APRS Packet Digipeating via the ISS
Bouncing APRS Packets off the ISS

Concept:
• Use the International Space Station's packet "digipeater" - to digitally repeat transmitted APRS packets back to any ground-based packet station
• This activity does not require any ISS crew member interaction or attention

Purpose:
• To digipeat APRS packets for hundreds or even a thousand miles via the ISS, and verify that these packets are logged by APRS tracking websites
What is APRS®?

- **Automatic Packet Reporting System®**
- A digital (non-voice) method of transmitting messages, status, and position – using specially formatted AX.25 packet messages
- TNC (Terminal Node Controller), similar to a computer dial-up modem, transmits packets and APRS data over the airwaves
- APRS is normally operated terrestrially – for 2m VHF in North America: 144.390 Mhz FM simplex
- Created by, and is a registered trademark of, Bob Bruninga WB4APR (www.aprs.org)
Packet Digipeating Concept

- Digitally repeating an AX.25 packet on simplex frequency using a store-and-forward method, e.g. like a children's Telephone Game (Chinese Whisper)
- Allows packets to travel farther using intermediate hops
APRS – Terrestrial vs. Satellite

**Terrestrial APRS Operation**
- 144.390 MHz (North America)
- Digipeating via ISS

**Satellite APRS Operation**
- 145.825 MHz
- Digipeating via ISS
ISS Overhead Pass Opportunities

- **Window of opportunity for transmitting to ISS**
  - Each ISS orbit period is about 90 minutes
  - 5 to 10 minute window per orbit pass
  - Groups of consecutive passes about twice a day, roughly 12 hours apart

- **Number of usable consecutive passes**
  Depends on your latitude, e.g.
  - 1 pass near equatorial latitudes
  - Up to 7 passes near the 50° latitude
  - But typically at other latitudes:
    - 1 to 2 usable passes within an 1 ½ hour period
    - Rarely: 3 usable passes in a 3 hour period
Ground Station Equipment Required

- Any Tech / Gen / Extra class amateur license
- 2 meter VHF transceiver
  - No PL tone required (i.e. old equipment OK)
  - 5 watts or less with Log-Periodic or Yagi antenna
  - 10 to 25 watts or less with ground-plane antenna
- 1200 baud packet TNC and/or software – plus transceiver model-specific TNC cable
- Antenna: beam, ground-plane, J-pole, eggbeater
- Computer with serial port and Internet access
- Satellite / ISS tracking software or website
- Orientation / compass, and local / UTC clock
Ground Station Equipment Setup

- No transceiver pre-amp normally required
- Transceivers w/o a data port require the speaker and microphone jacks be dedicated for TNC use
- Although some TNCs accept a GPS connection for APRS beacon operation – do not use with ISS
- Internet access is used to confirm logging by APRS websites of received packets by listening S Gates
AF6DS Mobile and Packet Go-kit

- Yaesu FT-1802 transceiver
- Kantronics MT1200 TNC
- Red-Dee-2 Connect PS-4T +
- Pelican case - model 1400
Ground-Plane (and J-Pole) Antenna

- No aiming required
  - Omnidirectional
  - Stationary
  - Works indoors too →
- Unity gain ($\frac{1}{4}$ wave)
  - More transmit power required than Log-Periodic or Yagi
  - 10 to 25 watts (to ISS)
- Radiation pattern
  - Low takeoff angle
  - Null at zenith

Arrow GP146-440 on PVC pipe
Other Antennas for Satellite Use

**Beam: Yagi / Log-Periodic**
- Aiming required
  - Directional radiation
- High gain
  - Less transmit power required than ground-plane antenna
  - 5 watts sufficient
- Better suited for outdoor use with handheld operation, weather permitting

**EggBeater**
- No aiming required
  - Omnidirectional
  - Stationary
- Unity gain
  - More transmit power required than Log-Periodic or Yagi
- Radiation pattern
  - Circular polarization
  - No null at zenith
- Expensive to buy, cheaper to build
ISS Station Operation

- ISS universal callsign alias: ARISS
  - Other callsigns: NA1SS, RS0ISS, DP0ISS, etc.
- Packet digipeating operations
  - 145.825 Mhz simplex FM
    (since September 2007)
  - ISS digipeater callsign: ARISS
- ISS beacon message:
  RS0ISS-4>CQ, SGATE:
  >ARISS - International Space Station (BBS/APRS on)
- More details at:
  http://spaceflight.nasa.gov/station/reference/radio/
  http://www.rac.ca/ariiss/oindex.htm
Ground Station Operation Overview

- **Setup**
  - Verify your setup with terrestrial APRS operation
  - Pre-program transceiver with Doppler frequencies
  - Set TNC parameters (in TNC Command mode)
  - Update TLE, track & predict ISS orbit passover

- **Operation**
  - Check websites for recent ISS packet activity
  - Adjust transceiver for Doppler shift, if necessary
  - Transmit APRS packet (in TNC Convers mode)
  - If ISS digipeated packet is not received by your TNC, then check at APRS tracking websites
  - If nothing logged, retry transmission in 1 minute
Compensating for Doppler Effect

- *Doppler Effect* frequency shift needs to be taken into account as the ISS approaches and recedes
  - ISS travels roughly 214 statute miles (344 Km) above the earth @ 17,500 mph (28,000 Kph)
  - Ground station transceiver should frequency compensate when the ISS is near AOS\(^1\) and LOS\(^2\)
  - Only compensate on high elevation passes
  - Compensation might not be required on 2m VHF, since Doppler shift is less than 3 Khz

\(^1\) AOS – Acquisition of Signal, i.e. ISS rising above the horizon
\(^2\) LOS – Loss of Signal, i.e. ISS dropping below the horizon
Transceiver Setup for Doppler Shift

- Pre-program AOS and LOS shift frequencies into the transceiver – using *odd-split* offsets
  - Most 2m transceivers have 5 Khz step minimum
    - AOS: Tx 145.820 Mhz, Rx 145.830 Mhz FM
    - LOS: Tx 145.830 Mhz, Rx 145.820 Mhz FM
    - TCA: 145.825 Mhz FM simplex (Tx = Rx)

  *TCA - Time of Closest Approach, i.e. maximum elevation*
Transceiver Memory Channel Settings

AOS (approaching)
Tx 145.820 Mhz
Rx 145.830 Mhz

TCA (traversing)
145.825 Mhz simplex
(Tx = Rx)

LOS (receding)
Tx 145.830 Mhz
Rx 145.820 Mhz

Azimuth / Elevation chart for
ISS orbit pass (in light blue)
annotated predict / gsat chart
ISS Pass Prediction

- **Pass prediction websites**
  - http://www.issfanclub.com
  - http://space.cweb.nl/space3d_iss.html
  - http://www.n2yo.com/?s=25544

- **Pass prediction computer freeware**
  - **Windows:**
    - SatScape
    - Orbitron
    - WXtrack
  - **Unix:**
    - gpredict
    - predict with gsat client
    - ktrack
 Orbital Description of Satellites

- A satellite's orbit can be mathematically described by Keplerian Elements – encoded in a format called Two-Line Element (TLE)
- TLE format:
  
  TLE format:
  
  | ISS | 25544U | 98067A | 08022.20136510 | .00020651 | 00000-0 | 12618-3 | 0 | 7634 |
  | 25544 | 51.6401 | 54.3302 | 0005382 | 315.0141 | 127.5080 | 15.77334577525339 |
  
- Satellite tracking software accepts TLE data
  - Make sure the orbital data is up-to-date, since the ISS orbit may be boosted by visiting US Space Shuttle or Russian Progress spacecraft
- Obtain the latest TLE data from:
  http://www.celestrak.com/NORAD/elements/stations.txt
Prediction SW – gpredict (Linux)

- World map
- Your location
- Satellites & orbits
- Az / El chart
- Future pass prediction
  - Time to AOS
- Doppler shift frequencies
- TLE updates
Prediction SW – predict / gsat
Click on **select your city** for pass prediction info

Click on **read more...** for activity reports
**Windows® Soundcard Packet Freeware**

- **AGWPE** – A Windows TNC emulator program for packet communications, using the PC's sound card, and a special serial cable:
  
  http://www.sv2agw.com/ham/agwpe.htm
  http://www.sv2agw.com/downloads/agwpe.zip

  The serial cable includes a circuit to ground the radio's PTT when AGWPE drives the serial RTS line high

  http://www.kc2rlm.info/soundcardpacket/
  http://www.jbgizmo.com/page28.htm

- **UISS** – An easy-to-use Windows program to designed to interact with the ISS and other satellites, and talks directly to AGWPE

  http://users.belgacom.net/hamradio/uiss.htm
APRS Types & Syntax

- There are 3 main APRS types: message, status, position (designated by the first character of the Convers mode string)
- These APRS types can be specified as follows (maximum 64 bytes):

  Position
  
  \[GG##gg]...message...

  where \(GG##gg\) is the Maidenhead grid square, e.g. cm87xi

  Status (>)
  
  >...comments...

  >GG##gg/-...comments...

  Message (:)
  
  :<9 character TOCALL>:...message...
e.g. APRS Position Type – Lat / Long

An example of specifying an APRS position type with latitude / longitude coordinates

!3720.00N/12205.00Wx/A=000100/Happy trails ISS !
! no timestamp, no APRS messaging capability
3720.00N 37.2000° N latitude
/ symbol table to use for displaying map icon
12205.00W 122.0500° W longitude
x display a X Windows icon on the APRS map
/A=000100 altitude @ 100 feet (optional field)
/ comment delimiter

APRS map symbol / icon info:
http://eng.usna.navy.mil/~bruninga/iss-aprs/issicons.html
http://eng.usna.navy.mil/~bruninga/aprs/symbolsX.txt
TNC Settings (via terminal session)

- TNC has two modes: Command and Convers
- Recommended settings in Command mode:
  
  mycall <your_callsign-ssid>
  passall on, monitor on, mcon on, flow on, paclen 70
  axdelay plus txdelay >= 3

  then set the unproto path string to:
  unproto aprs via ariss

  whereas for terrestrial operation the unproto path string
  would be something like: unproto aprs via wide2-1

  and turn beacon(ing) off

- Switch into Convers mode by typing:
  k or convers
Sending the ISS Digipeated Packet

What you type in TNC Convers mode to send, e.g.:

    [cm87xi]Happy trails ISS !<Enter>

What your TNC transmits (and what you see):

    AF6DS>APRS,ARISS:
    [cm87xi]Happy trails ISS !

What the ISS digipeats (and what you might see):

    AF6DS>APRS,RS0ISS-4*:          ARISS digipeated as RS0ISS-4
    [cm87xi]Happy trails ISS !

Note: you will see your callsign instead of AF6DS

- Digipeating station inserts an asterisk (*) after its own callsign in the packet string
- Packets with an asterisk (*) marked ISS callsigns are logged by SGate stations
ISS APRS Tracking Confirmation

Station List **Click here to see times in absolute UTC**

<table>
<thead>
<tr>
<th>Call</th>
<th>Messages</th>
<th>lat</th>
<th>lon</th>
<th>Age (dd:hh:mm:ss)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ISS</td>
<td>*</td>
<td>48.00930</td>
<td>-123.15490</td>
<td>00:00:00:03</td>
</tr>
<tr>
<td>RS0ISS-4</td>
<td>*</td>
<td>.</td>
<td>.</td>
<td>00:00:00:03</td>
</tr>
<tr>
<td>ISS-10</td>
<td>*</td>
<td>47.11828</td>
<td>-65.72127</td>
<td>00:00:00:03</td>
</tr>
<tr>
<td>ISS-5</td>
<td>*</td>
<td>51.62430</td>
<td>-94.15305</td>
<td>00:00:00:03</td>
</tr>
<tr>
<td>AF6DS</td>
<td>*</td>
<td>37.36667</td>
<td>-122.16667</td>
<td>00:00:00:04</td>
</tr>
<tr>
<td>W6MSU</td>
<td>*</td>
<td>38.05350</td>
<td>-121.36033</td>
<td>00:00:00:13</td>
</tr>
<tr>
<td>KD7YPG</td>
<td>*</td>
<td>.</td>
<td>.</td>
<td>00:00:00:19</td>
</tr>
<tr>
<td>N7OFW</td>
<td>*</td>
<td>45.80233</td>
<td>-122.70150</td>
<td>00:00:01:30</td>
</tr>
<tr>
<td>W7KKE 1</td>
<td>*</td>
<td>45.01100</td>
<td>-124.00583</td>
<td>00:00:02:05</td>
</tr>
</tbody>
</table>

station near top of list

click on link to see data (see next slide)
ISS APRS Tracking Confirmation

Position of AF6DS --- 3.6 miles southwest of Mountain View, CA --- Report received 10 seconds ago

Raw packet: AF6DS>APRS_RS0ISS 4*qA0, KK5MV-12:[cm87x]Happy trails ISS!

Support findU!

Links for AF6DS

AF6DS
Anatomy of an ISS Digipeated Packet

Raw packet: AF6DS>APRS, RS0ISS-4*,qAO,KK5MV-12: [cm87xi]Happy trails ISS!

- KK5MV (w/SSID of 12) is the SGate for this packet – QTH in Texas
- From Silicon Valley → ISS → Midland, Texas → Internet!
- 1200 mile city-to-city single-hop digipeat
- Thanks ISS and SGate stations like KK5MV!
Emergency Welfare Message via ISS

- During a major disaster (or for remote area operation), digipeat your APRS messages outside the region (via the ISS)
  - Infrastructure outage: power, phones, Internet, repeaters, or HF operation is unavailable / busy
  - Your operation needs to be totally self-sufficient
  - Digipeating 1000+ miles is possible via the ISS
- **Unreliable!** - no means to verify if your message reached APRS tracking websites
- Pre-arrange with concerned parties where to look for your status when a disaster occurs
Improving Your Chances for Success

- Verify packet / TNC setup terrestrially first
- Check for recent packet activity:
  - http://www.ariss.net
  - http://www.issfanclub.com
  - ISS digipeating typically available 24 hours/day, but might be off during: docking, EVA (spacewalks), etc.
- Check for and use the latest orbital data / tracking
  - http://www.issfanclub.com
- Distant ground or ISS packet collisions are often not detected by your TNC – so retry
- Contact is possible a few degrees above horizon, but a higher elevation has a better chance
Other Things to Note

- APRS CQ and ISS packet BBS usage also possible, but maybe difficult in heavy traffic
- Cost (new):
  - TNC: ~ $200+ USD
  - Antenna: GP ~ $35+ USD, Eggbeater ~ $300 USD
  - Software: freeware / open source available
- Turn off Rx Save (power management) mode in HTs, to allow proper decoding of received packets by the TNC – quicker battery drain!
Glossary

AOS – Acquisition of Signal (rise above horizon)
APRS – Automatic Packet Reporting System
AX.25 – X.25 packet protocol for Amateur radio
Digipeat(ing) – Digitally repeating packets
IGate / SGate – Internet / satellite gateway
ISS – International Space Station
Keplerian Elements / TLE – orbital description
Log-Periodic / Yagi – directional beam antenna
LOS – Loss of Signal (drop below horizon)
Packet – digital form of data transmission
TNC – Terminal Node Controller
Tracking Websites and Data

Satellite Tracking

http://www.issfanclub.com
http://www.ariss.net
http://www.amsat.org/amsat-new/tools/predict/
http://space.cweb.nl/space3d_iss.html

http://www.n2yo.com or http://www.n2yo.com/?s=25544
http://www.heavens-above.com

Keplerian Elements

http://www.celestrak.com/NORAD/elements/
http://www.amsat.org/amsat/ftp/keps/current/nasa.all
APRS Tracking and Map Symbols

APRS Tracking
http://map.findu.com/<your_callsign-ssid>
http://map.findu.com/<your_callsign>*
http://aprs.fi/info/<your_callsign>
http://www.aprsworld.net
http://www.jfindu.net
http://wx.findu.com/<your_callsign>

APRS Map Symbols and Icons
http://eng.usna.navy.mil/~bruninga/iss-aprs/issicons.html
http://eng.usna.navy.mil/~bruninga/aprs/symbolsX.txt
http://www.kc2hwb.com/APRS_symbols.htm
http://wa8lmf.net/aprs/APRS_symbols.htm
References

http://spaceflight.nasa.gov/station/reference/radio/
http://www.amsat.org/amsat-new/ariiss/#freqs
http://web.usna.navy.mil/~bruninga/iss-faq.html
http://www.marexmg.org/fileshtml/isspacketmanual.html
http://www.rac.ca/ariiss/oindex.htm
http://ronhashiro.htohananet.com/am-radio/spacecomm/getting-started-iss.html
http://www.arrl.org/tis/info/HTML/aprs/pos-reporting.html
http://www.users.cloud9.net/~alan/ham/aprs/aprs.pdf
Questions / Comments? and Thanks!

Any and all errors, omissions, misconceptions, and cheesy graphics are solely mine

af6ds@yahoo.com

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   Sponsor: Foothill Amateur Radio Society (FARS) – K6YA
Radiofest @ Monterey, March 2009
   Sponsor: Naval Postgraduate School ARC – K6LY
PCSat Digipeating
PCSat Digipeating Setup

- General info:
  
  http://eng.usna.navy.mil/~bruninga/pcsat.html

- PCSat operational again on Feb. 8, 2008

- Operational only during mid-day sun?

- Set the `unproto` path string to:
  
  unproto aprs via pcsat-1 (w3ado-1 is default)

- 145.827 Mhz FM simplex, ~ 145.825 Mhz

- PCSat Satellite Tracking:
  - Software – same as for tracking the ISS
  - Website: http://www.n2yo.com/?s=26931

- APRS tracking website URL:
  
  http://pcsat.aprs.org or http://pcsat.findu.com
TNC Operation with PCSat

- PCSat beacon message received by the TNC:
  W3ADO-1>ID, SGATE:
  W3ADO-1/R XBAUD/G MAIL-1/B

  W3ADO-1>BEACON, SGATE:
  T#714,132,138,145,142,214,00111111,0001,1

- An example of a TNC Convers mode send string:
  [cm87xi]APRS via PCSAT test<Enter>
# PCSat APRS Tracking Confirmation

Click here to see times in absolute UTC.

<table>
<thead>
<tr>
<th>Call</th>
<th>Messages</th>
<th>lat</th>
<th>lon</th>
<th>Age (dd:hh:mm:ss)</th>
</tr>
</thead>
<tbody>
<tr>
<td>_ANDE-10</td>
<td>*</td>
<td>30.25554</td>
<td>-78.63674</td>
<td>00:00:00:04</td>
</tr>
<tr>
<td>_PCSat</td>
<td>*</td>
<td>44.25515</td>
<td>-113.42513</td>
<td>00:00:00:04</td>
</tr>
<tr>
<td>_PCSat-5</td>
<td>*</td>
<td>58.04181</td>
<td>-96.31146</td>
<td>00:00:00:04</td>
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<tr>
<td>_ANDE-5</td>
<td>*</td>
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<td>AF6DS</td>
<td>*</td>
<td>37.33333</td>
<td>-122.08333</td>
<td>00:00:00:06</td>
</tr>
<tr>
<td><strong>KC9XG-4</strong></td>
<td></td>
<td>41.57167</td>
<td>-88.05500</td>
<td>00:00:00:09</td>
</tr>
</tbody>
</table>

Station near top of list.

Click on link to see data.

[http://www.findu.com/cgi-bin/pcsat.cgi](http://www.findu.com/cgi-bin/pcsat.cgi)

[http://pcsat.aprs.org](http://pcsat.aprs.org)
Anatomy of a PCSat Packet Digipeat

Raw packet: AF6DS>APRS,W3ADO-1*,qAo,N0AN:[cm87xi]APRS via PCSAT test

- N0AN is the SGate for this packet – QTH in Iowa
- From Silicon Valley → PCSat → Odgen, Iowa → Internet!
- 1500 mile city-to-city single-hop digipeat
- Thanks PCSat and SGate station N0AN!
Sending APRS Email via PCSat

- Service provided by WU2Z in New Jersey
- In TNC Convers mode, send the following string:

  :EMAIL :email_address message<Enter>

  where
  - callsign field is 9 characters between the colons(:), hence EMAIL is followed by 4 spaces
  - email_address and message is 64 bytes (chars) max, and separated by a space

- An example:

  :EMAIL :af6ds@yahoo.com testing email via pcsat
  (see next slide)
Anatomy of a PCSat Email Digipeat

Raw packet (from www.findu.com):
AF6DS>APRS,W3ADO-1*,qAO,W7XZ-6::EMAIL :af6ds@yahoo.com
testing email via pcsat

Received email:

<table>
<thead>
<tr>
<th>Date:</th>
<th>Fri, 15 Feb 2008 21:02:05 -0500 (EST)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date:</td>
<td>Date header was inserted by mta4.srv.hcvlny.cv.net</td>
</tr>
<tr>
<td>From:</td>
<td><a href="mailto:ksproul@rci.rutgers.edu">ksproul@rci.rutgers.edu</a> Add Mobile Alert</td>
</tr>
<tr>
<td>Subject:</td>
<td>APRS Message from AF6DS</td>
</tr>
<tr>
<td>To:</td>
<td><a href="mailto:af6ds@yahoo.com">af6ds@yahoo.com</a></td>
</tr>
</tbody>
</table>

testing email via pcsat

Message received by MacAPRS IGate station WU2Z
Located in NO BRUNSWICK, NJ
APRS path = AF6DS>APRS,W3ADO-1*,qAO,W7XZ-6

AF6DS

February 16, 2008 2:03 UTC
Backup Slides / Info
3 Usable Consecutive Passes in 3 Hrs