ParkinsonSat

NAVAL OSCAR-84

... APRS plus a new PSK31 Approach

AMSAT-UK Colloquium 2015

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WB4APR

- Senior Research engineer at the US Naval Academy
- 1970 - 1990 USNA
- 1984 developed CETS (Connectionless Emergency Traffic System) on C-64 for digital packet comms
- 1992 changed name of CETS to APRS
- 2001 developed PCSAT-1
- 2006 developed PCSAT-2 APRS satellite to fly on outside of ISS
- 2007 developed ANDE, RAFT and MARScom APRS amateur satellites for deployment by Space Shuttle
- 2015 completed PSAT, QIKCom-1, QIKCom-2

PSAT is one of five APRS-networked Amateur Radio satellites that will be in orbit during 2015. The others include PCSat-1, QIKcom-1 (set to launch in September), QIKcom-2 (set to launch in December) and the ARISS packet radio system on board the International Space Station since 2007.
USNA's APRS satellites

PCSAT-1 (NO-44)

AX.25 packet system for use as a UI digipeater, telemetry, command, control
W3ADO-1 1k2 and 9k6, PCSAT-1, PCSAT-2

launched September 30, 2001 from the Kodiak Launch Complex on Kodiak Island, Alaska
NO44 operates in a negative power budget
most passes only one lucky packet
hard to command

20150302075949,W3ADO-1>BEACON,SGATE,qAS,EA6XQ:T#002,077,092,088,067,215,11111111,0001,1
20150302080149,W3ADO-1>BEACON,SGATE,qAS,EA6XQ:T#004,159,159,036,209,215,11111111,0011,1
20150303091358,PCSAT-11>BEACON,SGATE,qAS,EA6XQ:T#001,141,067,063,071,218,11111111,0000,1
20131127014203,PCSAT-12>BEACON,SGATE,qAS,JA0CAW-6:T#007,096,081,119,123,217,11111111,0010,1
USNA's APRS satellites

PCSAT2

- suitcase-like Passive Experiment Container
- 10-meter PSK31 multi-user transponder
- FM voice repeater
- AX.25 packet system for use as a UI digipeater, telemetry, command, control

fm PCSAT2 to BEACON via SGATE WIDE ctl UI pid F0 T#143,164,139,155,143,146,11111111,0010,1
fm PCSAT2 to BEACON via SGATE WIDE ctl UI pid F0 >312242z OPS Normal. Enjoy! [de WB4APR]
fm PCSAT2 to BEACON via SGATE WIDE ctl UI pid F0 T#144,154,106,019,113,008,11111111,0011,1
fm DK3WN to CQ via PCSAT2* ctl UI^ pid F0 =4943.52N/00857.19E-Mike, JN49LR >>> www.dk3wn.info (UIV23)
fm PCSAT2 to BEACON via SGATE WIDE ctl UI pid F0 T#170,138,140,001,000,075,11111111,0000,1
USNA’s APRS satellites

ANDE-MAA (NO-61)

Atmospheric Neutral Density Experiment (ANDE) consists of two microsatellites launched from the Shuttle payload bay will measure the density and composition of the low Earth orbit (LEO) atmosphere while being tracked from the ground.

Mock ANDE Active (NO-61), 48cm, 52 kg
Fence Calibration (NO-62)

• December 2006 (Discovery) – December 2007
• laser experiment
• voice synthesizer
• AX.25 packet system for use as a UI digipeater, telemetry, command and control

ANDE Deorbit Award
AMSAT P3E donation (3 pixel: MAA)
USNA's APRS satellites

RAFT

Atmospheric Neutral Drag Experiment

- December 2006 (Discovery) – May 2007
- radar experiment (NSSS frequency 216.98MHz)
- laser experiment (Graz)
- PSK31 transponder
- voice synthesizer
- AX.25 packet system for use as a UI digipeater, telemetry and command, control

RAFT>BEACON, SGATE: T#026,086,102,037,065,070,00000000,000
RAFT>BEACON, SGATE: RAFT is on 145.825  US Naval Academy
RAFT>BEACON, SGATE: T#027,080,002,036,034,070,10000000,000
RAFT>BEACON, SGATE: T#030,078,002,035,034,069,10000000,000
RAFT>BEACON, SGATE: T#031,078,002,034,034,070,10000000,000
ParkinsonSat

- Initiated in 2006 with seed funding from The Aerospace Corporation and ONR (Office of Naval Research) in honor of the retirement of Dr. Bradford Parkinson, the original model evolved into a cubesat in 2008.
- Parkinson is an American engineer and inventor and United States Air Force colonel and best known as the father of the Global Positioning System.
- During the long wait for a launch opportunity, the design was changed and simplified in 2014.

The four deployable fixed solar arrays were removed as higher efficiency solar cells became available.

- 1U cubesat but in a 1.5U package
- 4 large and efficient solar cells per side
on command to deploy the antennas which are stowed for launch, the burn resistor heats, melting the nylon fishing line holding the wire antennas.

The offset solar reflective stripe compared to the black solar panels imparts a slight spin about the Z axis for good thermal balance. It also assures equal charge on the batteries which are charged one NiCd pair solar side panel.
PSAT power system

- The power system consists of six 1800 mAh NiCd cells.
- Everything runs on this bus with their own internal 5V regulators.
- Charging is provided by full string (8.4V) charging on the +Z, -Z and +X side.
- The other 3 side panels charge at 700mA into one pair of NiCd cells each.
- To save power, the CPU is put to sleep for 2.3 sec out of every 2.5 sec MA cycle.
PSAT power system

- power budget positive (normal APRS and PSK31 operations during eclipse season)
- PSK31 AUTO mode
PSAT power system

- battery voltage since July 20
- SAFE mode
PSAT antennas

VHF:
21" nitinol wire whip (53.3cm)

UHF:
two 6.25” nitinol wire (15.9cm)
fed with a 90 degree hybrid

HF:
72" nitinol wire (1.83m)
primary mission – PSK1 transponder

Uplink: 28.120 MHz, USB, BPSK31
Downlink: 435.350 MHz, FM, BPSK31

Brno University of Technology
PSK31 transponder

- it permits dozens of simultaneous PSK31 users to operate full duplex (up to 30)
- operating full duplex on PSK-31 is new and it will take a while for users to figure out how to do this

**PSK31 Transponder is ON for users**
The Brno University PSK31 transponder has been authorized for user uplinks and is working well

- operating passband range: 28.120160 MHz - 28.122560 MHz
- Output center frequency: 435.350 MHz with FM modulation

The *telemetry* channel at 315 Hz (PSAT) or 365 Hz (BRICsat) is *fixed* with no Doppler, since it is generated onboard into the FM downlink.
PSAT PSK31 telemetry

W3ADO beacon MODE NOF DET AGC VC IC TMP

MODE  A or B
      A - transmitter always on,
      B - transmitter turns on if BPSK31 signal is present

NOF  number of frame (0 ... 999)

DET  percentage of BPSK31 detection (0 ... 99%)

AGC  percentage of AGC operation (0 ... 99%)

VC   supply voltage (10 mVolts)

IC   power amplifier current (mA)

TMP  temperature of PA transistor (C)

W3ADO-5 beacon B 002 34 36 794 248 +24
W3ADO-5 beacon B 003 84 28 795 249 +25
W3ADO-5 beacon B 004 90 44 794 249 +26
W3ADO-5 beacon B 005 65 36 791 248 +26
W3ADO-5 beacon B 006 21 25 788 248 +26
PSAT PSK31 telemetry – PSK on

[PSK ON]
W3ADO-5 beacon A 023 00 22 807 251 +6
W3ADO-5 beacon A 024 00 22 806 251 +8
W3ADO-5 beacon A 030 03 23 795 252 +13
W3ADO-5 beacon A 031 00 22 794 252 +13
...
W3ADO-5 beacon A 040 00 23 790 249 +16
W3ADO-5 beacon A 041 15 23 788 249 +17
W3ADO-5 [reset]
W3ADO-5 beacon A 000 12 23 797 247 +16
W3ADO-5 beacon A 001 00 23 790 249 +17
[PSK AUTO mode ON]
W3ADO-5 beacon B 002 34 34 803 245 +12
W3ADO-5 beacon B 003 99 33 791 249 +15
PSK DopplerPSK

by Andrew Flowers K0SM

• experimental program to compensate the doppler shift on PSK31 uplinks

• it's 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
secondary mission – APRS digipeater

Uplink: 145.825 MHz, FM, 1k2 AFSK AX.25
Downlink: 145.825 MHz, FM, 1k2 AFSK AX.25

Byonics Micro-Trak TinyTrak4
previous APRS transponder

huge reduction from previous APRS transponders on PCSAT’s 1, 2, ANDE and RAFT missions – now reduced 18:1 in volume/mass
PSAT transceiver

- The Micro-Trak TinyTrak4 (MT-TT4) is a Byonics TinyTrak4 controller combined with a single channel, crystal controlled 500mW radio
- 5 telemetry channels

Transmitter
- RF Power output <+ 28 dBm
- Spurious Emissions -36 dBm
- Adjacent channel Transmission power -37 dBm
- FM Frequency Deviation (peak) +/- 3.5 kHz
- Enable timing 8 ms
- Current 280 mA @ 5 VDC

Receiver
- RF sensitivity @ 2dB SINAD -120 dBm
- RF sensitivity @ 1ppm BER -115 dBm
- RSSI Threshold -127 dBm
- RSSI Range 60 dB
- Blocking 88 dB
- Image and Spurious emission -70 dBm
- Adjacent channel rejection -70 dBm
- LO Leakage, re-radiated -60 dBm
- Current 8 mA @ 5 VDC
- Operating temperature -10 to + 60 C

- When the DIGI is on, the satellite callsign is PSAT
- When it is off (SAFE mode), the callsign is PSAT-1
- The ALIASes are the usual, ARISS, APRSAT and WIDE
- 4 packet types (BS2 telemetry, MT-TT4 telemetry, position, bulletins)
PSAT BS2 CPU telemetry

S#033814,0z290

S#0OOO0MM,CzWPS

S  upper case means the command receiver is awake and “s” means it is napping
#OOOO  is the orbit number (up to 9999)
MM  minute in that orbit  (00-95)
C  coil command mode (0,1,2)
z  orbits left in the 4 day reset counter (base 62)  
W  WOD telemetry RATE (1,2,3,4, etc. Every W MA counts) 0=off
P  POSITS enabled over 1 USA, 2 Europe, 3 Japan, 4 AuNz, 5 SA, 6 AF, 7 HI
S  SavePower in dark if 1. Normal if 0.
PSAT BS2 CPU telemetry – spin analysis

S#033814,0z290, qhDqhEqhFqhHqhIqhIpiJpiKpiLphLphMphM

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

sun vector triplets

xyz xyz xyz xyz xyz xyz xyz xyz xyz xyz

-----------------------------------------------
NdK NFK FLM jCN ajM MiJ NEJ GKM gCN bkJ LjJ NDJ

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

\[ y = a + b \cos(cx + d) \]
PSAT spin analysis

30 June -> 23 sec interval -> 2.6 rpm

17 July -> 7 sec interval -> 8.6 rpm

RF field strength analysis
PSK31 transponder

SpectraVue => continuum plot

Audacity => envelope curve
PSAT MT-TT4 CPU telemetry

T#815, 802, 361, 867, 491, 371, 00011000

T#SSS, VVV, III, XXX, YYY, ZZZ, 00011X00

<table>
<thead>
<tr>
<th>VVV</th>
<th>Bus Volts in mV</th>
</tr>
</thead>
<tbody>
<tr>
<td>III</td>
<td>Bus Current in mA</td>
</tr>
<tr>
<td>XXX</td>
<td>Temp +Z</td>
</tr>
<tr>
<td>YYY</td>
<td>Temp - Z</td>
</tr>
<tr>
<td>ZZZ</td>
<td>Temp Bat</td>
</tr>
</tbody>
</table>

where T = \[-1.26 \times 10^{-6} \times X^3 + 0.0028 \times X^2 - 2.215 \times X + 625\]

X has meaning: 0 = digi on
1 = digi off

20150629190509, PSAT>APRSON, ARISS, qAR, DK3WN-8: T#815, 802, 361, 867, 491, 371, 00011000
20150629190610, PSAT>APRSON, ARISS, qAR, DK3WN-8: T#816, 816, 085, 869, 494, 371, 00011000
20150629191115, PSAT>APRSON, ARISS, qAR, UA0SNV-1: T#821, 820, 086, 882, 488, 372, 00011000
20150629191216, PSAT>APRSON, ARISS, qAR, UA0SNV-1: T#822, 823, 086, 885, 489, 372, 00011000
20150629191317, PSAT>APRSON, ARISS, qAR, UA0SNV-1: T#823, 826, 083, 887, 493, 372, 00011000
PSAT position packets

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

Maintenance Operations

• fix orbit period
• fix MA counter
• fix longitude

Once the position is predictable, then we can use that data to only enable position reports and bulletins over countries with an Amateur Radio population.

extended timestamp:
AGW-OnlineKISS, OnlineKISS

[61 Bytes TIME Frame]
1 > C0 09 32 30 31 35 2D 30 37 31 35 2D 30 37 31 39 3A 31 39 3A 32 21 > 35 2E 35 37 30 20 55 54 43 3B 32 30 31 2E 35 3B 31 33 3A 32 41 > 3B 39 3A 39 2E 39 3B 32 3E 32 32 B0 45 3B 33 35 2E 32 38 B0 4E 61 > C0 2015-07-19 19:19:25.570 UTC;201.5;13.6;94.9;2.22°E;35.28°N
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.

the higher priority BLN0 is sent every 2 minutes and the other two are sent every 4 minutes on the alternating 2 which results in one bulletin per minute if enabled.

20150524130133,PSAT-1>APOFF,ARISS,qAR,ON7EQ-10::BLN0USA :PSK31 435.35 Up on 28.12
20150524080458,PSAT-1>APOFF,ARISS,qAR,HG8GL-5::BLN1USA :ARISS.NET & PCSAT.APRS.ORG
20150522100551,PSAT-1>APOFF,ARISS,qAR,ON7EQ-10::BLN2USA :See APRS.FI & 144.39 users
20150629222129,PSAT>APRSON,ARISS,qAR,DK3WN-8::BLN0EUR :PSK31 435.35 Up on 28.12
20150629222129,PSAT>APRSON,ARISS,qAR,DK3WN-8::BLN1EUR :Coming soon -> AMSAT-UK Colloquium July 24-26th at Guildford
20150629222130,PSAT>APRSON,ARISS,qAR,DK3WN-8::BLN2EUR :See APRS.FI & 144.80 users
UI-View

Screenshot of UI-View32 V2.03 [Europa (no borders)]

- **File**
- **Terminal**
- **Stations**
- **Messages**
- **Map**
- **Logs**
- **Lists**
- **Action**
- **Options**
- **Setup**
- **Help**

On the map:
- **From**: 17°51'8.2E, 48°55.11N
- **To**: 10°02'7.3E, 51°59.24N
- **Distance**: 404.5 miles, 651.5 km, 305 degrees

- **Record Controls**

- **User Interface**
- **Map Details**
- **Position Indicators**

- **Recent Log Entry**:
  - **JD87KN**: 13:05:02Z [Z1JS, PSAT PSAT ARISS Port-1 <UI C LEN-47>]
  - lat: 52°55.33N/008°36.65E/73 via PSAT NO-84 (UV32N)
http://www.findu.com/cgi-bin/raw.cgi?call=psat&start=24&time=1
http://www.findu.com/cgi-bin/raw.cgi?call=psat-1&start=320
<table>
<thead>
<tr>
<th>Time</th>
<th>Call Sign</th>
<th>Location</th>
<th>APRS ID</th>
<th>Data Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>2015-07-20 12:49:55</td>
<td>PSAT</td>
<td>PSAT</td>
<td>APS0000</td>
<td>0</td>
</tr>
<tr>
<td>2015-07-20 12:49:55</td>
<td>PSAT</td>
<td>PSAT</td>
<td>APS0000</td>
<td>0</td>
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<td>0</td>
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</table>
APRS services

It is easy to send an email from your ham radio using APRS. You may only send one line messages (67 total characters maximum).

:EMAIL :dk3wn@amsat.org This is a test via PSAT. 73

1:Fm DK3WN-1 To APRS Via PSAT*,ARISS* <UI C Pid=F0 Len=55> [UTC:18:35:28R]
 :EMAIL :dk3wn@amsat.org this is a test via PSAT. 73

---

APRS Message from DK3WN-1

OpenAPRS - APRS Message to Email Gateway [daemon@openaprs.net]

Sent: Wed 2015-07-01 18:35:29 UTC

this is a test via PSAT. 73

---

Date: 2015-07-01 18:35:29 UTC

From: DK3WN-1

To: dk3wn@amsat.org

---

OpenAPRS.Net Message to Email Gateway

... works also other satellites e.g. NO-44, BugSat-1 or ISS
APRS iGate

pass all packets heard on RF to APRS-IS

We need PSAT IGates in Hawaii, India, China and anywhere in the Southern Hempsisphere ...

So if you have ever thought about being a satellite IGate, now is the time. And the ideal OMNI antenna for PSAT is a simple 19.5” vertical whip over a large metal ground plane. An even better one (+2 dB) is a 3/4 wave vertical whip (58”) over a large metal ground plane.
APRS iGate
APRS IGate with Raspberry Pi and DVB-T stick

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
• multimon-NG decoder

MultimonNG a fork of multimon, it decodes the following digital transmission modes:
POCSAG512 POCSAG1200 POCSAG2400 EAS UFSK1200 CLIPFSK AFSK1200 AFSK2400 AFSK2400_2 AFSK2400_3 HAPN4800 FSK9600 DTMF ZVEI
PSAT - TLE

- PSAT was launched on a military rocket flight (DoD)
- we cannot get the TLEs directly from SpaceTrack
- we can get them from the satellite owner/operators

- CalPoly: [http://mstl.atl.calpoly.edu/~ops/keps/kepler.txt](http://mstl.atl.calpoly.edu/~ops/keps/kepler.txt)

- NORAD #40654 = ULTRASat1

```
PSAT
1 90720U 15202.10031234 +.00007994 +00000-0 +21237-3 0 00732
2 90720 054.9937 073.3874 333.9704 024.9228 15.14608693009316
```
USNA's APRS satellites

What’s next?

**QIKcom-1**

- Release from ISS in October 2015
- 1st APRS Terrestrial-User-Alerting Beacon Satellite
- flies on a host spacecraft (28V, no solar panels and ADCS)
- APRS transceiver (Byonics MT-TT4)
- MicroAmp-3
- 4 watts beacon transmitter (transmit on 144.39MHz and 144.80MHz APRS frequencies)

**QIKcom-2**

- launch December 2015
- 1st APRS TouchTone Satellite

- The full APRStt system is a complete two way system that enters APRS data using DTMF and lets the user receive APRS information by synthesized voice response.
ParkinsonSat
NAVAL OSCAR-84

... APRS plus a new PSK31 Approach

Thank you!

Mike Rupprecht, DK3WN
Bob Bruninga, WB4APR