APRS Packet Digipeating via the ISS

International Space Station

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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:

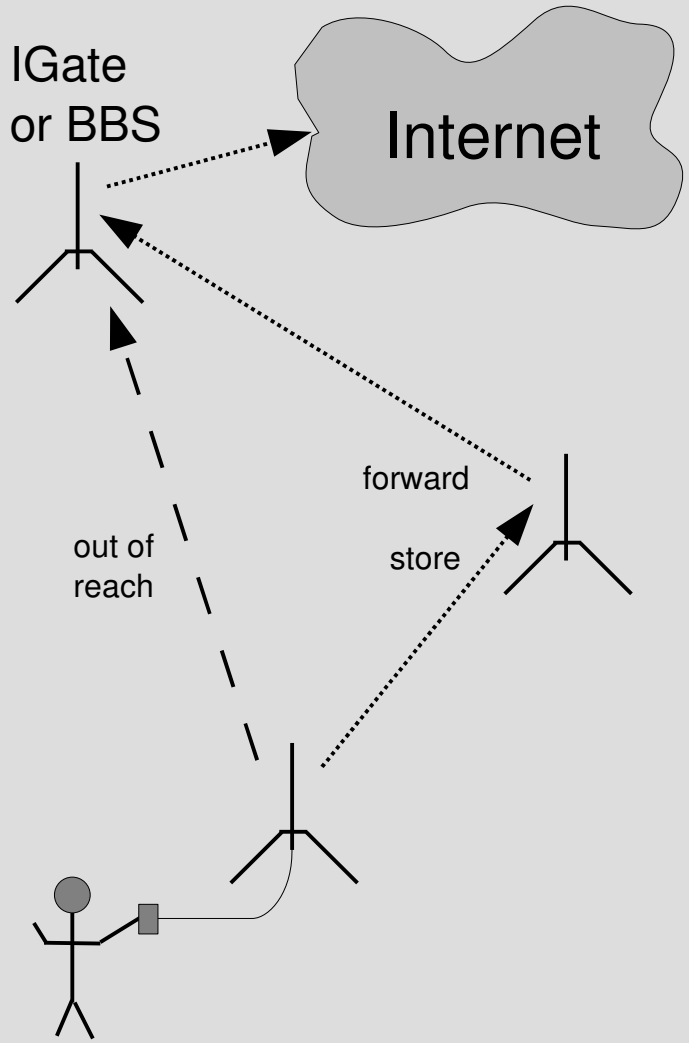
- To digipeat APRS packets for hundreds or even a thousand miles via the ISS, and verify that these packets are logged by APRS tracking websites

What is APRS®?

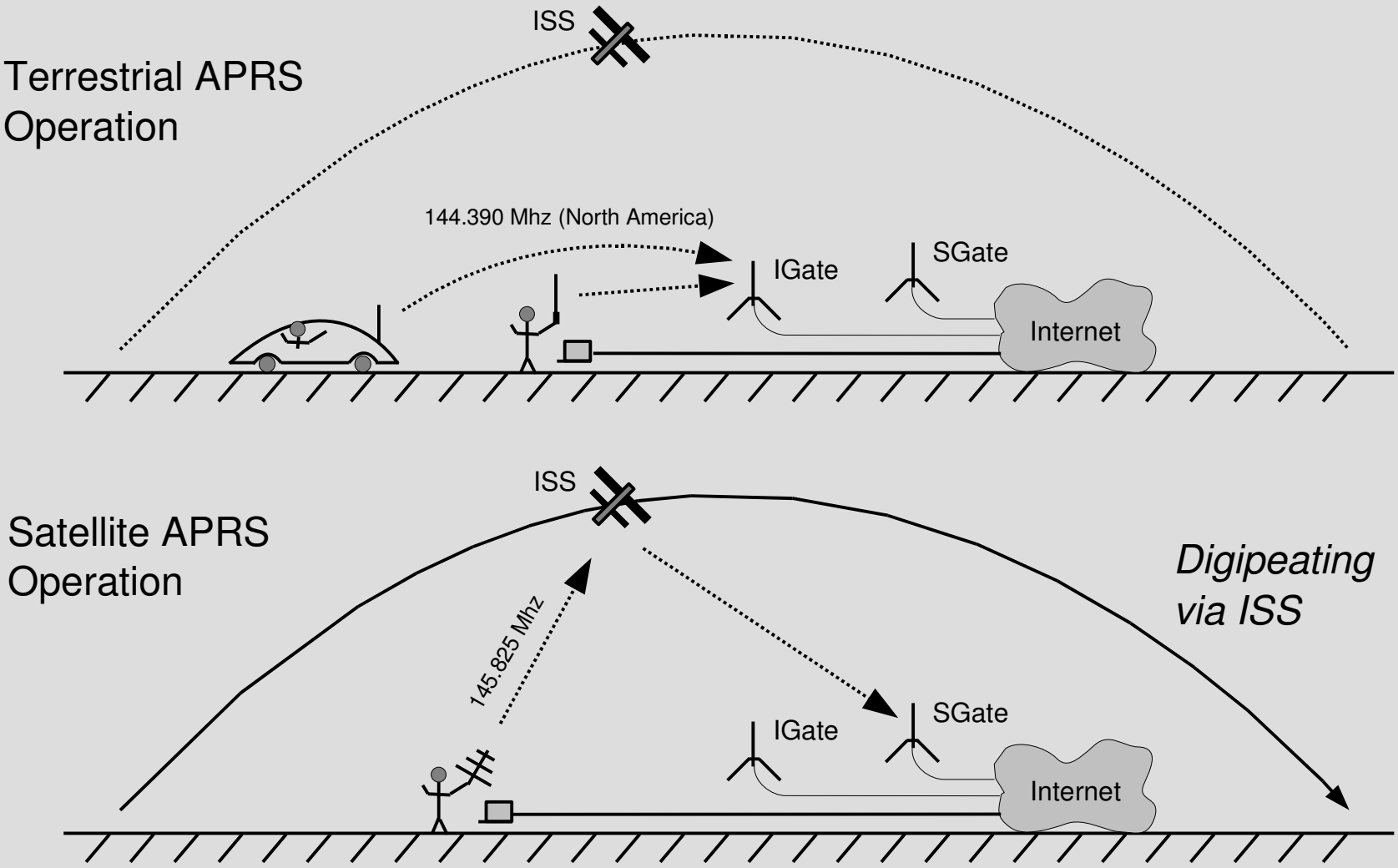
- **A**utomatic **P**acket **R**eporting **S**ystem®
- A digital (non-voice) method of transmitting messages, status, and position – using specially formatted AX.25 packet messages
- TNC (Terminal Node Controller), similar to a computer dial-up modem, transmits packets and APRS data over the airwaves
- 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



ISS Overhead Pass Opportunities

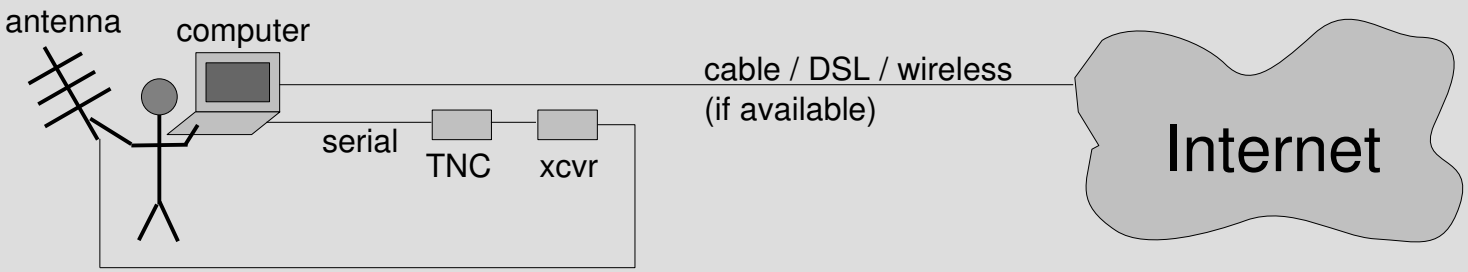
- Window of opportunity for transmitting to ISS
  - Each ISS orbit period is about 90 minutes
  - 5 to 10 minute window per orbit pass
  - Groups of consecutive passes about twice a day, roughly 12 hours apart
- Number of usable consecutive passes

  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

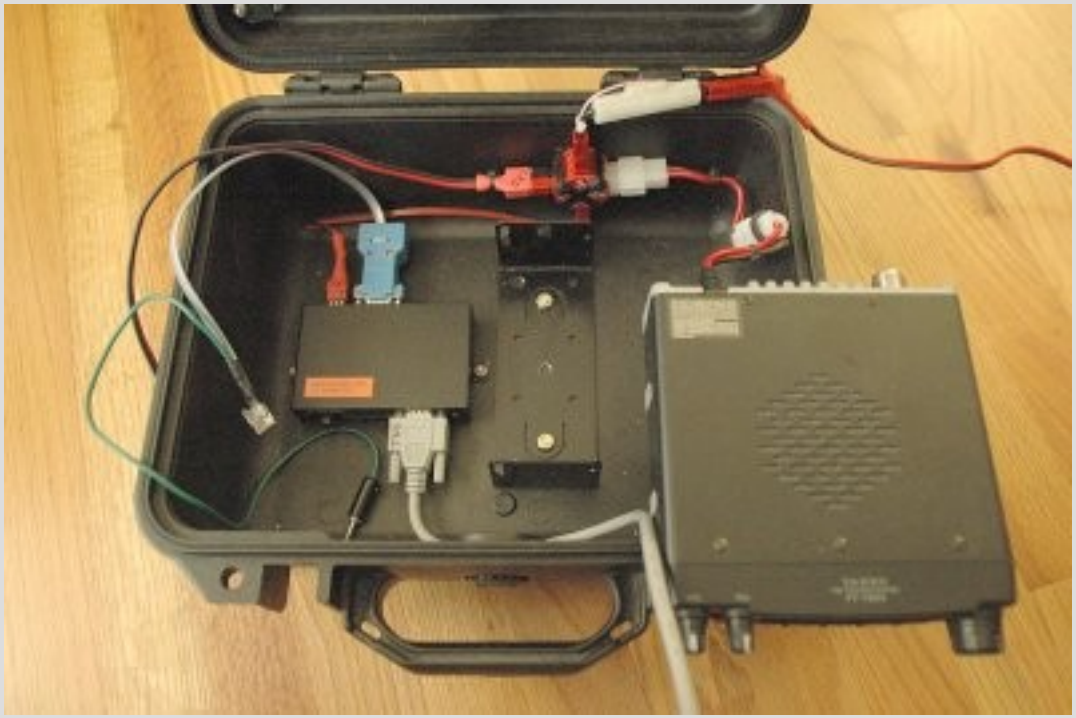
Ground Station Equipment Setup



- 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 (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

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

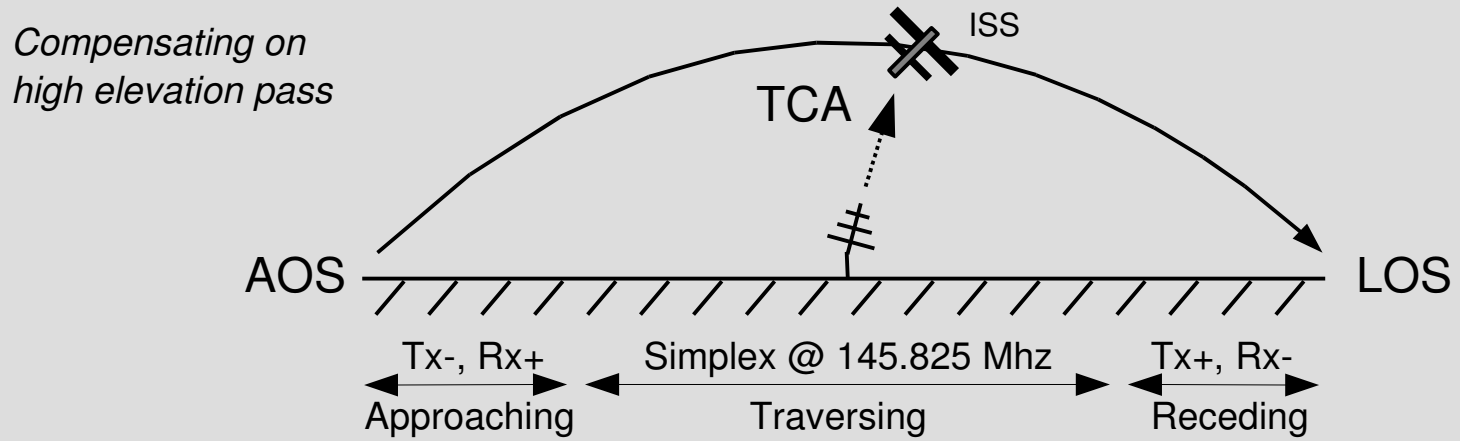
- Setup
  - Verify your setup with terrestrial APRS operation
  - Pre-program transceiver with Doppler frequencies
  - Set TNC parameters (in TNC Command mode)
  - Update TLE, track & predict ISS orbit passover
- Operation
  - Check websites for recent ISS packet activity
  - Adjust transceiver for Doppler 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 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



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

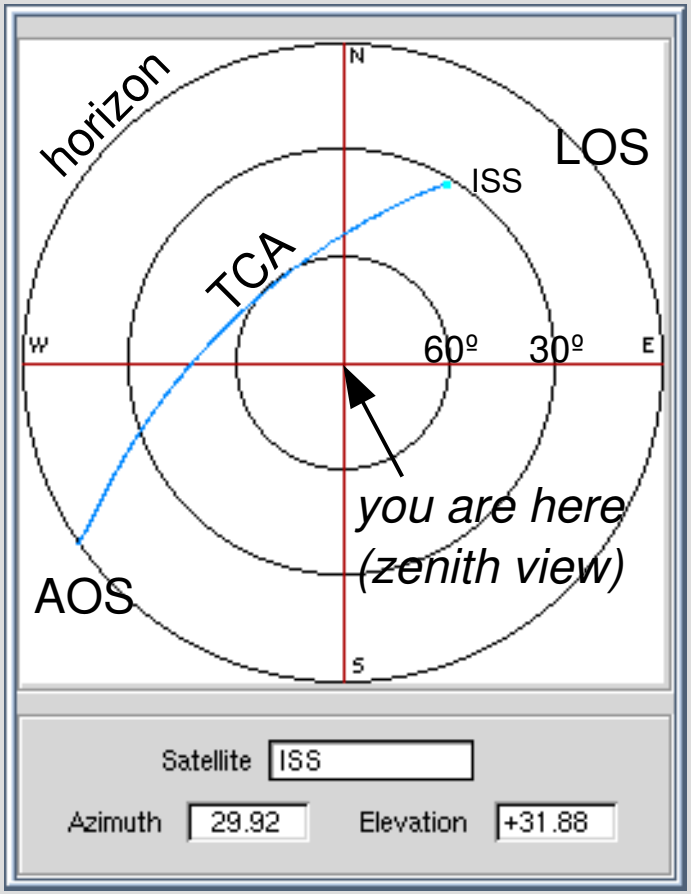
    AOS: Tx 145.820 Mhz, Rx 145.830 Mhz FM

    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

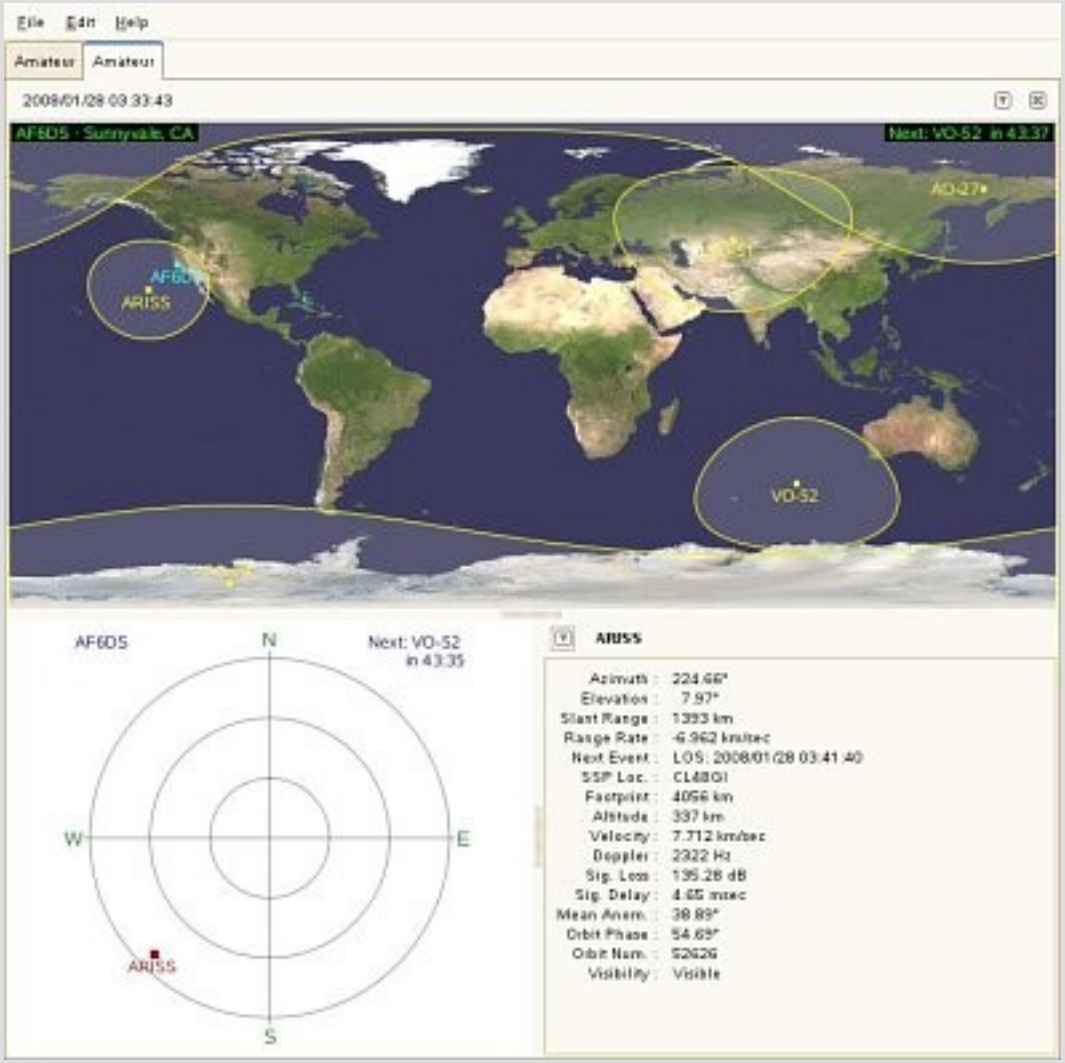
- A satellite's orbit can be mathematically described by Keplerian Elements – encoded in a format called Two-Line Element (TLE)
- TLE format:

```
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:

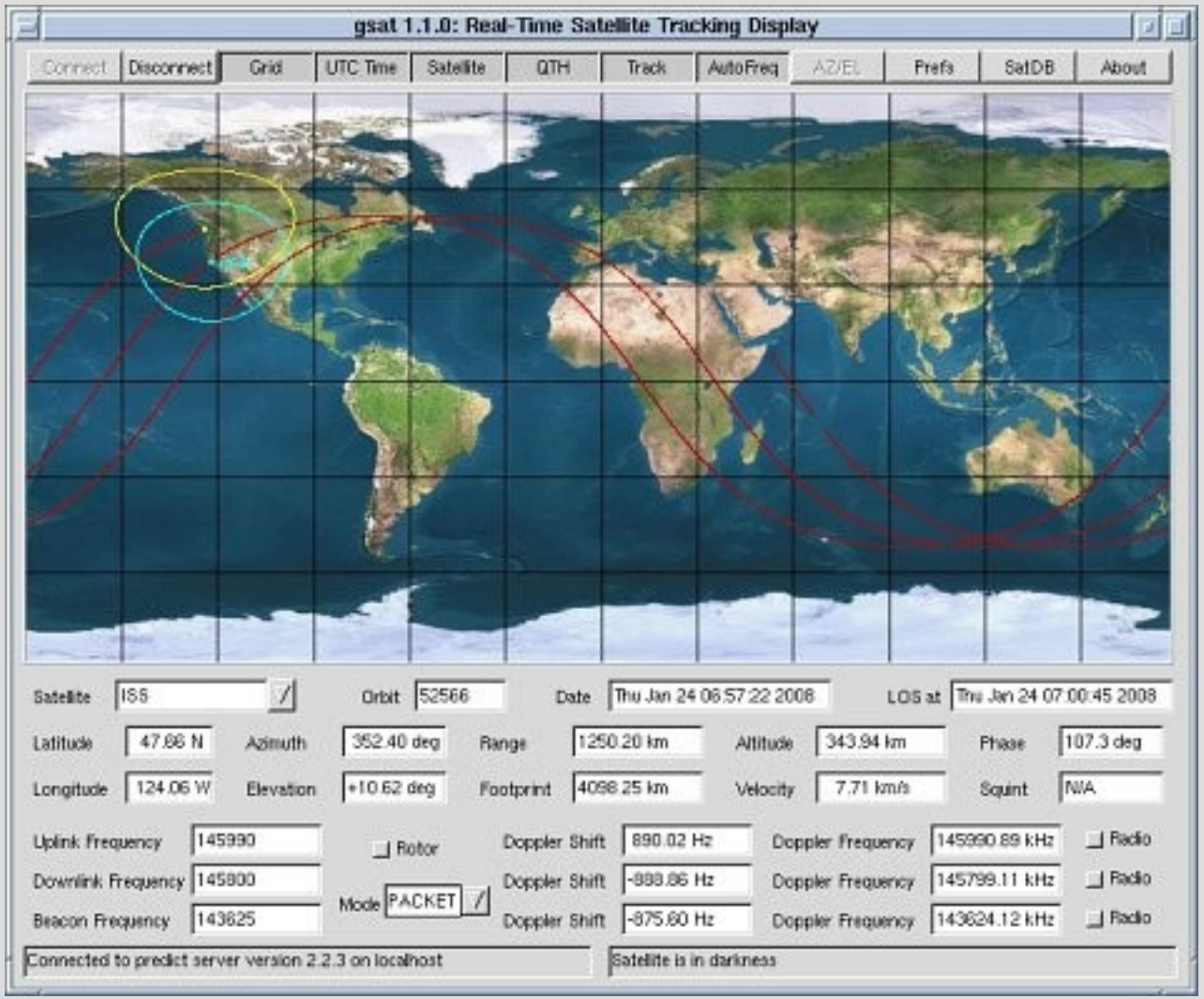
`http://www.celestrak.com/NORAD/elements/stations.txt`

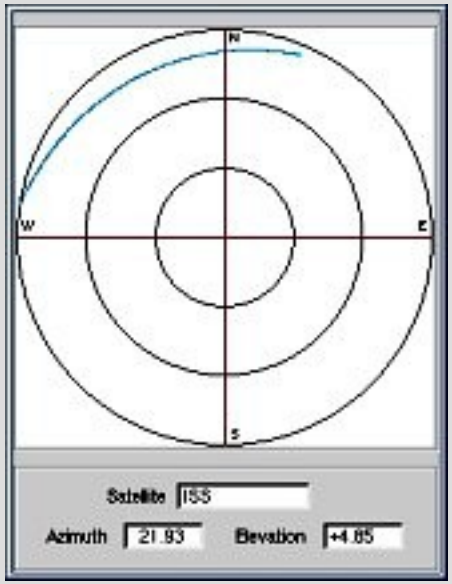
Prediction SW – `gpredict` (Linux)



- 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`	37.2000º 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`

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):

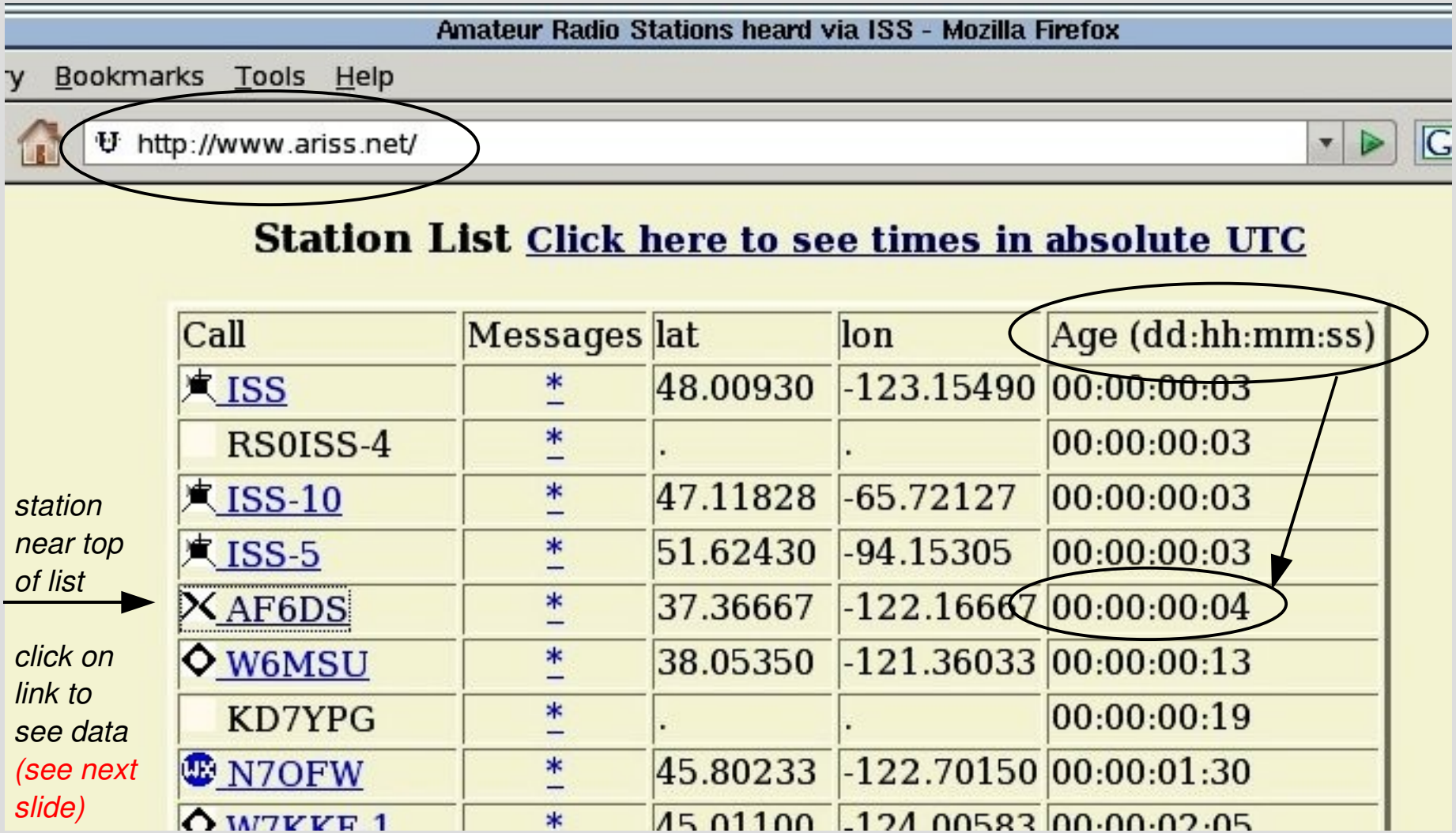
```
AF6DS>APRS,RS0ISS-4*:
[cm87xi]Happy trails ISS !
```

ARISS digipeated as RS0ISS-4

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

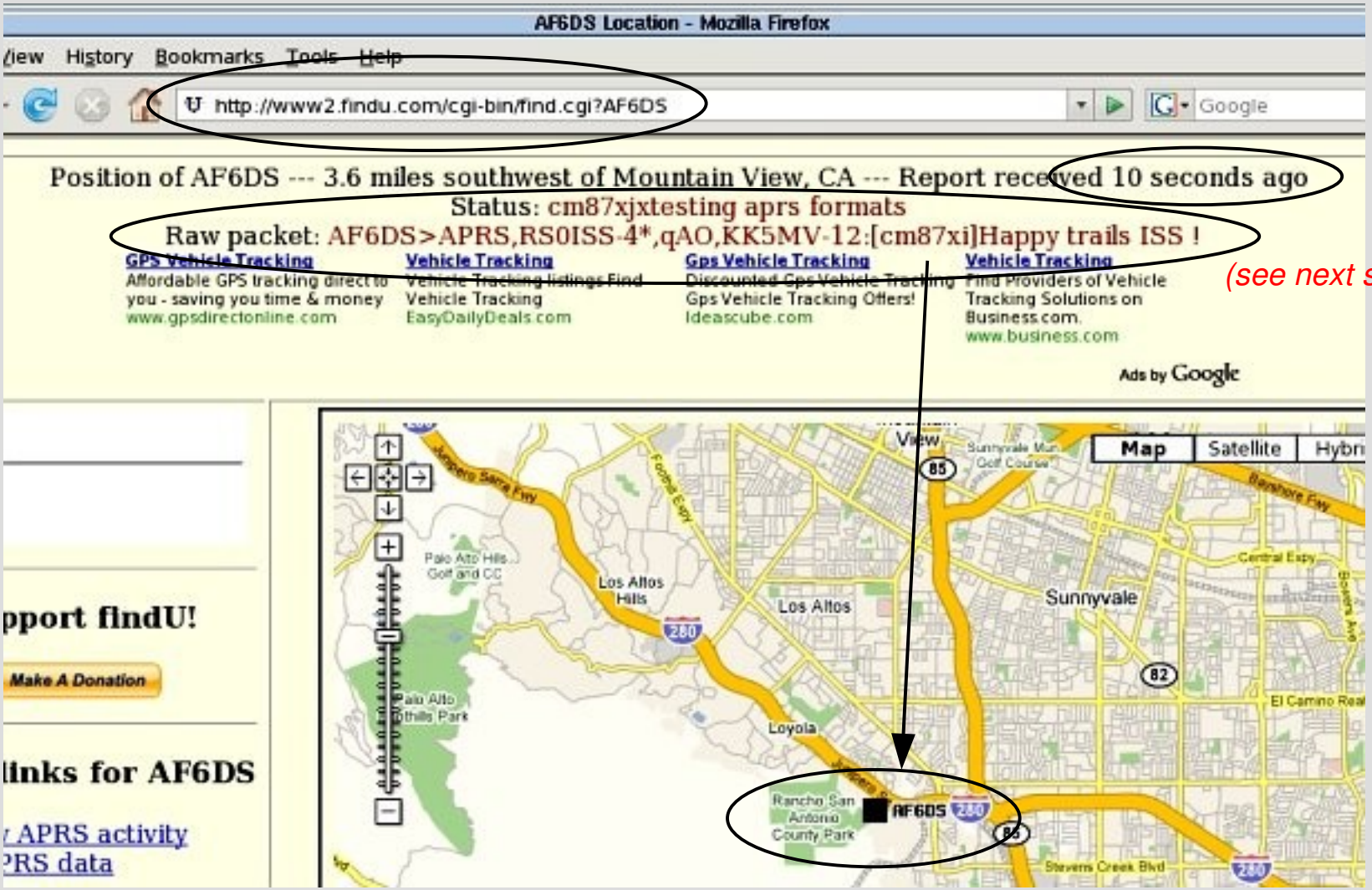
ISS APRS Tracking Confirmation



station near top of list

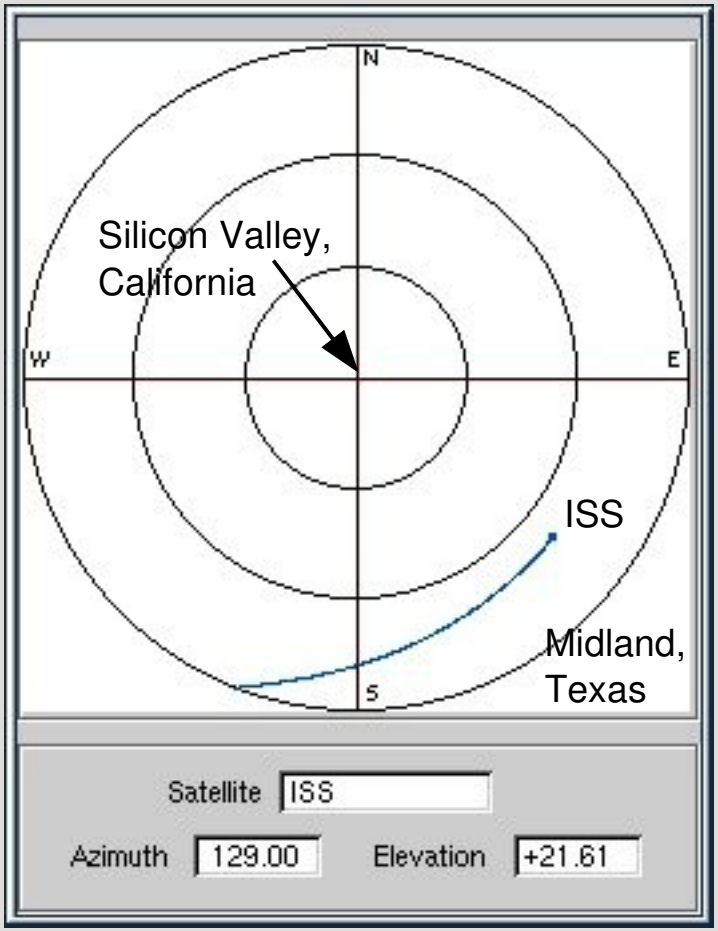
click on link to see data (see next slide)

ISS APRS Tracking Confirmation



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 !

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.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/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

af6ds@yahoo.com

Many thanks to the following who provided valuable comments: KE6AFE, N5VHO, KI6TSF, et al.

Presented at:

- Am Tech Day @ SLAC, March 2008 & January 2009
  - 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>
```

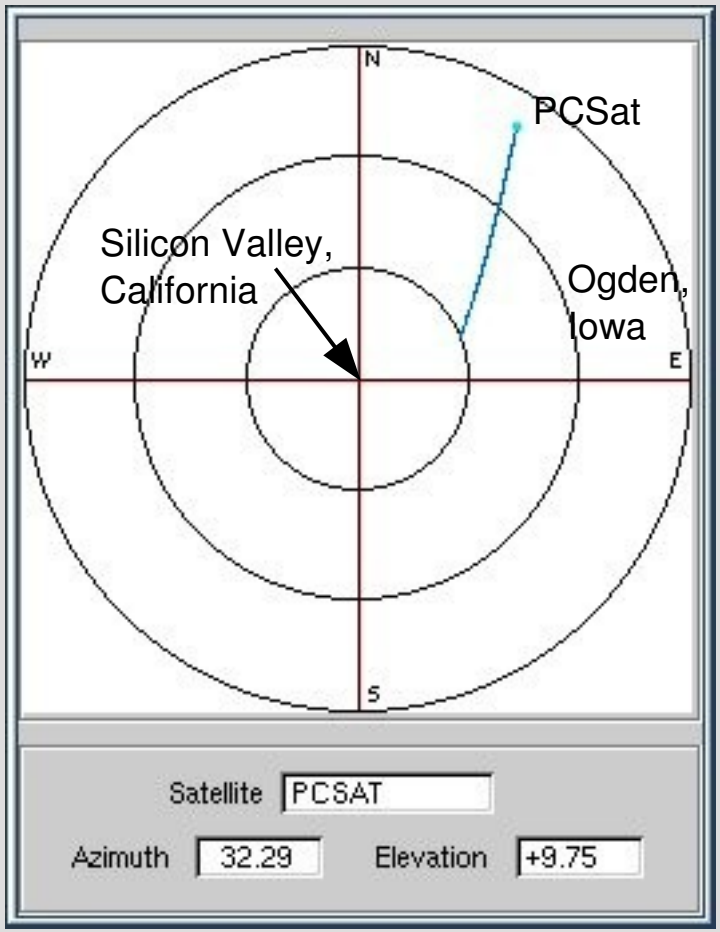
PCSat APRS Tracking Confirmation

station 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 → 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`):

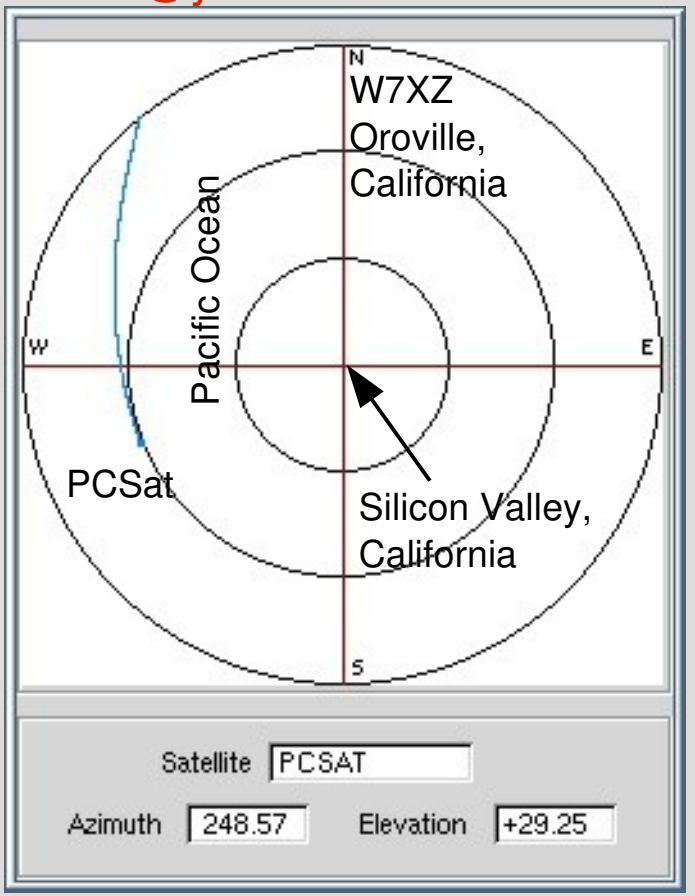
AF6DS>APRS,**W3ADO-1***,qAO,**W7XZ-6**::EMAIL :af6ds@yahoo.com
testing email via pcsat

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
```



Backup Slides / Info

3 Usable Consecutive Passes in 3 Hrs