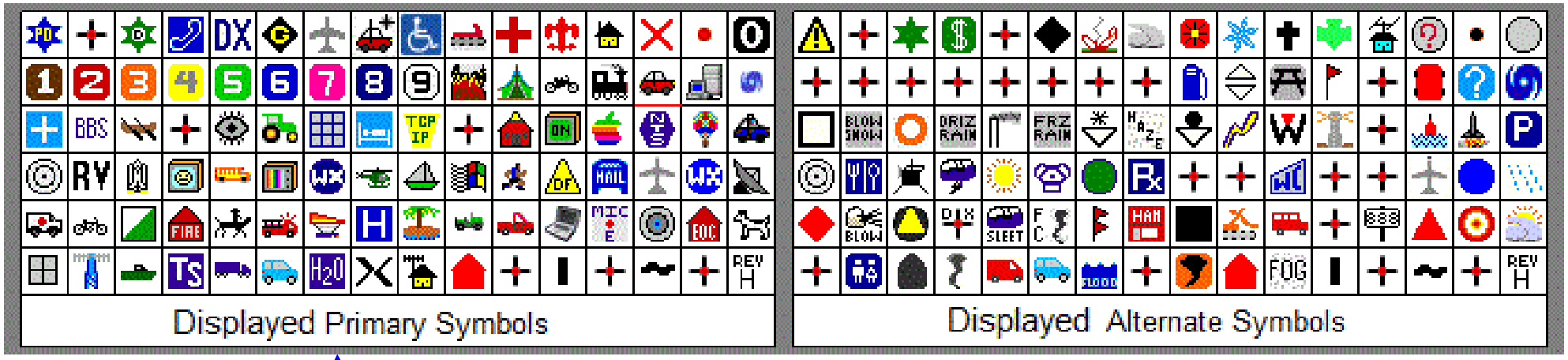
APRS is Amateur Radio's GIS system *



300 stations
In 35 miles

Find any station, Any map, Anywhere- http://aprs.fi

APRS is Amateur Radio's GIS system *



The Who, What, When, Where, Why How of communications

Call or Obj Name

Posit Data

Time Stamp

47 character comment text

Find any station, Any map, Anywhere- http://aprs.fi

Amateur Satellite Ground User Applications Focus

OR

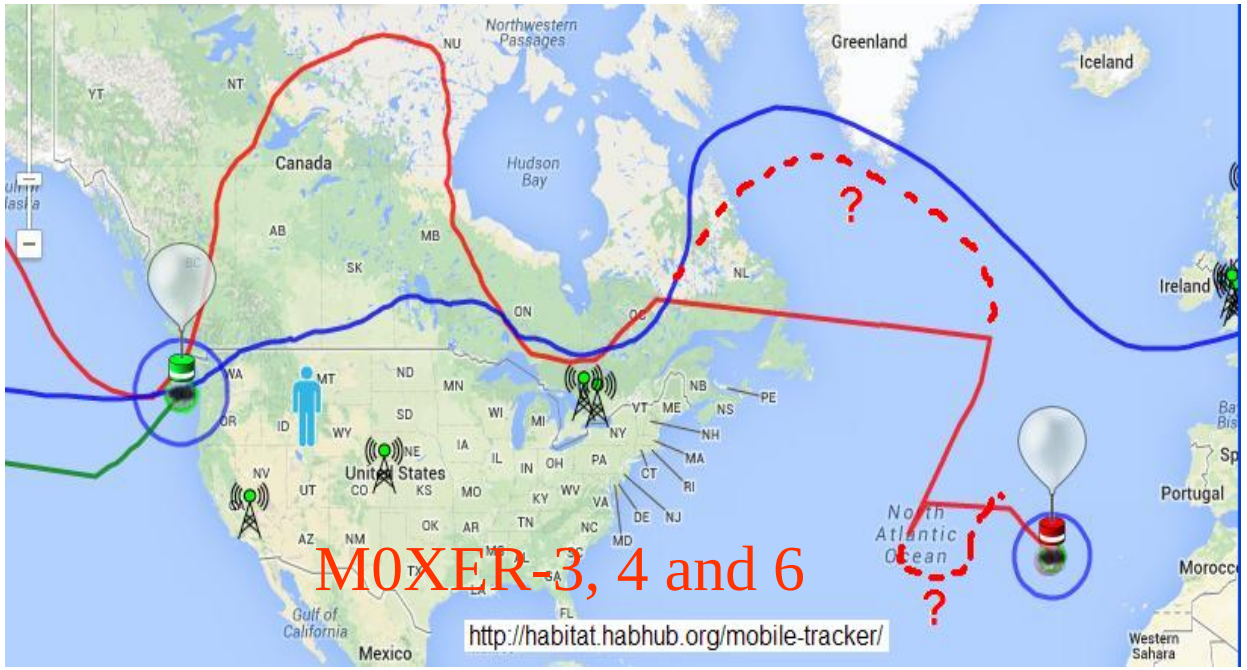
OR

OR

Why do we need Amateur Data Relay Satellites?

Global Wilderness Areas (90% of Earth)

Terrestrial APRS stops at the coastline and frontier



Live Global Amateur Balloon Tracking experiments need satellite relay

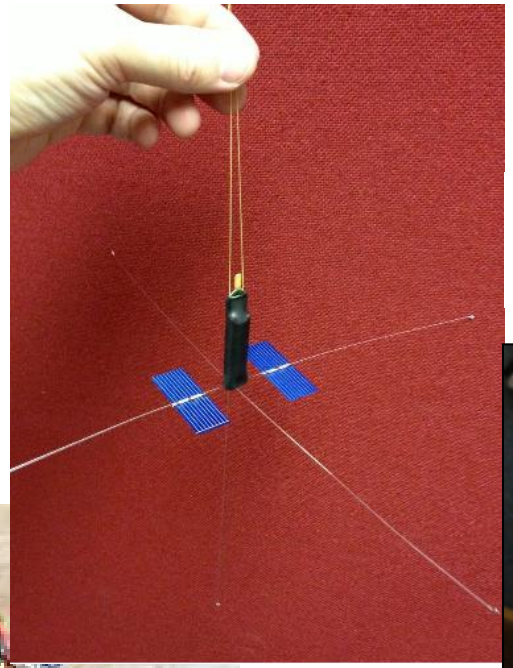
As well as boats, buoys, hikers, travelers gathering data and learning

Example Remote Sensor Experiments using APRS

Very Simple

APRS transmitter

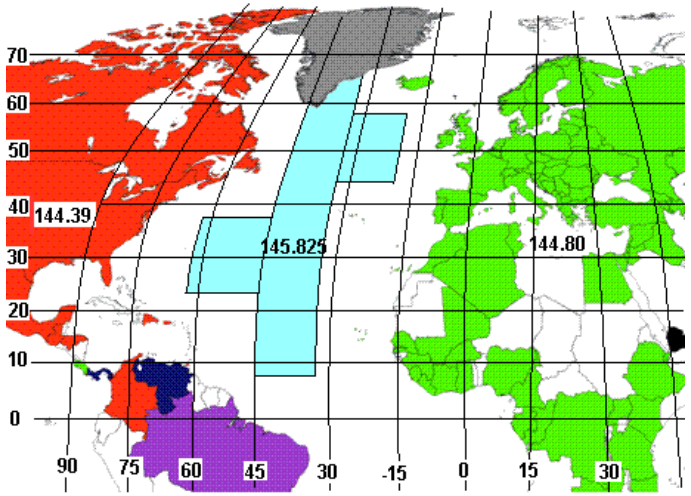
GPS



But now ‘Round the world is common

Why We Need APRS Satellites

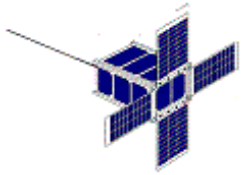
- Transatlantic APRS balloon launched and tracked through terrestrial network
- Lost comms over Atlantic Ocean
- It could have been picked up by our Psat/Pcsat transponder or the ISS



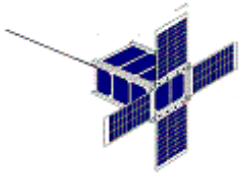
Possible APRS TransAtlantic Freq Plan

Broader Student involvement using a Ground Terminal **Operational Concept**

Ground Terminal Applications Focus (force tracking and text-messaging)



Supports Student Experiments
Worldwide Amateur Radio tests
and Emergency Response Comms



The Yard Patrol Craft

Education

Force

Multiplier!

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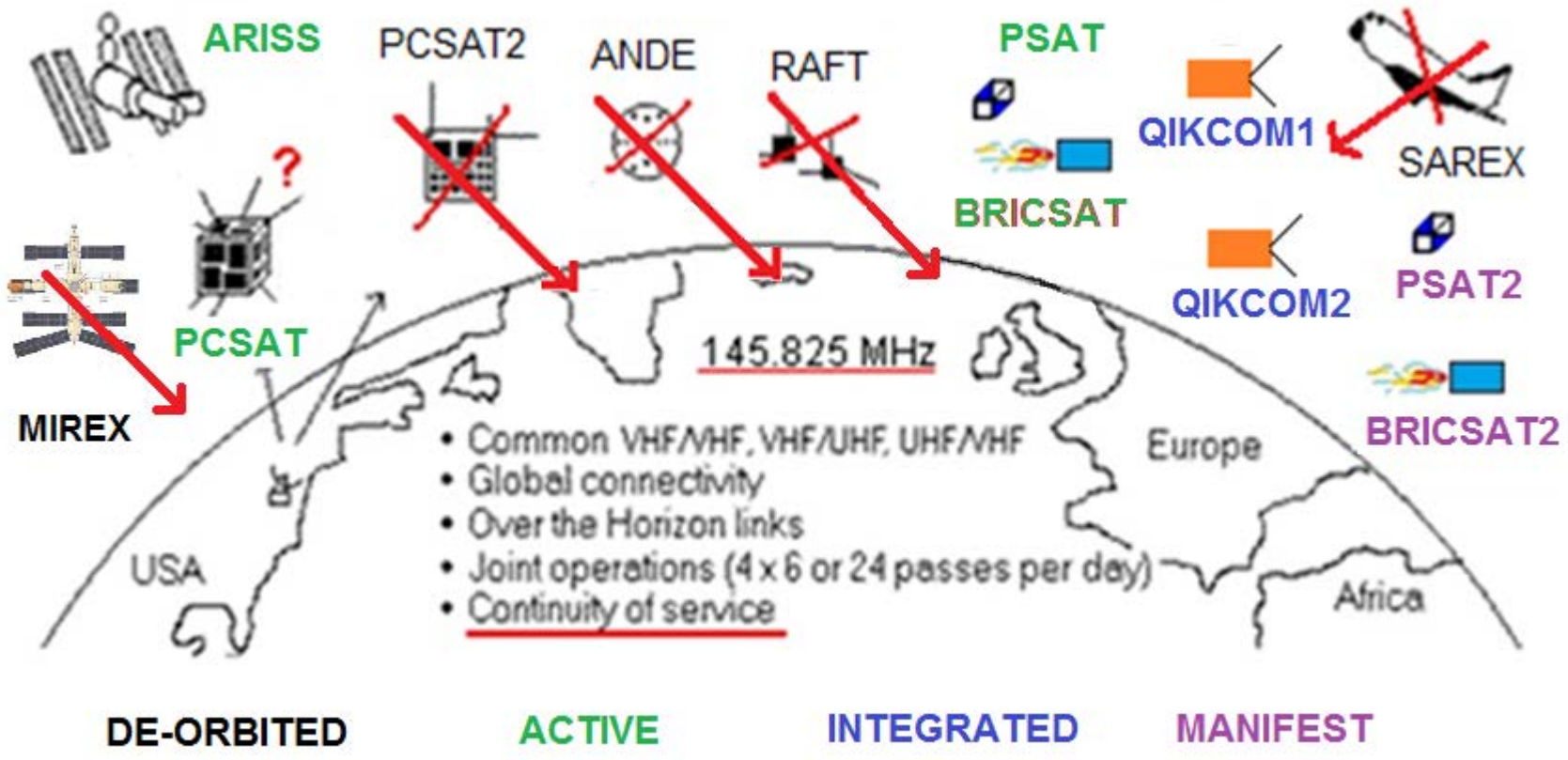
Not just our students but other Hams are involved

"When you have *no comms*, 1200 baud text/data is great!"

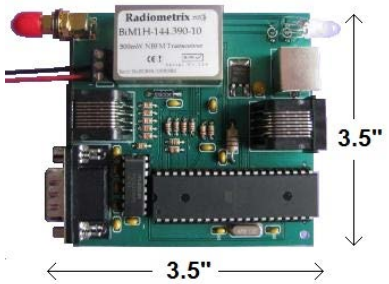
CAPT Chas Richard

W4HFZ

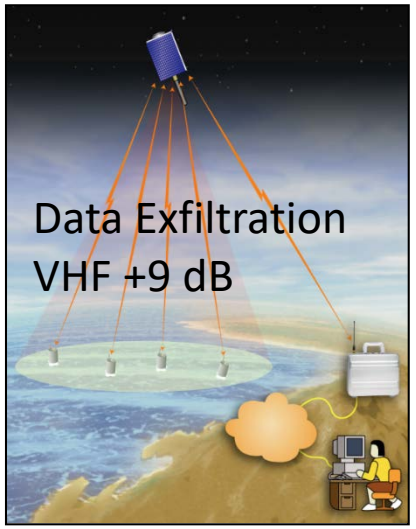
USNA Amateur Satellites



PSAT Remote Data Relay Applications

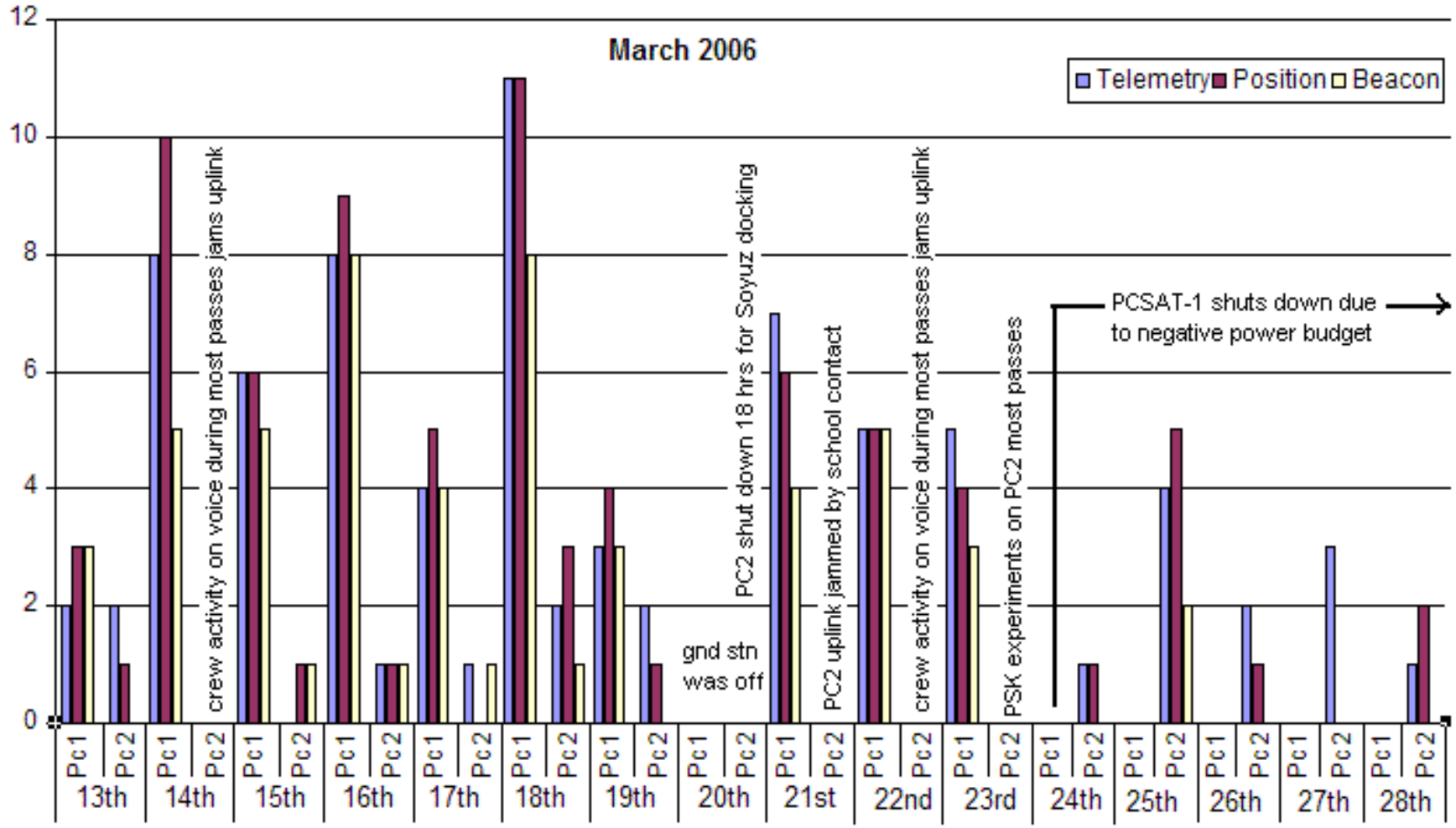


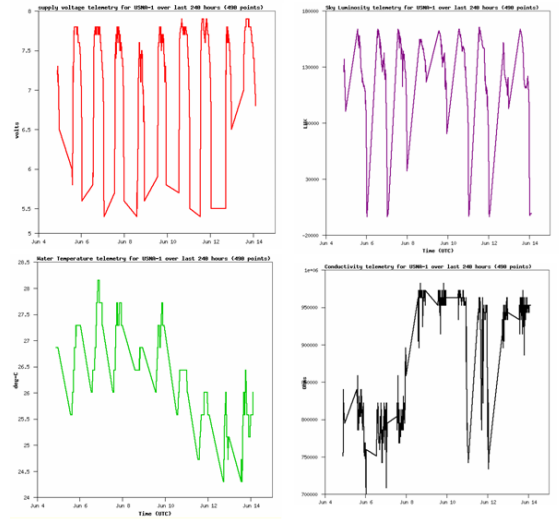
Psat Space Transponder flown on as many spacecraft as possible provides continuity to remote data sensing…

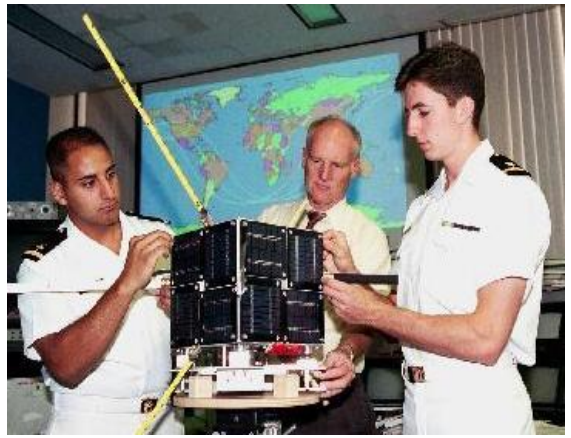


And enhances student access to space education and applications

Number of Buoy Packets Received Per Day via PCSAT-1 and PCSAT2

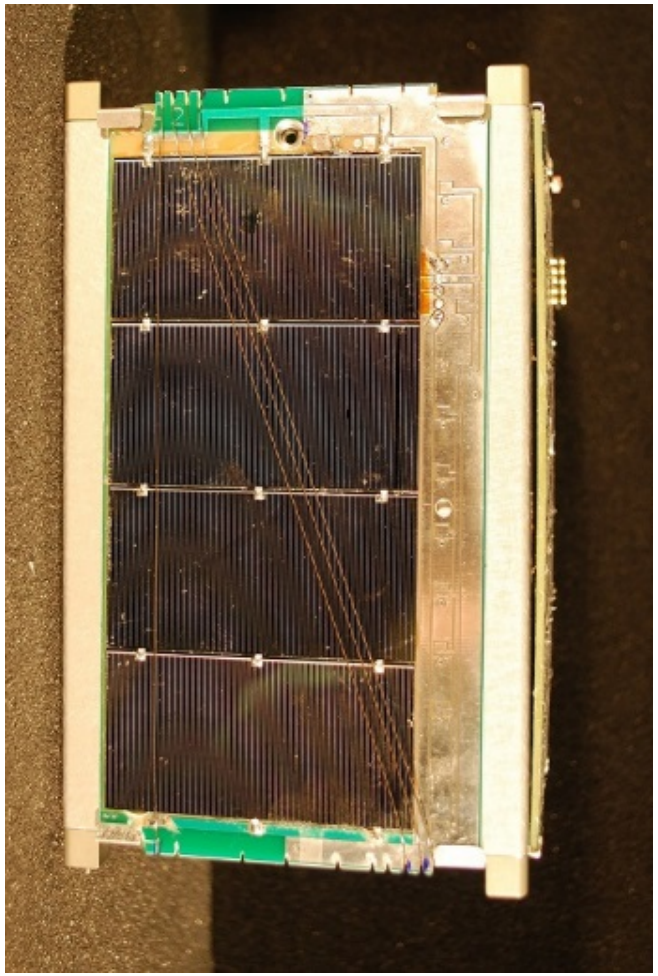


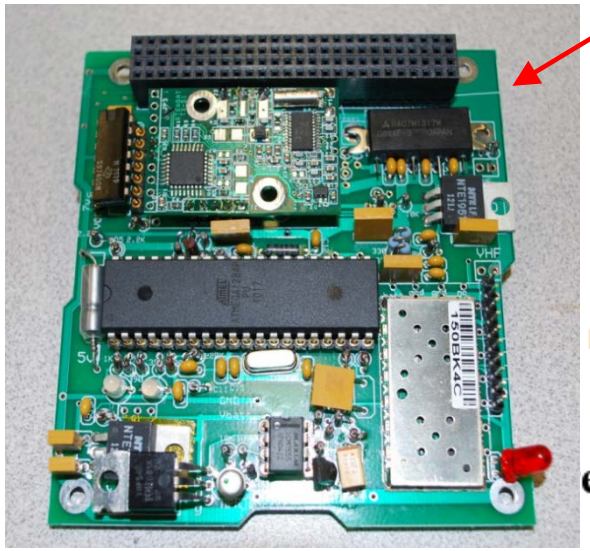


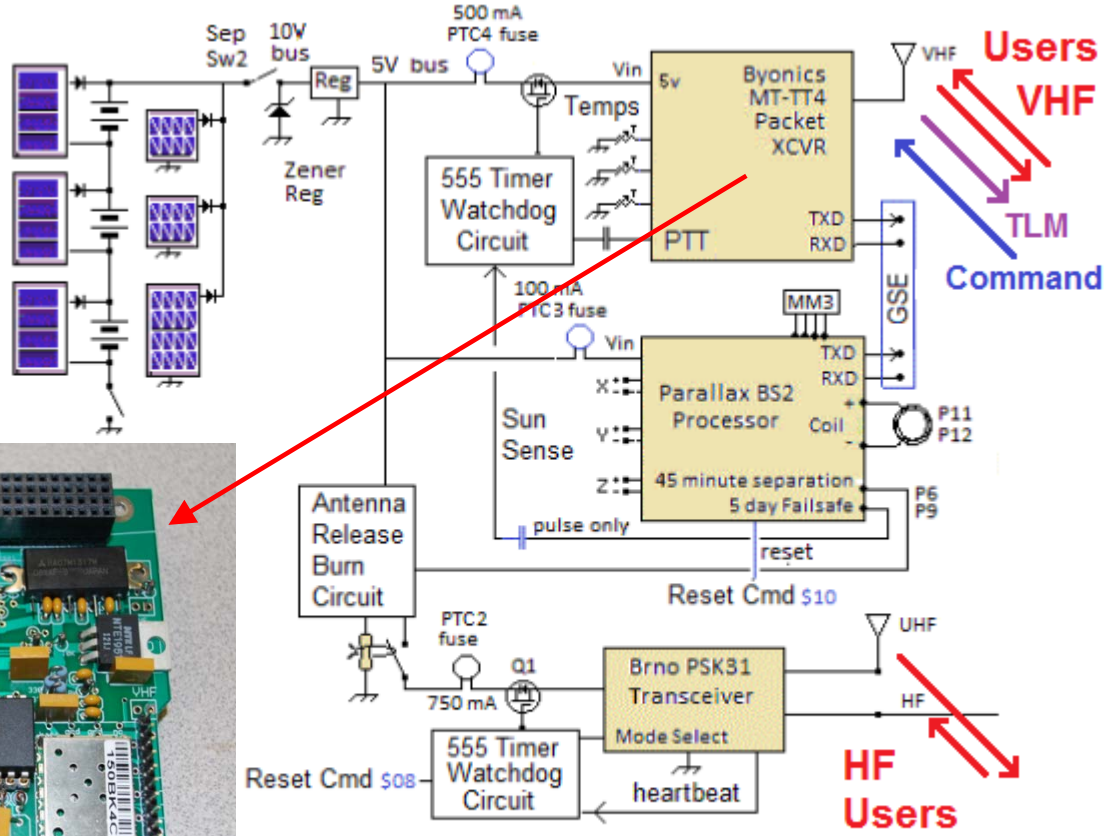


Unique PSAT Power, Comm, Xponder & ADCS

Accredited Engineering majors now require hands-on Design-Build-Fly type projects

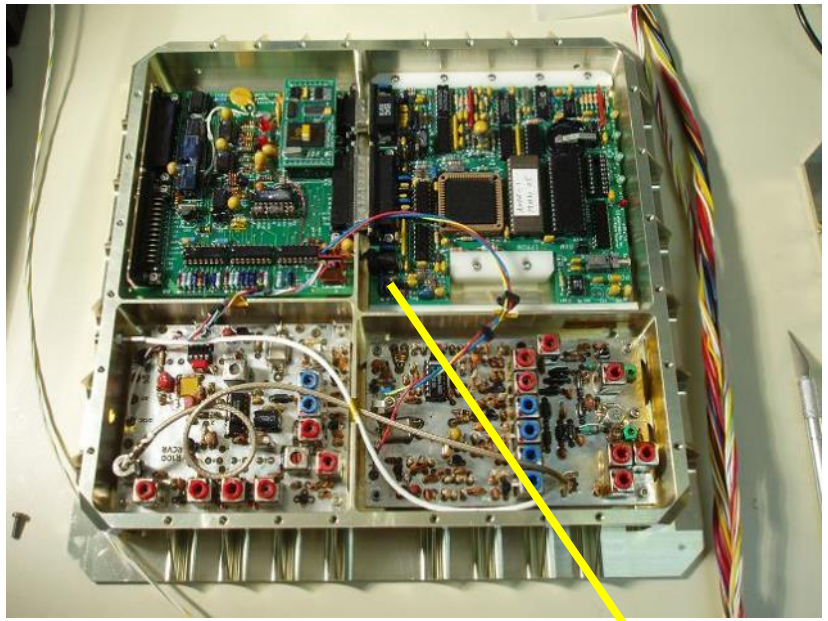






e 3: PSAT System Block Diagram

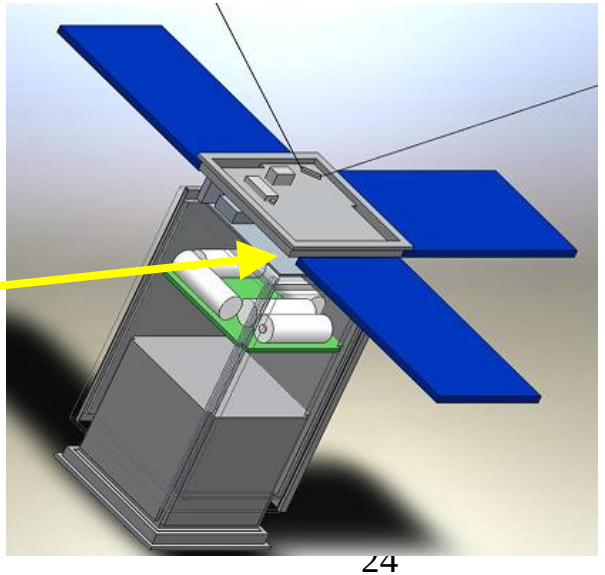
Huge reduction from transponders on PCSAT's 1,2, ANDE and RAFT missions



Earlier reductions to 5" cubesat on RAFT (2006)

4:1

Now reduced 18:1 in volume/mass for 4" cubesat 2009



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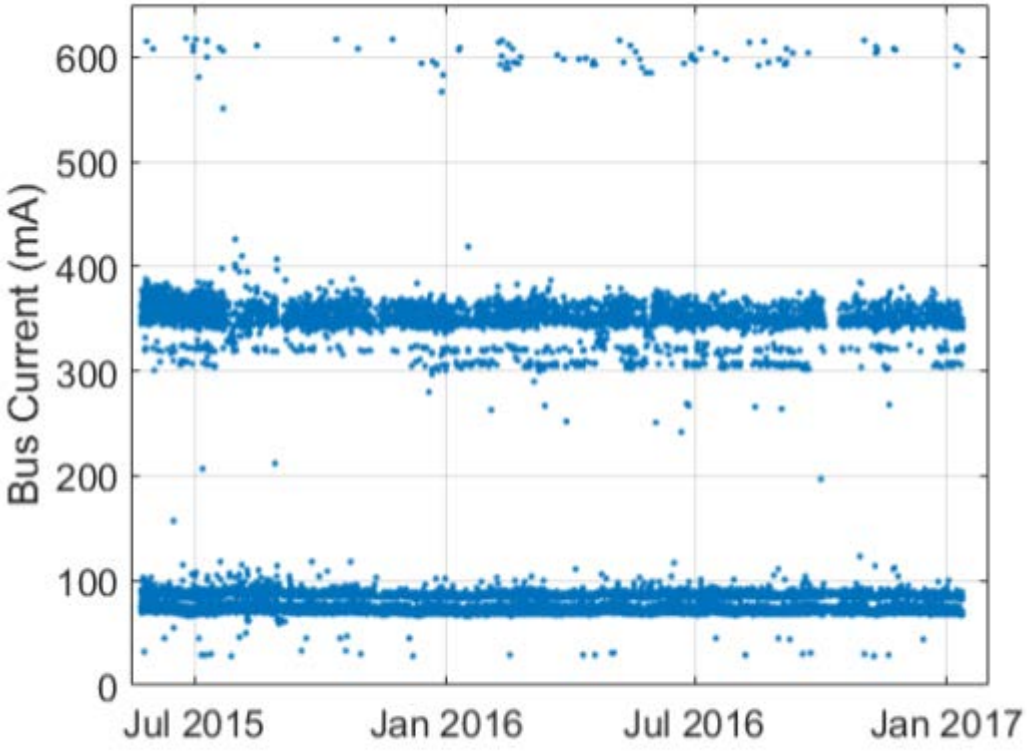
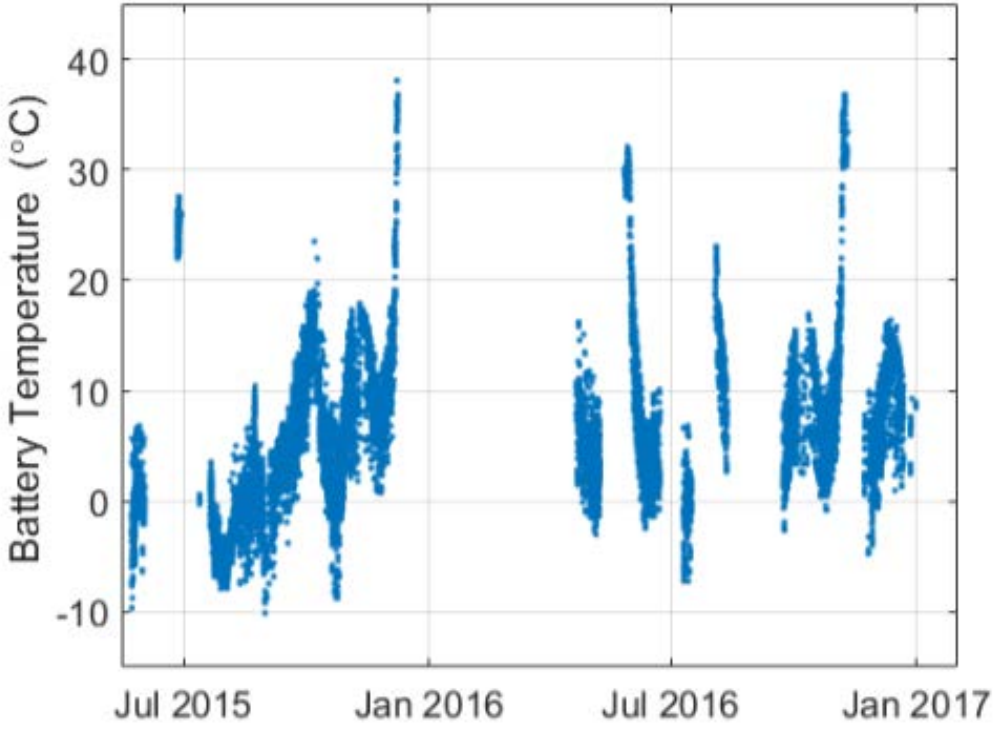
VHF Comm Board has 5 channels Analog TLM

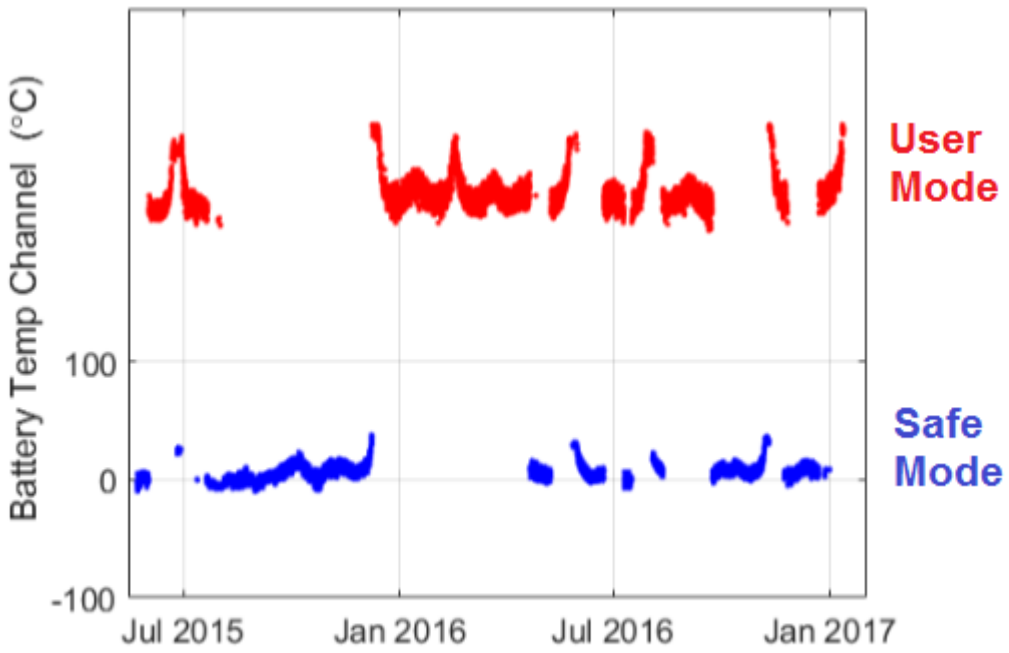


System Current Load Telemetry History



Battery Temperature Over 18 Month Period

Battery Temperature channel shared with User Mode Bit



Channel 5 Data Showing Power-save Mode

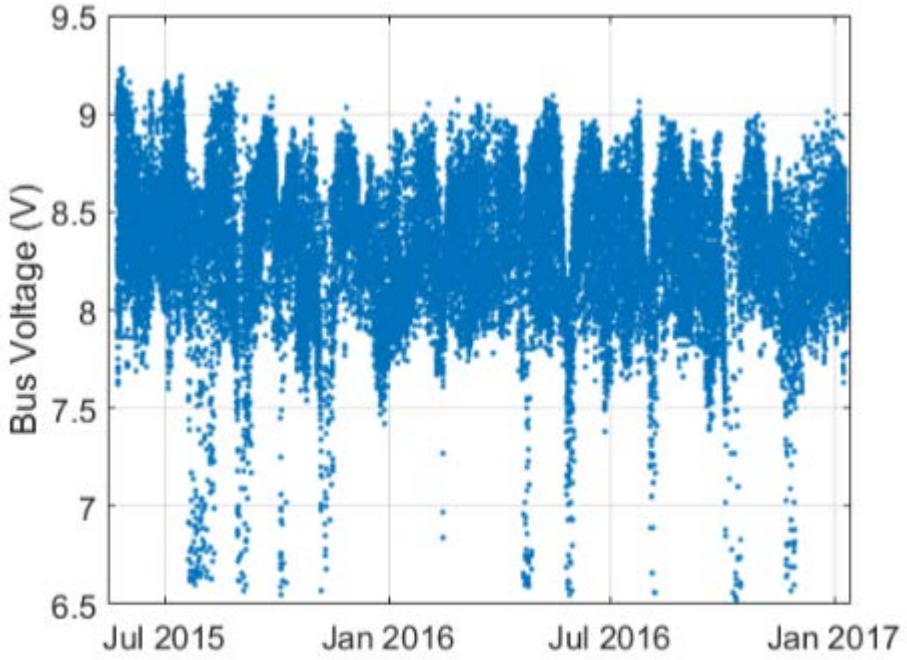


Figure 13: Bus Voltage Telemetry History

Accredited Engineering majors now require hands-on Design-Build-Fly type projects

Battery Temperature channel shared with User Mode Bit

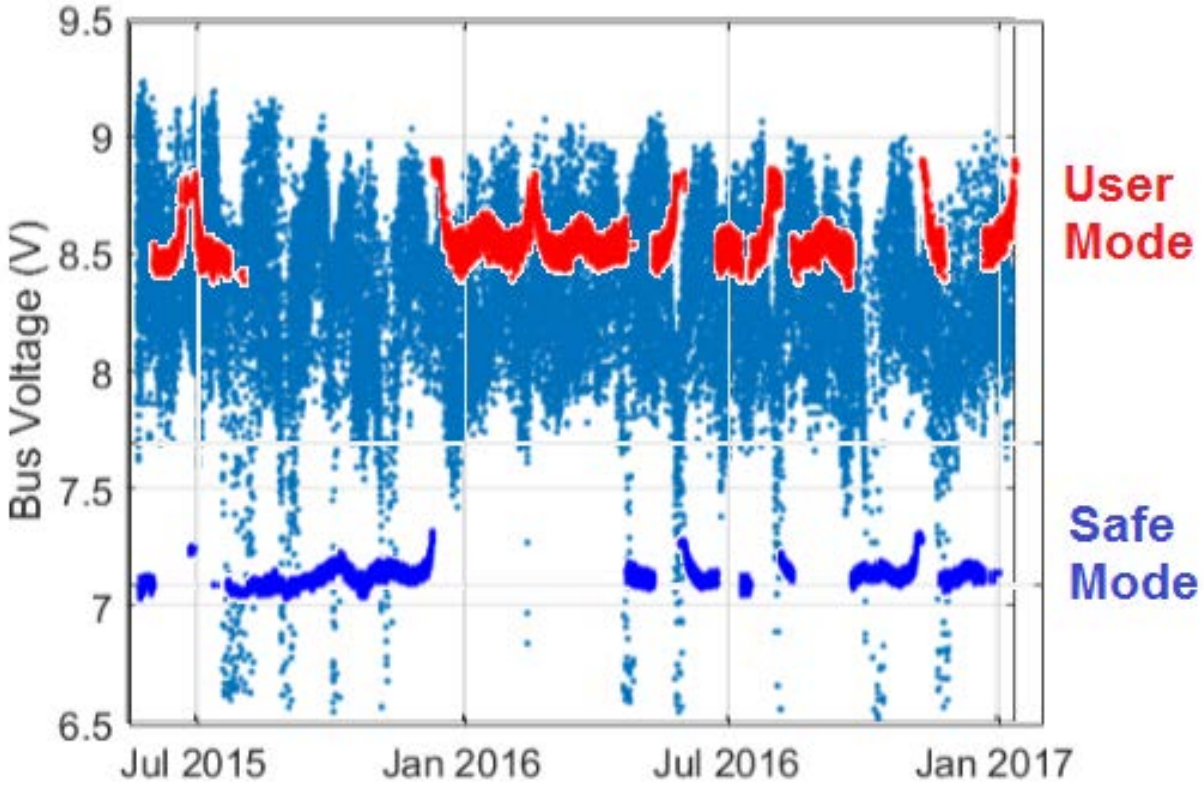


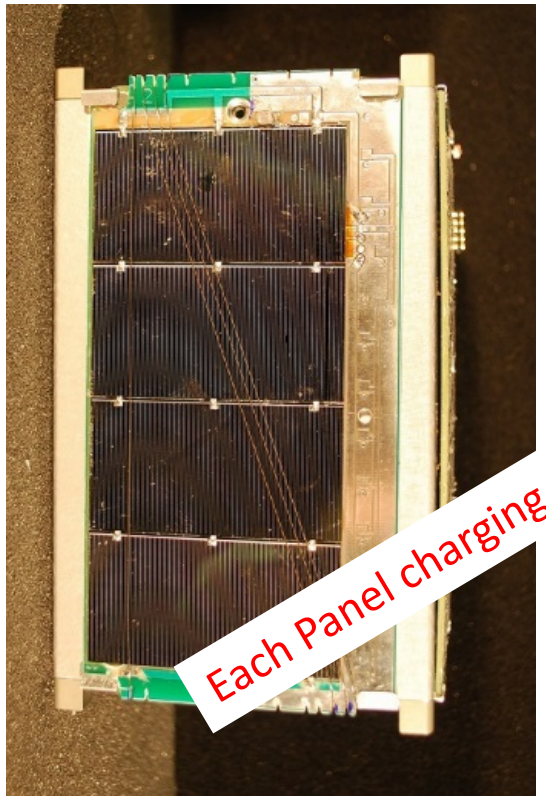
Figure 13: Bus Voltage Telemetry History

Overlaying, shows low-Voltage events triggered Safe Mode

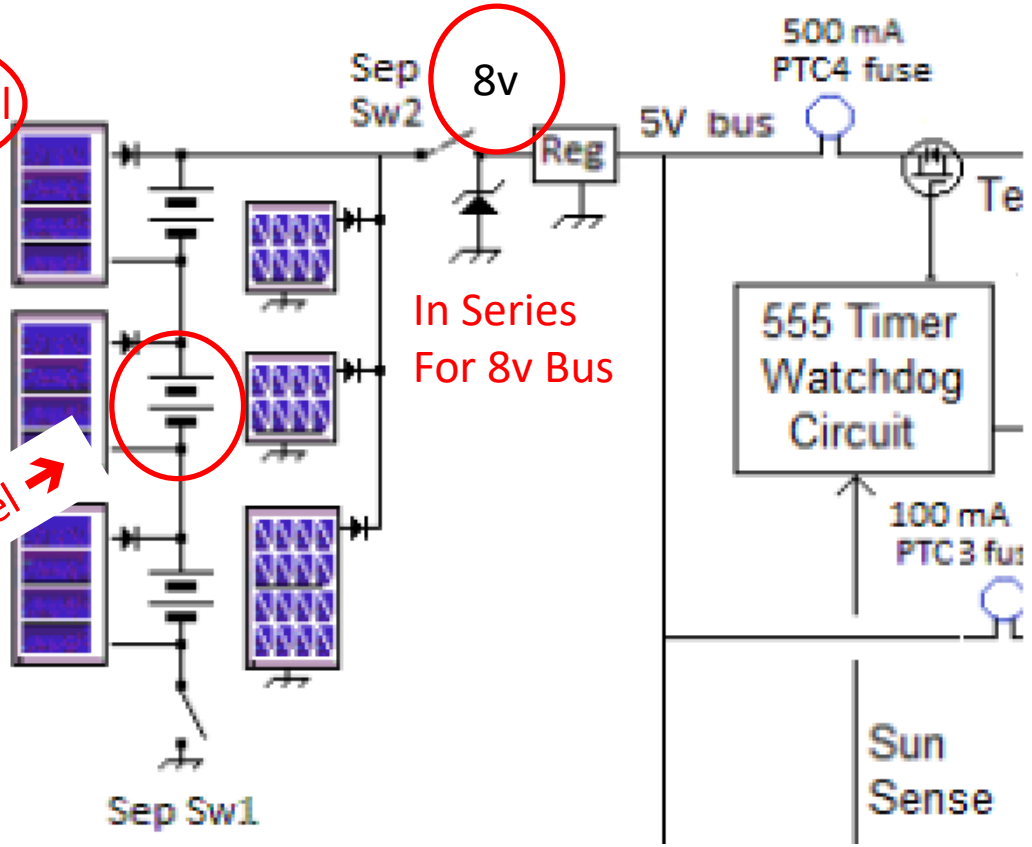
It also shows that early on we were not diligent in restoring user mode until user demand pretty much requested it later on.

Unique PSAT EPS system and Radiative Spin

Terrestrial Si Cells. Total cost $4 per panel



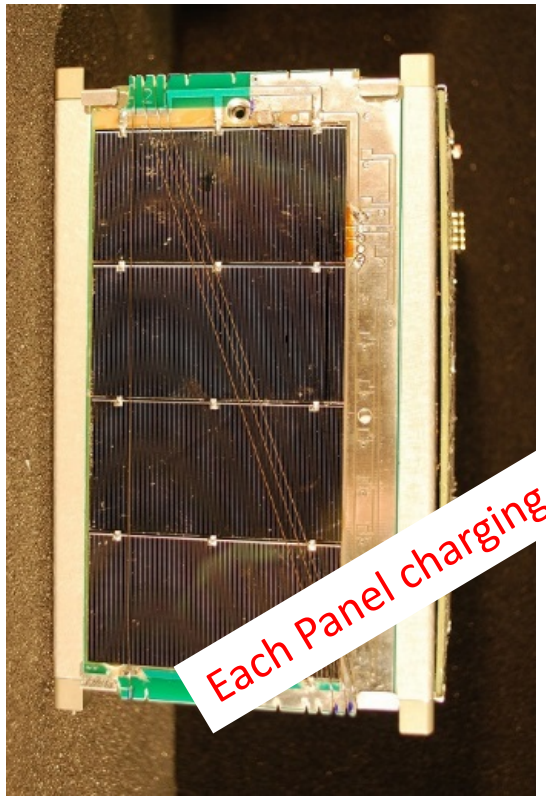
Each Panel charging NiCd's in parallel



Good packing factor

Unique PSAT EPS system and Radiative Spin

Terrestrial Si Cells. Total cost $4 per panel



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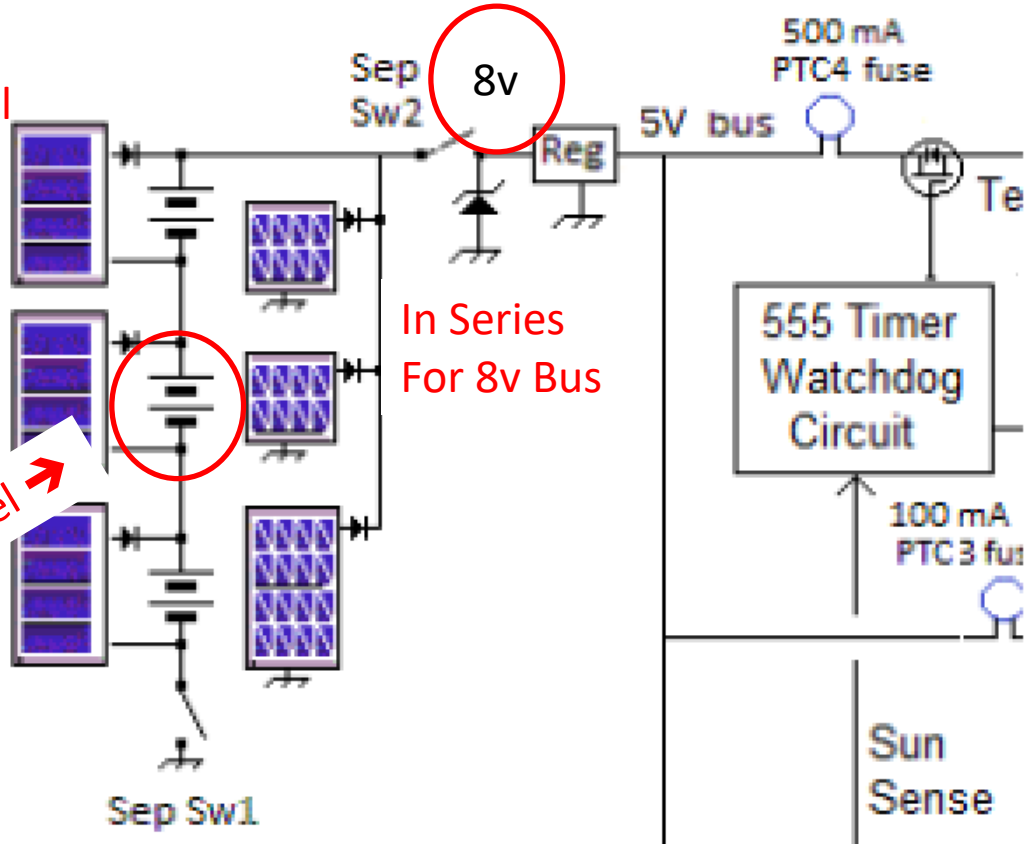

Requires Spin!

Unique PSAT EPS system and Radiative Spin

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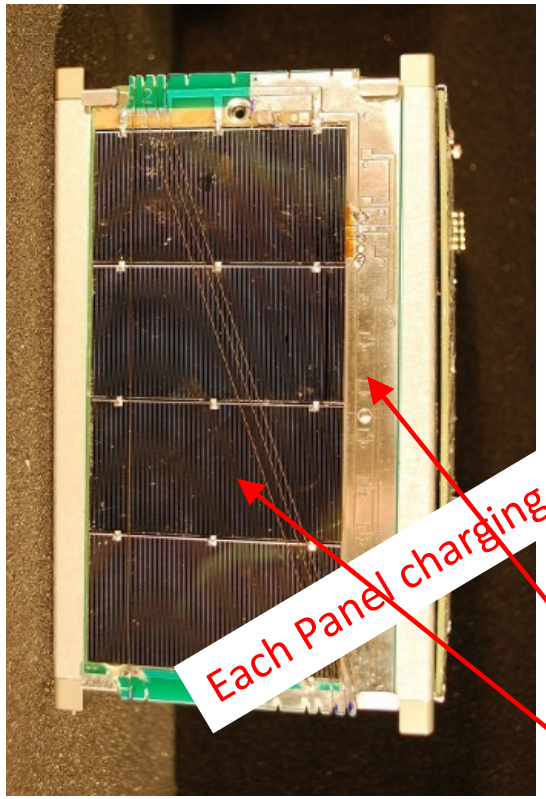
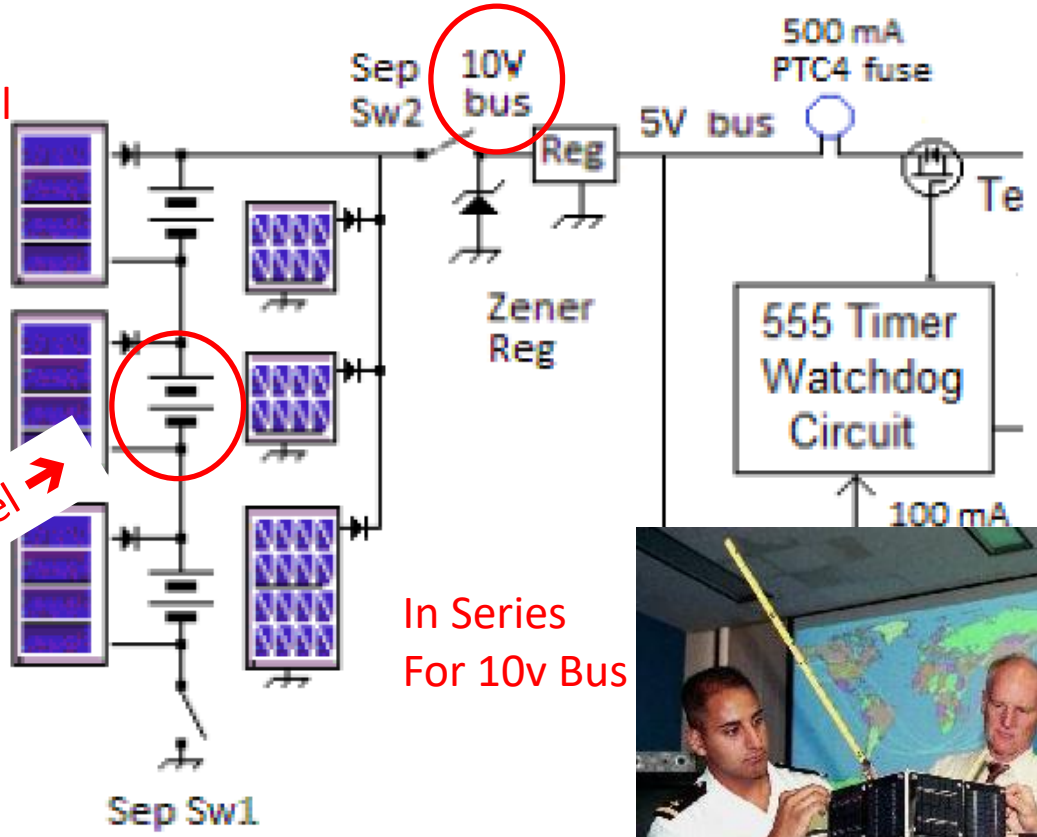
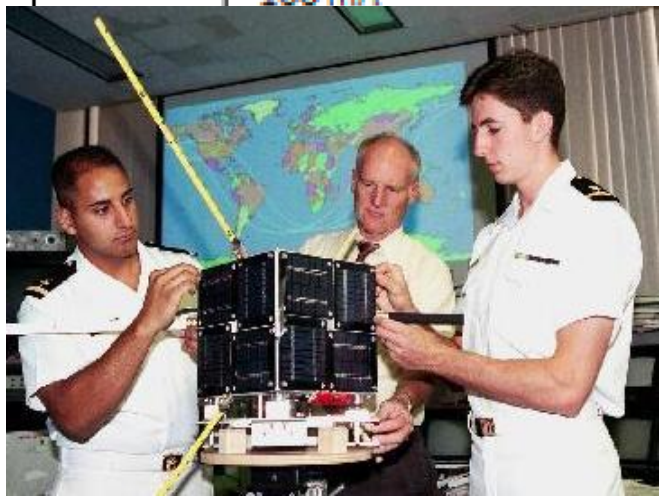




Each Panel charging NiCd's in parallel

In Series For 10v Bus

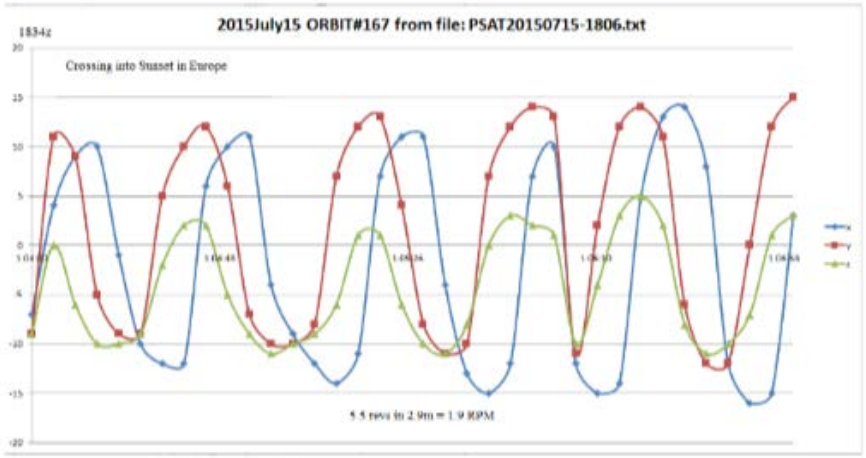


Requires Spin!

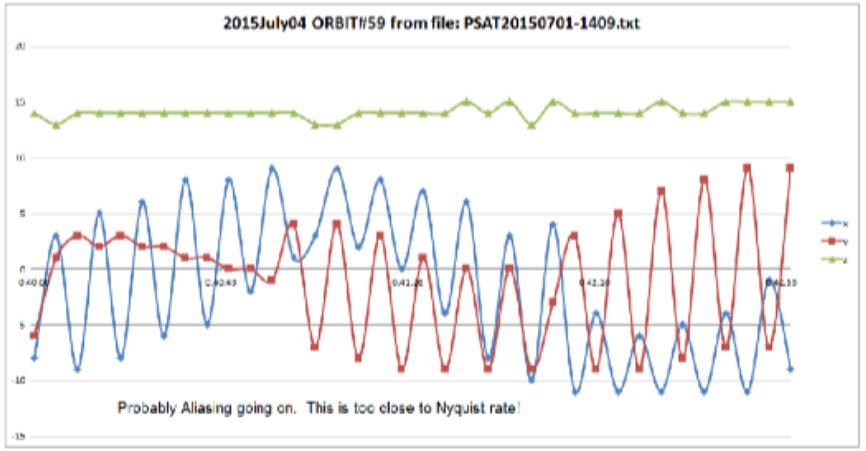
Notice offset color scheme!

0.6 – 0.8 RPM on PCSAT since 2001

PSAT Radiative Spin Plots and Aliasing



Representative Plot Displaying Z Axis "Wobble"



Representative Plot of Z Axis Aligned with Sun Vector

The assumed aliased 11.5 RPM rate of the X sensor is sketched as a dotted line

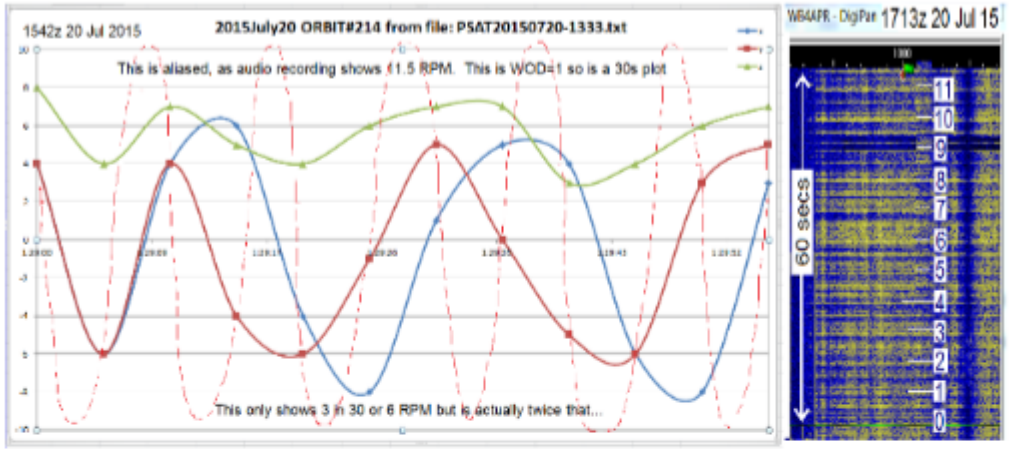
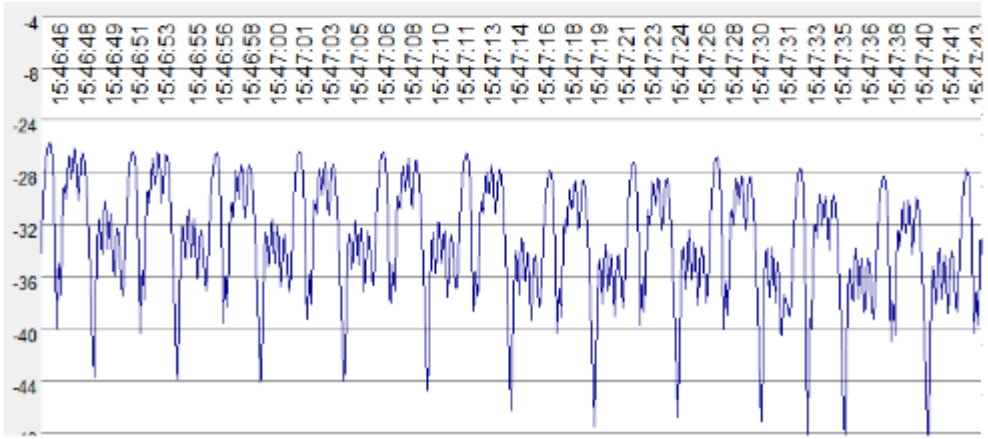
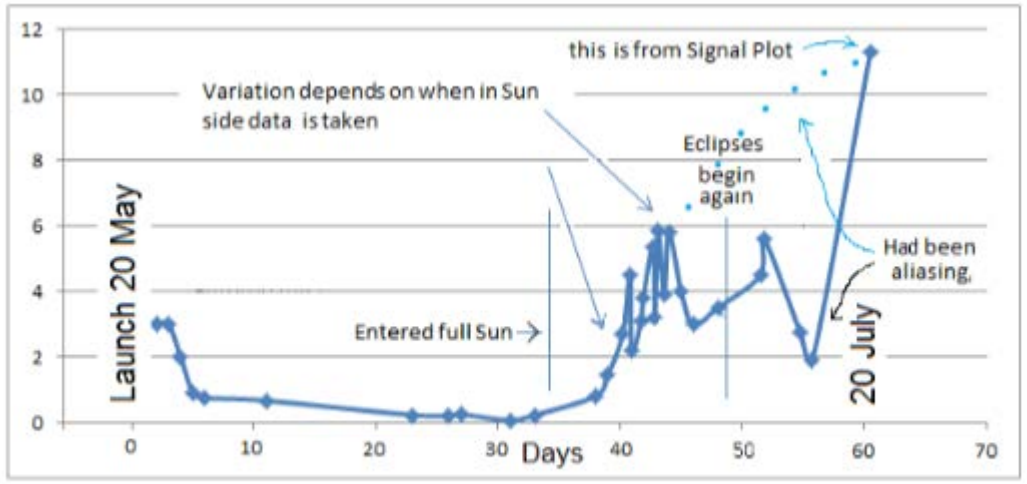


Figure 20: Highest Observed Spin Rate

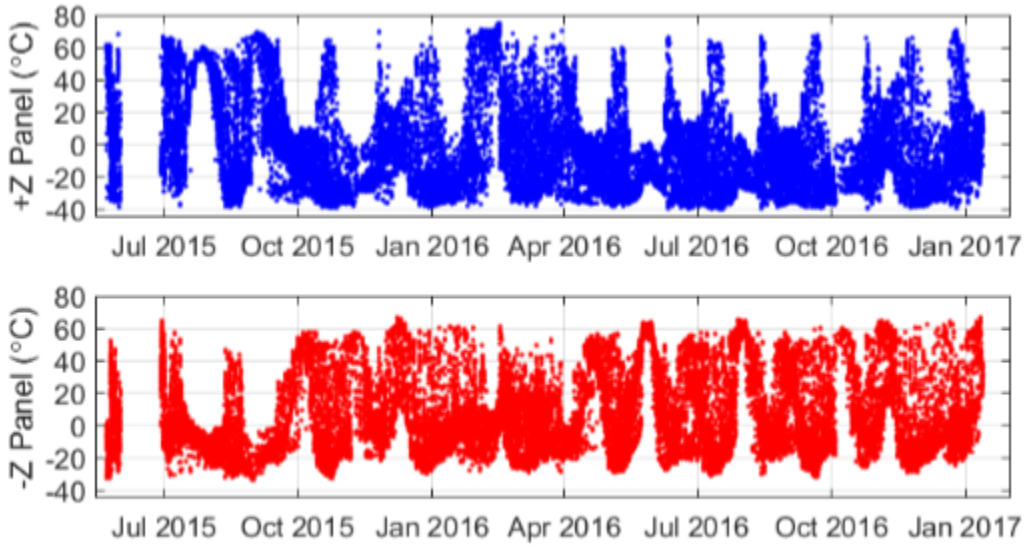


DK3WN Signal Strength Plot over 1 minute

PSAT Radiative Spin



PSAT RPM Data Derived from Sun Vector Telemetry

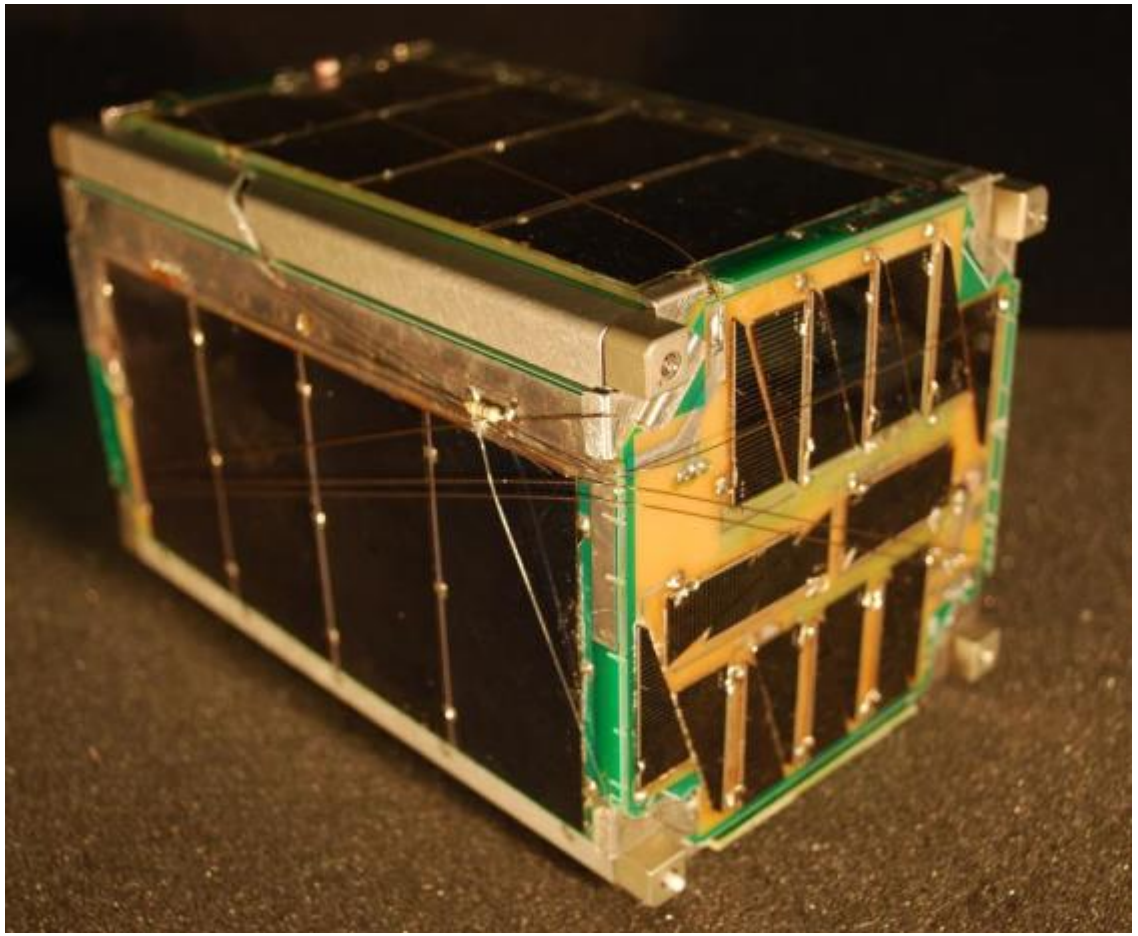


+Z and -Z Panel Temperature Telemetry History

Initial Spin plot (manual) decayed to near Zero
Then in full sun period spun up to over 10 RPM

Each +Z/-Z Temperature peak shows a period when they spin is END-ON to the Sun.

Wrapping 4 Antennas to one Burn Resistor



Two 6” UHF whips
Orthogonal

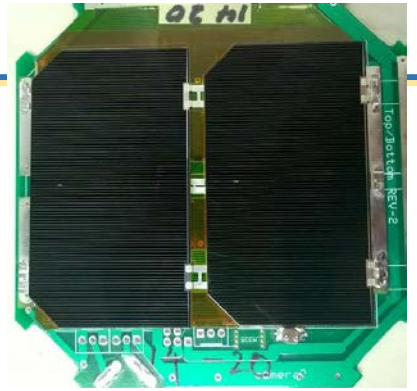
One 19” VHF whip

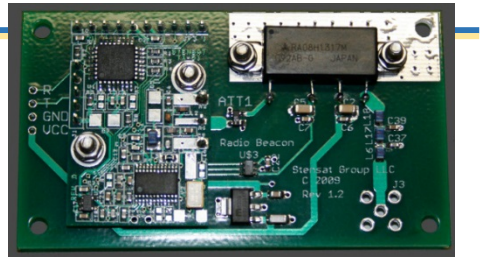
One 72” HF whip

3rd Enable Switch

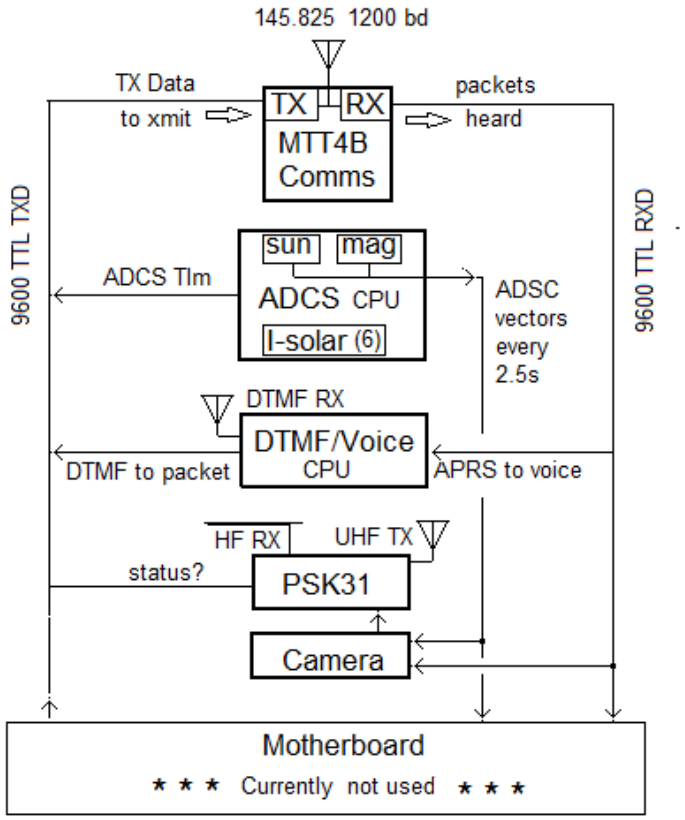
PSAT-2 is full up Cubesat with $20,000 solar cells

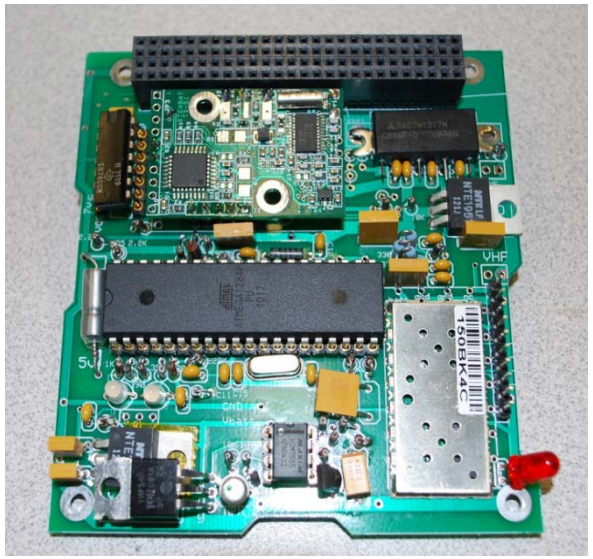
(double the power 3W)



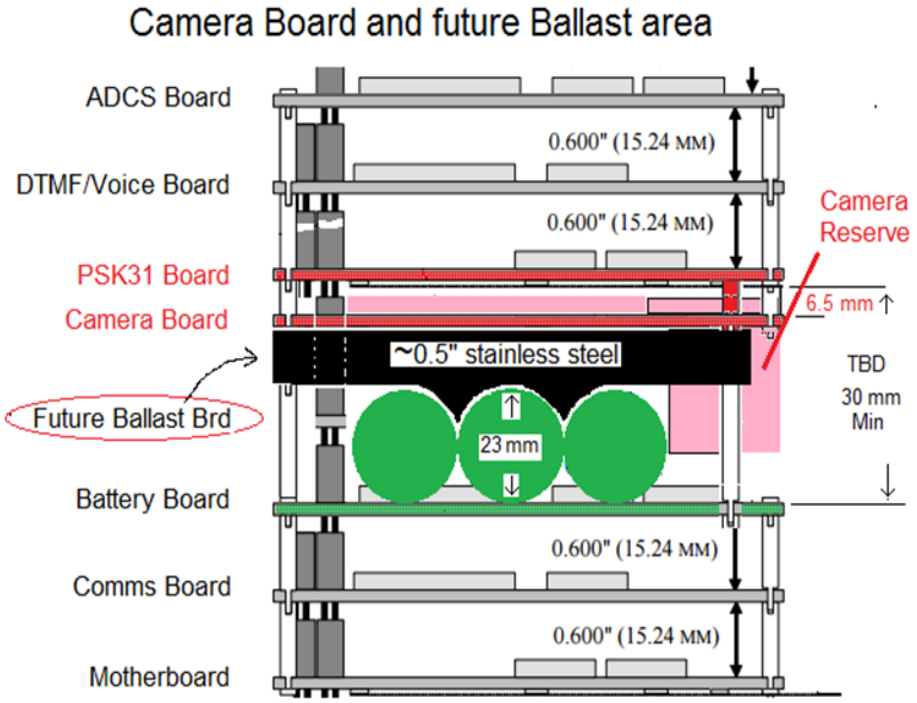


9600 baud UHF downlink





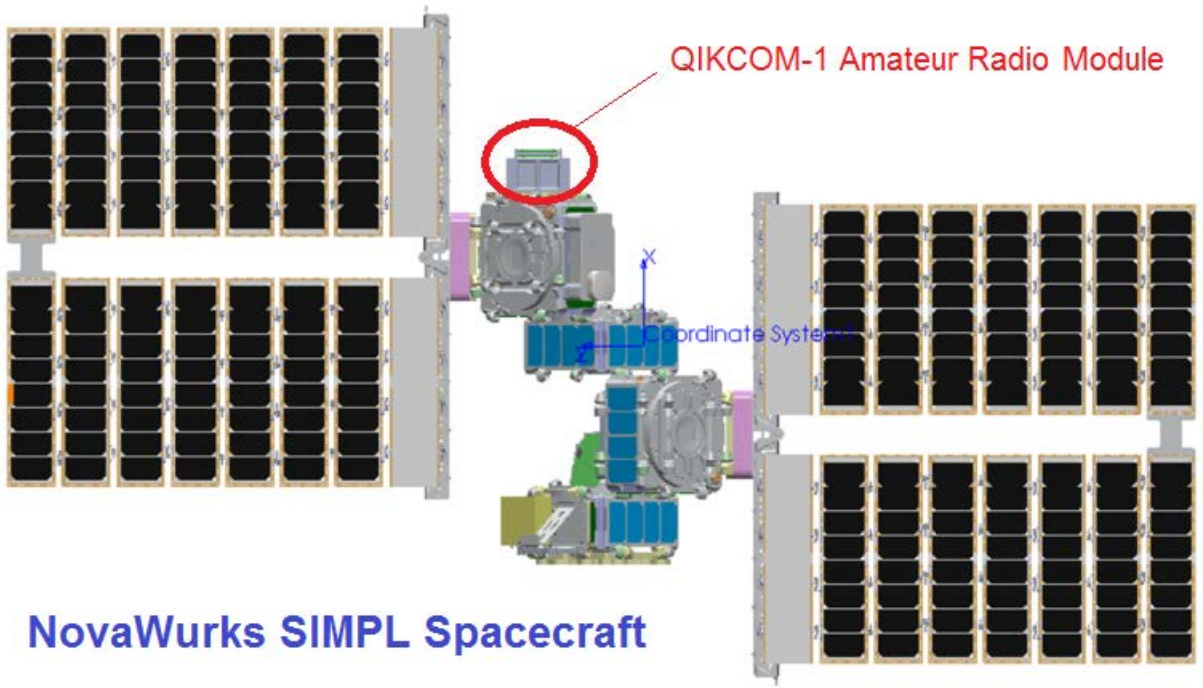
SATT4 Comms Board VHF & UHF and watchdog system

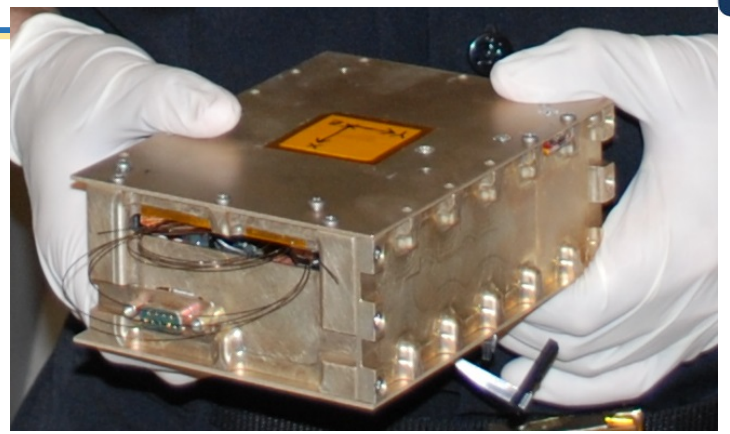


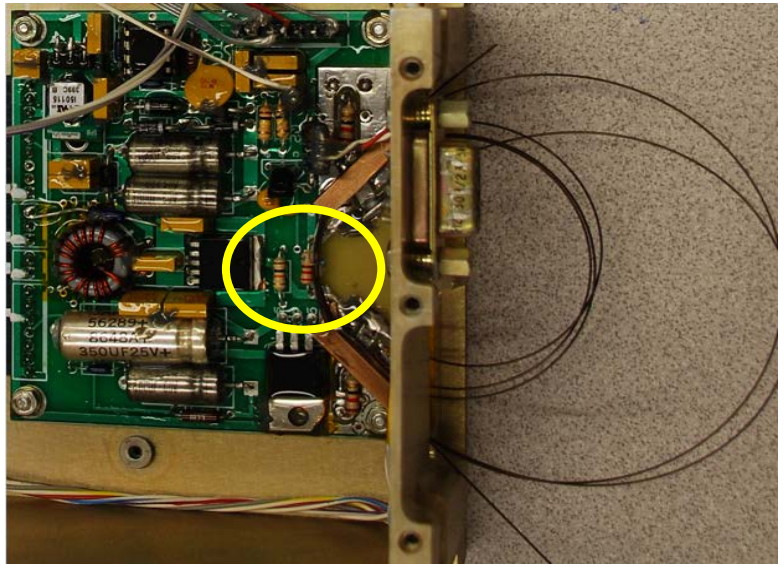
QIKCOM-1 APRS DIGIPEATER

On ISS Awaiting Deploy

Unique Antenna Deployment System





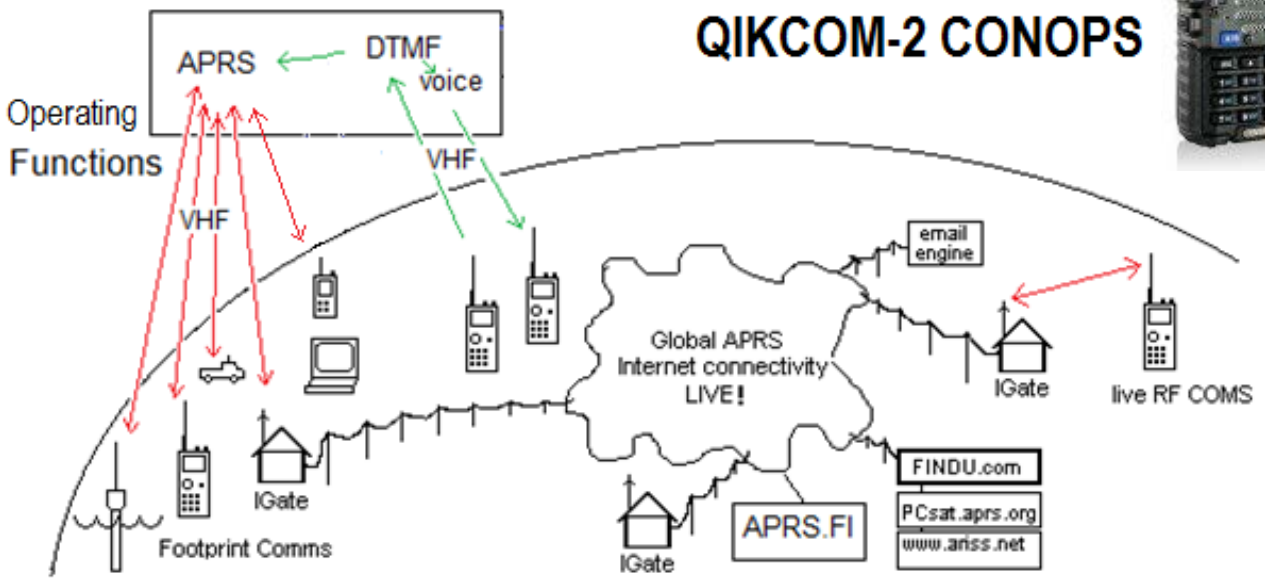


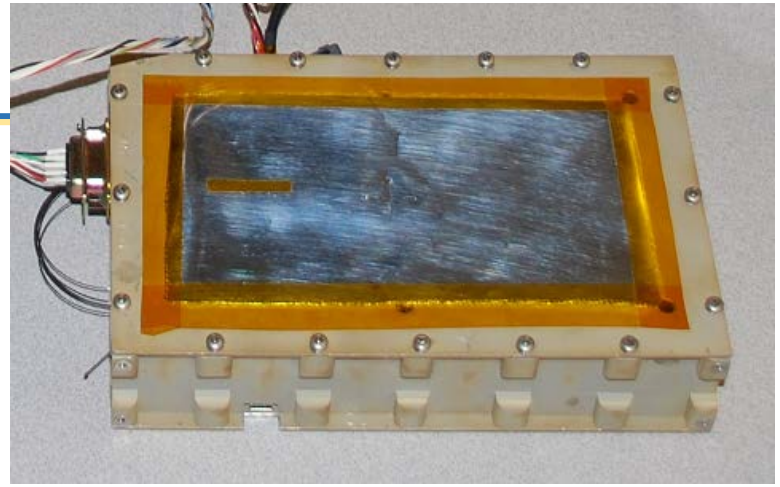
QIKCOM-2

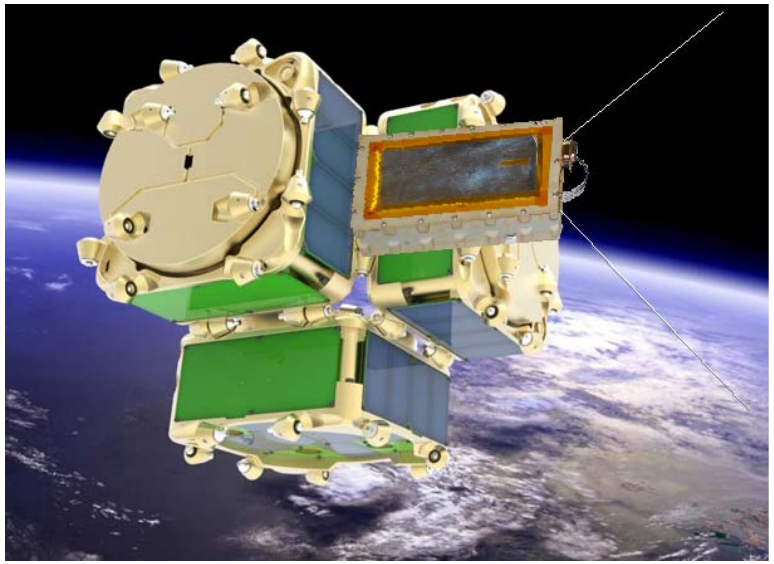
APRS and DTMF Digipeater

Converts DTMF to APRS and also Voice downlink

APRStt (touchtone)

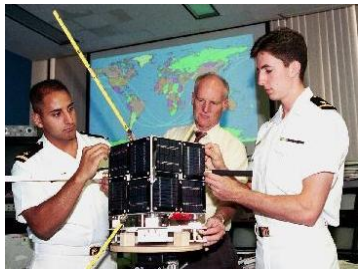




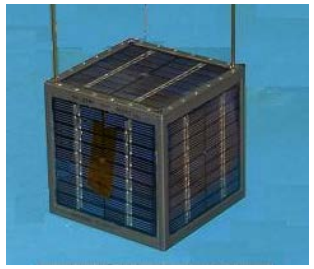


NovaWurks DARPA eXCITe mission

Not one of these missions was funded by external research $$$

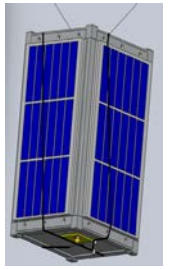


PCSAT (2001)

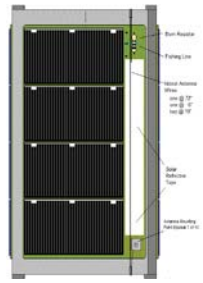


RAFT(2006)

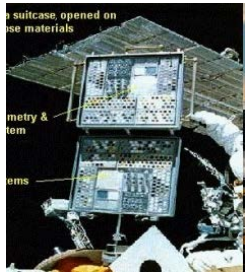
ARISS on ISS



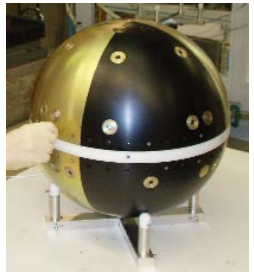
PSAT(2015)



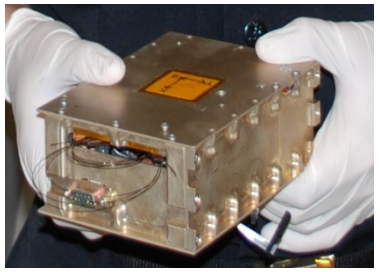
PSAT-2(2017)



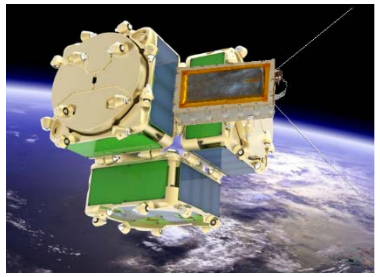
PCSAT2(2006)



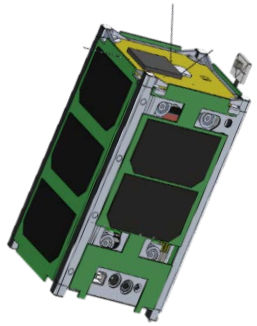
ANDE(2006)



QIKCOM-1 on ISS



QIKCOM-2 (Aug 2016)



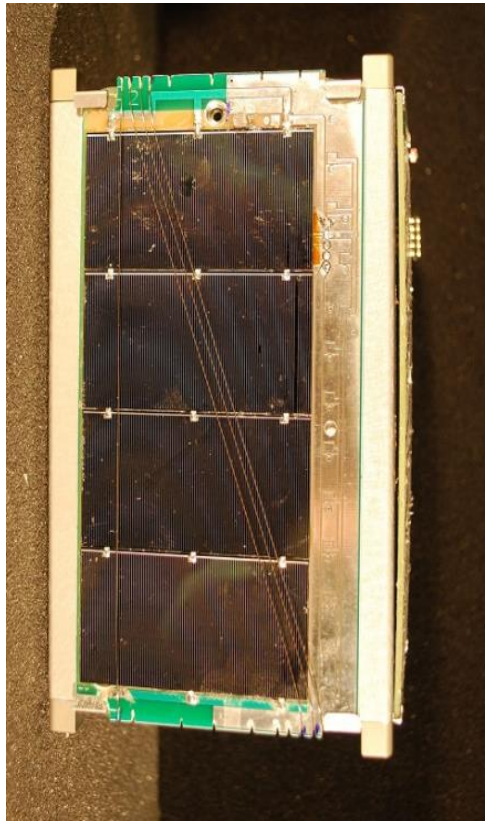
BRICSAT2 (2017)

Funding is/was general support for undergraduate capstone student projects, some Gift funds and FREE RIDES

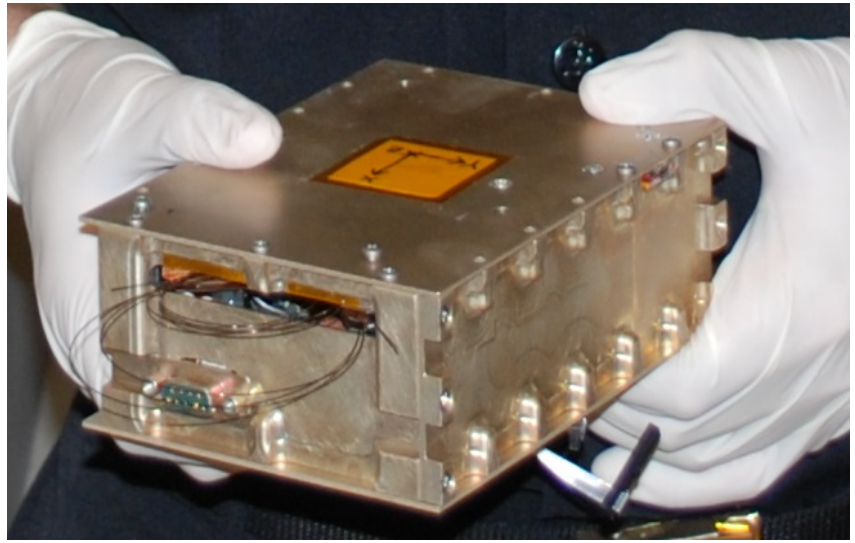
The Amateur Satellite Service provides students vital access to space at low cost

- As long as missions meet the rules :
  - a mission that serves the general Amateur Community and/or
  - provides self training and investigations relative to radio Technique
  - and the operations are without any pecuniary or conflicts interest
- For communications experiments it has several unique features:
  - Very large cadre of communications participants and volunteers
  - Worldwide users without specific a priori listing in the license
  - With these numbers, can fully load and test protocols
  - Greater frequency options – for exploring radio technique (23 bands)
  - Can use COTS hardware (which meets FCC amateur criteria)

BACKUP



Byonics MTT4B redesigned for Cubesat Comand/Control



USNA Amateur Satellite Command and control, telemetry, and 2-way User data relay

Licensing Distinctions:

Experimental and NTIA: [License the hardware and the institution]

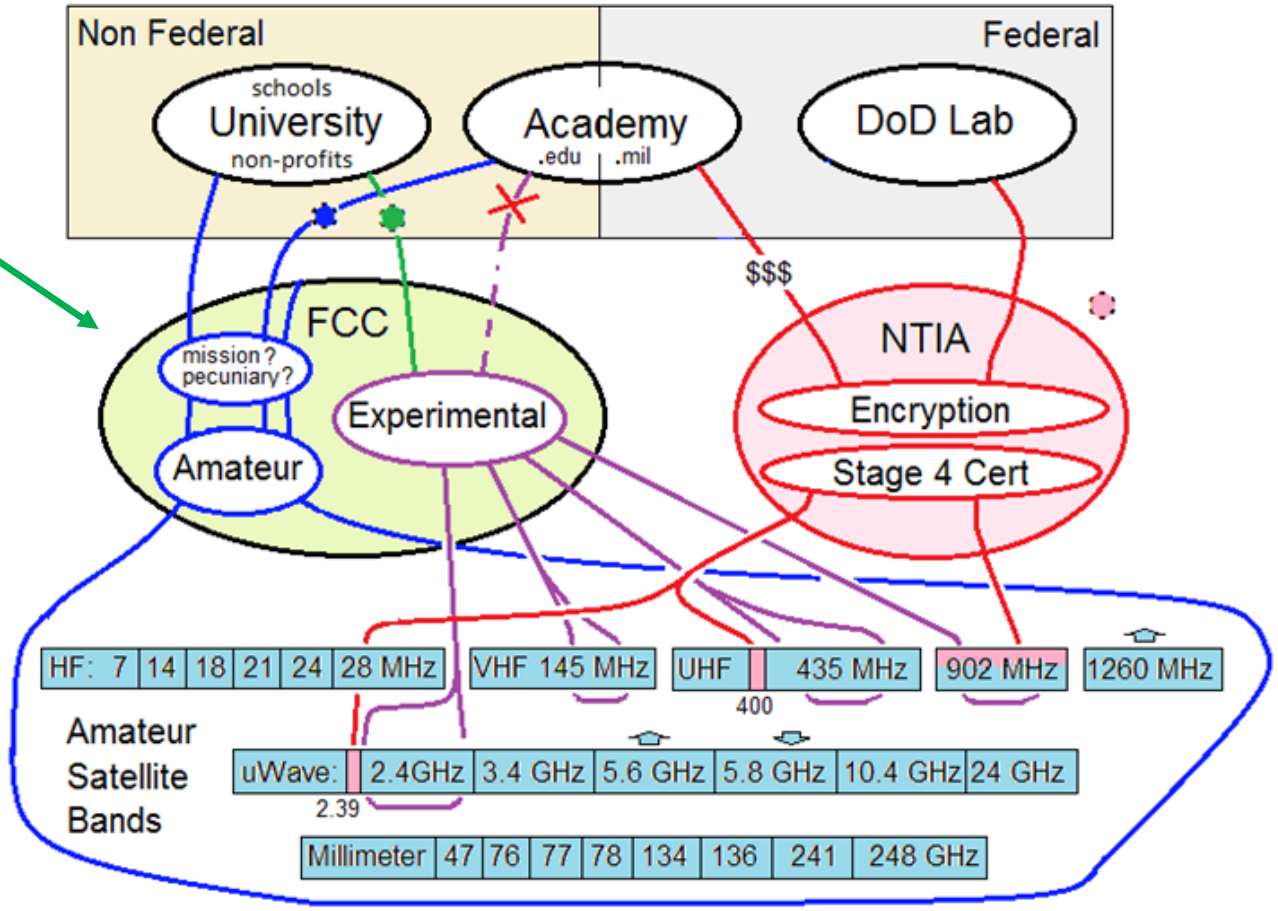
An FCC Experimental or an NTIA license is for a specific satellite, a specific launch, a specific mission and is given to an institution for that purpose for that satellite

Amateur Satellite License: [uses the existing license of the control operator]

Public Notice 2013: note[1]… rules do not… issue a specific amateur satellite license….
FCC Part 97: Any Amateur station can be a space station.
Any License class operator can control the space station…

FCC Public Notice of 2013 clarified Amateur and Experimental Licenses:

- It clarified the rules for experimental and amateur licensed spacecraft
- It did NOT require all research or university satellites to be experimental
- It did NOT change any specifics with the Amateur Satellite Service that has worked well for the last 57 years and over 300 satellites
- It did NOT say that individuals at government or Federal institutions cannot build/operate Amateur Satellites



- 2013 FCC clarification of Experimental Licenses
- Naval Academy Student Amateur Satellite missions
- Experimental is not possible for Federal Academies or Labs
- NTIA has no comparable Experimental license class

These are the FCC Amateur Satellite Rules

FCC RULES, PART § 97.207 Space station.

(a) Any amateur station may be a space station... Any class operator... may be the control operator of a space station...

(b) A space station must be capable of effecting a cessation of transmissions by telecommand whenever... ordered by the FCC.

(c) The following frequency bands and segments are authorized to space stations:

(1) The 17, 15, 12, and 10 m bands, 6, 4, 2 and 1 mm bands; and

(2) [segments in the] 7, 14, 145, 435, 2400 MHz and 3, 5, 10, and 24 GHz bands

(d) A space station may... retransmit... signals of Earth stations and other space stations.

(e) A space station may transmit one-way communications.

(f) Space telemetry transmissions may consist of specially coded messages... to facilitate communications or related to the function of the spacecraft.

(g) The license grantee of each space station must make ... notifications...

(1) Pre-space notification... Appendix 4 ... including [orbital debris mitigation]:

(i) Statement ... [on] limiting the amount of debris...

(ii) Statement [assessing]... probability of accidental explosions...

(iii) Statement ... limiting... the probability of ... collisions...

(iv) Statement detailing the post-mission disposal plans...

(v) If any ... item ... changes..., a replacement ... notification shall be filed...

(2) An in-space station notification...no later than 7 days following [activation]...

(3) A post-space station notification... no later than 3 months after termination...

The International Amateur Radio Union

INFORMATION FOR DEVELOPERS OF SATELLITES
PLANNING TO USE FREQUENCIES IN THE AMATEUR-SATELLITE SERVICE

"***Amateur Satellite Service:*** A radio communication service [using space stations on Earth satellites] for the purpose of self-training, intercommunication and technical investigations carried out by amateurs, that is, duly authorized persons interested in radio technique solely with a personal aim and without pecuniary interest." [RR 1.56] [RR 1.57]

> Commission rules and policy explicitly permit instructional personnel to operate while being compensated in the course of classroom instruction.
> [and] not confined to the physical confines of a normal classroom"

The purposes of an amateur satellite should be to:

(1) Provide communication resources for the general amateur radio community and/or

(2) Self training and technical investigations relating to radio technique. [See RR 1.56, 1.57, and 25.2.]

http://www.iaru.org/amateur-radio-satellite-frequency-coordination.html

"Radio technique" means having a reasonable possibility of application to radio communication systems. Examples relating to radio technique include, but are not limited to:

55 years of Amateur Satellites in space by the hundreds

- communication protocols
- attitude determination methods
- command and control procedures
- receivers, transmitters, and transponders
- antennas
- sensors to study spacecraft performance
- telemetry protocols
- power controls and supplies for use in space
- spacecraft computers, memory, operating systems, programs, and related items
- radiation effects on electronic components
- radio wave propagation
- meteor trail reflection
- measurements of the orbital environment

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55 years of Amateur Satellites in space by the hundreds

http://www.iaru.org/amateur-radio-satellite-frequency-coordination.html

License Class Is not determined by any of these Technical Explorations And Experiments

* * *

Nor by ownership

* * *

License Class Is determined by Comms Mission

FCC Public Notice DA:13-445 of 15 Mar 2013

Three Spacecraft Licensing Procedures:

Part 25: commercial and remote sensing
Part 5: experimental operations
Part 97: Amateur Radio Satellites

Amateur radio transmissions
are primarily for the purpose of exchanging messages with other amateur stations, and our rules prohibit "communications in which the station licensee or control operator has a pecuniary interest, including communications on behalf of an employer...."

> Commission rules and policy explicitly permit instructional personnel to operate while being compensated in the course of classroom instruction.
> [and] not confined to the physical confines of a normal classroom"

For experimental licenses,
The scope of permitted services includes experimentation under contractual agreement with the United States Government, and communications essential to a research project.

FCC Public Notice DA:13-445 of 15 Mar 2013

Three Spacecraft Licensing Procedures:

Part 25: commercial and remote sensing
Part 5: experimental operations
Part 97: Amateur Radio Satellites

Unintended consequence:
Most universities, etc (without an amateur radio mission) filed for experimental licenses and the rare amateur satellites were lost in the noise.
"Everyone" in the launch business expected to see a spacecraft LICENSE before manifesting a payload.

Amateur radio transmissions
are primarily for the purpose of exchanging messages with other amateur stations, and our rules prohibit "communications in which the station licensee or control operator has a pecuniary interest, including communications on behalf of an employer...."

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For experimental licenses,
The scope of permitted services includes experimentation under contractual agreement with the United States Government, and communications essential to a research project.

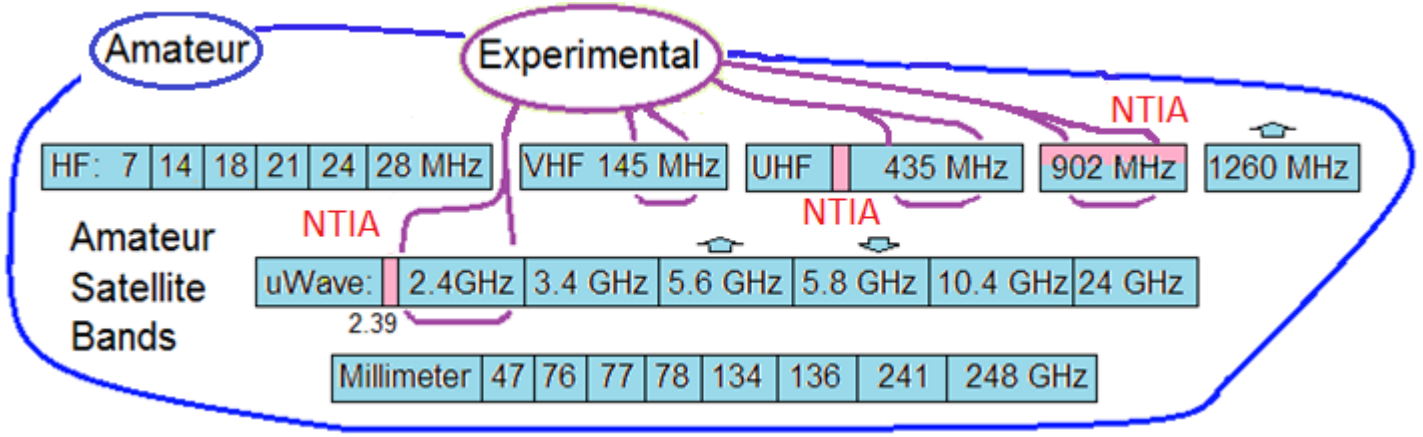
Catch 22 But the FCC does not issue any license or documentation for Amateur Satellites

Small Satellite / Cubesat Frequencies

For ***amateur radio service satellite*** operations, available frequencies are identified in Section 97.207(c) of the rules. [IE, 7, 14, 18, 21, 24, 28, 145, 435, 902, 1296, 2400, 5600, 10,000 MHz, etc]

For ***experimental operations***, there are no specific bands identified in the rules, and operations are on a temporary, non-interference basis, … Common frequencies authorized for small satellite operations to date have been for the 145-148 MHz, 420-450 MHz, 902-928 MHz (ISM), and 2.390-2.450 GHz bands.

Federal frequency bands commonly used for small satellite operations … include 420-450 MHz, 902-928 MHz, 2.390-2.395 GHz, and 2417-2450 GHz.



Most smallsat/cubesat Experimental and NTIA assignments come from within the Amateur Satellite Bands

[The Amateur Radio and AMSAT Position]

ARRL The national association for AMATEUR RADIO™

ADMINISTRATIVE HEADQUARTERS
225 Main Street, Newington,
Connecticut, USA 06111-1494
phone: 860-594-0200 www.arrl.org

To: Karl Kensinger, FCC International Bureau
From: David Sumner, ARRL (and AMSAT)
Date: January 14, 2014
RE: Small satellites

. . .

We appreciate the Commission's ongoing efforts to prevent commercial and governmental exploitation of the frequency allocations to the amateur and amateur-satellite services. [in the] Public Notice of March 15, 2013

. . .

However, we are finding that ~~there is continuing confusion~~ among the builders of small satellites such as CubeSats, particularly among those whose projects are conducted under the auspices of universities and other educational institutions.

[The Amateur Radio and AMSAT Position (continued)…]

ARRL, AMSAT and NSF endorse the use of the amateur-satellite service by non-commercial, university CubeSats. Use of the amateur-satellite service is mutually beneficial to the radio amateur and university communities since:

1. It helps provide more satellites that amateur radio operators can use.
2. It enables universities to engage the world-wide amateur radio community in gathering telemetry information from their satellites.
3. It promotes awareness of amateur radio to university students and licensing of new operators as well as helping to develop the next generation of amateur satellite builders.

AMERICAN RADIO RELAY LEAGUE

QST Official Journal

International Secretariat of The International Amateur Radio Union

Why do we use 3rd party Volunteer Amateur Control Operators?

Station Control — who may operate a transmitter

All stations operating in the amateur service and the amateur-satellite service, including space stations and Earth stations, must be controlled by "duly authorised persons," that is, individual licensed amateur radio operators who must be acting "solely with a personal aim and without pecuniary interest." [See RR 1.56 and 1.57]

Even with these limitations, organisations and amateurs have common interests and work together for their mutual benefit.

AMSAT-NA, for example, is an organisation that owns and builds space stations to operate in the amateur-satellite service. However, because it is an organisation and not an individually licensed radio amateur, it may not control an amateur station.

Licenses under which AMSAT-NA owned [satellites] are operated may be ... an individually licensed amateur radio operator. [or] an amateur radio club ... where a licensed ... trustee (the person responsible) for the club station.

http://www.iaru.org/amateur-radio-satellite-frequency-coordination.html

Why do we license our Amateur Missions via a 3rd party Volunteer?

In every case, one individual, a licensed amateur radio operator who is neither employed nor paid by the organisation is legally responsible for the operation of each amateur station or amateur-satellite station.

Commonly, the licensee is an unpaid member of the organisation owning the amateur station equipment or is a volunteer acting in close association with it. In these cases, the owner's interest and the licensee's "personal interest" are usually the same.

Of course, it is…possible…that the licensee or trustee of an amateur satellite station may determine that something he or she is requested to do is not in accordance with the rules and regulations of the licensing administration. If this happens, the licensee will inform the organisation and, if possible, they will work out a solution together that satisfies and protects both.

Thus, the individual responsibility of each licensed amateur radio operator, imposed by the Radio Regulations, works as a legal safety check for the organisation and the amateur to protect both of their interests and those of the amateur-satellite service as well.

This arrangement has worked successfully and effectively for AMSAT-NA and its predecessor organization since the first amateur satellite (OSCAR I) in 1961.

http://www.iaru.org/amateur-radio-satellite-frequency-coordination.html

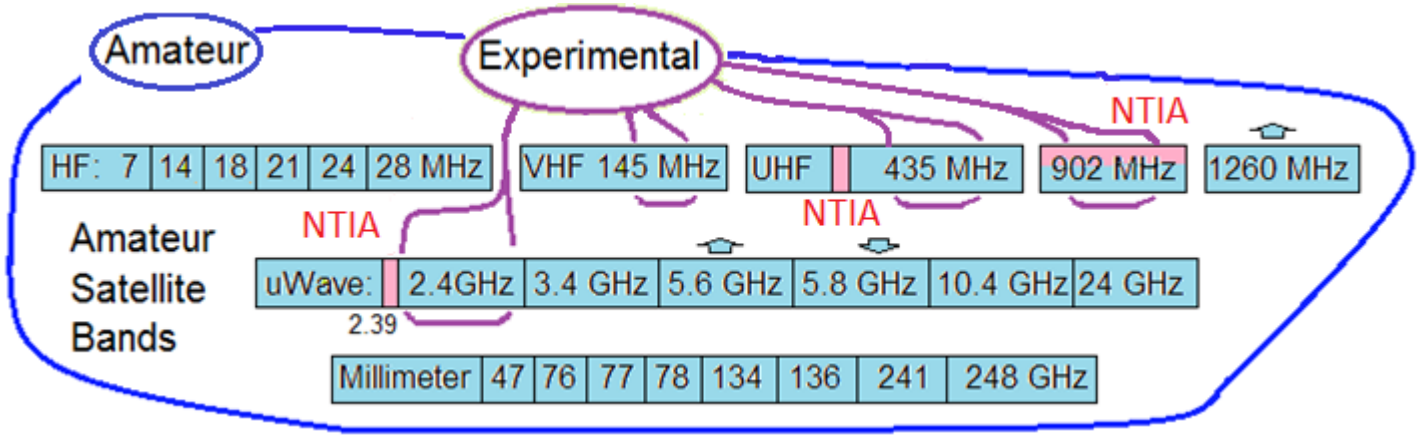
NTIA Freqs 449 MHz up & 900 MHz down are not workable

449 MHz band is full of megawatt Doppler Wind Profilers blocking uplinks around the world

There is no NTIA stage 4 certified cubesat scale radio in production for under $70,000

The NTIA now says that 900 MHz is no longer available (its full of unlicensed gadgets anyway)

Ergo - The only viable NTIA Cubesat command and control is now Sband (half-duplex)

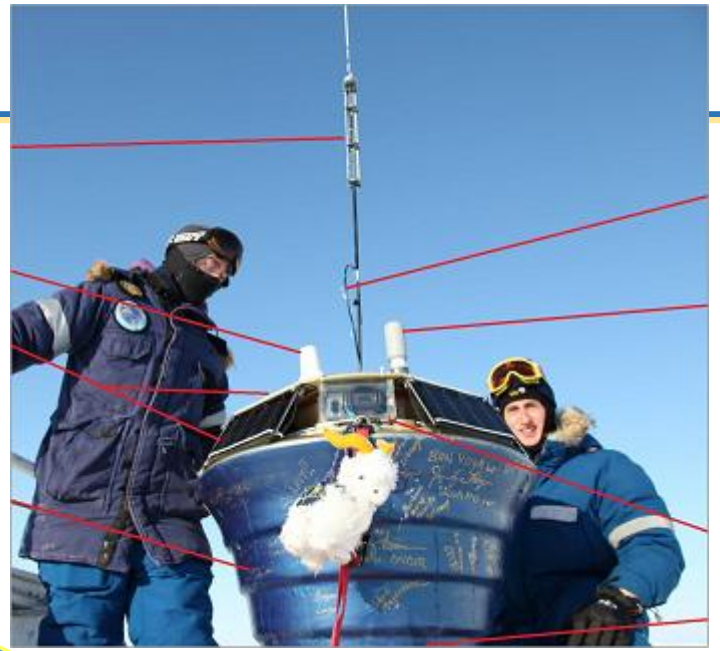


Most smallsat/cubesat Experimental and NTIA assignments had come from within the Amateur Satellite Bands

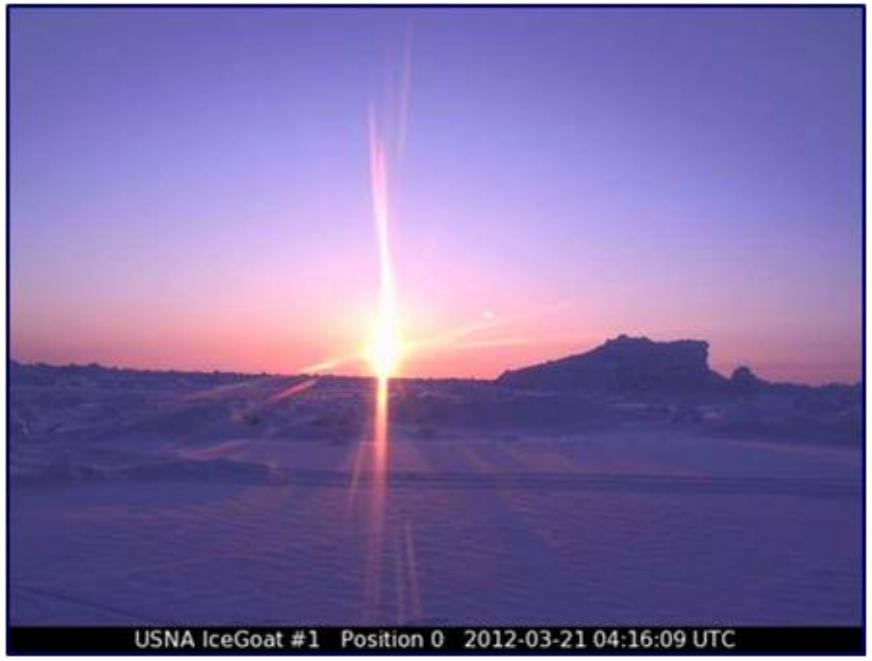
Similarly the Amateur Satellite Service builders will not use 2.4 GHz for WIFI interference reasons

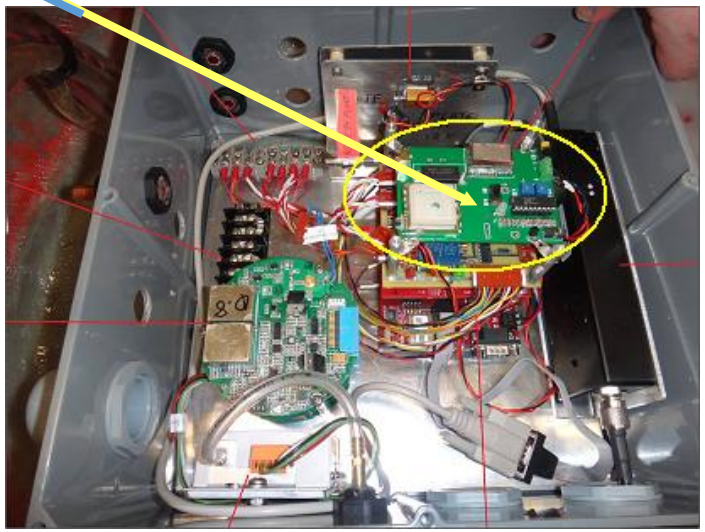
Arctic Buoy Student Experiment

- USNA Arctic Buoy deployed March 2012



The APRS piece





The USNA developed Cubesat comms card

Mission: Common low cost Cubesat Amateur Radio Transponder

Hardware: VHF simplex data radio on 145.825 MHz

Size/Mass/Power: 3.4” square, 1W orbit average

Antenna: 20” thin wire whip antenna

Benefit: Space Education AND ground experiments with student access

High visibilty to worldwide educational institutions, fosters collaboration, orders of magnitude greater student experimental access to space systems (ground segment).

- Amateur Radio User Relay mission
- Independent telemetry command/ control channel,
- RS232 serial data, 16 on/off discretes, backdoor reset capability.
- Worldwide Telemetry Beacon access via global station network.

145.825 MHz

Byonics MTT4B redesigned for Cubesat Comand/Control

FCC Public Notice DA:13-445 of 15 Mar 2013

Who Should Apply? For amateur radio service satellite operations, the amateur satellite control Operator… [who] should have the ability to remove the satellite from a launch… and [cease] operations.

The Commission's Part 97 [Amateur Rules] rules do not provide for the issuance of a specific amateur satellite license document, but instead require a licensed amateur operator to provide information to the Commission prior to launch of the satellite.

For experimental operations, the applicant should be the party that … controls decisions about the satellite's mission…, design, construction, tendering… to a launch… provider or … launch integrator, and operations of the satellite once on orbit. This is in most cases a university or research institution, but may also be a commercial venture seeking to test equipment for developmental purposes.

FCC Public Notice DA:13-445 of 15 Mar 2013

What Information is Required to Apply?

For Amateur pre-launch notifications:

a. A draft "Appendix 4" notification for submission to the International Telecommunications Union (ITU) Radio Regulations. The draft notification should be prepared using the ITU software "SpaceCap," which can be downloaded from the following link: http://www.itu.int/en/ITUR/software/Pages/spacecap.aspx.

b. A letter from the International Amateur Radio Union (IARU) indicating [frequency] coordination.

FCC Public Notice DA:13-445 of 15 Mar 2013

What Information is Required to Apply?

For experimental licenses, applicants must first obtain an FCC Registration Number at https://fjallfoss.fcc.gov/coresWeb/publicHome.do.

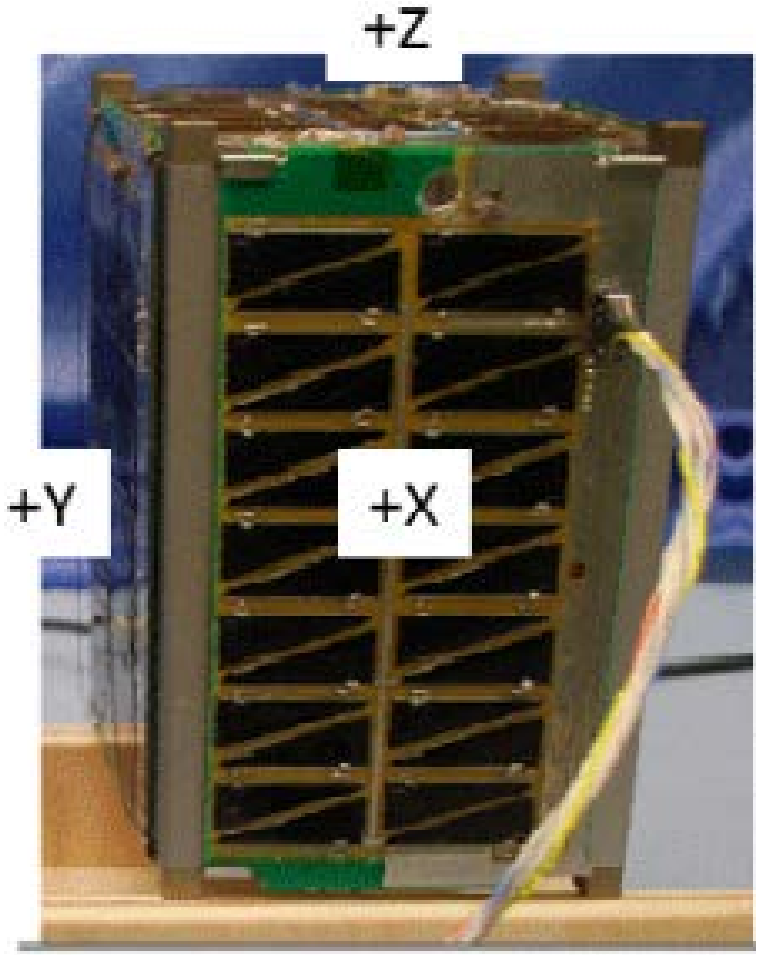
Then submit its license application through the Office of Engineering and Technology's (OET) Experimental Licensing system; or,

For operations lasting less than six months…, an applicant should apply for Special Temporary Authority (STA) at https://apps.fcc.gov/oetcf/els/forms/STANotificationPage.cfm.

When is Coordination with Federal Governmental Agencies Necessary? An applicant's proposed satellite operations may affect spectrum used by Federal Government entities. OET will determine [if it should] coordinate with the NTIA [and/or be] subject to special conditions.

PSAT Power, Comm, Xponder & ADCS

Accredited Engineering majors now require hands-on Design-Build-Fly type projects



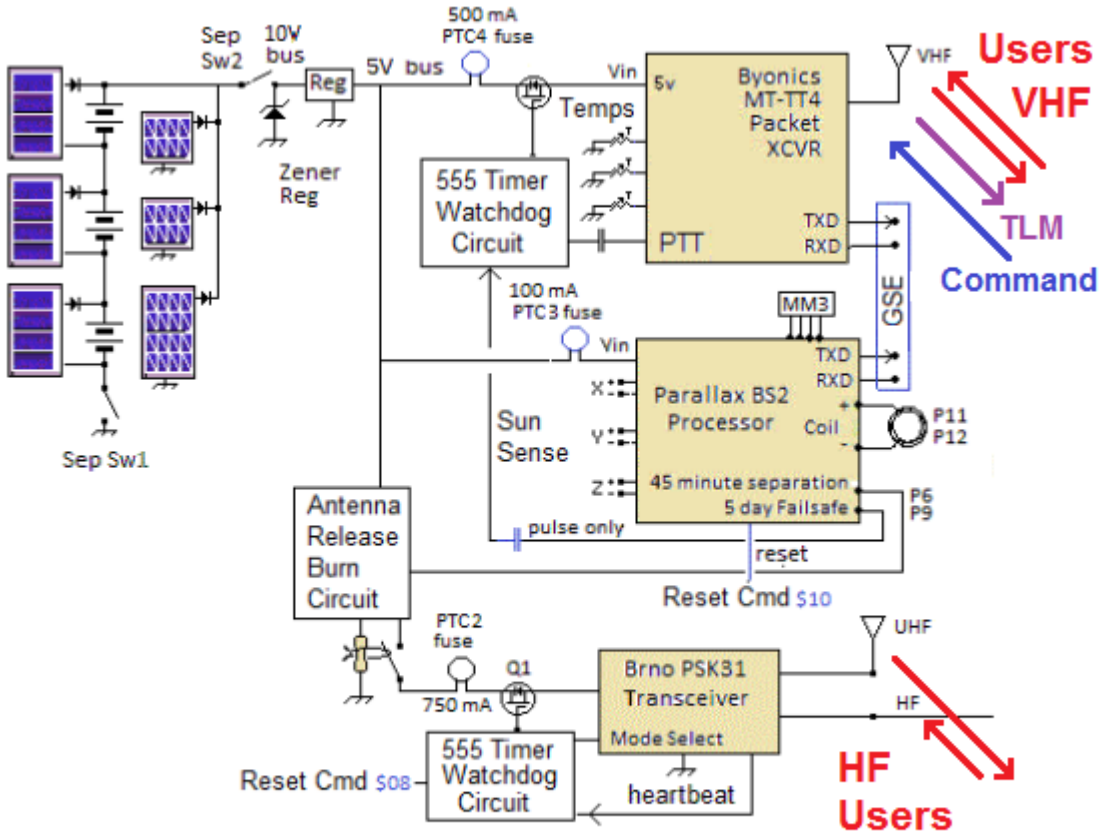
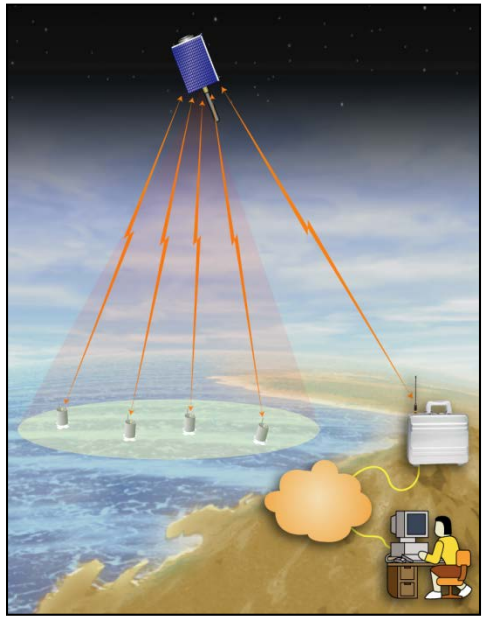
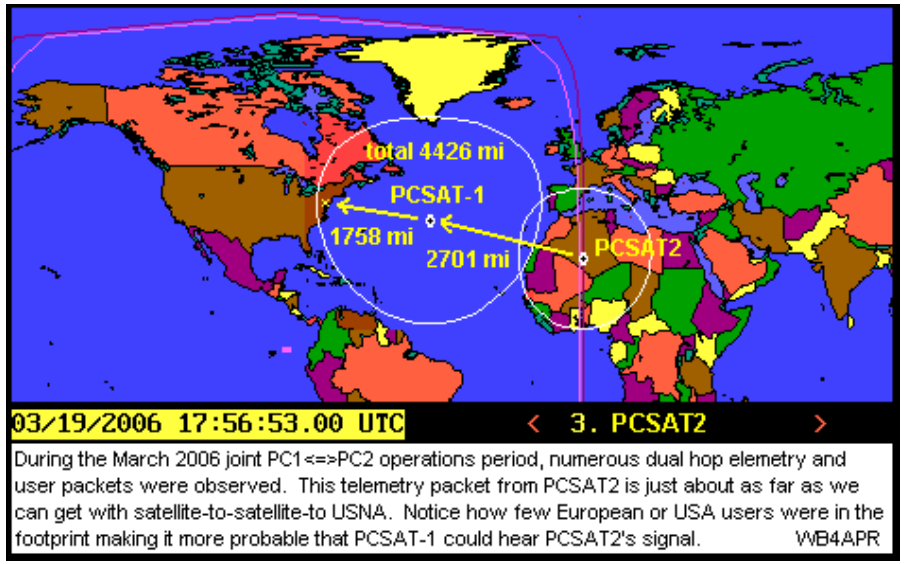


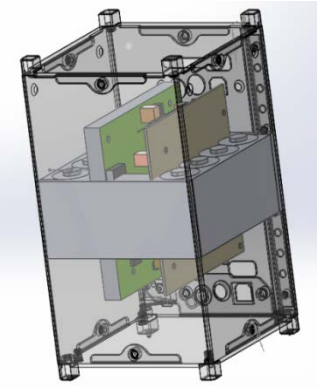
Figure 3: PSAT System Block Diagram

APRS Satellite Applications





- Wilderness Position and Status Reporting
- Off-shore Worldwide Position and Texting
- Remote Data Collection
- Comms Experiments (dual hop)



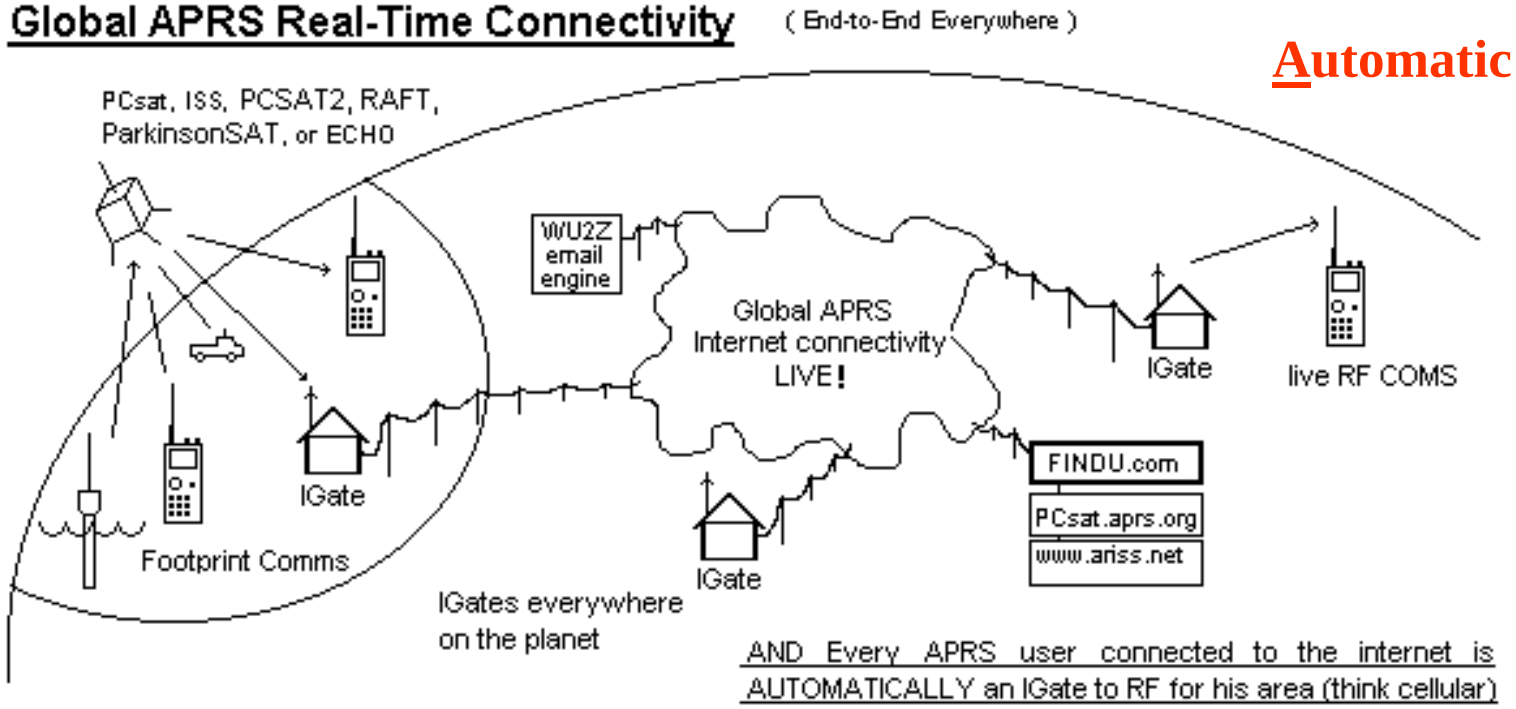
Licensed Radio Amateurs are Everywhere

"When you have *no comms*, 1200 baud text/data is great!"

CAPT Chas Richard

W4HFZ

The USNA Global Internet linked Amateur Data Network



Automatic Packet Reporting System

APRS Packet Radio Network has evolved worldwide from USNA beginnings in 1993

Internet Linked for live Communications, telemetry and data

Global Wilderness Areas (90% of Earth)

- Live Global APRS Balloon Tracking Web Page