APRS via the ISS – A Quick Tutorial

International Space Station

Photo credit: NASA

Sending APRS Packets via the ISS

Concept:
- To have the International Space Station "*digipeat*" digitally repeat your transmitted APRS packet(s) to any ground-based Internet-linked station (called *SGate*)
- Verify that your ISS digipeated message was recorded by APRS tracking websites

Purpose:
- For fun – and possibly for sending emergency messages out-of-area (although unreliable)

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 USA: 144.390 Mhz FM simplex
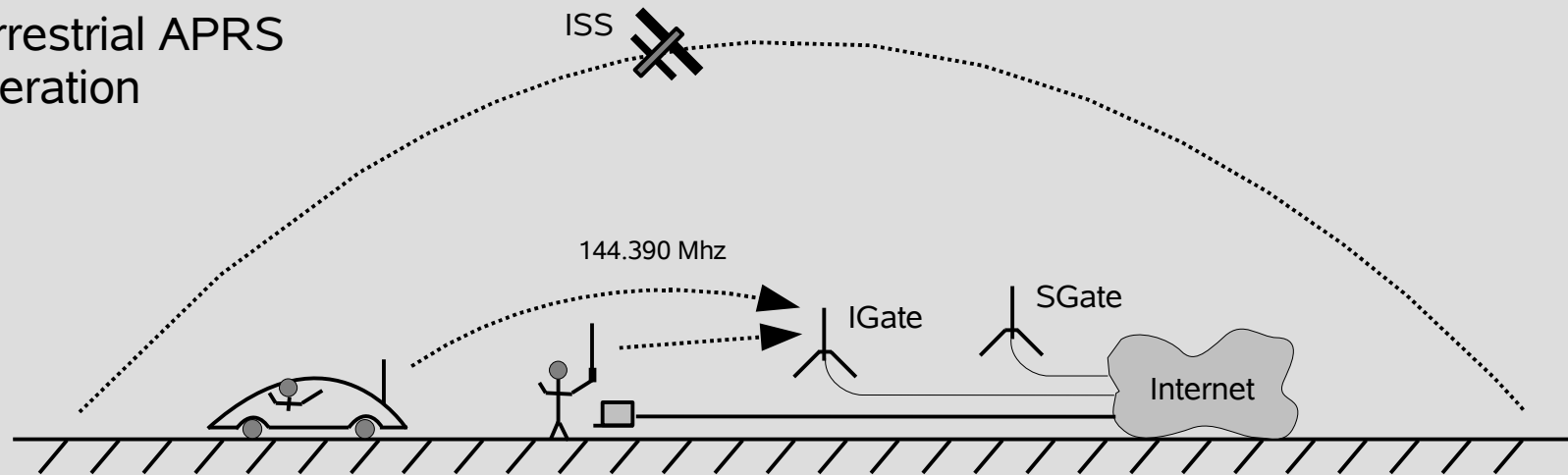- Created by, and is a registered trademark of, Bob Bruninga WB4APR (`www.aprs.org`)

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)
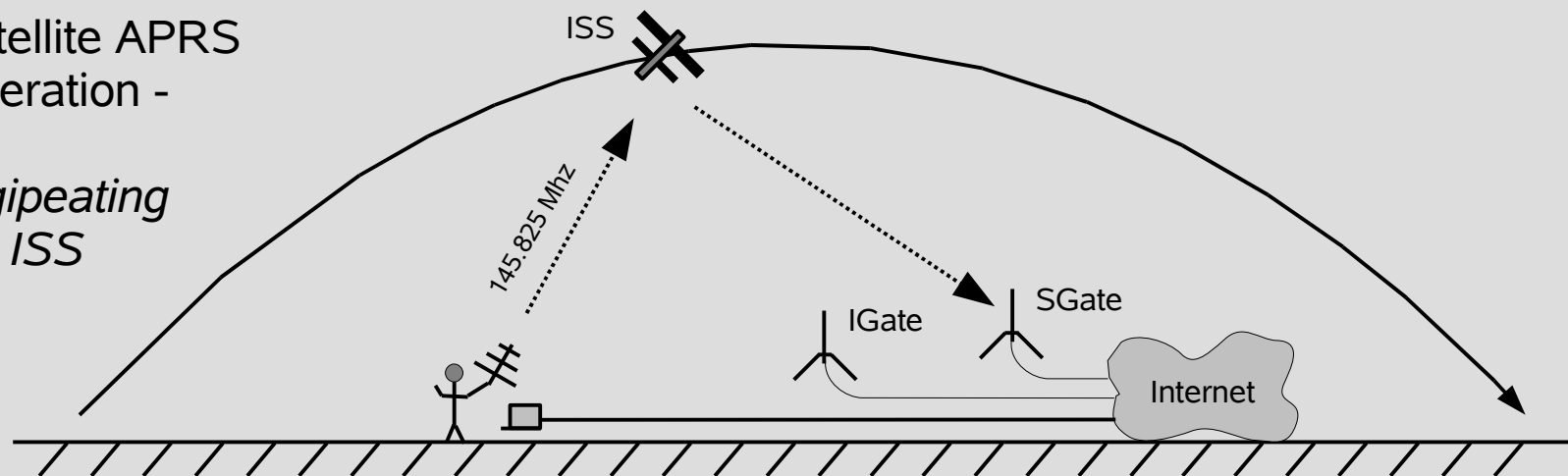- Allows packets to travel farther using intermediate hops

IGate or BBS

Internet

forward

out of reach

store
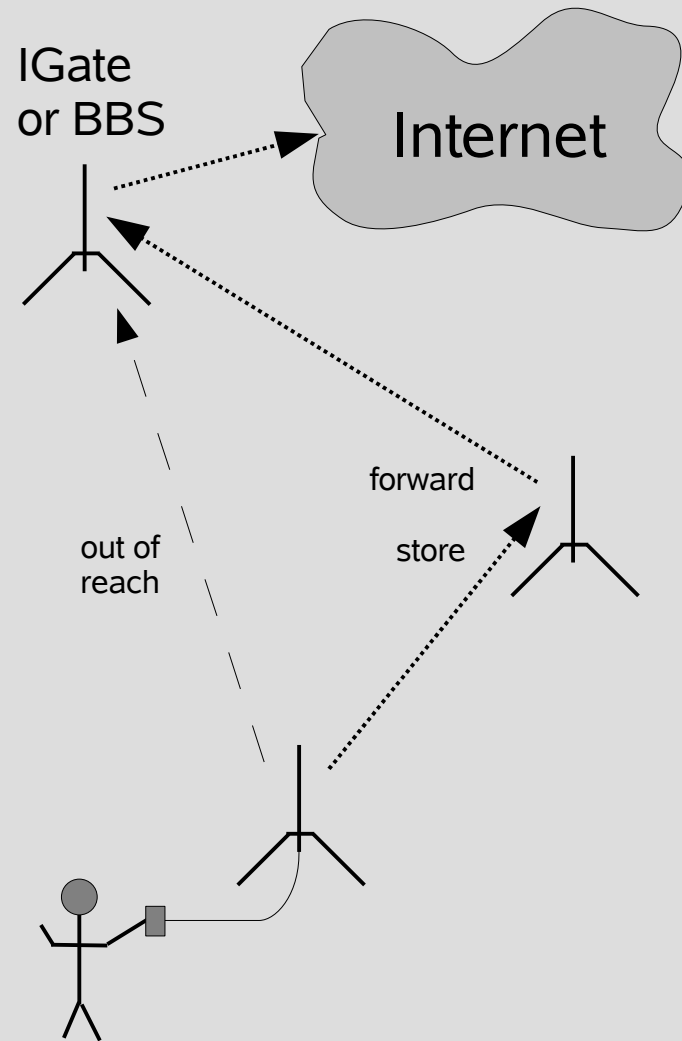
APRS – Terrestrial vs. Satellite

Terrestrial APRS
Operation

ISS

144.390 Mhz

IGate

SGate

Internet

Satellite APRS
Operation -

*Digipeating
via ISS*

ISS

145.825 Mhz

IGate

SGate

Internet

AF6DS

ISS Pass Opportunity

- 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

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:
    - `predict` with `gsat` client
    - `gpredict`
    - `ktrack`

ISS Station Operation

- ISS universal callsign alias: ARISS
  - Other callsigns: NA1ISS, RS0ISS, DP0ISS, etc.
- Kenwood TM-D700, etc. on-board the ISS
- Packet digipeating operations
  - 145.825 Mhz simplex FM
    since September 2007 – hopefully it will be permanent
  - 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 Equipment Required

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

Ground Station Equipment Setup

antenna   computer

serial   cable / DSL / wireless
(if available)

TNC   xcvr
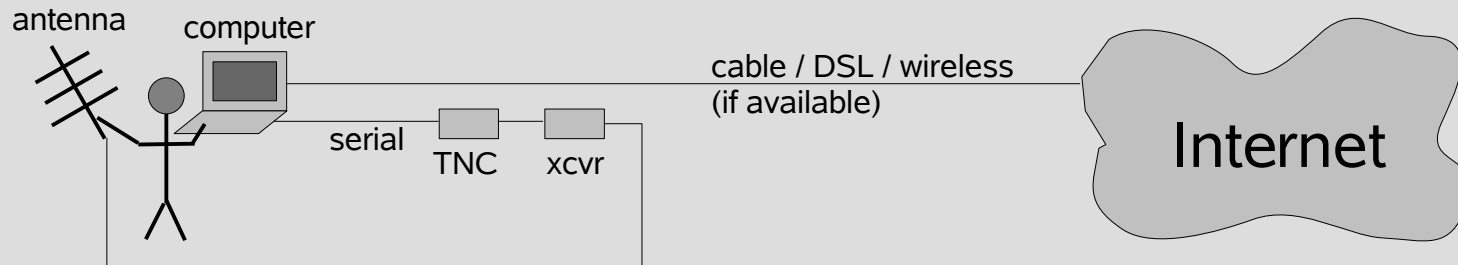
Internet

- Internet access might be unavailable in disaster and remote areas or mobile ops
- No transceiver pre-amp normally required
- Transceiver mic and speaker connections are dedicated to the TNC – voice ops unavailable
- Some TNCs accept a GPS connection for APRS beacon operation (don't use with ISS)

Typical Interfaces for TNC Hardware

Kantronics KPC-1

Ground-Plane Antenna

- No aiming required
  - Omnidirectional
  - Stationary
  - Works indoors too →
- Unity gain (¼ 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

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 is a factor when the ISS is approaching and receding
  - ISS travels roughly 214 statue 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

*Compensating on
high elevation pass*

ISS

TCA

AOS

LOS

Tx-, Rx+   Simplex @ 145.825 Mhz   Tx+, Rx-

Approaching   Traversing   Receding
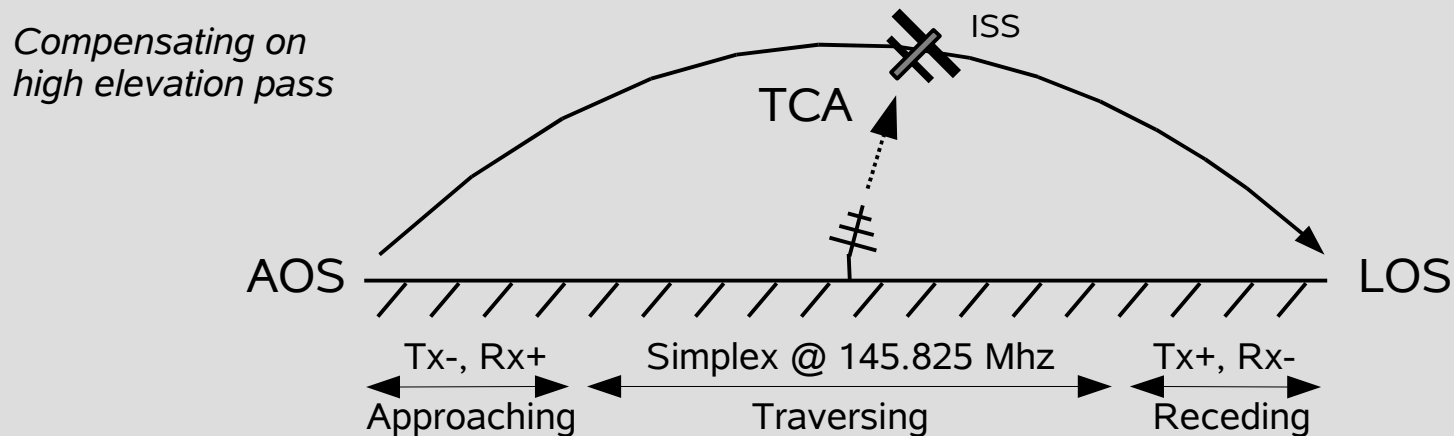
- ## Pre-program AOS and LOS shift frequencies into the transceiver – using *odd-split* offsets
  - Most 2m transceivers have 5 Khz step minimum

    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

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AOS / TCA / LOS Frequency Adjust
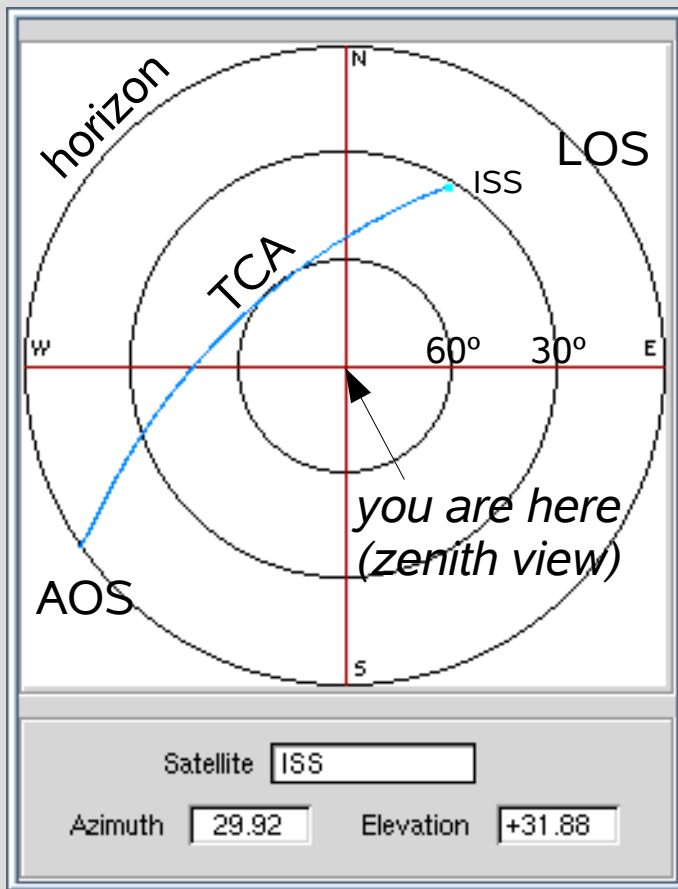
Azimuth / Elevation chart for
ISS orbit pass (in light blue)
annotated `predict` / `gsat` *chart*

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

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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`

APRS Type / Syntax (Convers mode)

- There are 3 main APRS types: message, status, position (designated by the first character of the Convers mode string)
- In TNC Convers mode, these 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...`

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`	37.2000º N latitude
`/`	symbol table to use for displaying map icon
`12205.00W`	122.0500º 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
```

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)
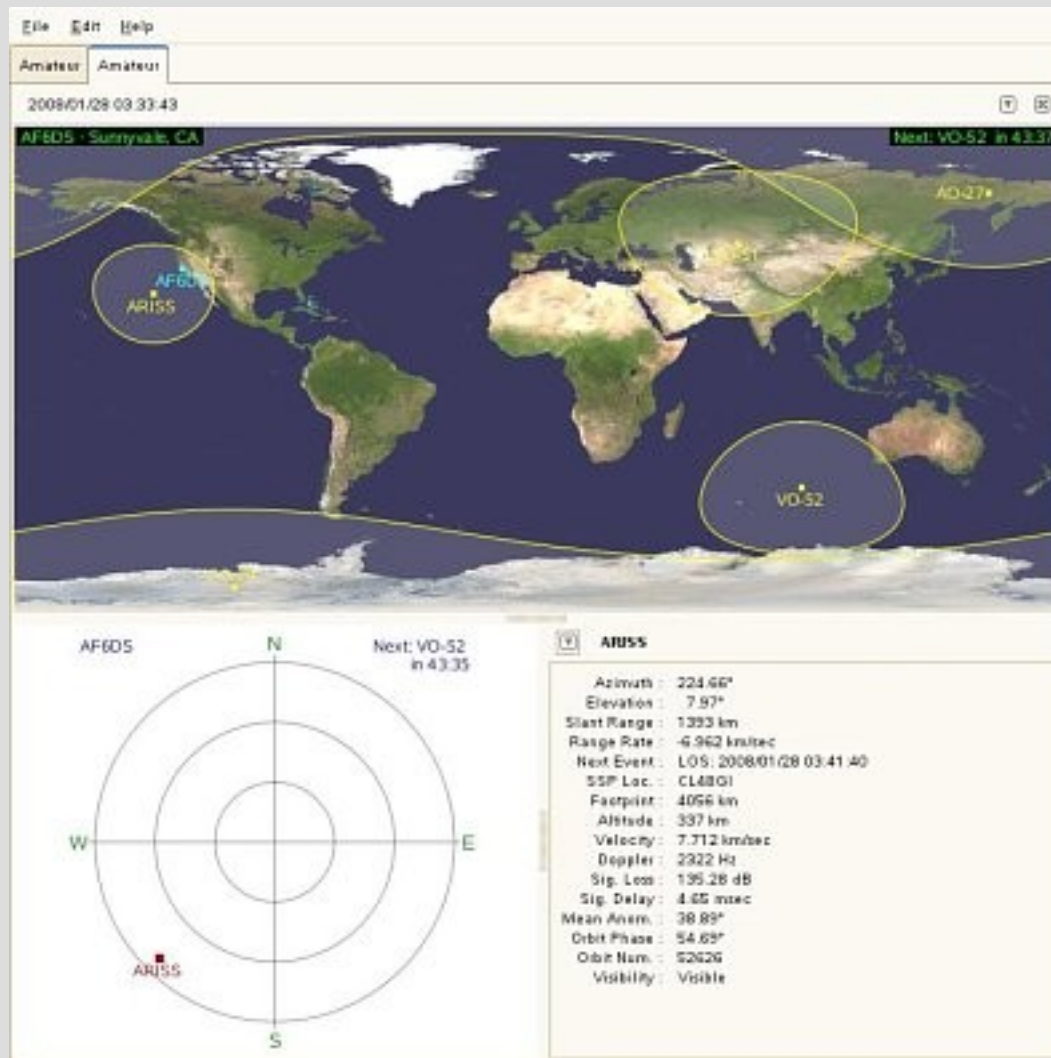
- World map
- Your location
- Satellites & orbits
- Az / El chart
- Future pass prediction
  - Time to AOS
- Doppler shift frequencies
- TLE updates

Prediction SW – `predict` / `gsat`
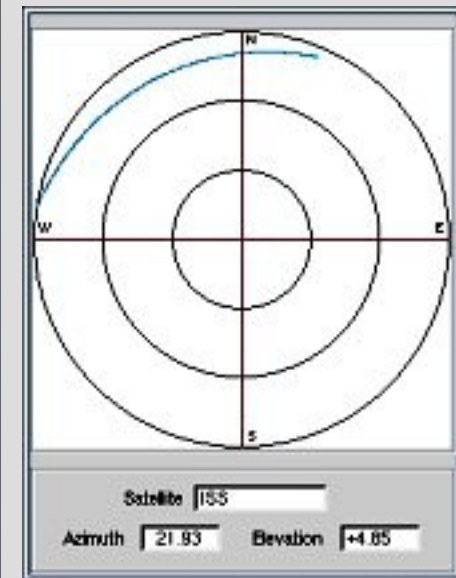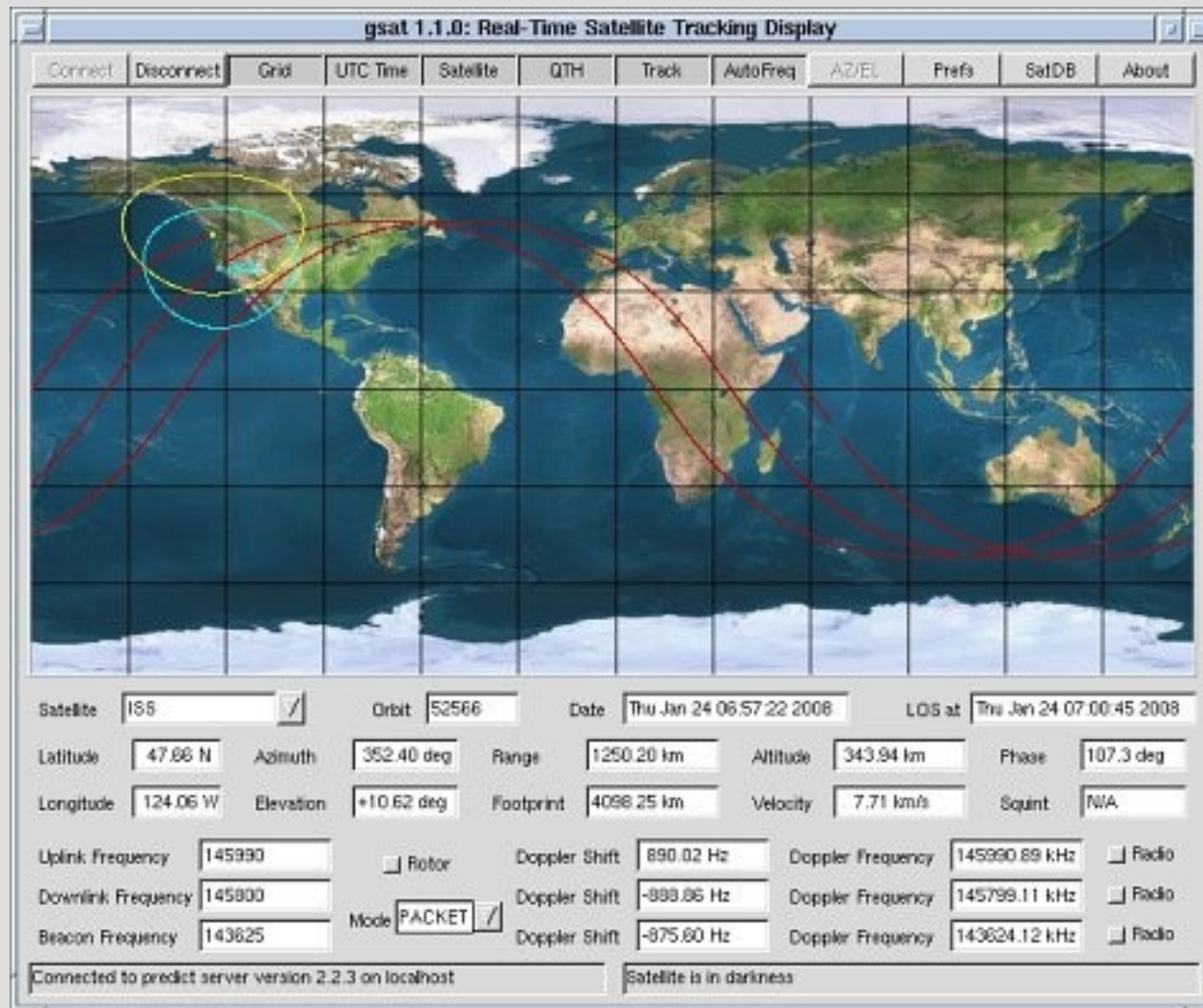
Prediction Website – `issfanclub.com`

Click on **select your city**
for pass prediction info

Click on **read more...**
for activity reports

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

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 →

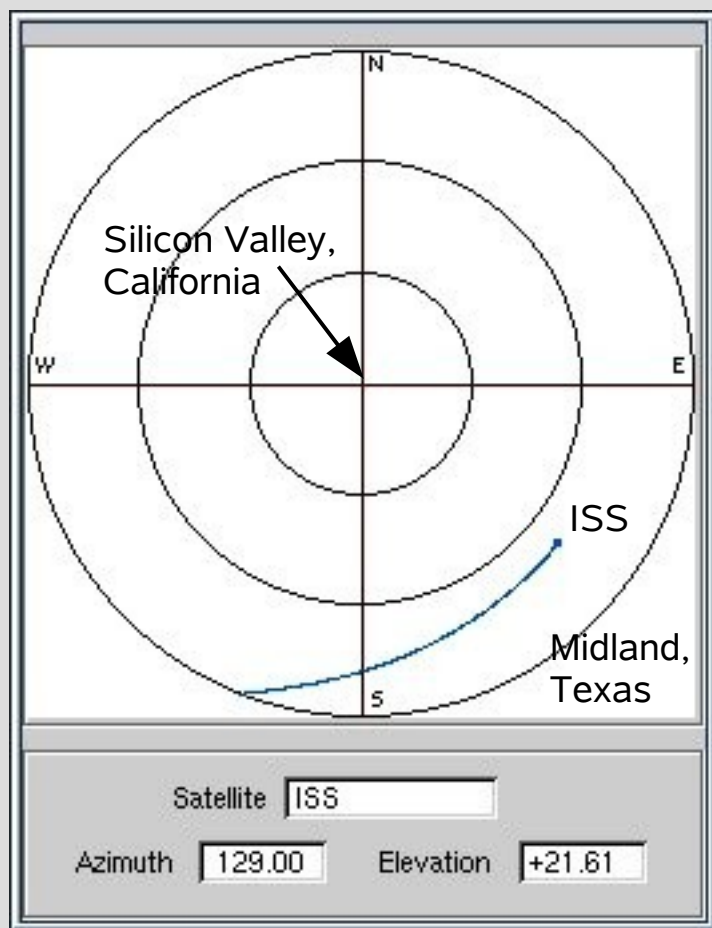*click on link to see data (see next slide)*

ISS APRS Tracking Confirmation

(see next slide)

Anatomy of an ISS Digipeated Packet

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

Silicon Valley, California

ISS

Midland, Texas

Satellite ISS

Azimuth 129.00   Elevation +21.61

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 available 24 hours/day, but might be off during: docking, EVA (spacewalks), etc.
- Check for and use the latest orbital data
  - `http://www.celestrak.com/NORAD/elements/`
  - `http://www.issfanclub.com` – website tracking orbital data may get out-of-date occasionally
- Distant ground or ISS packet collisions are often not detected by your TNC – so retry

Other Things to Note

- Cost:
  - 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!
- APRS CQ and ISS packet BBS usage also possible, but maybe difficult in heavy traffic

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.htohananet.com/am-
   radio/spacecomm/getting-started-iss.html
http://ronhashiro.htohananet.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/aprssig/aprsspec/spec/aprs101/APRS
   101.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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And many thanks to the following who reviewed this presentation and provided comments:
KE6AFE, N5VHO

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 w3ado-1` (`w3ado-1` is default callsign)
- Same FM simplex frequency of 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 Confimation

Amateur Radio Stations heard via PCSat, ANDE and RAFT - Mozilla Firefox

ry   Bookmarks   Tools   Help

http://www.findu.com/cgi-bin/pcsat.cgi   ← http://pcsat.aprs.org

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

Satellite PCSAT

Azimuth 32.29   Elevation +9.75
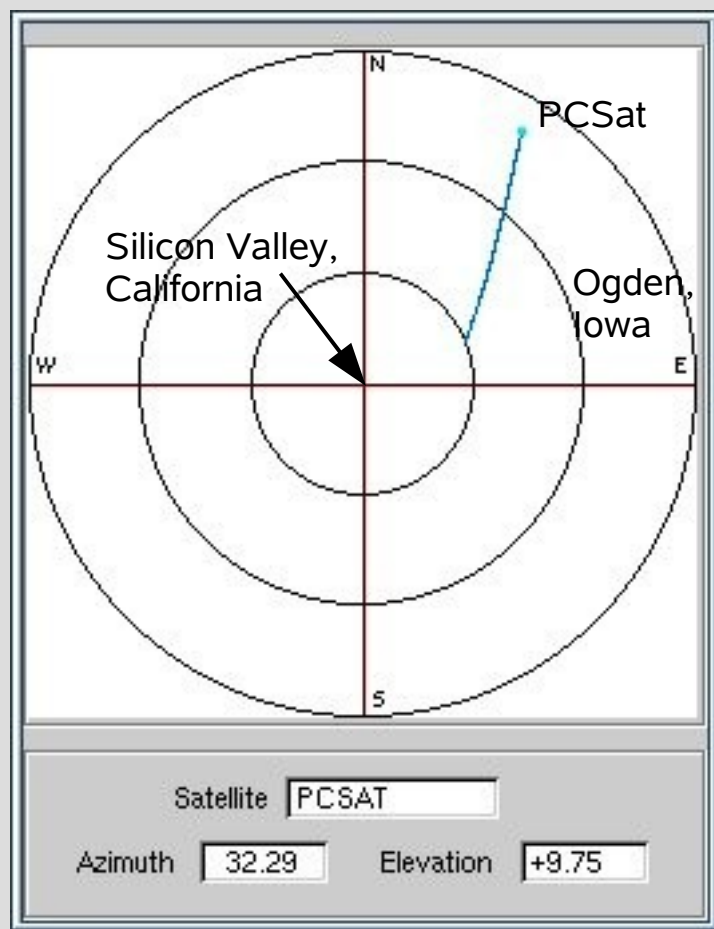
February 15, 2008 15:33 UTC

- 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)

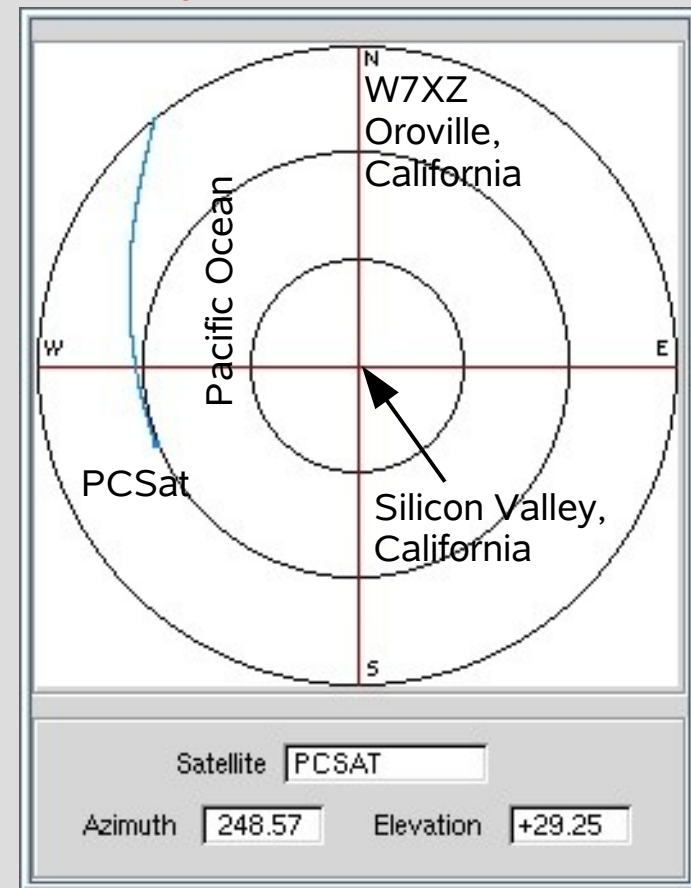# Anatomy of a PCSat Email Digipeat

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

Received email:

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
```
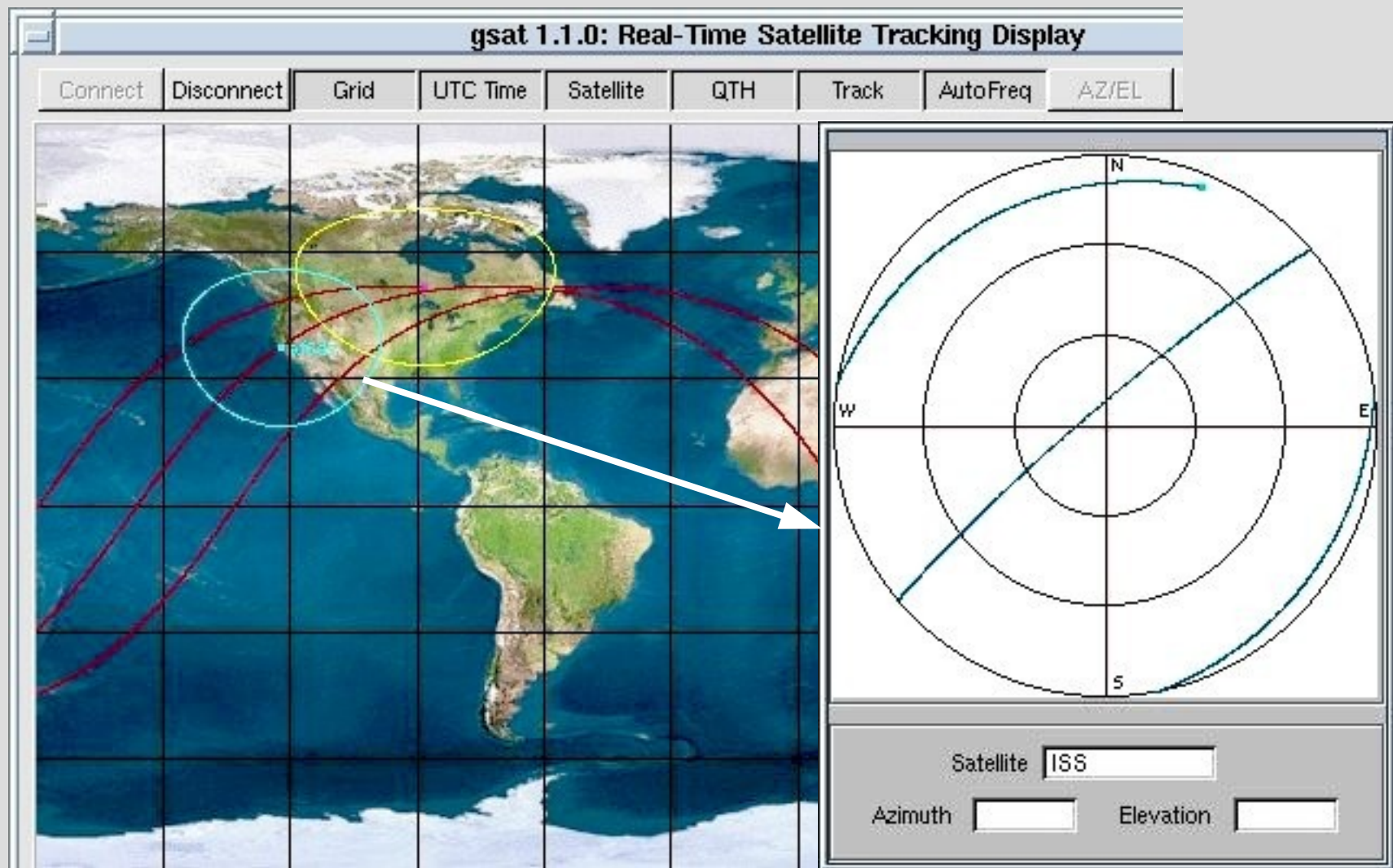

W7XZ
Oroville,
California

Pacific Ocean

PCSat

Silicon Valley,
California

Satellite PCSAT

Azimuth 248.57   Elevation +29.25

Backup Slides / Info

3 Usable Consecutive Passes in 3 Hrs