# An Introduction to Amateur Satellites


*Presented by*

**EMILY CLARKE**

**WØEEC@AMSAT.ORG**


**This presentation available online at http://www.PlanetEmily.com/W0EEC**

# About Your Presenter

- Website: http://www.PlanetEmily.com
- AMSAT: SF Bay Area Coordinator
- Project OSCAR: VP, Member of the Board of Directors
- Licensed as an amateur in February 2003
- Over 6400 satellite contacts
- Awards include VUCC, W4AMI, WAC
- US, AMSAT winner of AO-40 Birthday Bash contest
- Also a member of ARCA, MSARC

# What Is An OSCAR

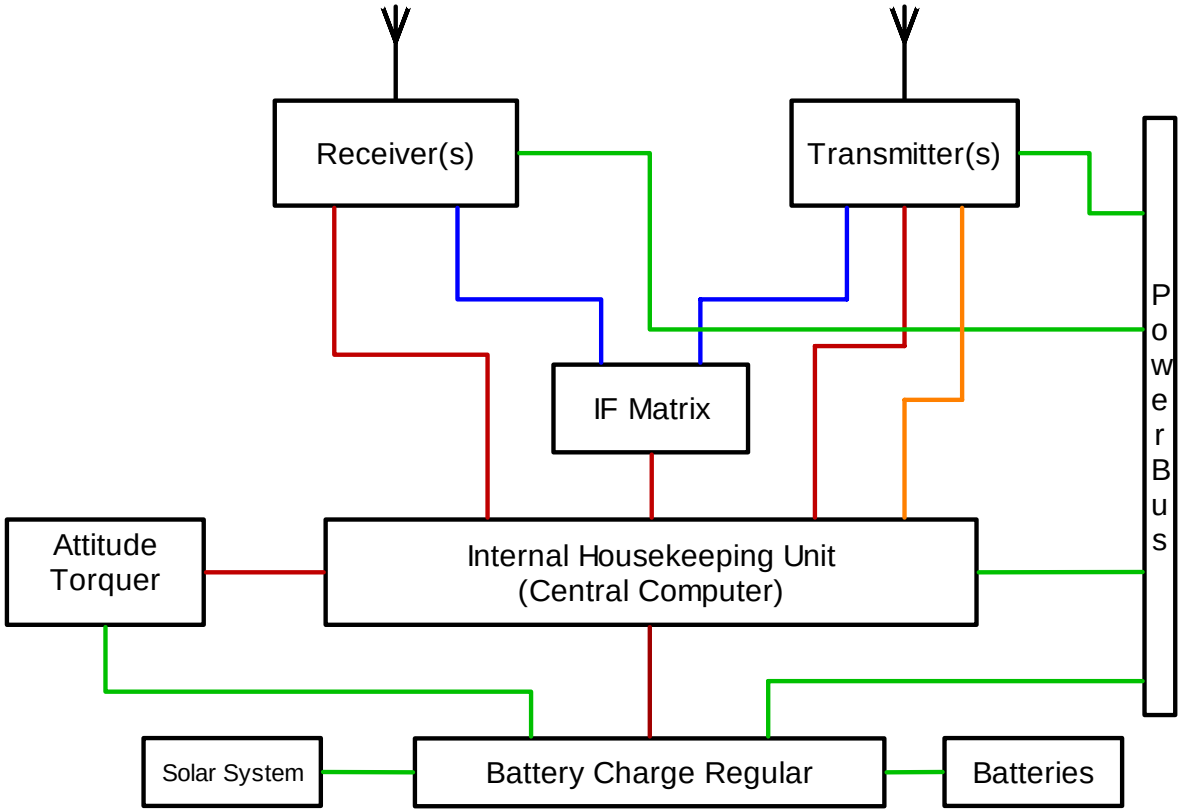
- An OSCAR is an **O**rbiting **S**atellite **C**arrying **A**mateur **R**adio
- Built for non-commercial purposes
- Originally built by Project OSCAR members in garages in Silicon Valley
- Now built by and/or funded by members of AMSAT and AMSAT affiliates
- Originally a “bleep sat” but now carry sophisticated repeaters or transponders
- Are encouraged to carry sensors and other scientific experiments

Chuck Towns K6LFH in his garage with OSCAR-II

# Why Use Amateur Satellites?

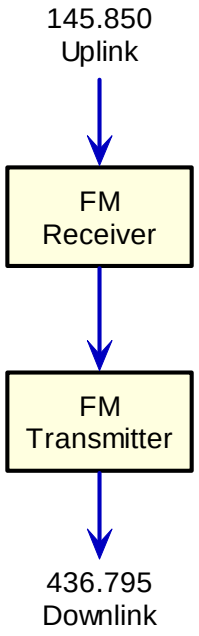
| Traditional Shortwave | Amateur Satellites |
|---|---|
| Available when bands are open | Available when in range |
| Wide bandwidth | Bandwidth is satellite dependent |
| Band openings unpredictable | Satellites have timely orbits |
| Range depends on ionosphere height | Range depends on satellite height |
| If you can hear it you can work it | If you can hear it you can work it |
| Requires large property for antennas | Can be worked with as little as an HT |
| Turning radius of Yagis is large | Turning radius of Yagis is small |
| Large load bearing azimuth rotator | None or small az/el rotators |
| Modes depend on band/bandplan | Modes depend on satellite design |
| Beacons aid propagation | Beacons herald satellite availability |
| General or better license | Technican license |

# How a Satellite is Designed

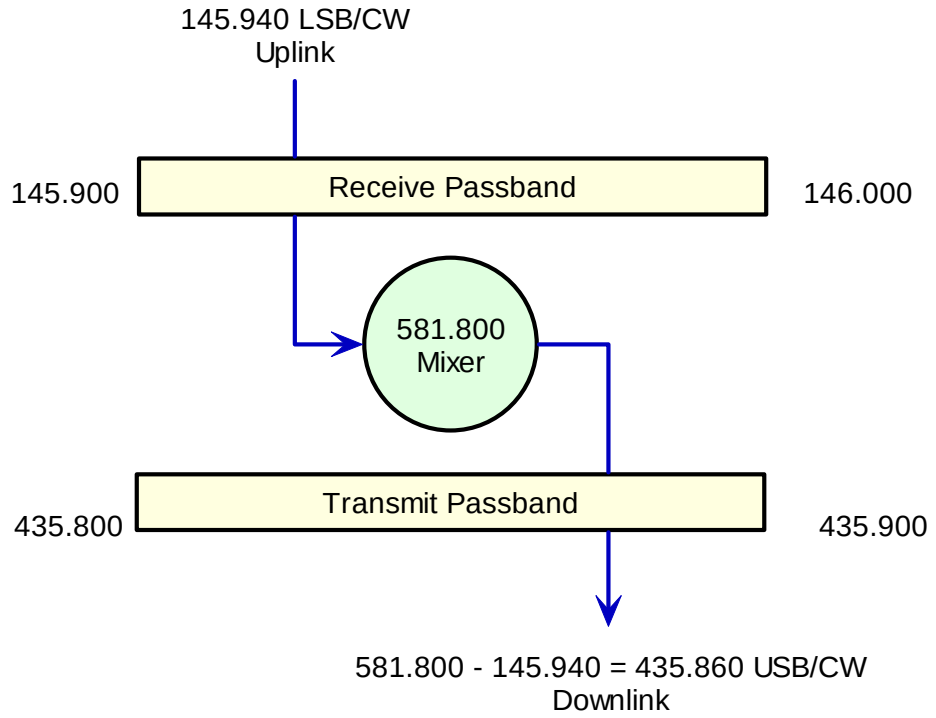


# FM Repeater vs Linear Transponder

Single Channel NFM Repeater




100 KHz Wide Linear Transponder

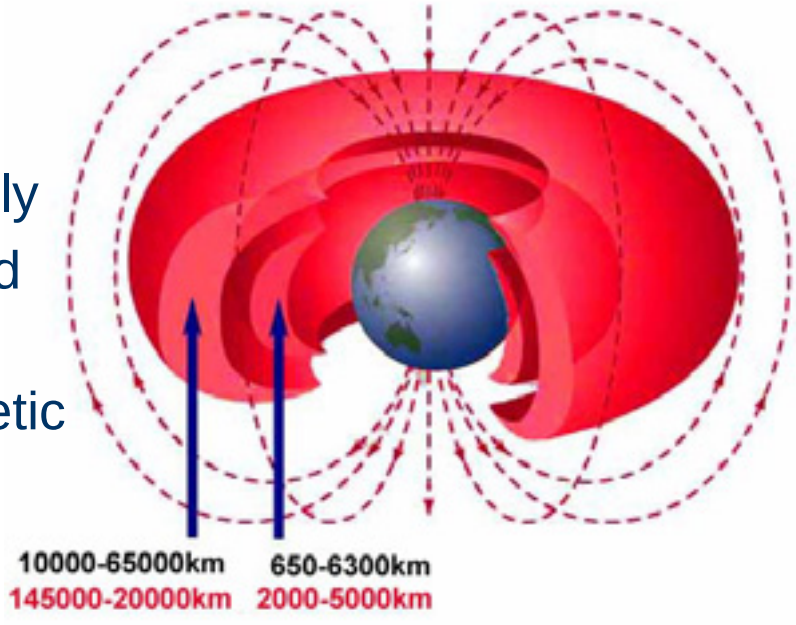


# Some Important Terms

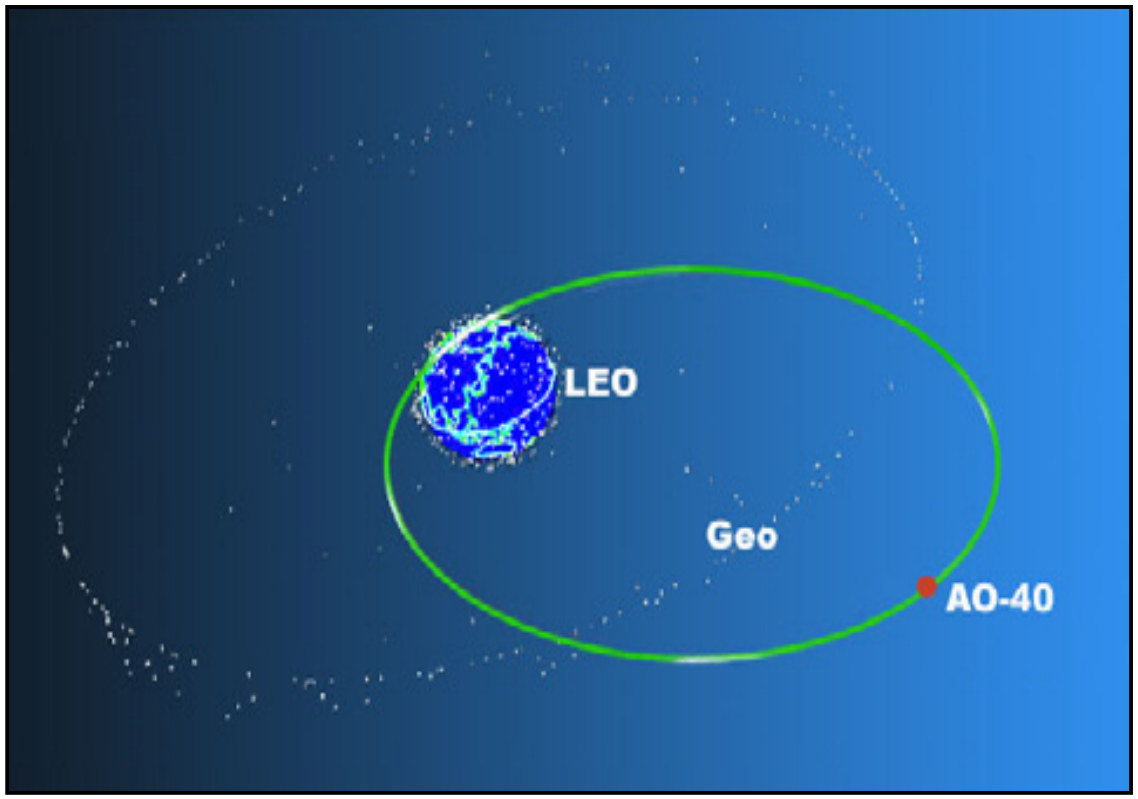
| | | |
|---|---|---|
| **Orbit** | ⇨ | The **path** a satellite travels around the earth |
| **Doppler** | ⇨ | A **shift** in frequency caused by satellite motion |
| **LEO** | ⇨ | A satellite in **L**ow **E**arth **O**rbit (400-2000km) |
| **HEO** | ⇨ | A satellite in a **H**igh **E**arth **O**rbit ( > 20,000km) |
| **GEO** | ⇨ | A satellite in a **Geo**synchronous orbit (35,680km) |
| **Uplink** | ⇨ | The frequency used to **transmit** to a satellite |
| **Downlink** | ⇨ | The frequency used to **receive** a satellite |
| **Footprint** | ⇨ | A circular area where the satellite is **line of sight** |
| **Apogee** | | When the satellite is at it's **highest** alititude |
| **Perigee** | | When the satellite is at it's **lowest** altitude |
| **Inclination** | | The **angle** of the satellite where equator = zero |

# The Van Allen Belts

- The Van Allen belts are regions of protons and electrons, held captive by the magnetic influence of the Earth
- Radiation is concentrated and closest to the earth at the poles (aurora)
- Satellite orbits are designed to spend as little time as possible in the belts or avoid them completely
- Satellites that travel in and around the belts may be damaged
- Levels change because of magnetic storms, nuclear explosions



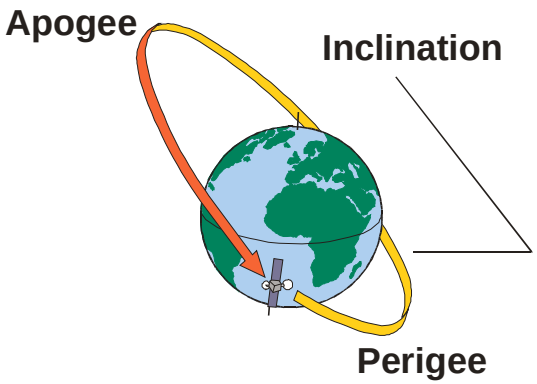
# Basic Orbit Comparison

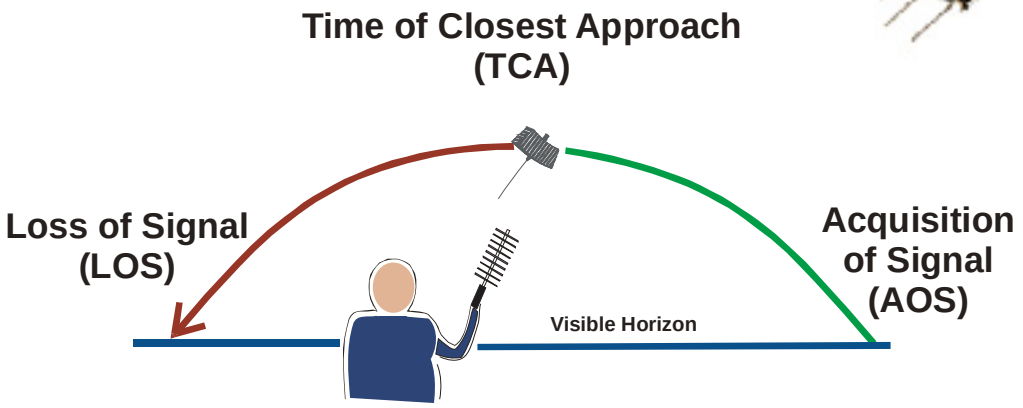



LEO – 90-120 minutes per orbit vs AO-40 19.6 hours per orbit

Graphic courtesy of MacDoppler Pro

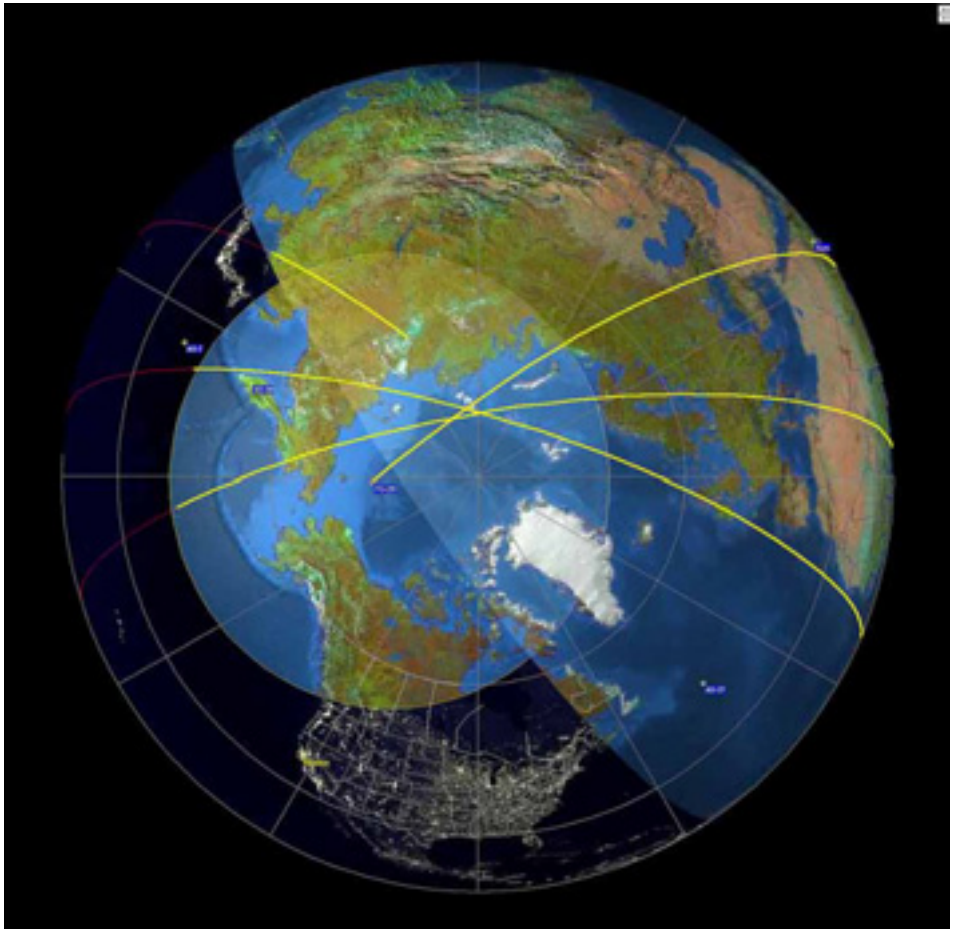
# Satellite Orbit Tracks




- Artificial satellites travel in an arc determined by height, eccentricity, and inclination.
- **Inclination** can range from $0^{o}$ (equitorial) to $90^{o}$ (polar)
- The time the satellite is visible (in range) to an observer is called a satellite "**pass**". During the pass, you are in the "**footprint**"
- The altitude of the satellite above the earth determines the length of the orbit and pass or "**time on station**" and mutual coverage

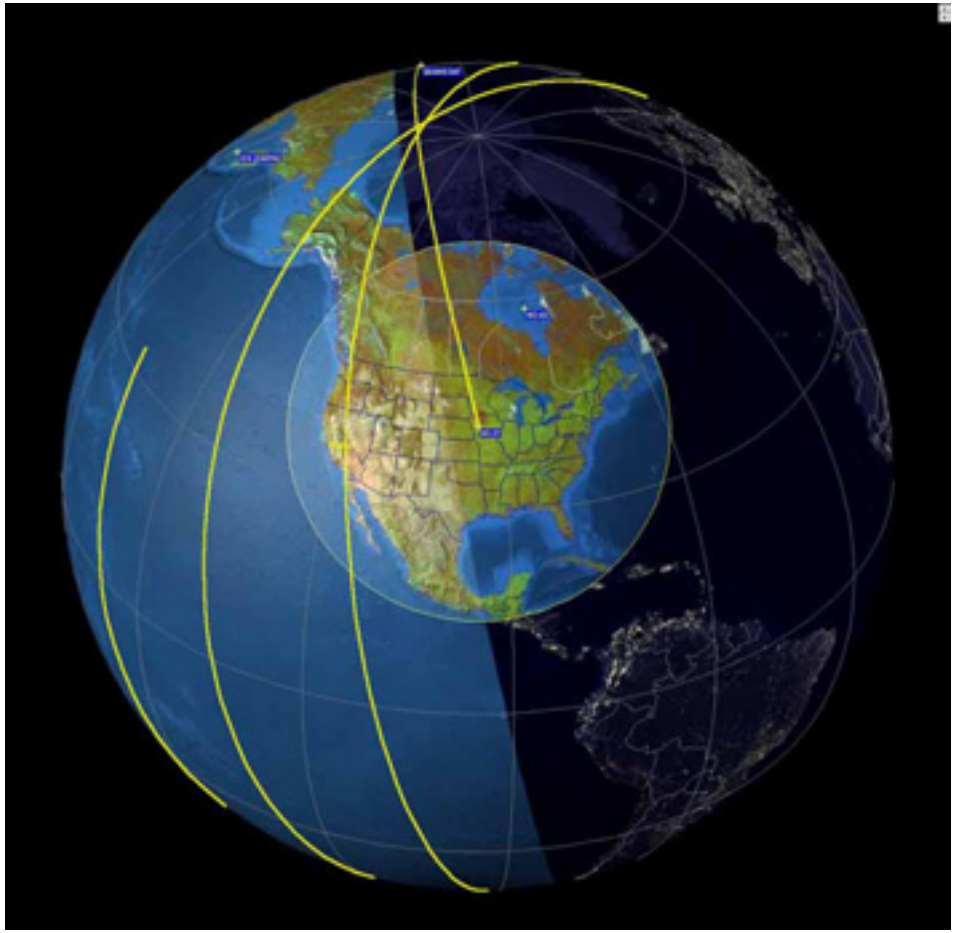
# Orbit Type – Sun Synchronous



- Passes near the pole
- Spends time in sun and eclipse depending on altitude
- Available at the same time of day every day.
- Batteries required when eclipsed
- All parts of planet receive equal access

FO-29, AO-51

# Orbit Type – Dawn to Dusk



- Special Sun-Synchronous that follows the line between daylight and darkness
- Passes near the pole
- Spends most of the time in sun and very little in eclipse
- Batteries required when in eclipse but very low charge/discharge rates
- All parts of planet receive equal access

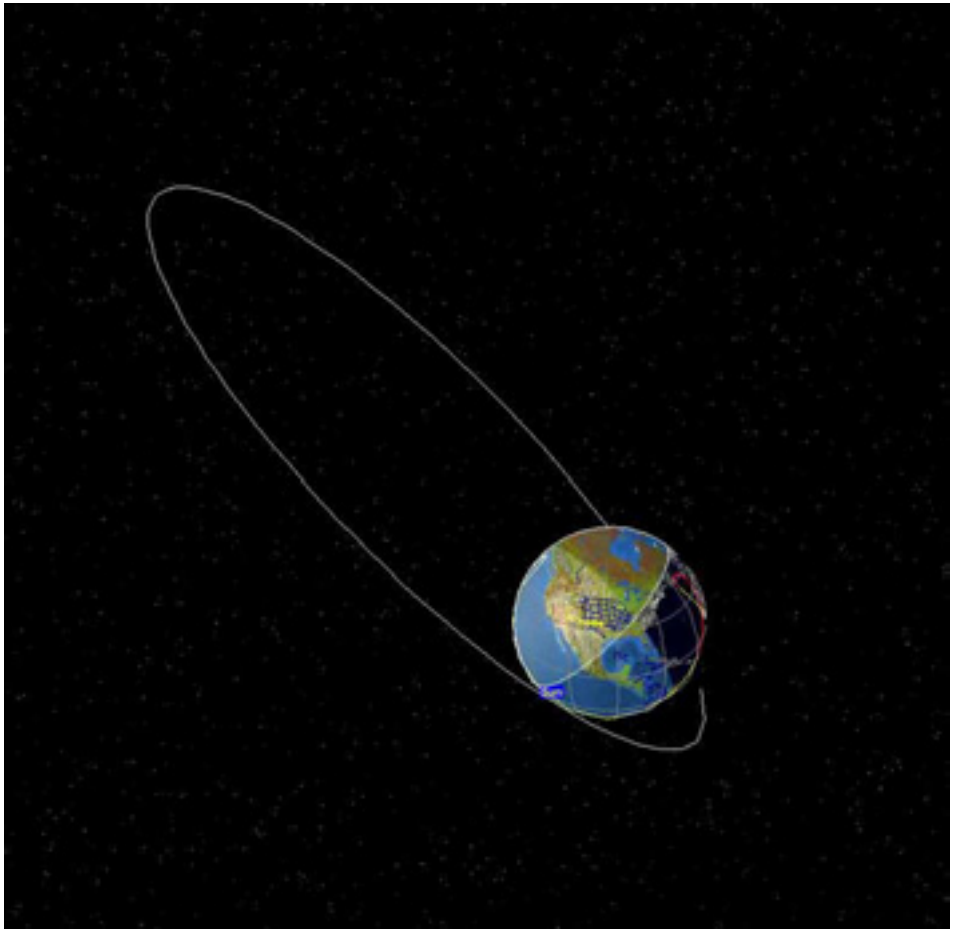
AO-7, AO-27

# Orbit Type – Inclined

- Circular orbit that is equally inclined in northern and southern hemispheres
- Spends most of the time in sun at some times, and most in eclipse at other times.
- Batteries required when in eclipse
- All parts of planet receive equal access

SO-41, SO-50, RS-15, ISS

# Orbit Type – Molniya



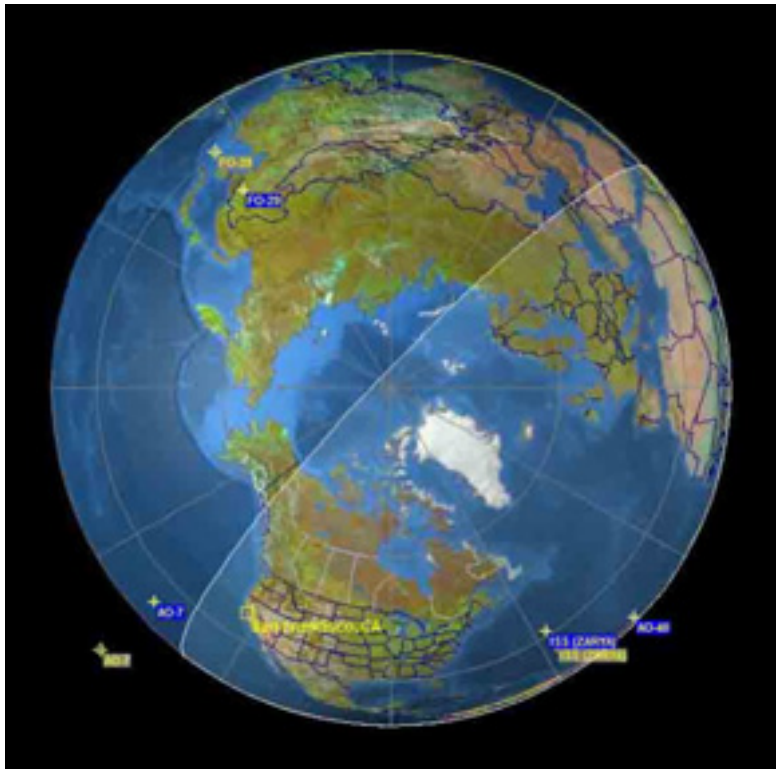
- Highly elliptical orbit with apogee inclined to target location
- Spends most of the time in sun
- Batteries required when in eclipse
- All parts of planet do not receive equal access

AO-40 (Planned), Eagle, Express

# Satellite Coverage

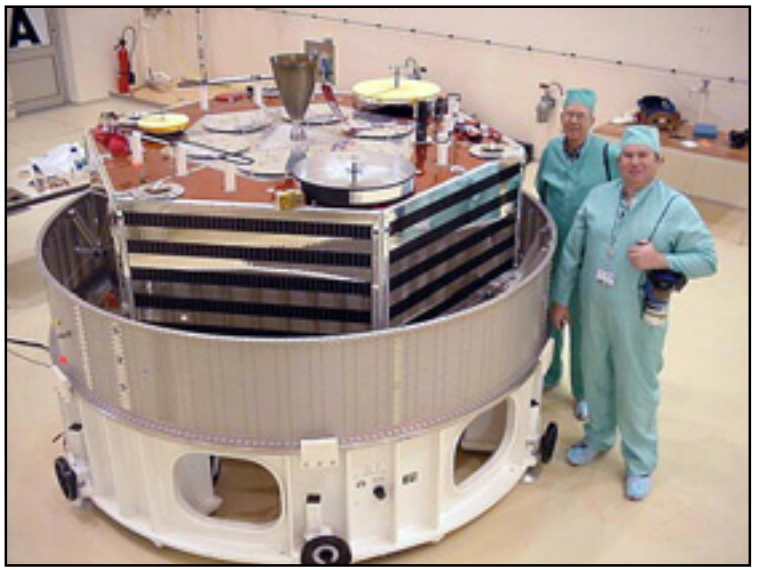
FO-29 Coverage - Continental

AO-40 Coverage - Hemispherical



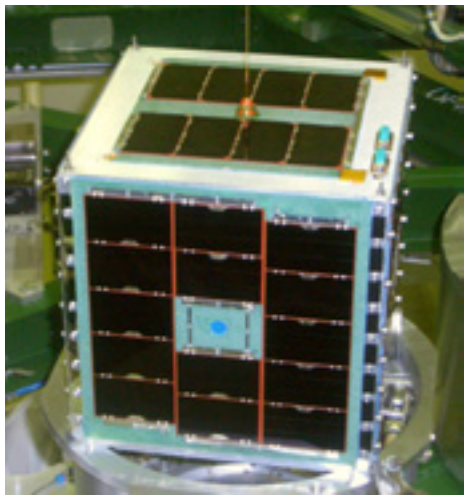
# High Earth Orbit (HEO)

- HEOs are satellites that orbit the earth at distances greater than 35,000km
- Pass times range from 12-18 hours
- Linear transponder (SSB/CW) only
- Inclined elliptical or geosynchronous orbit
- Operates over many bands
- AO-40 currently suffering from a low battery bus condition



# Low Earth Orbiting (LEO)

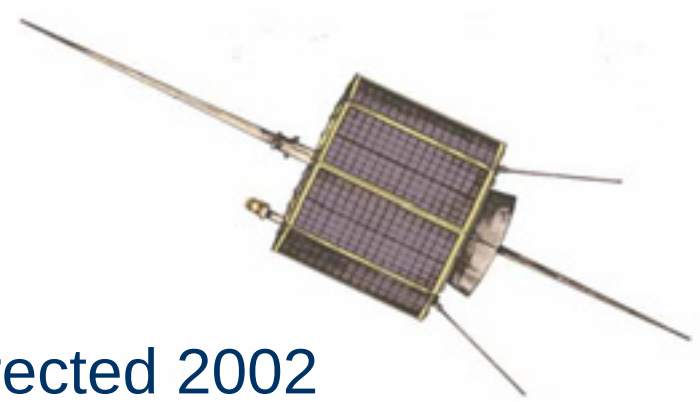
- LEOs are satellites that are orbiting the earth from 400-2000 km.
- Pass times range from 12 to 22 minutes
- Linear Transponder (SSB/CW) or FM repeater
- Typically operate in the 2m/70cm bands
- Polar or high inclination orbit
- FM LEOs also referred to as the “easy sats”



AMSAT-ECHO
(AO-51)

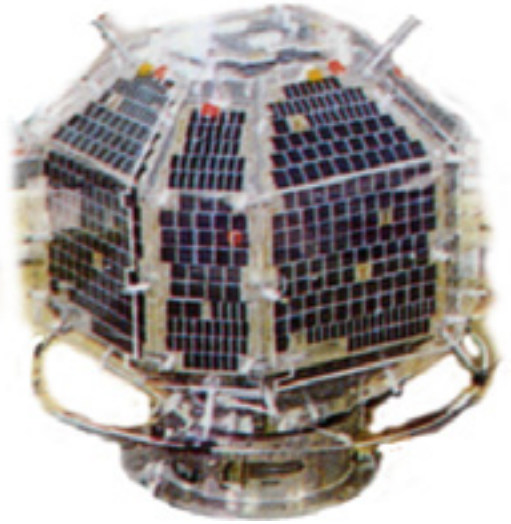
# AMSAT OSCAR - 7

- Launched Nov 1974 into sun-synchronous orbit
- Mode A Linear Transponder
  - 29.450 USB/CW Downlink
  - 145.900 USB/CW Uplink
- Mode B Linear Transponder
  - 145.950 USB/CW Downlink
  - 432.150 LSB/CW Uplink
- Battery failure in 1981, resurrected 2002
- Operational only in sunlight (no batteries)



# Fuji-OSCAR 29 (JAS-2)

- Built by Japan Amateur Radio League
- Launched July 1996 into a polar orbit
- Mode JA Linear Transponder
  - 145.900-146.000 LSB/CW Uplink
  - 435.800-435.900 USB/CW Downlink
  - Inverting
- Digital Store and Forward BBS (non-operational)
- Digitalker



# AMRAD OSCAR – 27

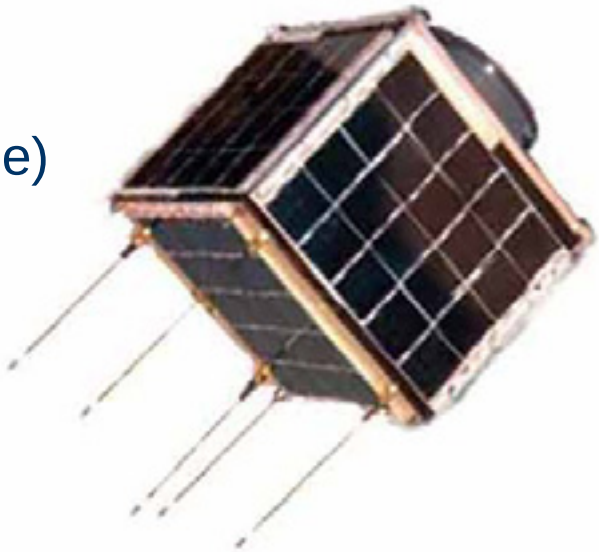
- Piggy-backed on a commercial satellite Eyesat-1
- Launched into sun synchronous orbit September 1993
- Single Channel FM Repeater
  - 145.850 Uplink
  - 436.795 Downlink
- Turned on and off by timer
- Only on for 6 minutes on south to north pass over northern hemisphere
- Turned off mid-summer and mid-winter when in eclipse at poles

# Saudisat 1C (SO-50)

- Launched into high inclined orbit December 2002
- Single Channel FM Repeater
  - 145.850 uplink
  - 436.795 downlink
- Must be manually turned on by a control operator
- Requires PL-67 to access the repeater

# AMSAT Echo

- Launched June 2004 into Sun Synchronous Orbit
- FM Voice Repeater
  - 435.225 Downlink
  - 145.920 Uplink (requires PL-67 tone)
- 9600bps AX.25 FSK Digital
  - 435.150 Downlink with telemetry
  - 145.860 Uplink
- Additional SSB/CW
  - 10m - 23cm Receive
  - 13cm Transmitter
- PSK-31 Mode



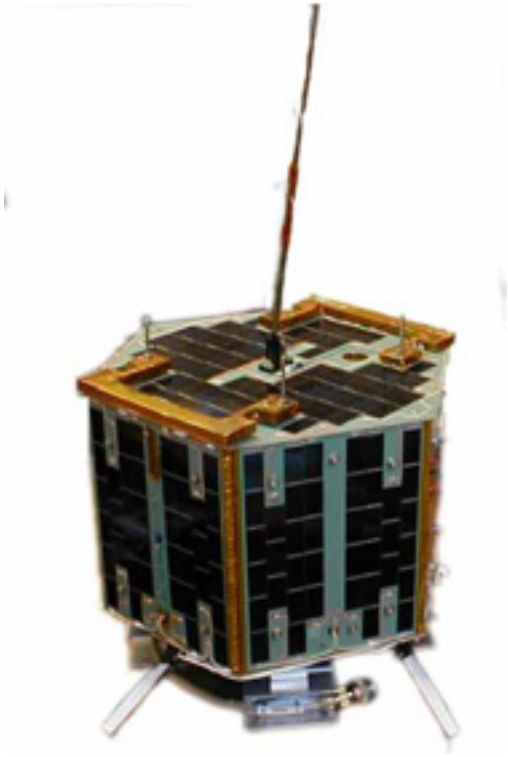
# Packet Satellites

## APRS Digipeaters

- PacSAT (AO-16)
- Sapphire (NO-45)
- ISS (Zarya)

## Bulletin Boards

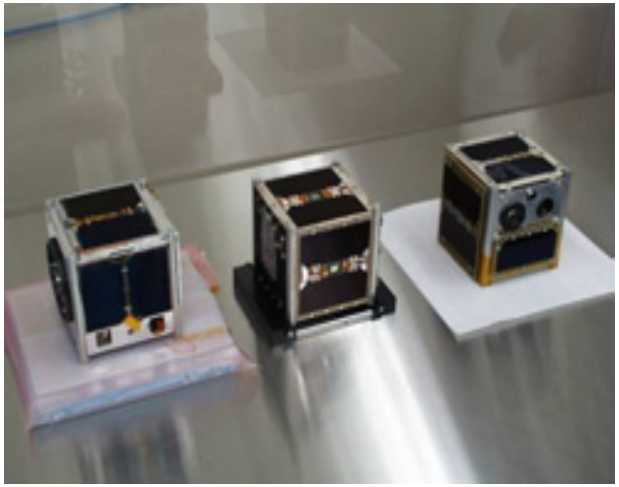
- UOSat-5 (UO-22)
- Sapphire (NO-45)
- ISS (Zarya)
- GerwinSat (GO-32)
- TuingSat (MO-46)
- Echo (AO-51)



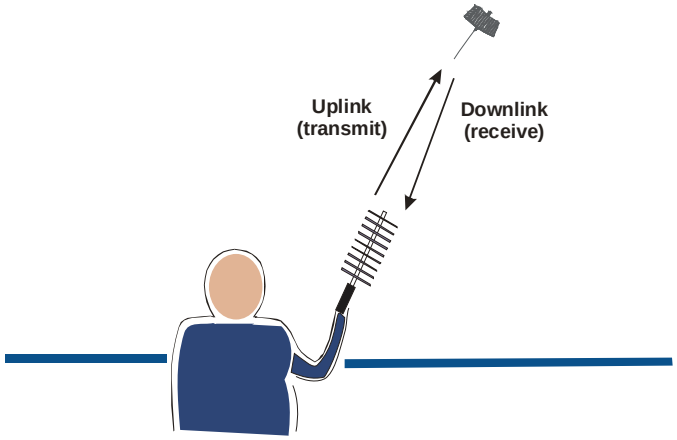
Sapphire (NO-45)

# Cubesats

- Cubesats are picosatellites housed in 10cm cubes common to all designs.
- They share a common launcher called a P-POD that can launch 3 or 6 satellites at one time.
- Developed at Stanford University in Palo Alto, California with Cal Poly San Luis Obisbo developing the P-POD.
- Many Cubesats from many countries have been launched (Cute-1, CanX1, XI-IV, AUSat, Quakesat…)
- More to be launched in July 2004.



# Operating a Satellite




Satellites don't have the physical space to separate receive and transmit antennae a great distance, so they use different bands

Traditional LEO Modes:

Mode A = 10m/2m

Mode B = 2m/70cm

Mode J = 70cm/2m

New satellite band designations are paired letters, eg U/V, L/S, etc.

| | |
|---|---|
| V=2m | C=7.5cm |
| U=70cm | X=3cm |
| L=23cm | K=1.5cm |
| S=13cm | Q=5mm |

# Minimum Requirements

- All mode 2m/70cm radio or Dual VFO HT
- Dual Band Arrow Antenna or high gain whip antenna
- Palm computer with tracking software
- Patience

WØEEC QSOs with WH6BIE via UO-14 from California to Hawaii – 4000km

# Ideal Ground Station for LEOs

- Cross beam or circularly polarized Yagi or helical
- Computer tracking system
- Computer controlled AZ-EL rotators
- Full-duplex dual band radio computer controlled tuning
- TNC and Soundcard Interface for TLM and Packet
- APRS Software
- Mast mounted receiver preamps
  ( Rule of thumb - it's better to have big ears than a big mouth.)

Photo courtesy of K6IA

# More Stations

VE7WFG

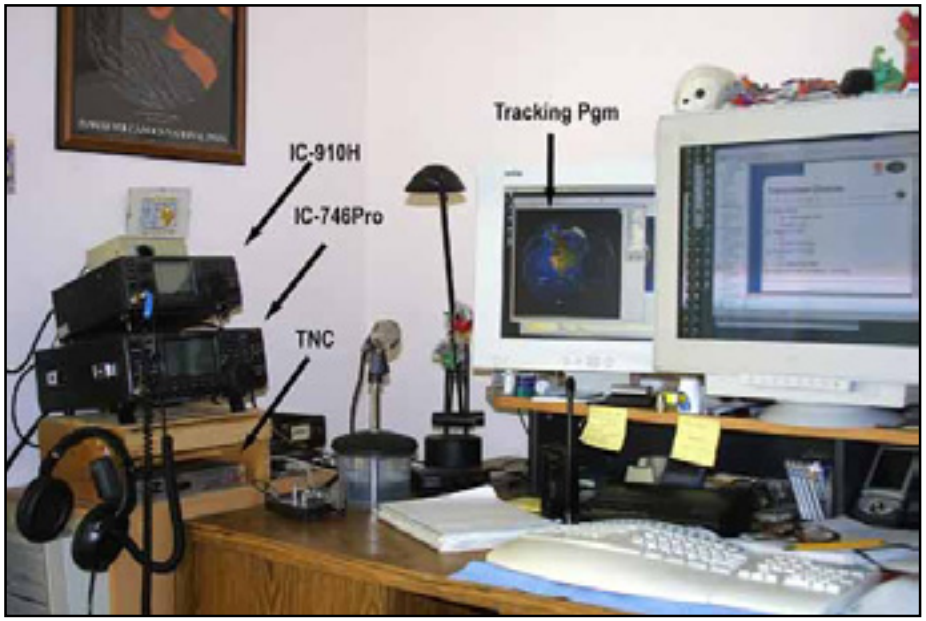
WB0DRL

KG6IAL

W0EEC

# Transceiver Choices

- Icom 910H
  - 2m –100W/70cm-75W
  - Optional 23cm
- Yaesu FT-847
  - 2m-50w/70cm 50w
  - HF
- Kenwood TS-2000
  - 2m-100W/70cm-50w
  - HF and Optional 23cm
- Used (FT-736, IC-820/21, IC-970)




WØEEC Shack

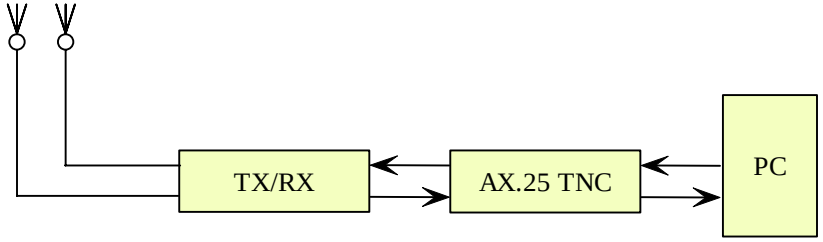
# Antenna Choices

Antenna selection depends on desired results:

| Antenna Type | Half Power Beam Width | Typical Gain (dB) |
|---|---|---|
| Monopole | 360°x80° | 2.5 |
| Dipole | 360°x120° | 2 |
| Log Periodic | 60°x60° | 6 |
| Yagi | 50x50° | 12 |
| Helix | 40°x40° | 10 |
| Small Dish | 30°x30° | 18 |
| Large Dish | 1°x1° | 45 |

# Packet Station

- Packet stations send data to the satellite using a TNC to modulate and demodulate the signals




- May be 1200 bps, but newer satellites like Echo use 9600bps up to 78,400 bps.
- Some just repeat digital packets (digi-peat) or may have a store-and-forward bulletin board system.
- Telemetry is also sent using packet data

# Satellite Tracking Programs

## PC

- Nova For Windows
- SatPC32 for Windows
- SCRAP

*Available at the AMSAT web site!*

- Satscape
- Orbitron

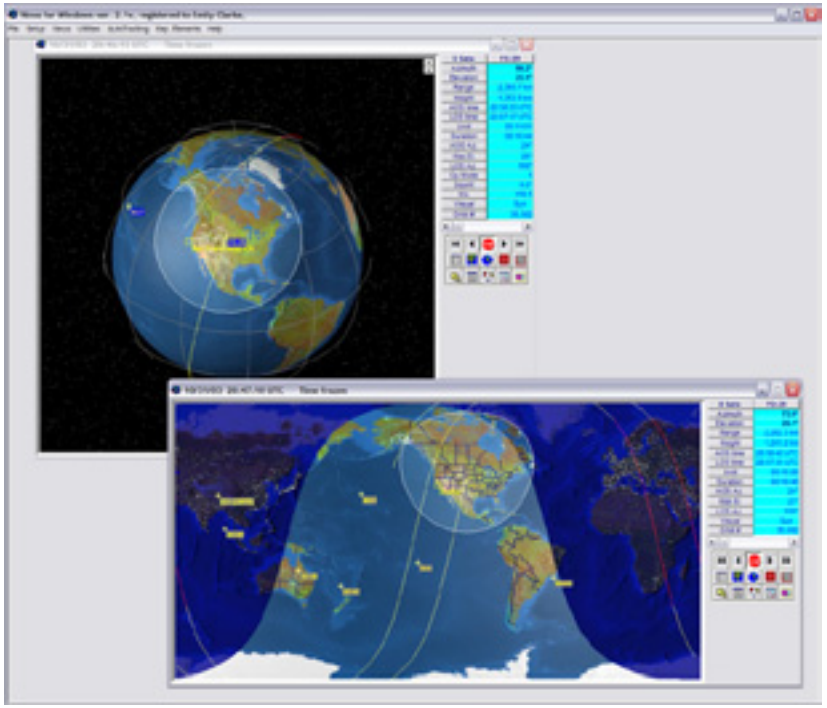
## MacIntosh

- MacDoppler Pro

*Contact Dog Park Software*

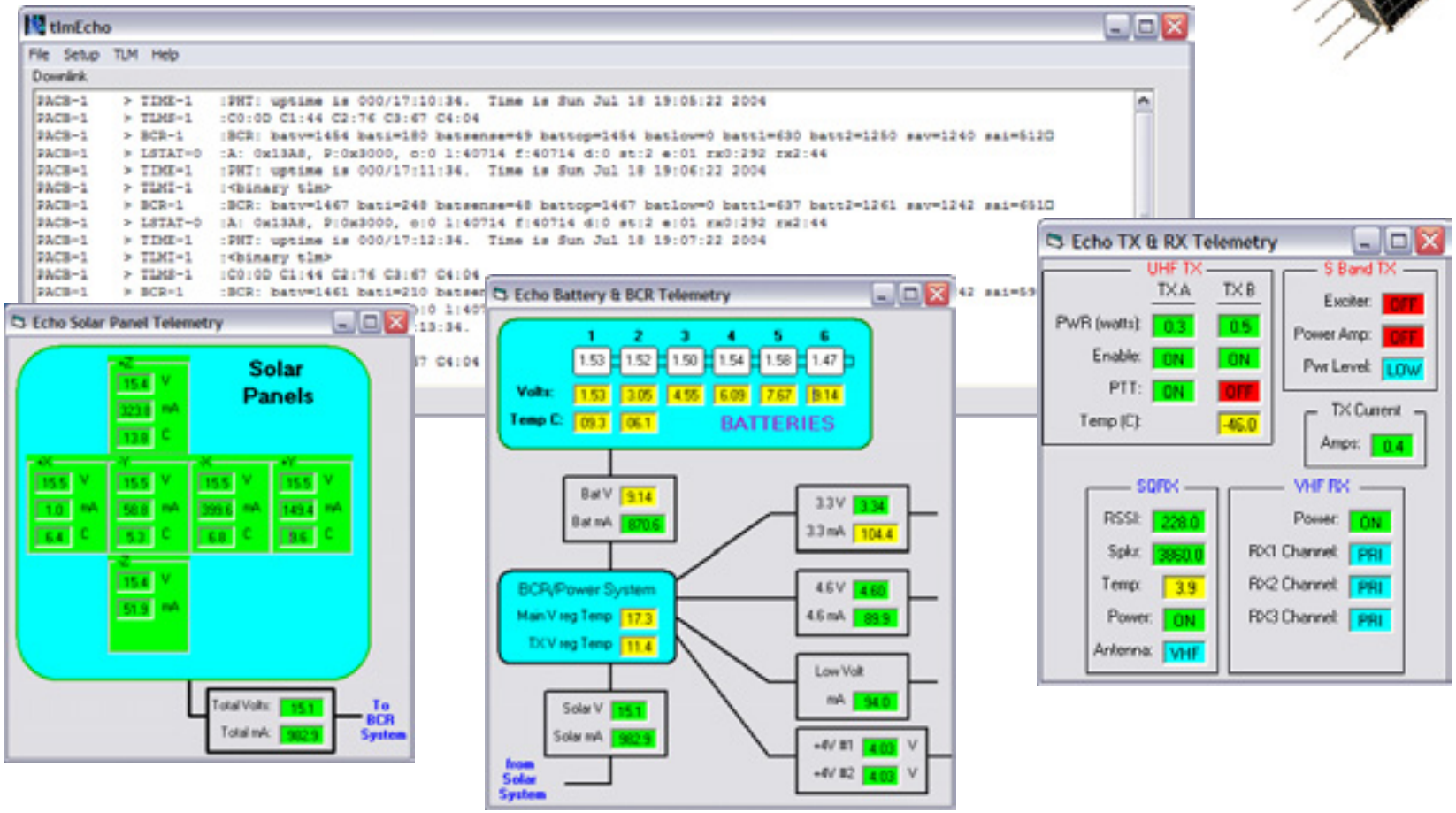
## PDA

- PetiTrack for Zaurus
- PocketSat for Palm and PalmPC



Nova for Windows

# Echo Telemetry Decoded



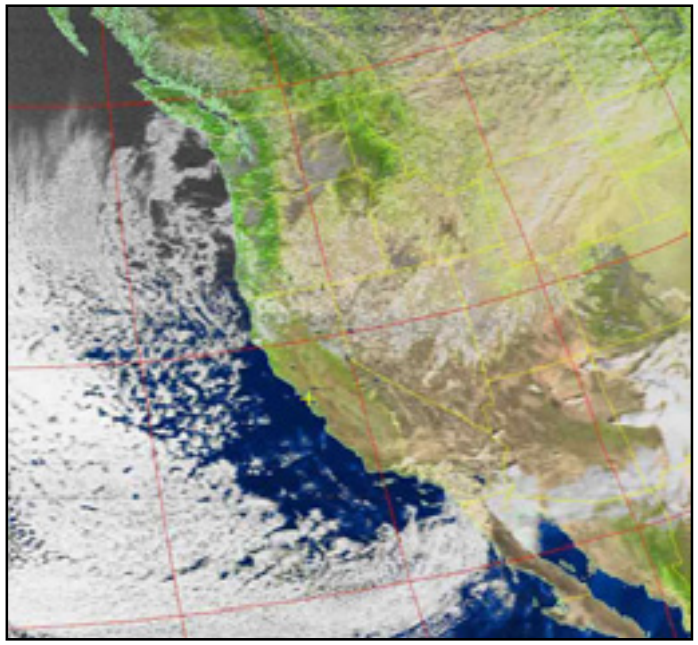
# Keplerian Elements

```
AO-7
1 07530U 74089B 04140.70617484 -.00000029 00000-0 10000-3 0 2774 2
07530 101.6834 187.8825 0012044 277.9198 82.0507 12.53568957350341
```

- Keplerian Elements are a mathematical model of a satellites orbit
- Used by tracking programs to predict where the satellite is at a given time
- Need to be updated periodically (esp ISS – it can be maneuvered)
- Most tracking programs do this over the internet
- Two formats –
  - NORAD Two Line Elements (TLE – most common)
  - AMSAT Verbose Format

# Other Interesting Software

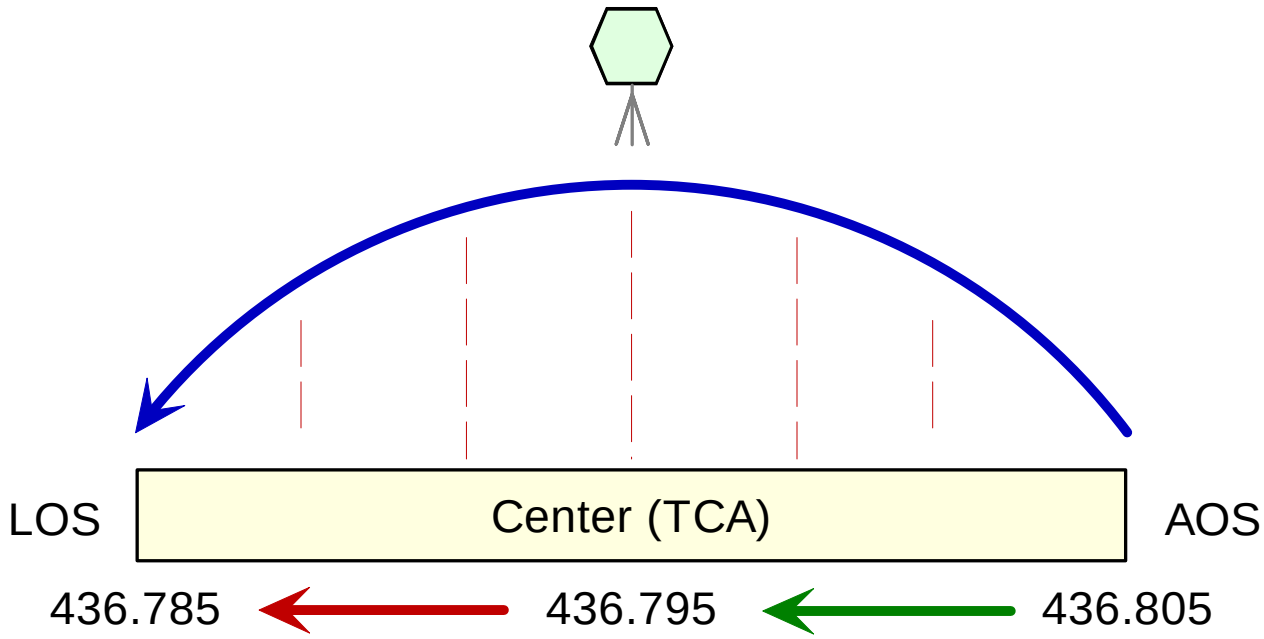
- MixW, MMSSTV, PSK31 Deluxe and Digipan
- UI-View32 for APRS
- WXToImg for Weather Satellites
- WinPack and WiSP for PacSat operations



NOAA-17 imagery 10/30/2003

# Doppler for Beginners - Receiving

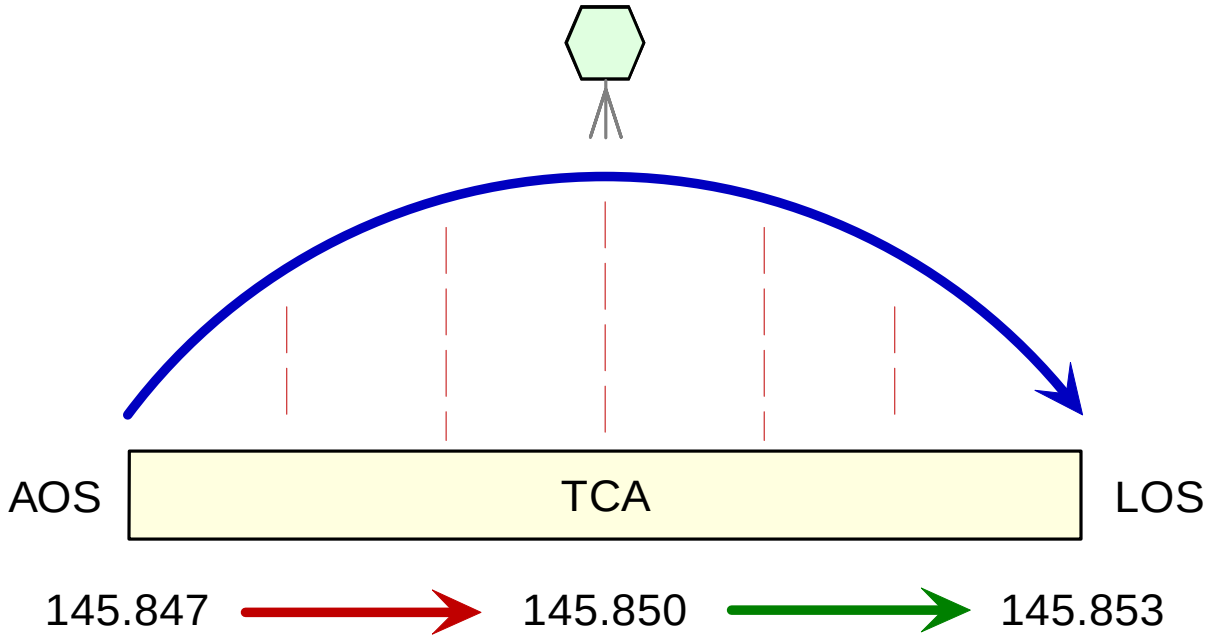
Satellite transmits at 436.795




The overriding rule of thumb is to tune so you can hear other stations clearly.

# Doppler for Beginners - Transmitting

Satellite receives at 145.850




It is not always necessary to tune your transmitter on FM, but is necessary on SSB to stay on frequency with other stations

# Dealing with Doppler (AO-7)

- The passband is noisy, so pick a place near 145.950 that is quiet.
- Tune your transmitter so you hear a normal voice on the downlink frequency.
- Adjust your transmitter to keep your receive frequency locked in place.
- If in a net on SSB/CW, keep your receiver tuned to the other stations and make minor changes in your transmitter if needed.

# Groundstation Considerations

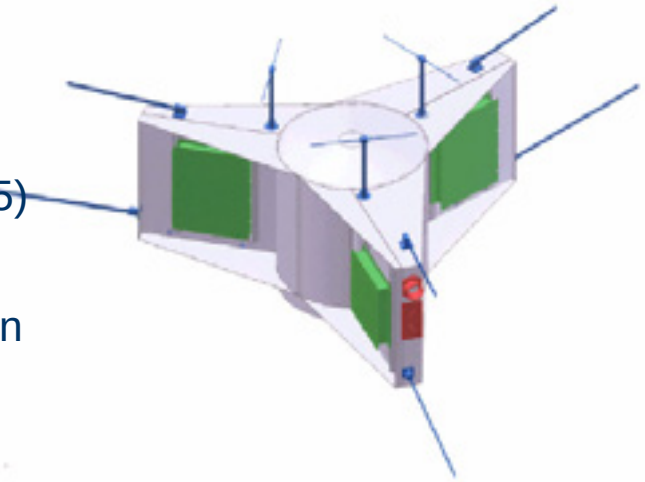
- Invest heavily in your receive setup and use preamps as needed
- Use filters in Mode J (V/U) to eliminate desense
- Use flexible low-loss coax (LMR-240 Ultra Flex, Belden 9913) on booms and rotatable fixtures
- Keep coax runs as short as possible
- Use circular polarization whenever possible
- Keep everything grounded including computer equipment

# General Operating Procedures

- Listen for the satellite beacon or other operators before transmitting
- Work full duplex with headphones so you can monitor the quality of your own downlink
- Keep your squelch off and your DSP on
- Use as little power as needed to complete the QSO (especially on AO-7)
- When pileups occur, give your information (callsign, gridsquare) quickly
- Be courteous to other operators

# Future Satellite Launches

- VUSat: AMSAT-India
  - SSB/CW transponder polar LEO Launch Sept, 2004
- BLUESat: University of New South Wales
  - Digital Store and Forward LEO (PACSat) (2005)
- PCSat-2: US Naval Academy
  - APRS Digipeater on ISS delayed until Shuttle in service
- P3E “Express”: AMSAT-DL
  - SSB/CW multimode linear transponder HEO (2006)
- Eagle: AMSAT-NA
  - SSB/CW multimode linear transponder HEO (2006/7)



P3E Concept Drawing
courtesy of AMSAT-DL

# About Project Oscar

- Website: http://www.projectoscar.net
- Our mission is to advocate and promote the use of amateur satellites
- Incorporated in 1960 by hams in Silicon Valley
- Built the first four OSCAR satellites
- International, primarily based in Silicon Valley
- Membership open to hams actively operating and advocating amateur satellites

# About AMSAT

- Website: http://www.amsat.org
- Non-profit foundation founded February 1969 in Washington D.C.
- Mission is to develop and provide satellites and technology used or useful for amateur radio
- International with member organizations in over 32 countries
- Launching a new FM satellite called Echo in June 2004 (contributions gladly accepted)

# Join AMSAT

- AMSAT membership starts at $39 per year
- Membership includes subscription to the AMSAT Journal and discounts on publications, software and apparel
- Your membership helps to support the amateur satellite program
- Contributions for specific satellites is greatly appreciated (and tax deductible)

# Questions and Answers

AMSAT

PROMOTING AMATEUR SATELLITES
PROJECT OSCAR
HAMS HAVING FUN