Cubesat Remote Data & Comms Transponders

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A satellite relay channel for Amateur Satellite User data anywhere on earth. PSAT
Cubesat Remote Data & Comms Transponders

A satellite relay channel for Amateur Satellite User data anywhere on earth.

The Earth    The Climate    The Wildlife
The Air    The Water    Humanity

Human-to-Human communications
Remote Robot communications
Cubesat Remote Data & Comms Transponders

A satellite relay channel for Amateur Satellite User data anywhere on earth.

Engineering Educational Objective:

One or two semester student engineering projects

Individual engineering responsibility

Low cost

Driven to completion

Where Failure (learning) is an option
Cubesat Remote Data & Comms Transponders

A satellite relay channel for Amateur Satellite User data anywhere on earth.

Problem with Spacecraft segment focus:
Multi-year, often delayed, expensive small cubesats do not well meet these particular undergraduate objectives.
Solution: Ground Terminal Applications Focus

Supports Student Experimenters worldwide
Quicker Student involvement using a Ground Terminal Operational Concept

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

Supports Student Experimenters
School missions/movements
Theater area communications
and Emergency Response Comms

The Yard Patrol Craft

13th Co Army/Navy Football Run Comms by USNA Radio Club
W3ADO

30 Nov 2001
de WB4APR

Education
Force
Multiplier!
APRS Local & Global Internet linked Data Network

Global APRS Real-Time Connectivity

- PCSat, ISS, PCSAT2, RAFT, ParkinsonSAT, or ECHO
- Footprint Comms
- IGates everywhere on the planet
- AND Every APRS user connected to the internet is AUTOMATICALLY an IGate to RF for his area (think cellular)

APRS Global Packet Radio Network
Internet Linked for live Communications

Automatic Packet Reporting System
Arctic Buoy Student Experiment

- USNA Arctic Buoy deployed March 2012

The APRS piece
Example Remote Sensors using **APRS Protocol**

Very Simple

**APRS transmitter**

**GPS**
Why We Need Psat Satellite Transponders

- 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
Global Wilderness Areas (90% of Earth)

• Live Global APRS Balloon Tracking Web Page
Global Wilderness Areas (90% of Earth)

M0XER-3, 4 and 6

• Live Global APRS Balloon Tracking Web Page

http://habitat.habhub.org/mobile-tracker/
Tiny M0XER APRS (balloon data) payloads

434 MHz

‘M0XER-4
‘round-da-world
“APRS” Tracking

Track any experiment anywhere and collect data

Tactical situational awareness
Hand-Held Satcom via APRS & Psat

Ground Terminal is Walkie-Talkie, and Palm Pilot

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

CAPT Chas Richard
MAREA* Rover Projects (ARRL)

- STEM School projects
- Excite kids with Robotics
- Drive anywhere on Earth!
- Via APRS links

*http://www.arrl.org/marea-ham-radio-robotics
Ground Terminal Applications Focus

Tactical Situational Awareness and Text Messaging

Last 100 stations!

Direction & Distance

Frequency and Tone
APRS Experiment Data Access (via internet)

http://map.findu.com/wb4apr* to see data on ANY experiment in the world

APRS Stations Near WB4APR-9 (last 240 hours)

* Click to see all stations on map

Based on the USNA Automatic Packet Reporting System
Tracking (on Google Earth)

http://aprs.fi

Tactical situational awareness
Findu.com Telemetry Plots

Live Example:  www.aprs.org/wb4apr-15.html
Our Amateur Satellite Data Relay Problem

- **ISS** – Always there, but does not cover the poles

- PCSAT-1 since 2001, but only works when it wants to…

- NEED a continuous presence in space for these relays!

- The **more** the better!
Dual Hop Operations with PCSAT-1 and PCSAT2:

During the March 2006 joint PC1<=>PC2 operations period, numerous dual hop telemetry and user packets were observed. This telemetry packet from PCSAT2 is just about as far as we can get with satellite-to-satellite-to USNA. Notice how few European or USA users were in the footprint making it more probable that PCSAT-1 could hear PCSAT2’s signal.
All on 145.825 MHz

APRS in Space
Automatic Packet Reporting System

- 2001 PCSAT-1 Prototype Comm (semi-operational)
- 2006 PCSAT2 on ISS (returned after 1 year)
- 2007 ANDE de-orbited in 1 year
- 2008 RAFT de-orbited in 5 months
- 2007 Present ISS semi-operational due crew settings
- 2014 CAPE II AX.25 U of Louisiana (Nick Pugh)
- 2015 PSAT APRS and PSK31

APRS space frequency is published as 145.825

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

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

Earlier reductions to 5” cubesat on RAFT (2006)

APRS Global data network
AX.25 A single 3” Square card 145.825 MHz

Mission: Remote Data Relay, Data Exfiltration, Remote Sensor Relay

Benefit: Support Space Education on the ground through space applications and student experimental access

Hardware: VHF simplex data Xsponder 145.825 MHz

Size/Mass: < 10 cu.in (1 PCB 3.4” square), <0.1kg

Power: < 1W orbit average, 5 volts.

Integration Requirement: Simply, on/off (or *)

Structure Impact: Needs 19” thin wire whip antenna (1 cu.in)

Benefit to Spacecraft: High visibility to worldwide educational institutions, fosters collaboration, orders of magnitude greater student experimental access to space systems (ground segment). * Independent back-up telemetry command/ control channel, RS232 serial data, 16 on/off discreetes, backdoor reset capability. Worldwide Telemetry Beacon access via global station network.

APRS Global data network
Psat APRS Network Architecture

Global Volunteer Ground Station Network
Internet Linked for live Telemetry

APRS Global data network
Global Volunteer Groundstations
feed live downlink into Internet
70 APRS Satgates hear ISS, but only 10 hear PSAT (-17 dB)
APRS iGate

APRS IGate with Raspberry Pi and DVB-T stick

DK3WN

http://www.kubonweb.de/?p=130
http://www.mstewart.net/super8/aprs/RASP/index.htm
http://n5dux.com/ham/raspberrypi/igate.php

Raspberry PI iGate APRX with soundmodem
https://www.youtube.com/watch?v=MtUnuJn_70o
Communications Mission Background

APRS is everywhere *(Remote Data Relay)*

Focus:

"Network Centric" & Remote Sensor Experiments

300 stations
In 35 miles

Find any station, Any map, Anywhere- http://aprs.fi
APRS Terrestrial Data Relay Network

- Supports over 20,000+ terrestrial users and experimenters.
- But stops at the shoreline and has huge holes in the wilderness.
Satellite Users more sparse – Need to Track to Use

APRS Global data network

PCSAT2 User Plot 18 Apr 06
There are terrestrial network holes everywhere

Just like cell coverage,

Maybe 70% of USA users are actually out of range of the terrestrial network in rural areas

And the terrestrial user does not know when the next APRS satellite is in view…
Our next QIKCOM-1 has an alert Beacon

When over USA, a 1 minute beacon on terrestrial frequency:
- **Won’t** be heard amongst the din on the terrestrial freq in coverage areas
- **Will** be heard by mobile out of range of terrestrial connectivity
- Format is QIKCOM-1: 145.825MHz. Tune to operate
- One-button satellite access!
- On the front panel of the radio!
Remote Sensor Baseline

Naval Academy Student Project
- If free-floating, do not disturb.
- If aground, move to deep water and advise bruninga@usna.edu
- If later than 30 Nov 2006, recover and advise above.

Psat
USNA-0601

2006  15:1 reduction  2008

See Buoy Location and Telemetry at
http://www.ew.unsa.edu/~bruninga/buoy4.html

Piggrem
Remote Buoy Baseline Test – Success of 1 min Xmit rate
If it flies, it could have an APRS transponder on it

- If it is off the ground we want a TRANSPONDER on it!
- Range at 5000’ = 100 miles
QuickLook: Global APRS Data Network

- **aprs.fi** - Every Packet on Earth

- **ariss.net** - Every packet via ISS

- **pcsat.aprs.org** – Every packet via PCSAT
Psat Transponder & Aux Payload

75% Payload Space Available! (only 50% shown here)

- 18 cu.in for Transponder
- External 19” whip antenna
- 68 cu.in for Aux Payload (SPMS?)
- Aux payload gets 4” external panel
- Aug payload gets .5 kg – self contained
- 1 to 3W average power for aux payload

APRS Global data network

Vandegriff
PSAT Unique parallel-charge EPS Design

- Uses 2 NiCd cells per solar panel

Passive Battery Charge Regulation

Four 0.8V GaAs-Sn PV cells per Panel

The spacecraft uses passive differential solar radiation pressure to gently roll about the Z axis about 0.2 RPM.

Each side panel then equally charges two NiCd cells at 1.4V each. Cells are oversized so that worst case peak charge current remains below 0.15 safe trickle charge of NiCd.

The Transmitter key line is inhibited until the spacecraft is commanded into an operational mode. The key circuit is a NMOS transistor. The transmitter is burst-mode packet system, keyed up only a second or so at a time.
Unique Power Attitude – Z coil ADCS

- Uses only one Z coil for attitude control
  - Fires only within +/- 20 deg of Equator
  - Solar Panel angle better than 95% power
  - Higher reliability
  - Passive Spin maintenance

Differential Radiation Spin
PSAT’s mass is centered in Z

- For Maximum MOI about Z
- Batteries to outside for MOI & Shielding
- Stainless steel belt around everything
PSAT BS2 CPU telemetry – spin analysis

s#033814, oz290, qhDqhEqhFqhHqhIqhIpiJpiKpiLphLphMphM
	sun vector triplets

xyz  xyz  xyz  xyz  xyz  xyz  xyz  xyz  xyz  xyz  xyz  xyz

0z200 -> WOD=2 -> 12 samples every 5 sec

values A-Z = +1 to +26, a-z = -1 to -26

DK3WN
• When we find the time we are really looking forward to understanding our Solar Radiative Spin system.
PSAT: Aux PSK31 Transponder Payload

- Flew on PCSAT2 on ISS but astronaut broke off HF antenna
- Flew on RAFT but took 1 kW uplink and negative power budget
- Now Operational since May 2015 launch of PSAT and BRICsat
- Both transponders built at Brno Univ, Czech Republic.

28 MHz SSB uplinks

435.350 FM downlink

APRS Global data network
PSAT: PSK31 Transponder Payload !!!

Built Dr. Mirek Kasal OK2AQK and students Tomas Urbanec, P. Váguner

HF Linear RX  FM XMTR
PSK DopplerPSK

by Andrew Flowers K0SM

- experimental program to compensate the doppler shift on PSK31 uplinks
- its a PSK31 transmitter that is merged with an orbital propagator to cause your the transmitted signal to drift exactly opposite to uplink doppler effect

http://www.frontiernet.net/~aflowers/dopplerpsk/dopplerpsk.html
Imagine turning a 6’ HF whip on a 7” spacecraft Ground plane!

Any instrument connection detunes SWR to infinity

So, Put Analyzer inside!
PSAT Nitinol Wire Whip Antennas

- Burn resistor test leads to power supply
- HF unwound in plane of photo
- HF is not caught here but is held tangent due to drag of remainder of HF antenna off to right
- UHF1
- UHF2
- VHF

APRS Global data network
Wrapping Antennas to one Burn Resistor

2 Orthogonal UHF whips
One VHF whip
One 6’ HF whip
3rd Enable Switch
PSAT position packets

!48 . N\027 . ES120/999/W3ADO s#000133,0z090

PSAT can generate its own APRS position report from a simple Lat/Long orbit table.
PSAT bulletin packets

PSAT contains 3 bulletins for every country area, BLN0USA, BLN1USA, BLN2USA for example over the USA. The same geographical areas are used for sending Bulletins.

PSAT-1>APOFF,ARISS,qAR,ON7EQ-10::BLN0USA :PSK31 435.35 Up on 28.12
PSAT-1>APOFF,ARISS,qAR,HG8GL-5::BLN1USA :ARISS.NET & PCSAT.APRS.ORG
PSAT-1>APOFF,ARISS,qAR,ON7EQ-10::BLN2USA :See AFRS.FI & 144.39 users
PSAT>APRSON,ARISS,qAR,DK3WN-8::BLN0EUR :PSK31 435.35 Up on 28.12
PSAT>APRSON,ARISS,qAR,DK3WN-8::BLN1EUR :Coming soon -> AMSAT-UK Colloquium July 24-26th at Guildford
PSAT>APRSON,ARISS,qAR,DK3WN-8::BLN2EUR :See AFRS.FI & 144.80 users
How not to Make a Satellite

Stop adding neat features…

Make sure it fits
The boards stack across and zero clearance

- For Maximum MOI about Z
- Batteries to outside for Shielding
Chip Radiation Shielding?

Epoxy Lead squares over critical chip dies
Our Next APRS Satellites

QIKcom-1

- APRS system (PSAT)
- Release from ISS in October 2015
- flies on host spacecraft (28V, no solar panels or ADCS)

QIKcom-2

- launch December 2015
- 1st APRS TouchTone Satellite
- APRSStt is a complete two way system that enters data using DTMF and receives APRS information by synthesized voice response.
QIKCOM-2 converts DTMF to both Voice and APRS and APRS data to voice!

With QIKCOM-2, not just APRS but DTMF data sources can be relayed among all users.
The 324 Grid system has 99 grids...
Position to 60 miles in 4 digits

The table at right begins at 00 thru 99 to give worldwide 4 digit Grids for the next APRS DTMF satellite using DTMF only.
Standard Message communications (4 bytes)

- Since 1800’s for telegraph
- Since 1927 or so for radio
- Most of the time, most of what is said, has been said before
- Q2 has 99 messages and 99 modifiers
Remember, lots of Space APS here on Earth

- STEM School projects
- Excite kids with Robotics
- Drive anywhere on Earth!
- Via APRS links

*http://www.arrl.org/marea-ham-radio-robotics*