

APRS Packet Digipeating via the ISS



International Space Station

Photo credit: NASA

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:

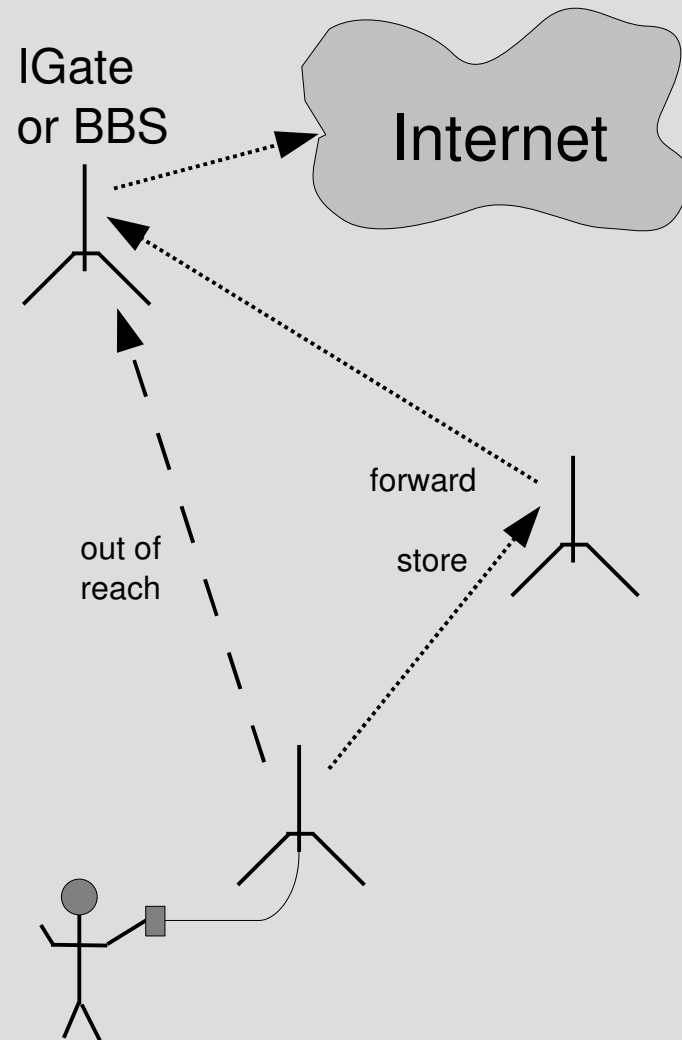
- To digipeat APRS packets for hundreds or even a thousand miles via the ISS, and verify that these packets are logged by APRS tracking websites

What is APRS[®]?

- **A**utomatic **P**acket **R**eporting **S**ystem[®]
- 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)

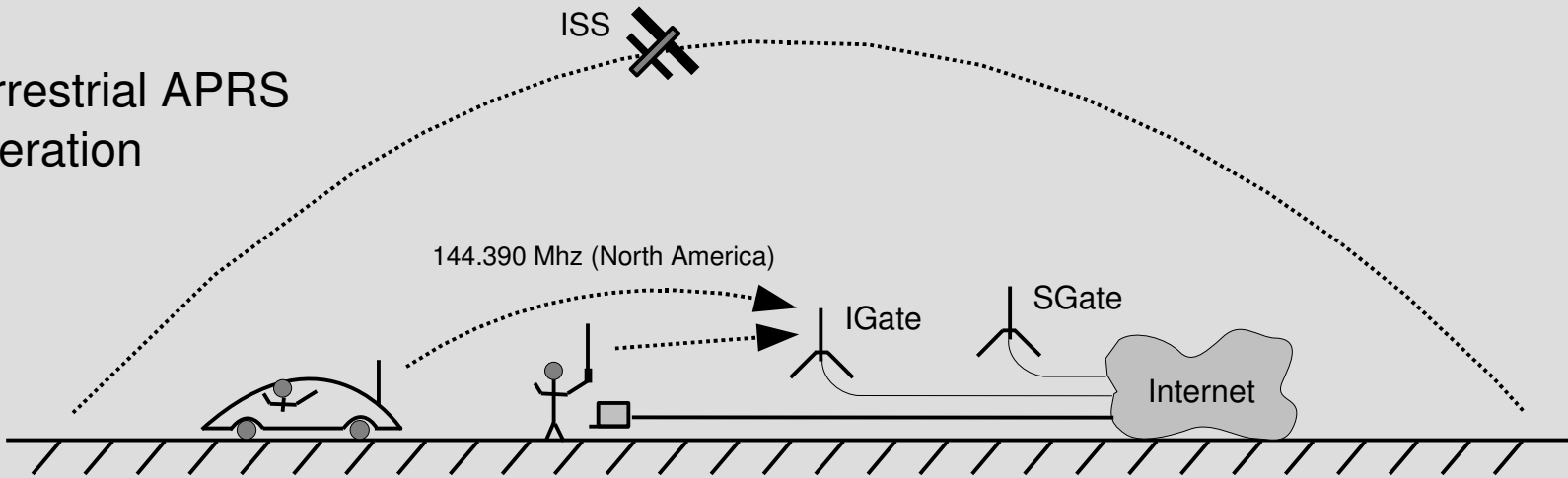
Packet Digipeating Concept

- 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

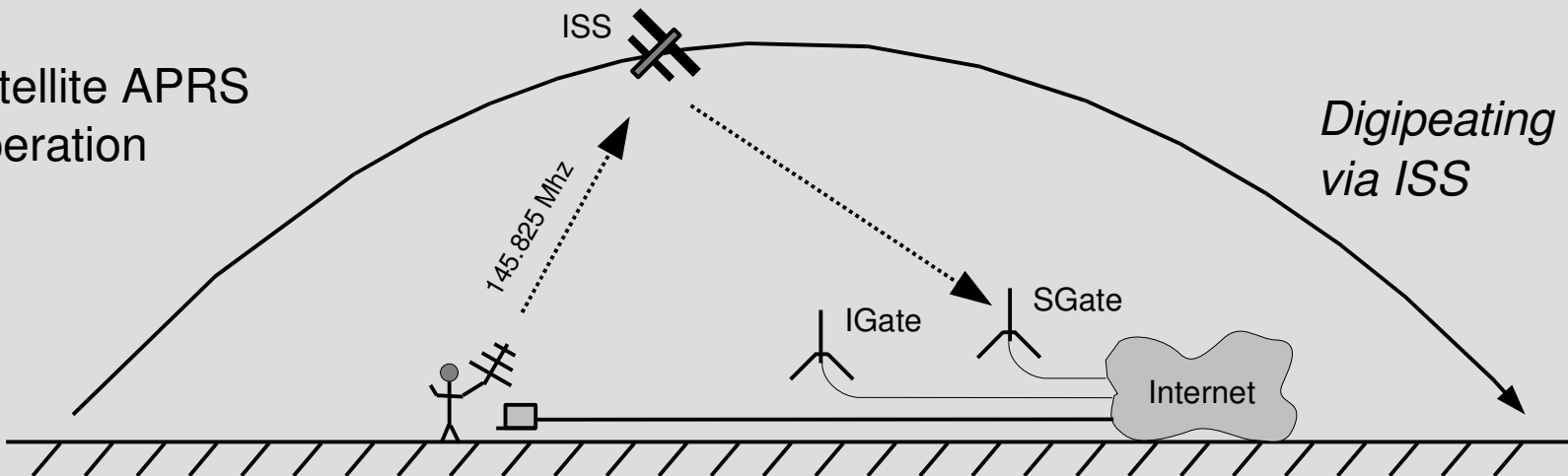


APRS – Terrestrial vs. Satellite

Terrestrial APRS Operation



Satellite APRS Operation



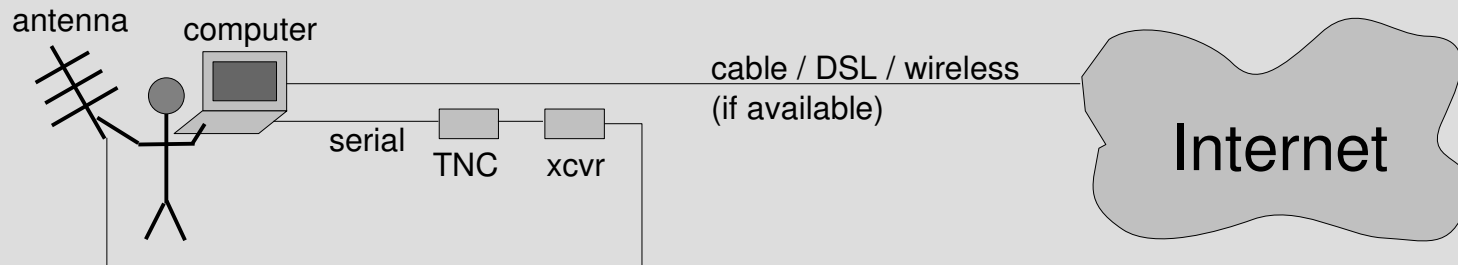
ISS Overhead Pass Opportunities

- 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 SGates

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



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/ariss/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

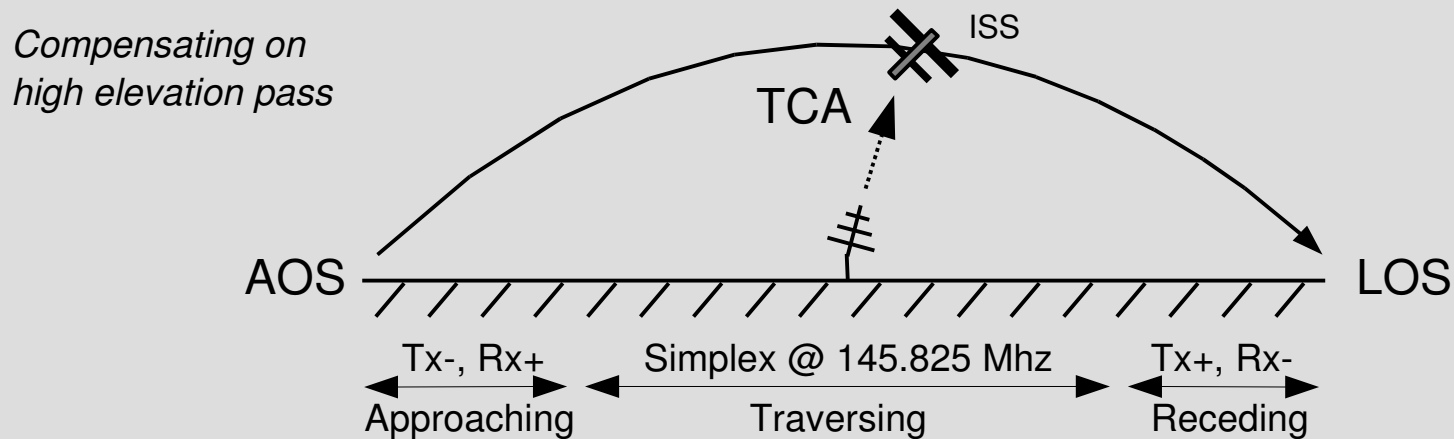
Compensating for Doppler Effect

- *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 AOS¹ and LOS²
 - 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

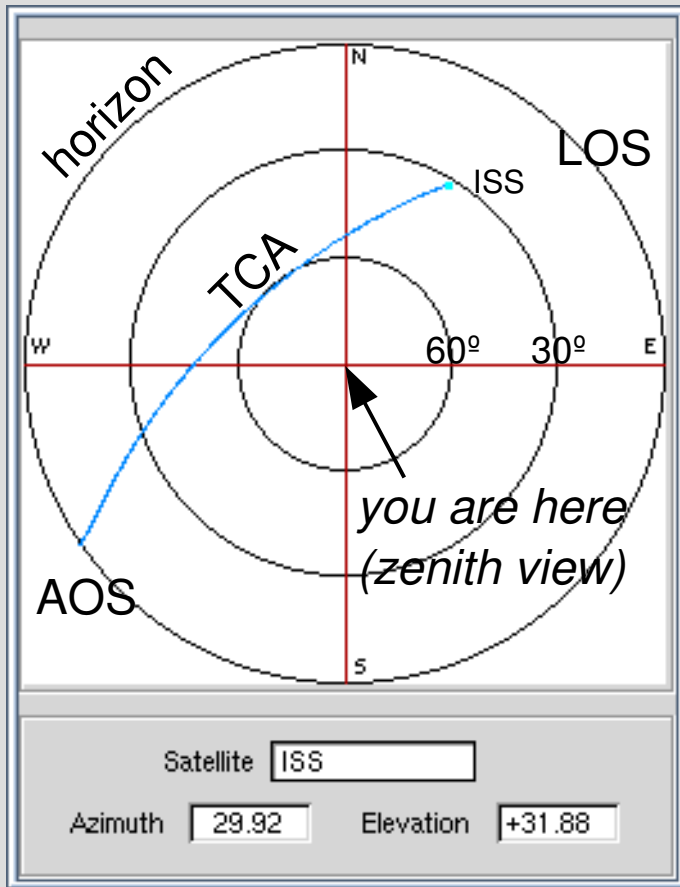
² LOS – Loss of Signal, i.e. ISS dropping below the horizon

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



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

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

ISS Pass Prediction

- Pass prediction websites

- `http://www.issfanclub.com`
- `http://space.cweb.nl/space3d_iss.html`
- `http://www.n2yo.com/?s=25544`
- `http://www.amsat.org/amsat-new/tools/predict/`

- Pass prediction computer freeware

- `http://www.amsat.org/amsat-new/tools/software.php`
- **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:

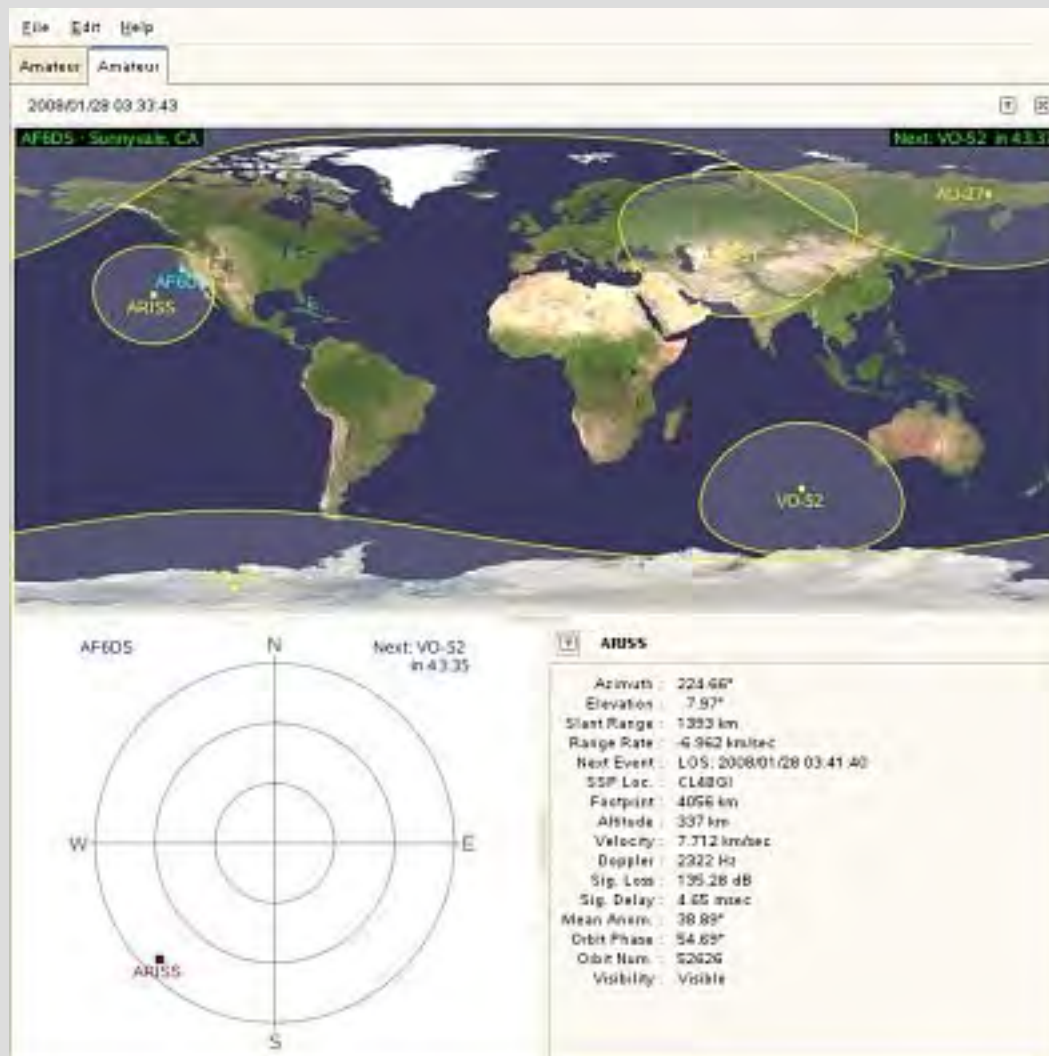
ISS

```
1 25544U 98067A 08022.20136510 .00020651 00000-0 12618-3 0 7634  
2 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:

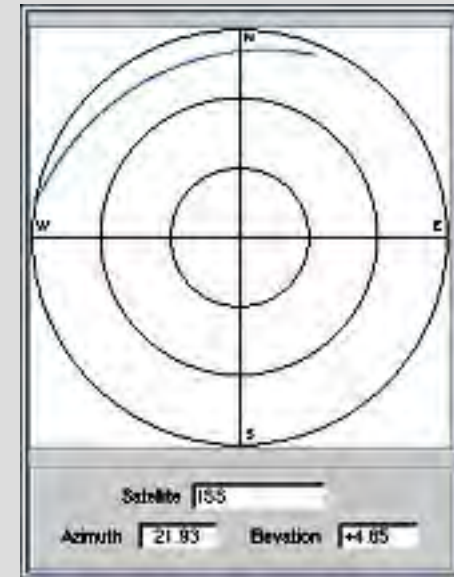
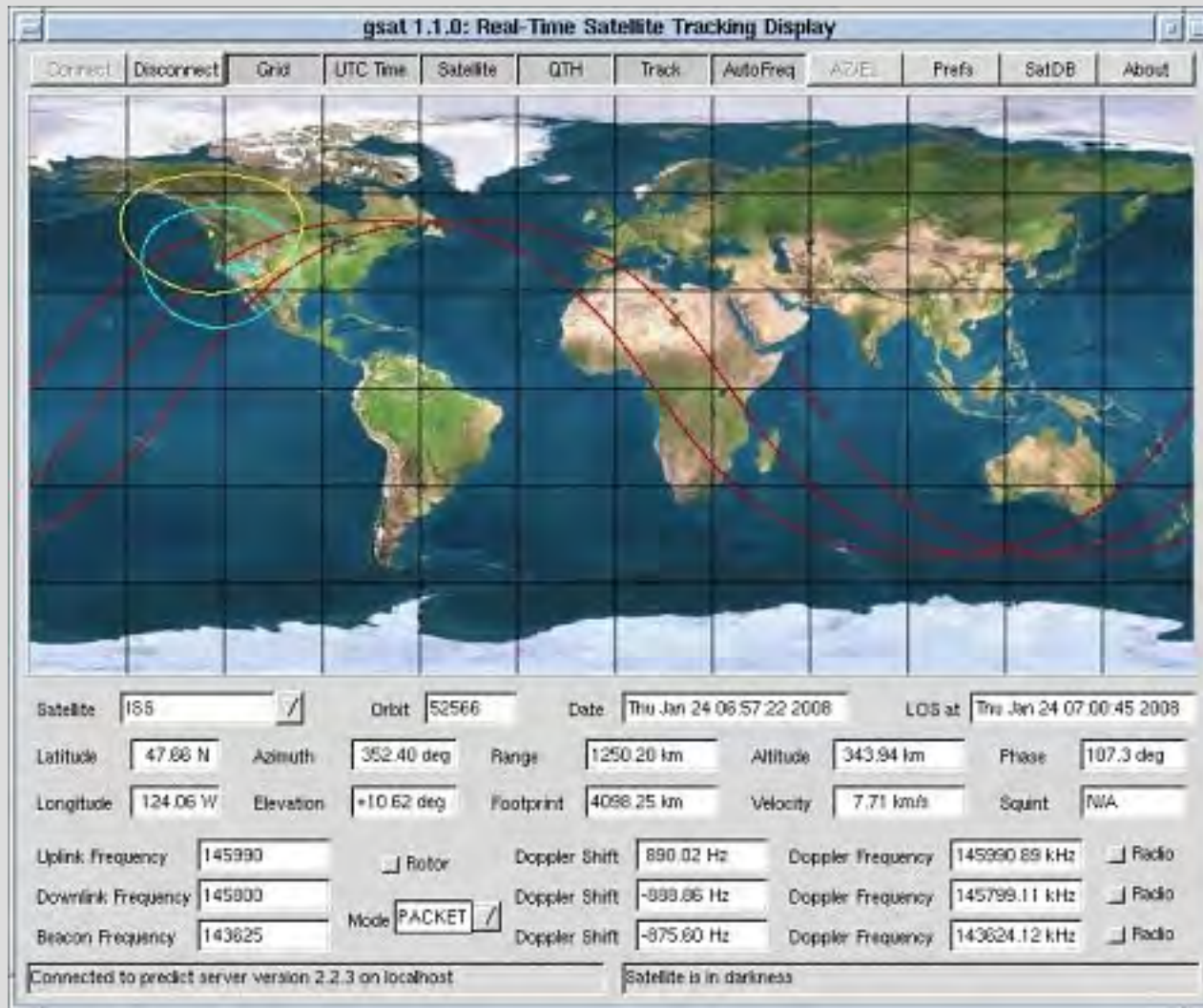
<http://www.celestrak.com/NORAD/elements/stations.txt>

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



Prediction Website – issfanclub.com



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

Amateur Radio Stations heard via ISS - Mozilla Firefox

File Bookmarks Tools Help

http://www.ariss.net/

Station List [Click here to see times in absolute UTC](#)

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

station near top of list →

click on link to see data (see next slide)

ISS APRS Tracking Confirmation

AF6DS Location - Mozilla Firefox

View History Bookmarks Tools Help

U <http://www2.findu.com/cgi-bin/find.cgi?AF6DS> Google

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

Status: cm87xjxtesting aprs formats

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

GPS Vehicle Tracking Affordable GPS tracking direct to you - saving you time & money www.gpsdirectonline.com

Vehicle Tracking Vehicle Tracking listings Find Vehicle Tracking EasyDailyDeals.com

Discounted Gps Vehicle Tracking Gps Vehicle Tracking Offers! Ideascube.com

Find Providers of Vehicle Tracking Solutions on Business.com. www.business.com

Ads by Google

Support findU!
Make A Donation

Links for AF6DS
[APRS activity](#)
[APRS data](#)

Map Satellite Hybrid

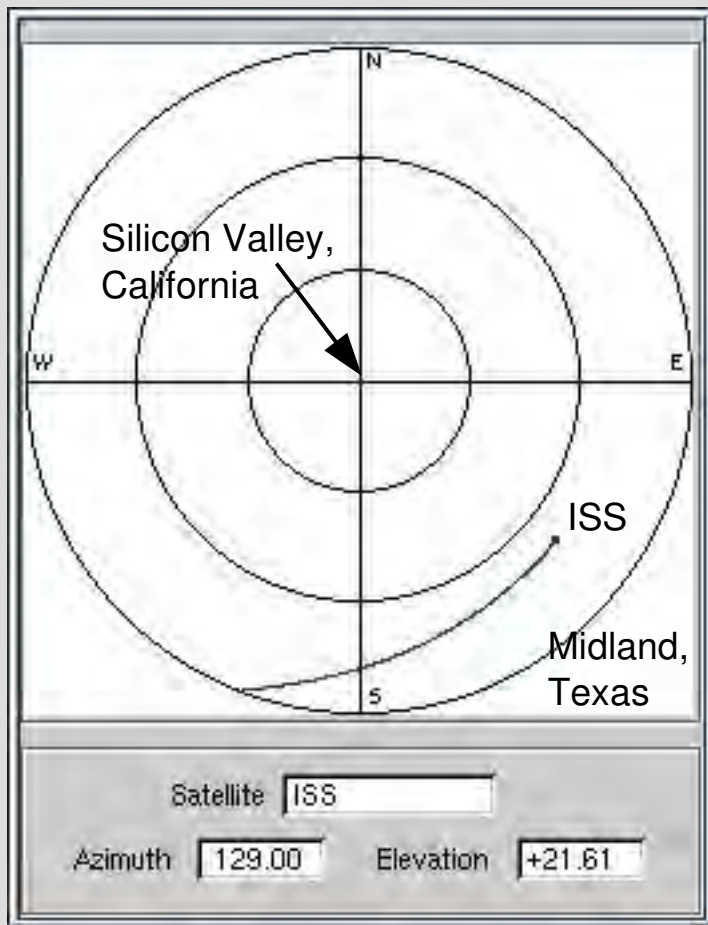
Los Altos Hills Los Altos Sunnyvale

Rancho San Antonio County Park AF6DS

(see next slide)

Anatomy of an ISS Digipeated Packet

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



January 25, 2008 04:07 UTC

- 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 !

AF6DS

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.celestrak.com/NORAD/elements/>
 - <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/ariss/#freqs>
<http://web.usna.navy.mil/~bruninga/iss-faq.html>
<http://web.usna.navy.mil/~bruninga/astars.html>
<http://www.marexmg.org/fileshtml/isspacketmanual.html>
<http://www.rac.ca/ariss/oindex.htm>
<http://ronhashiro.htohanenet.com/am-radio/spacecomm/getting-started-iss.html>
<http://ronhashiro.htohanenet.com/am-radio/spacecomm/doppler-and-the-iss.html>
http://www.amsat.org/amsat-new/information/faqs/Intro_sats.pdf
<http://www.arrl.org/tis/info/HTML/aprs/pos-reporting.html>
<ftp://ftp.tapr.org/aprssi/aprssi/spec/spec/aprs101/APRS101.pdf>
<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

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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



Station List [Click here to see times in absolute UTC](#)

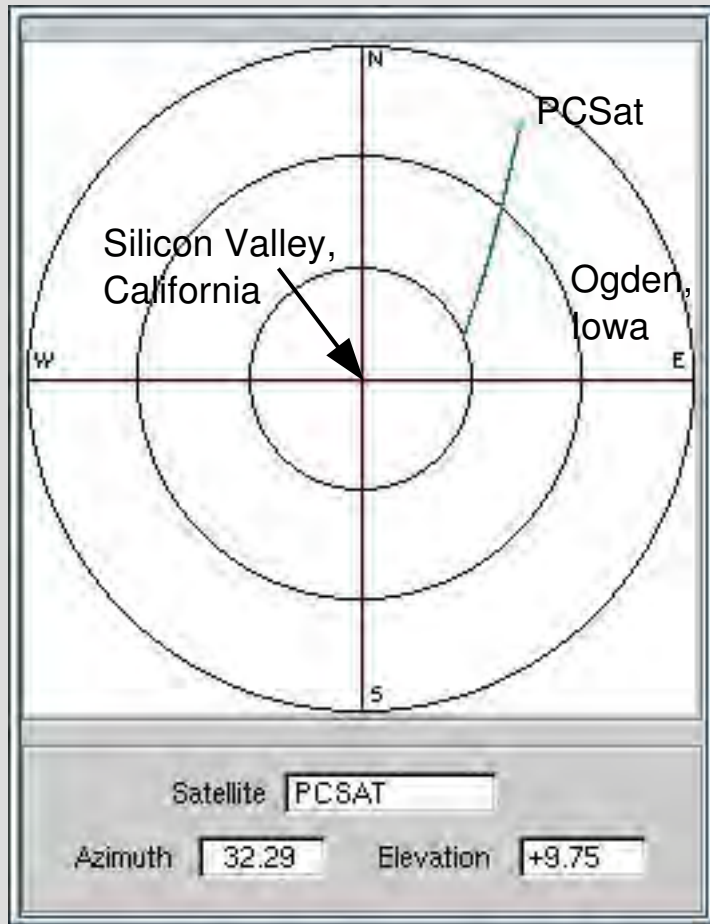
Call	Messages	lat	lon	Age (dd:hh:mm:ss)
ANDE-10	* -	30.25554	-78.63674	00:00:00:04
PCSat	* -	44.25515	-113.42513	00:00:00:04
PCSat-5	* -	58.04181	-96.31146	00:00:00:04
ANDE-5	* -	15.74077	-91.96631	00:00:00:04
PCSAT-10	* -	66.53775	-63.02673	00:00:00:04
ANDE	* -	0.38764	-103.27485	00:00:00:04
AF6DS	* -	37.33333	-122.08333	00:00:00:06
KC9XG-4	* -	41.57167	-88.05500	00:00:00:09

station
near top
of list

click on
link to
see data

Anatomy of a PCSat Packet Digipeat

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



February 15, 2008 15:33 UTC

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

AF6DS

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`):

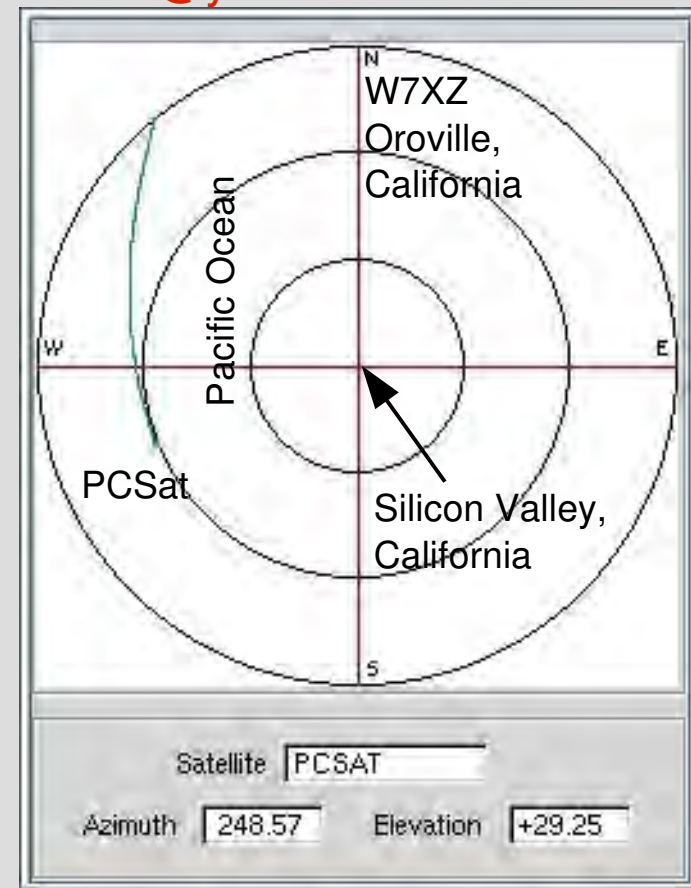
**AF6DS>APRS,W3ADO-1*,qAO,W7XZ-6::EMAIL :af6ds@yahoo.com
testing email via pcsat**

Received email:

```
Date: Fri, 15 Feb 2008 21:02:05 -0500 (EST)
Date: Date header was inserted by mta4.srv.hcvlny.cv.net
From: ksproul@rci.rutgers.edu [Add Mobile Alert]
Subject: APRS Message from AF6DS
To: af6ds@yahoo.com

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
```



Backup Slides / Info

3 Usable Consecutive Passes in 3 Hrs

