

# Introduction to Amateur Radio Satellites

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HamCom – June 2009

# Introduction

- AMSAT
- What can you do / expect?
- What do you really need?
- Satellite antennas you can build
- Which satellites? When?
- Tracking basics

# AMSAT



- Radio Amateur Satellite Corporation
- Worldwide – AMSAT-NA, AMSAT-UK, AMSAT-DL, AMSAT India
- All volunteers – only one employee (Martha)
- Design, build, and launch amateur radio satellites
- Founded in 1969 as an educational organization
- First amateur radio satellite, OSCAR-1, launched in 1961 by Project Oscar

# What's it all about? What are amateurs doing?

- Experimenting with new modes of communications – FEC, SSTV, APRS
- Advanced digital signal processing
- Analyzing spacecraft telemetry and orbits
- Designing and building spacecraft
- Talking to other amateurs around the world and on the International Space Station
- Having **fun!** Why satellites? It's a lot like “Fishing”

# What can you expect?

- Satellite passes are extremely predictable (unlike HF / shortwave propagation)
- Grid square chasing / W.A.S. / “DX” chasing
- Satellites operate in one or more modes – not everything on the satellite is turned on all of the time
- Voice – single sideband (SSB) and FM
- Data – APRS and Instant Messaging like communications, telemetry, “flying BBS”

# What can you expect?

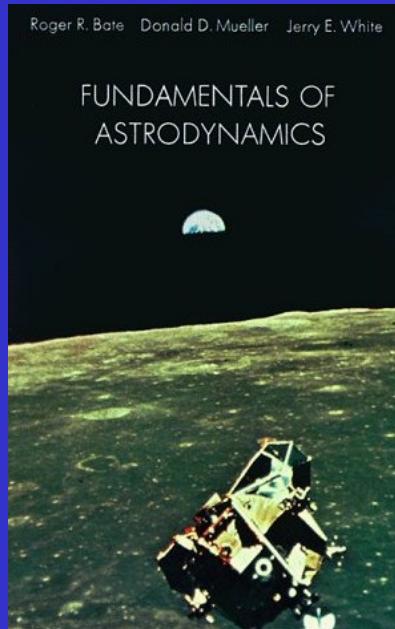
- Some aspects are fast and dynamic – new and different things are always happening.
- You might have to check your email and/or the website(s) to keep up and to find out what's happening this week.
- *Last October*: Richard Garriot, W5KWQ, was a visitor on the International Space Station and was sending down **slow scan TV pictures on two meters**. One week later he returned to Earth.

# Some of what's up this week

- Delfi-C3 in science mode – BEACON only (2m downlink, free soundcard software)
- VO-52 linear transponder 435up/145down
- AO-51 power output increased; telemetry temporarily turned off; in F.D. mode soon
- SO-50 FM “bent-pipe” transponder 2m up/70cm down
- AO-7 Alternating between Mode A and B every 24 hours. Mode A 145MHz up/29MHz down; Mode B: 435 MHz up; 145 MHz down

# Every week

- Looking to learn something but your free time is limited? Some things don't quickly (if at all). Orbital mechanics, much like Ohm's Law, hasn't changed much recently.



Methods of Orbit  
Determination

Fundamentals of  
Astrodynamics



WARNING: May cause headaches.

# What kind of equipment do you need to use the satellites?

“The **MYTH**” is that you need:

- multiple large antennas
- great Big **HUGE** satellite dishes
- hundreds of watts of power
- thousands of dollars worth of radios
- years of your time just to learn the basics before you can do anything

# What kind of equipment do you need? (“The MYTH”)



Note the car for scale



# What kind of equipment do you need? (“The **MYTH**”)



# What kind of equipment do you **REALLY** need?

“The REALITY” : you can *get started* with just a two meter FM HT, a 70cm HT (a hand held scanner), and some home made antennas. Or, do you have an all-mode all-band radio like an FT-817?

- Which satellite(s) do you want to use? What do *you* want to *do*? Some satellites use FM. Others use SSB/CW. What equipment do you already have?

# Arrow Antenna and FT-817



Photo W5UI Keith Pugh at Dayton 2008

# Equipment for beginners



Photo by Douglas Quagliana, KA2UPW

# Equipment for beginners



**HR2600  
28MHz (10M)  
for receive**

**Hamtronics  
435 MHz  
downconverter**

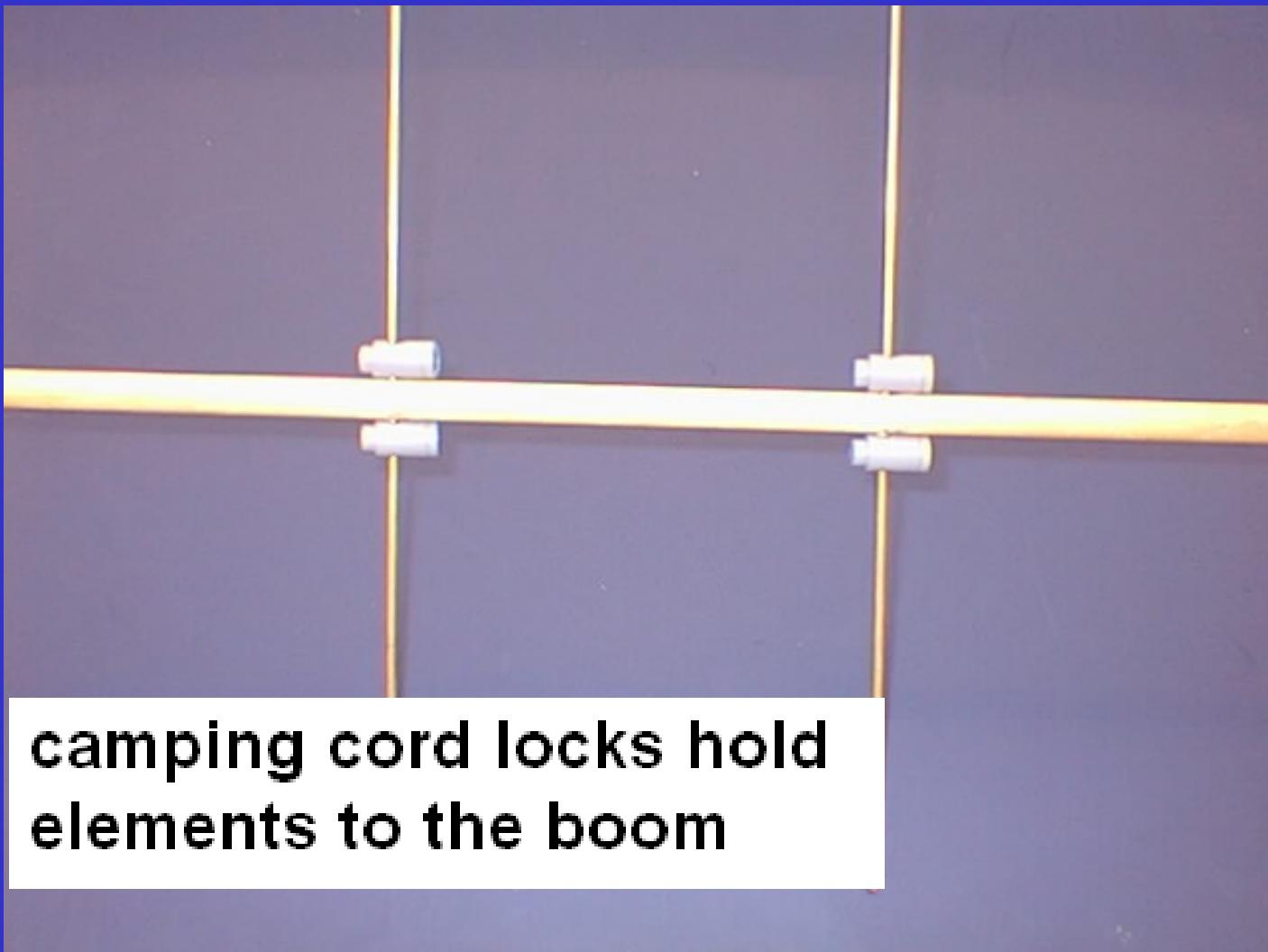
**5/8-wavelength 146 MHz  
(2M) antenna with  
homemade magnetic  
mount**

**Homemade 435 MHz  
Quagi (~\$10) antenna**

**1980's vintage  
146 MHz (2M) HT  
(1.5 watts)**

**D.E.M. 435 MHz  
preamplifier**

# Equipment for beginners - Closeup



**camping cord locks hold  
elements to the boom**

Photo by Douglas Quagliana, KA2UPW

# Equipment for beginners who build

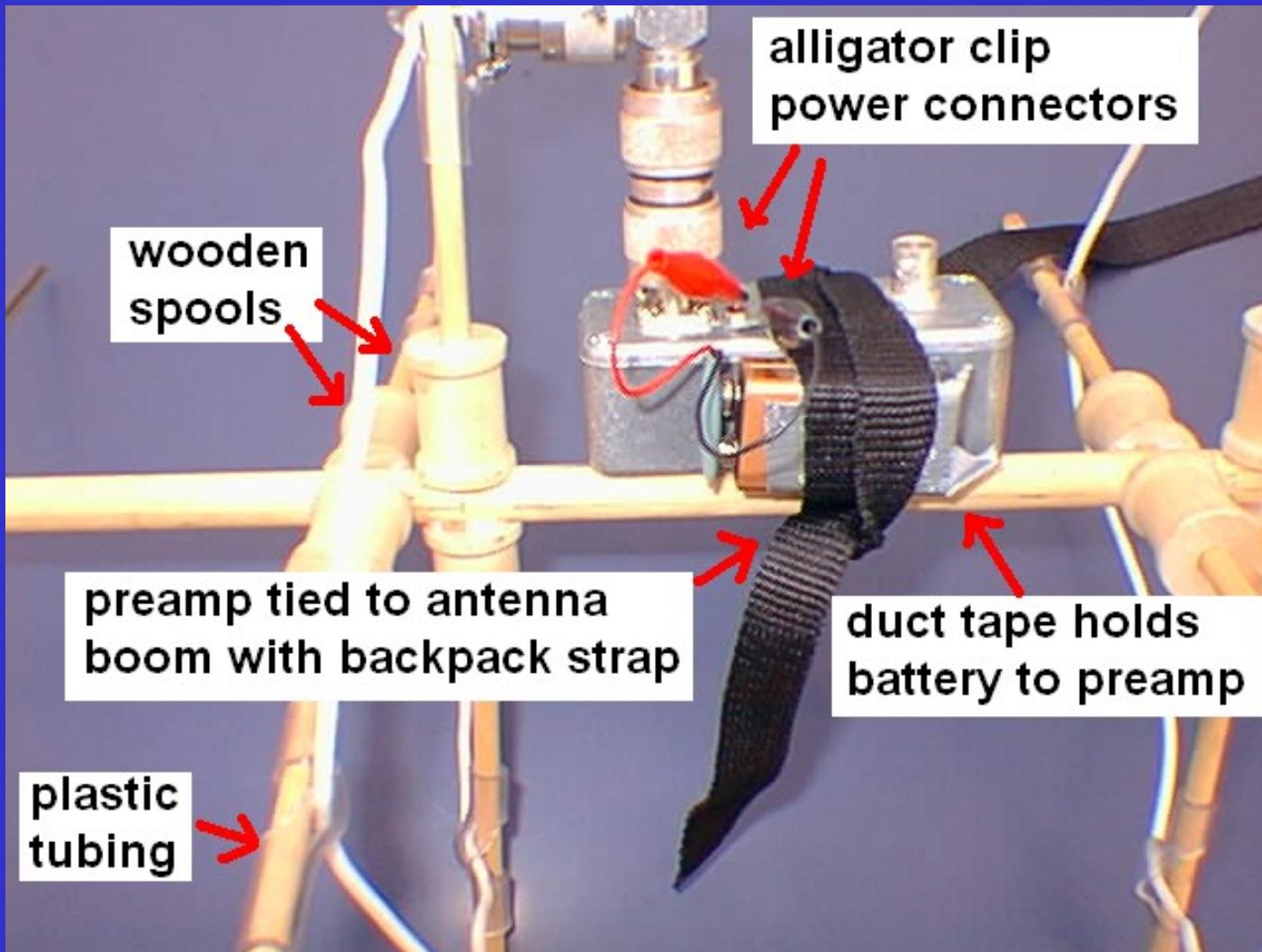


Photo by Douglas Quagliana, KA2UPW

# Equipment for beginners who buy

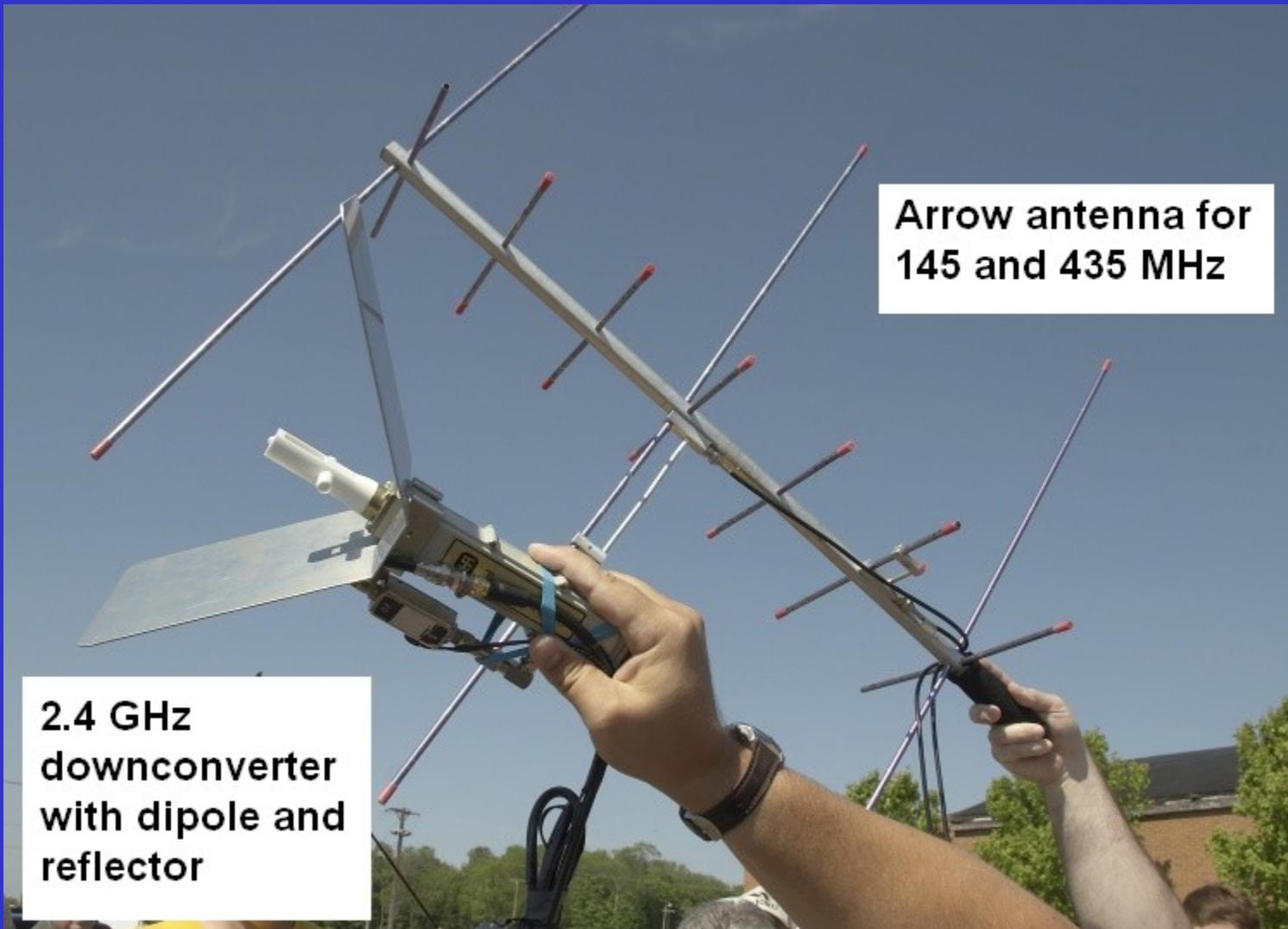


Photo by Tom Clark, W3IWI

# Building Antennas Satellites

- Why does an antenna work well?
  - Because it was expensive?
  - Because it has:
    - Metal pieces
    - Right Size
    - Correct Shape
    - Proper Position/Distance from other pieces of metal
- Hey, want to buy a bridge? You can't just go "buy" a bridge, you have to make one.
- "Engineering is the art of making what you want from things you can get." -Jerry Avins

# Building Antennas Satellites

- Regular magnetic mount vertical (145 MHz) - homebrew from deck parts at hardware store
- Kent Britain's "Cheap Yagis" (145 MHz, 435 MHz and higher) [www.wa5vjb.com](http://www.wa5vjb.com) or google "cheap yagi"
- Arrow or homebrew arrow (145 and 435 MHz)
- Cardboard and foil corner reflector (435 MHz)
- Simple 2.4 GHz antennas: umbrella dish, homebrew helix, patch antenna from a mint tin, cardboard and aluminum foil horn antenna

# Cardboard & Aluminum Foil Antennas



**2.4 GHz horn  
antenna for  
receive**



**435 MHz transmit  
antenna with corner  
reflector**

Photo by Douglas Quagliana, KA2UPW

Photo by Anthony Monteiro, AA2TX

# Antennas - 2.4 GHz is *not* scary

**satellite dish  
from metallic  
thread stitched  
into an umbrella**

Crossing threads  
don't need to  
touch.

Mesh spacing  
is important.



# Antennas - 2.4 GHz is *not* scary

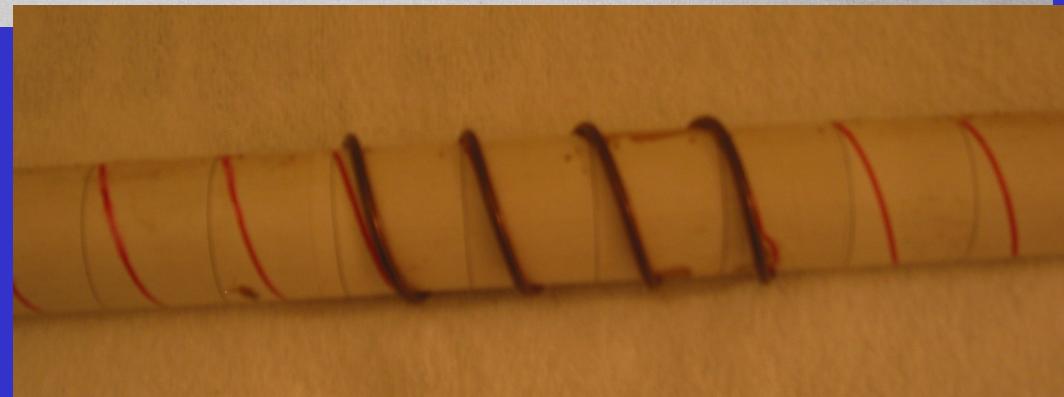
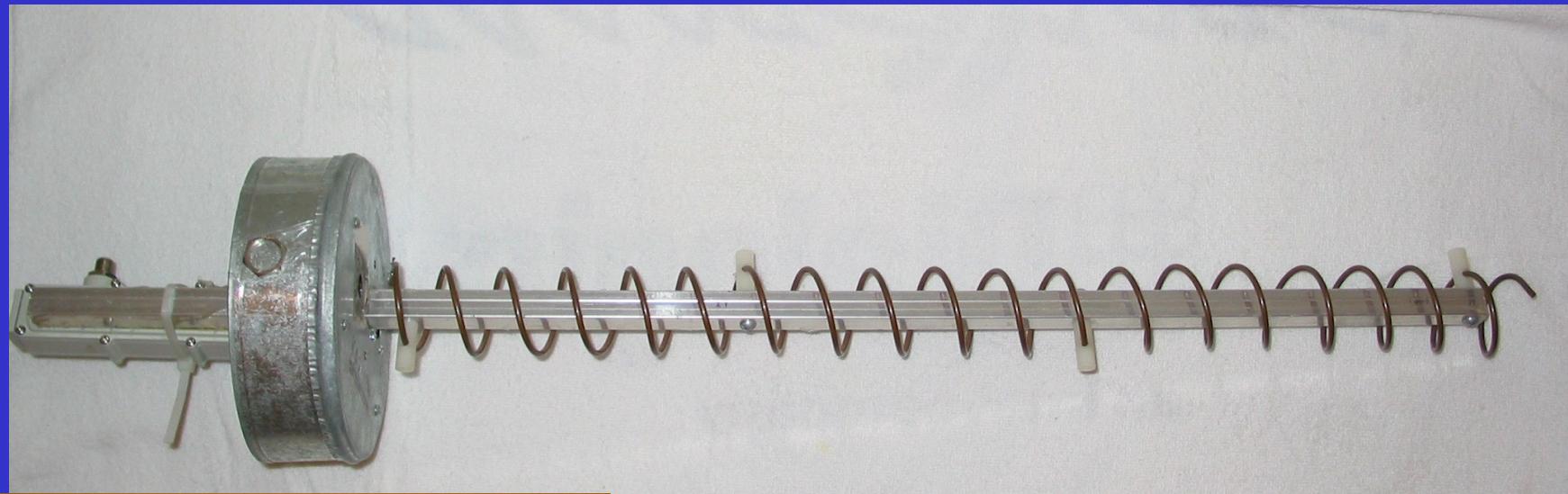
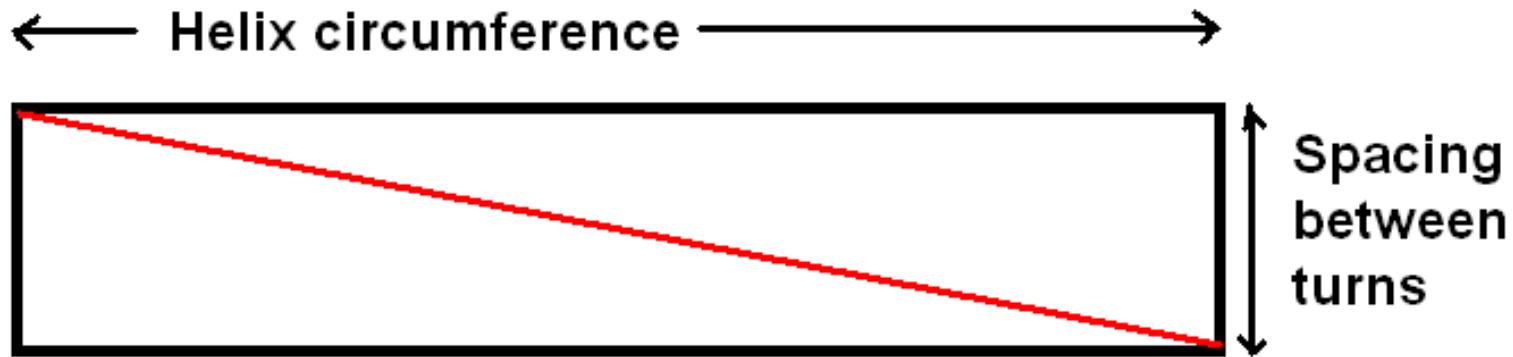


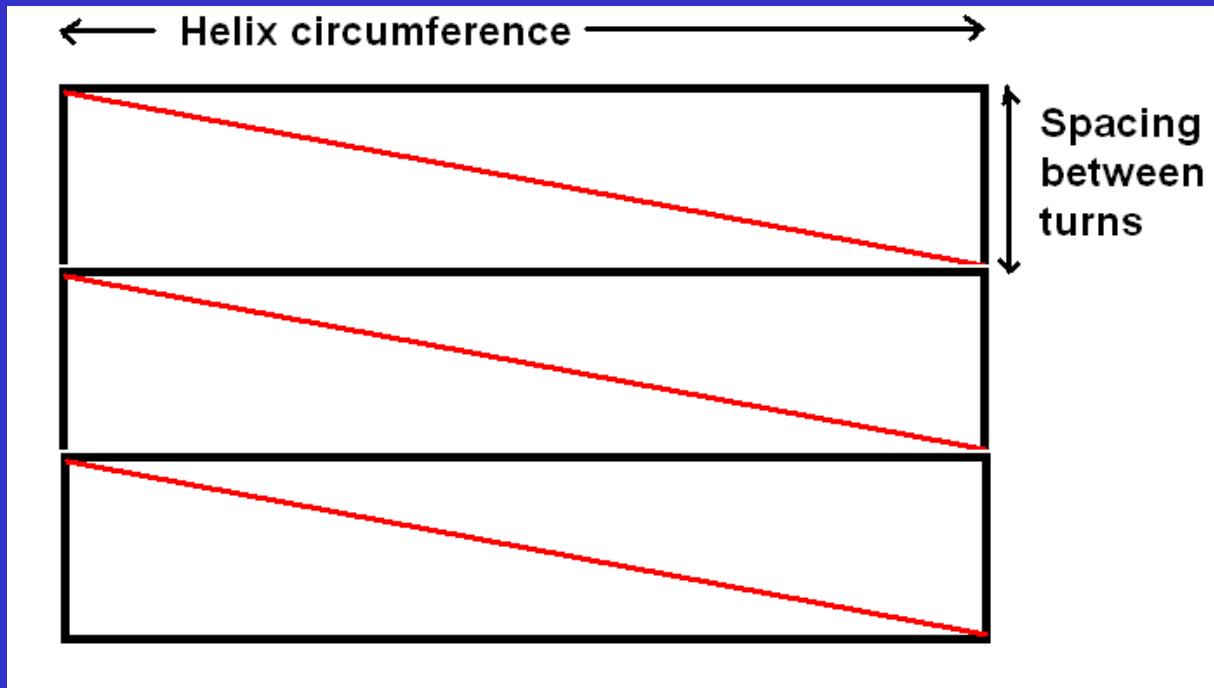
Photo by Douglas Quagliana, KA2UPW

# How to build the perfect helix



Make a template on paper that uses the dimensions of the helix to define a "box" and then draw a diagonal through the box.

# How to build the perfect helix



**Make as many boxes as you have turns.  
Glue the template to the wooden dowel.**

# Adhesive foil tape and 24-inch snow sled/saucer parabolic (almost) dish



**It's almost  
parabolic**



**It's close enough to  
parabolic that we still  
get plenty of gain.**

# 2.4 GHz patch antenna -K3TZ design



7.5 dBi gain at 2.4 GHz, just measure, cut, and solder.  
There's only ONE solder joint. And you probably  
already have a bunch of these mint tins.

Photos by Douglas Quagliana, KA2UPW

# Which satellites are active “now?”

- Not all satellites are active all the time
- Satellite have “modes” – selected receivers and transmitters are turned on and off according to a published schedule. What's on *TODAY*? 2.4 GHz? 144 MHz? voice? data? slow scan TV?
- See AMSAT News bulletins (ANS), amsat-bb mailing list, AMSAT website
- Echo (AO-51), Hamsat (VO-52), AO-7 (sunlit only), AO-27, ISS, SO-50, PCSAT (sunlit only)... and more!

# Which satellites are active “now”?

Operational OSCAR Satellite Status Summary												
<a href="#">All OSCAR Satellites</a>   <a href="#">Future Satellites</a>   <a href="#">Satellite Frequencies</a>   <a href="#">Satellite Chronology</a>												
Operational [▲]   Semi-Operational [▶]   Non-Operational [▼]   Future Launch [▲]   Unknown [?]												
Name	Beacons	HF	VHF	UHF	L-Band	S-Band	C-Band	X-Band	K-Band	APRS	Packet	Schedule
<a href="#">KKS-1</a>	▲											
<a href="#">PRISM</a>	▲											
<a href="#">STARS</a>	▲											
<a href="#">RS-30</a>					▲							
<a href="#">CO-66</a>	▲				▲							<a href="#">SEEDS II webpage</a>
<a href="#">DO-64</a>	▲		▲	▶								<a href="#">DO-64 Webpage</a>
<a href="#">COMPASS-1</a>	▶			▶								<a href="#">Command News</a>
<a href="#">CO-65</a>	▲			▲	▶							<a href="#">CO-65 Command Blog</a>
<a href="#">CAPE-1</a>	▶											
<a href="#">GeneSat-1</a>	▲											

Table from <http://www.amsat.org/amsat-new/satellites/status.php>

# Schedule for AO-51 Echo

Command Team and Operations Group AO-51 News

June 2009 AO-51 Schedule

June 1 - June 14

FM Repeater, V/U - Uplink: 145.920 Mhz FM Downlink: 435.300 Mhz FM

9k6 Telemetry - Downlink: 435.150 Mhz FM

June 15 - June 19

FM Repeater, V/S - Uplink: 145.880 Mhz FM Downlinks: 2401.200 Mhz FM

June 20 ARRL Kid's Day. Please limit QSOs to those with youth participants.

FM Repeater, V/U - Uplink: 145.880 Mhz FM - Downlink: 435.300 Mhz FM

9k6 Telemetry - Downlink: 435.150 Mhz FM

June 21 - June 28 Field Day is June 27th-28th. One contact each per FD rules!

FM Repeater, V/U - Uplink: 145.920 Mhz FM Downlink: 435.300 Mhz FM

# When is the satellite available for you at your location?

- Amateur satellites are not geostationary (yet)
- Satellites in earth orbit appear to move -- rise (AOS) and set (LOS) at predictable times.
- These times are *different* every day.
- Azimuth (N-S-E-W) and elevation change
- Satellite “footprint” determines who is in range of the satellite which determines who can use the satellite to communicate
- Satellite “modes” determine what receivers and transmitters are turned on today or on this satellite pass

# Tracking Satellites

- Originally tracked using simple rotating paper “computers”
- Tracking computer programs will calculate rise and set times, maximum elevation (the angle above the horizon) and minute to minute pointing directions in azimuth (N-S-E-W)
- Numerous tracking programs exist for Macs and PCs running Windows, Linux as well as cellphones, iPod touch, etc.

# Tracking Satellites

- *Any* computer is fast enough to track and predict satellites (HP-48, C64, XT, ...Pentium)
- Enter in your latitude, longitude
- Enter orbital elements (Keplerian elements)
- Graphical display or tabular text output
- You need to keep the orbital elements current (less than two weeks old)
- Your computer's clock needs to be accurate

# Tracking Satellite

- Or, use [www.heavens-above.com](http://www.heavens-above.com) and select your location and then click on “Radio amateur satellites”
- Or, get predictions online at  
<http://www.amsat.org/amsat-new/tools/predict/>
- AMSAT Software Archive / Tracking  
<http://www.amsat.org/amsat-new/tools/softwareArchive.php>  
<http://www.amsat.org/amsat-new/tools/software.php>

# Tracking Programs - Nova



# Tracking Programs - Nova

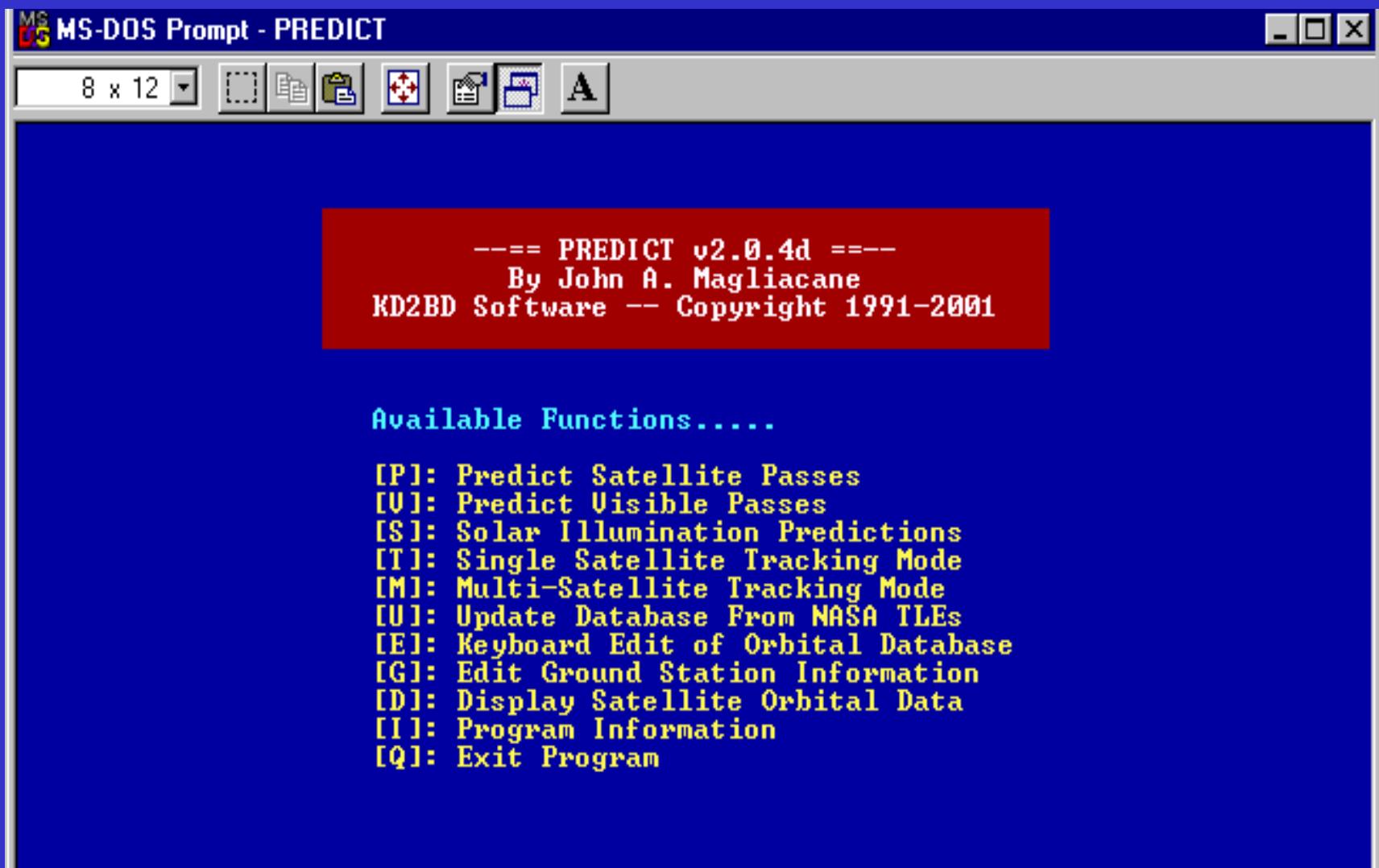
5/30/05 20:15:27 Loc. Wizard

2 Sats	HAMSAT	AO-51
Azimuth	102.3°	22.0°
Elevation	-21.3°	-6.3°
Range	3,762.2 mi	2,549.5 mi
Height	399.9 mi	498.7 mi
AOS time	21:56:14 Loc	21:41:26 Loc
LOS time	22:05:05 Loc	21:54:46 Loc
Until	01:40:46	01:25:59
Duration	00:08:51	00:13:19
AOS Az.	107°	132°
Max El.	7°	22°
LOS Az.	21°	5°
Visual	Eclipse	Sun
Orbit #	382	4,814

**Control Buttons:**

◀◀	◀	STOP	▶	▶▶
☰	World Map	Globe	Flag	Satellite View
☰	Map View	Orbit View	azel View	Plot View

# Tracking Programs - Predict



# What do *you* want to *do*?

- Just make a single satellite contact, just for the fun/challenge of it or to say “I did it”
- Make many CW / voice satellite contacts, grid square chasing, DX chasing, DXCC
- Send and receive data / packet BBS / APRS
- Experiment with digital signal processing
- Collect and analyze actual satellite telemetry
- Help build a satellite
- Perform ranging, satellite orbital mathematics

# What I Do: Digital Signal Processing

- Reed Solomon / Viterbi decoder error detection *and correction*
- Same technology that NASA/JPL used on Voyager missions at outer planets
- Turbo codes (Phase 3E)
- Easy! All you need is a computer and a soundcard connected to your radio!

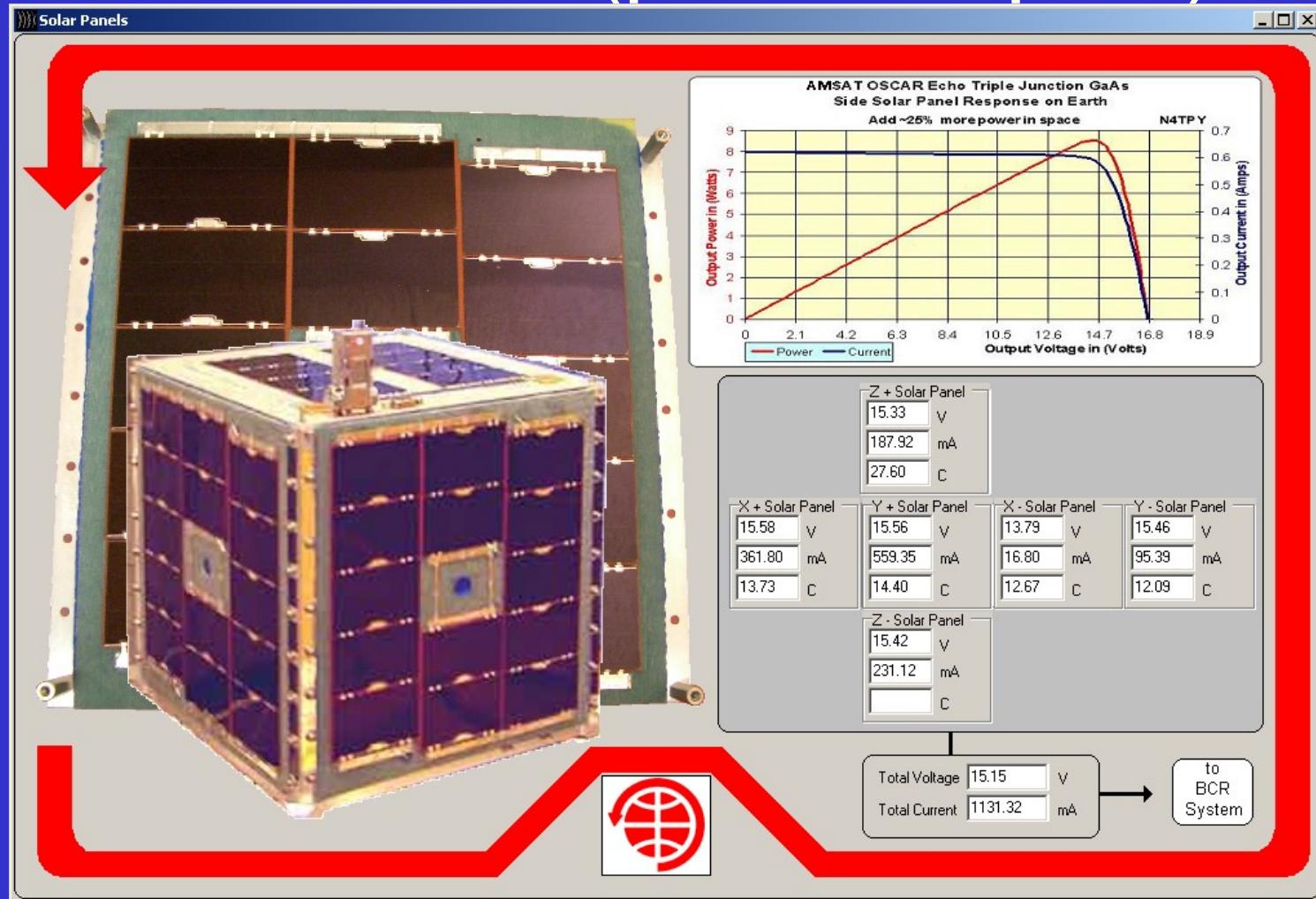
# What I Do: Digital Signal Processing

- Moderate computer (any Pentium computer should work fine)
- Sound card
- Radios (you, *or your friends*, must have a radio)
- Download FREE software from the Internet
- Go!

# More Digital Signal Processing

- 9600 or 38400 baud reception with a sound card (no modem, no TNC)
- Audio from the radio goes to the sound card.
- DSP software takes the audio and “makes bits” to demodulate the data
- You decide what to do with the bits!

# Analyzing Solar Panel Telemetry from AO-51 (power? spin?)



# Analyzing Power Telemetry from AO-51 (batteries charged?)

The image shows the AO-51 Battery Control Regulator (BCR) hardware and its corresponding software interface. The hardware consists of two main components: a top tray containing batteries and a bottom tray containing the Power Control Unit (PCU). The software interface displays real-time data from both components.

**Battery / BCR**

**Batteries**

- Individual Battery Cells
- Temperatures
- Cumulative Voltages
- Battery Voltage
- Battery Current

Cell	Volts	Temperature
#1	1.40	12.62 degrees C
#2	1.42	12.57 degrees C
#3	1.42	
#4	1.41	
#5	1.47	
#6	1.37	

**Battery Control Regulator**

Temperatures

Main V reg Temp	26.19	TXV Reg Temp	19.30
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Regulated Voltages

3.3 Volt	3.33	4.6 Volt	4.60
3.3 mA	66.50	4.6 mA	165.16

Low Voltage mA

55.00	+4V #1	4.03	Volts
	+4V #2	4.03	Volts

POWER CONTROL UNIT  
Ver 1.0 Model B

BCR tray

# Analyzing Telemetry from AO-51

**Telemetry As Text**

0	TX A Power	0.19	Watts	27	Low V I	55.00	Counts	54	Txt bcd ratio	6.00	Ratio	
1	TX B Power	0.63	Watts	28	Batt I	748.73	mA	55	Bat Mgmt	0.00	State	
2	Torqr Cap V	398.48	V	29	Tx I	0.97	Amps	56	WOD State	2.00	State	
3	Bat V	8.48	V	30	Bat sign	50.00	Counts	57	EDAC Errors	80.00	Counts	
4	Cell 5V	7.10	V	31	SQRX RSSI	4095.00	Counts	58	TXHang	0.00	Counts	
5	Cell 4V	5.64	V	32	SQRX Spkr	4095.00	Counts	59	CmdTmrLen	14976.00	Secs	
6	Cell 3V	4.23	V	33	Torqr 1.2V ref	0.00	V	60	CmdTmrEnd1	7309.00	Counts	
7	Cell 2V	2.82	V	34	Torqr Sense	4095.00	Counts	61	CmdTmrEnd2	17960.00	Counts	
8	Cell 1V	1.40	V	35	Not Used	2042.00	Counts	62	WODTimeLeft	548.00	Mins	
9	4.6V Exp I	165.16	mA	36	S Osc Temp	12.09	Deg C	63	Last Mode	1.00	Counts	
10	4.6V Exp V	4.60	V	37	TX B Temp	46.03	Deg C	64	spare	0.00	Counts	
11	3.3V I	66.50	mA	38	Not Used	2047.00	Counts	65	EDAC A0	13.00	Adr	
12	3.3VV	3.33	V	39	S PA Temp	12.67	Deg C	66	EDAC A1	191.00	Adr	
13	Total Array I	1131.32	mA	40	Temp +Z	27.60	Deg C	67	EDAC A2	5.00	Adr	
14	Total Array V	15.15	V	41	Not Used	2047.00	Counts	68	EDAC A3	3.00	Byte	
15	+X I	361.80	mA	42	Temp +Y	14.40	Deg C	69	EDAC A4	3.00	Byte	
16	-X I	16.80	mA	43	Temp -Y	12.09	Deg C	70	EDAC A5	35.00	Byte	
17	+Y I	559.35	mA	44	Temp +X	13.73	Deg C	71	EDAC A6	80.00	Counts	
18	-Y I	95.39	mA	45	Temp X	12.67	Deg C	72	Auto TX Pwr	0.00	Counts	
19	+Z I	187.92	mA	46	Bat 1 Temp	12.62	Deg C	73	BatMgmt State	1.00	Counts	
20	-Z I	231.12	mA	47	Bat 2 Temp	12.57	Deg C	74	reserved	0.00	Counts	
21	+X V	15.58	V	48	Main Reg Temp	26.19	Deg C	75	reserved	0.00	Counts	
22	-X V	13.79	V	49	TX V Reg Temp	19.30	Deg C	76	reserved	0.00	Counts	
23	+Y V	15.56	V	50	+4V #1 V	4.03	V	77	reserved	0.00	Counts	
24	-Y V	15.46	V	51	+4V #2 V	4.03	V	128	Bat I	---	mA	
25	+Z V	15.33	V	52	PHT time	15.00	Secs	129	Bat I	---	mA	
26	-Z V	15.42	V	53	Digipeat	0.00	On/Off					

**TLM timestamp = 2007 Apr 13 14:08:29**

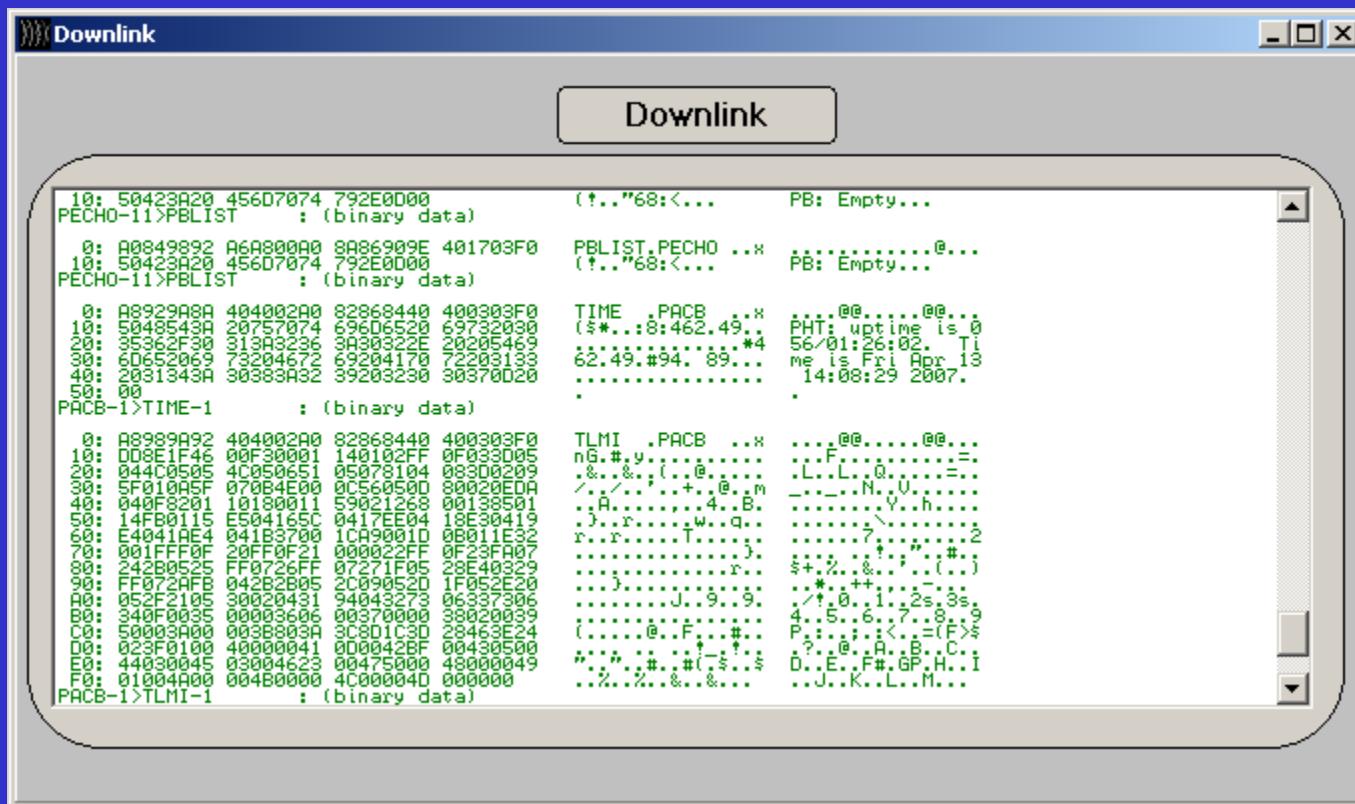
Display Raw Values

Legend:

- This channel has changed
- This value is outside the limits

# AO-51 Telemetry

- Live telemetry data as transmitted from the satellite via radio or real time via the Internet or from the FTP archives (your choice)



# Tips for using satellites

- MOST IMPORTANT – Listen! The satellite WILL hear you – don't transmit if you can't hear the signal from it.
- Get a preamp – huge improvement.
- Practice receiver tuning because Doppler causes the signal's frequency to shift lower during a satellite pass.
- Drop your callsign at just the right moment – this takes practice.

# Tips for satellites

- Start with a simple station that will let you make contacts, then make your station better and fancier.
- If you want, you can avoid the “big gun” stations by carefully selecting passes by day-of-week, by time of day, and/or by who is/isn’t in view of the satellite (hint: look at the footprint in the satellite tracking program)

# Tips for satellites

- Before trying “Satellite/Mobile” set up your station at home. Verify you have all the parts and that they all work together. Then take it on the road.

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- For working satellites while “mobile” (parked) from the back of your car, **always** carry an extra set of car keys so you won't get locked out.

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- For working satellites while “mobile” (parked) from the back of your car, **always** carry an extra set of car keys so you won't get locked out. (Don't ask how I know this.)

# The Future

- Suitsat 2 – Russian spacesuit “hand launched” from the International Space Station will contain radios and slow scan TV using an advanced software defined radio (SDR). Launch date: estimated in 2010
- Phase 3E and Eagle (high earth orbit with passes lasting several hours)



NASA Photo

# The Future

- ISS – Columbus module (now in orbit!)
- KiwiSat (2009? - Modes UV, LV)
- “Go Mars” (Phase 5) for science and exploration not communications
- Geostationary opportunity  $\frac{1}{2}$  cubesat

??? Questions ???

What questions do you have?

???

# Bonus Slide – Internet Links

- AMSAT website: [www.amsat.org](http://www.amsat.org)
- Keplerian Elements mailing list:  
<http://www.amsat.org/mailman/listinfo/keps>
- K3TZ patch antenna with PDF / CAD drawings:  
<http://www.qsl.net/k3tz/index.html>
- Cheap Yagis: <http://www.wa5vjb.com/references.html>
- 435 Quagi: Dec 1987 QST magazine
- Suitsat: [www.suitsat.org](http://www.suitsat.org)

# Bonus Slide #2 – More Internet Links

- Cardboard Aluminum foil 2.4 GHz horn antennas:  
[http://www.barc.org/ao40\\_antennas/rxantenna.html](http://www.barc.org/ao40_antennas/rxantenna.html)
- Cardboard Aluminum foil 435 MHz transmit antenna:  
[http://www.barc.org/ao40\\_antennas/txantenna.htm](http://www.barc.org/ao40_antennas/txantenna.htm)  
(note: URL ends in htm not html)
- [www.downeastmicrowave.com](http://www.downeastmicrowave.com)
- Willow and Sabins:  
<http://www.quagliana.com/willow/WillowSabins.zip>