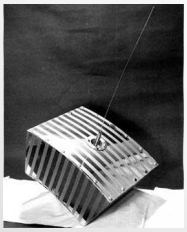
MCWA Meeting August 1, 2017

Basics of Amateur Satellite Operation in the current era

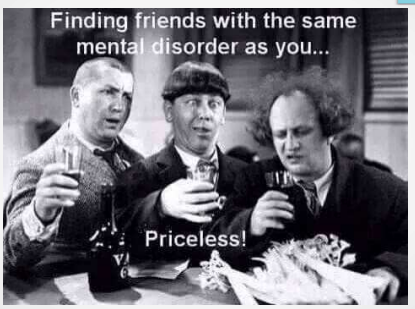
(using gear you may already own or may acquire at reasonable cost – cheap or free)

OSCAR-1 to OSCAR-88 Now

- AMSAT was founded to continue the efforts, begun in 1961, by Project OSCAR, a west coast USA-based group which built and launched the very first Amateur Radio satellite, OSCAR, on December 12, 1961, barely four years after the launch of Russia's first Sputnik.



If you were looking for more crazy ideas for ham radio … Welcome!



AMSAT – Keeping Amateur Radio in Space

- AMSAT designs, builds and operates experimental satellites and promotes space education
  - » Focus is on coverage and availability
- Partnerships
  - » NASA, ARISS – Human Space Flight
  - » Education: Foundations, Universities
  - » LEO satellite projects and education outreach
- Technical and scientific innovation
- Training and development
  - » Designers and Operators.

Tips on Getting Started ...

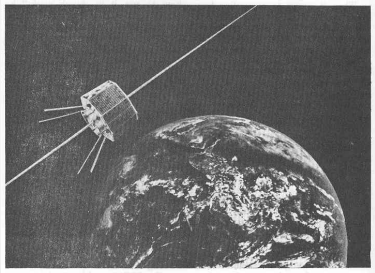
First a few slides showing how we got to where we are today

AMSAT Vision for the Future

Deploy satellite systems

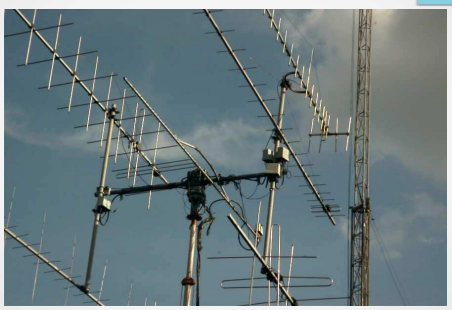
- » Wide area
- » Continuous coverage
- Participation in human space missions
- Support a stream of LEO satellites
  - » Developed in cooperation with the educational community and other amateur satellite groups.

OSCAR-7



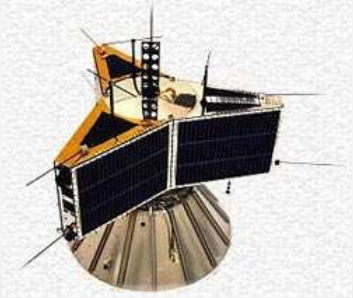
An artist's conception of AMSAT-OSCAR-7, the most sophisticated amateur satellite in orbit. It was built and is continually monitored by a team of international amateur radio operators.

Antennas for HEO Needed to be Big



Many elements, circular polarization, az-el rotors ...

OSCAR-10 & OSCAR-13 High Earth Orbit

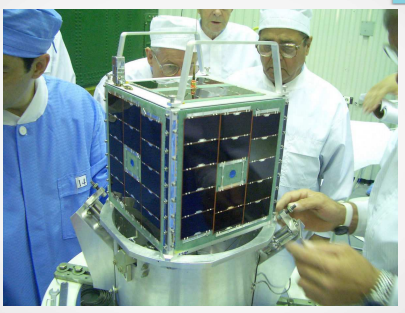


AO-40 Antennas … the bigger the better

Tell me how you're going to get this one past the Old Lady

OSCAR-40 High Earth Orbit

UO-14 & AO-51 FM Satellites



Introducing an era of easier to operate satellites

Antennas became more manageable for the average ham

The Arrow Antenna – 3 elements on VHF and 7 elements on UHF

AMSAT Worldwide

- Argentina, Australia, Belgium, Brazil, Denmark, Finland, Germany, India, Italy, Japan, Netherlands, New Zealand, Portugal, South Africa, Spain, Sweden, Turkey, United Kingdom
- Coordination between AMSAT-NA and international AMSAT organizations on satellite projects may be limited or restricted by the United States International Traffic in Arms Regulations (ITAR) and/or Export Administration Regulations (EAR).
- US Government says satellite makers are classified as munitions suppliers – including amateur satellites.

Another manageable satellite antenna

The Elk Antenna – Log Periodic for VHF and UHF

The ITAR Law Says AMSAT is a Munitions Supplier

Changing Times

- So, if High Earth Orbit is so excellent for coverage why aren't we making more of them?

2018 Launch Cost

SCHEDULE & PRICING

Spaceflight is the only rideshare provider to offer published commercial pricing. Our list pricing is based upon satellite volume, mass, and orbit destination assuming a 2018 launch. Pricing may change based upon launch vehicle selected. For satellite constellation deployment options, or launch needs outside of this pricing table, please contact us with your mission requirements.

	Containerized			Satellite Class						
Payload Type	3U	6U	12U	50 kg	100 kg	150 kg	200 kg	300 kg	450 kg*	750 kg*	1000 kg*
Length (cm)	34.05	34.05	34.05	80	100	100	100	125	200	300	350
Height/Dia(cm)	10.00	10.00	22.63	40	50	60	80	100	150	200	200
Width(cm)	10.00	22.63	22.63	40	50	60	80	100			
Mass (kg)	5	10	20	50	100	150	200	300	450	750	1000
Price – LEO	$295	$543	$995	$1,750	$3,950	$4,950	$5,950	$7,950	$17,500	$22,000	$28,000
Price – GTO	$915	$1,400	$2,750	$4,600	$8,400	$9,800	$11,200	$14,000	CALL	CALL	CALL

Prices are in thousands (USD).

Satellite Launch Type	Price
1U CubeSat to Low Earth Orbit	$150K / Rideshare
3U CubeSat to Low Earth Orbit	$295K
3U CubeSat to Geostationary Transfer Orbit (High Earth Orbit)	$915 K
AO-40 Phase 3 Class High Earth Orbit	$9,8 Million

Source: http://www.spaceflight.com/schedule-pricing/

NASA ElaNa Launch Opportunities

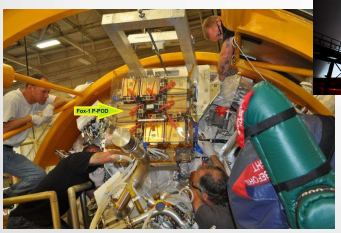
Educational Launch of Nanosatellites

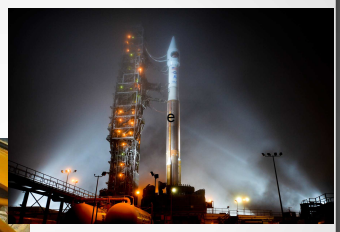
NASA's CubeSat Launch Initiative provides opportunities for small satellite payloads built by universities, high schools and non-profit organizations to fly on upcoming launches.

Through innovative technology partnerships NASA provides these CubeSat developers a low-cost pathway to conduct scientific investigations and technology demonstrations in space, thus enabling students, teachers and faculty to obtain hands-on flight hardware development experience.

3, 2, 1 … Ignition and Liftoff!

Below: The arrow points to our seat aboard the launch vehicle.

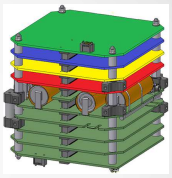


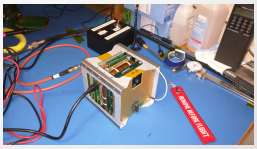


Above: Fox-1A launched on October 5, 2015 aboard a United Launch Alliance Atlas-V from Vandenberg Air Force Base, California. NASA got us a ride with a satellite for the NRO.

AMSAT's Fox-1 CubeSats

FM repeater, sponsored experiments, solar cells, antennas, batteries all in a 10 cm x 10 cm x 10 cm package,





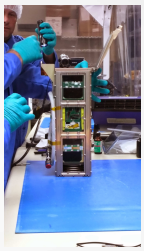
Copy AMSAT Fox With Your 2M FM Rig

AMSAT Fox	Uplink FM 67.0 HZ	Downlink FM	Launch
Fox-1A (AO-85)	435.170 MHz	145.980 MHz	Operational Now
RadFXSat-1 Fox-1B	435.250 MHz	145.960 MHz	~ 21 Sept 2017
Fox-1Cliff	435.300 / 1267.300	145.920 MHz	4Q 2017 – 1Q 2018
Fox-1D	435.350 / 1265.350	145.880 MHz	Late 2017

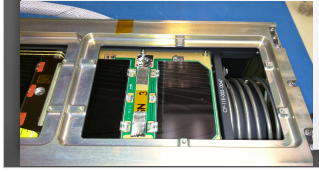
How to Fly a CubeSat

Left: Fox-1A completes pre-launch acceptance testing.

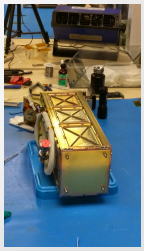
Right: Three 1U Cubesats are integrated into the P-POD deployer.



Below: A completed P-POD deployer ready for the rocket.



Left: The CubeSats are ejected from the P-POD deployer by a big spring when the remotely controlled trap door opens.



STEM Projects Are a Win-Win for Amateur Radio (and AMSAT)

- Discovered that no organization is willing to donate to a ham radio project just so a bunch of guys can talk with each other.
- Many donors can be found at private, personal, and government funding levels if a project is proposed for STEM Education – Science, Technology, Engineering, Mathematics
- AMSAT Fox CubeSat support was earned by proposing student level STEM experiments in space … which happened to have an amateur radio repeater aboard.

AMSAT and Space Science

- **AMSAT Fox-1A (AO-85)**
  - Sponsored by NASA ELaNa grant
  - Vanderbilt University low energy proton radiation experiment
  - Penn-State University Erie – Micro-Electrical-Mechanical Systems (MEMS) experiment (gyroscope on a chip)
- **RadFXSat-1 Fox1B**
  - Sponsored by Vanderbilt NASA ELaNa grant
  - Advanced Vanderbilt low energy proton radiation experiment
  - MEMs gyroscope

RadFXsat-2 Fox1-E

Launch: No Earlier Than December 2017
NASA ELANA XX mission
Virgin Galactic Launcher One Mojave Air & Space Port Mojave, CA
Orbit: LEO (Low Earth Orbit)

Transmit power: 400 mW (Minimum)
Bandwidth: 30 kHz
Transponder: Mode JA (V/u) analog inverting
Beacon: 435.750 MHz 1200 baud BPSK
Uplink: 145.860 MHz – 145.890 MHz LSB/CW
Downlink: 435.790

Instead of a single FM channel, it will have a 30 KHz wide analog inverting transponder, with separate a 1200 baud BPSK telemetry downlink.

Fox-1E **will carry a radiation effects experiment similar to RadFxSat (*Fox-1B*) but will study the new FinFET technology, along with the standard *Fox-1* Penn State University–Erie Attitude Determination Experiment (ADE). It will not include any experiments requiring high speed telemetry since that will not be supported.**

AMSAT and Space Science

- **Fox-1Cliff**
  - Flight purchased through AMSAT fundraising
  - Additional flight for next in the series of Vanderbilt radiation experiments
  - MEMS gyroscope
  - Virginia Tech VGA camera for earth photography
  - L-band uplink experiment (1267.300 MHz FM)

SO-50 UHF FM downlink

SO-50, Saudi-OSCAR-50

Orbit: LEO (Low Earth Orbit)

Size: 35 x 35 x 35 cm (13.7” inch cube)

Weight: 11 kg (~24 pounds)

Transmit power: 250mW

Uplink: 145.850 MHz FM voice + 67.0 Hz CTCSS tone
Downlink: 436.790-436.800 MHz FM voice

AMSAT and Space Science

- **Fox-1D**
  - University of Iowa High Energy Radiation CubeSat Instrument (HERCI)
  - Van Allen Laboratory at University of Iowa
  - Mapping radiation in low earth orbit in preparation for xray and radiation measurement on future CubeSats
  - Virginia Tech VGA camera for earth photography
  - L-band uplink experiment (1267.350 MHz FM)

AO-7 VHF and 10 meter SSB/CW

AO-7 was launched in 1974 and was operational for 6.5 years until a battery failure ceased operation in mid 1981.

June 21, 2002 reawakening when Ni-Cd short circuit opened.

Now operational only on power from solar panels

Mode A: 145.850 – .950 MHz uplink and 29.400 – .500 MHz downlink [SSB/CW], non-inverting

Mode B: *432.175 – .125 MHz uplink and 145.925 – .975 MHz downlink [SSB/CW], inverting

ISS Amateur Radio Operation

ARISS Temporary Operational Status

5 watt Ericsson HT substituted for failed Kenwood transceiver until ARISS upgraded system becomes operational.

ISS Amateur Radio Frequencies

Voice Downlink 145.800 MHz FM (Worldwide)

Voice Uplink 144.490 MHz FM (Regions 2 & 3 the Americas, Pacific)

145.200 MHz FM (Region 1 Europe, Central Asia,Africa)

VHF Packet 145.825 MHz FM simplex (Worldwide)

UHF Packet 437.550 MHz FM simplex (Worldwide)

Cross-band repeater 437.800 MHz FM uplink (Worldwide)

145.800 MHz FM downlink (Worldwide)

HAM TV (DATV) 2.395 GHz, 2.422 GHz, 2.437 GHz, 2.369 GHz downlink (Worldwide)

ARISS Interoperable Radio System

ARISS Planning New Amateur Radio Equipment

ARISS Interoperable Radio System

Higher power operation is planned to resume on the ARISS amateur radio configuration

5W, 10W, 25 W power levels from a modified-for-human-spaceflight Kenwood D-710GA dual-band transceiver

New interoperable power system, to allow ham radio equipment to be used anywhere on ISS is included in the ARISS update

The radio alone is unusable without the power supply; it requires 13.8 V DC

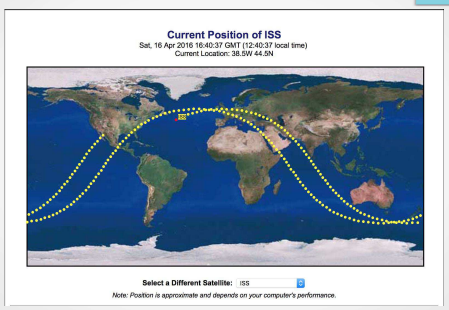
ISS provides 120 V dc in the US segment and 28 V dc in the Russian segment.

The entire system is required to meet NASA and Roscosmos human spaceflight safety standards.

Certification testing estimated to cost $200K

Donate at www.amsat.org

Web Tracking - http://www.amsat.org/track/index.php

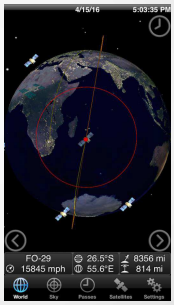


iPhone Tracking Apps

GoSatWatch (Apple iOS)
This $9.99 application works on both iPhones and iPads.

Satellite Explorer Pro (Apple iOS)
This is a free application for Apple iPhones and iPads by Tom Doyle, W9KE

PocketSat3 (Apple iOS)
The PocketSat3 application is available in versions for iPhone and iPad. It is more expensive than the other apps described above, selling for $24.99.



Web Tracking - http://www.n2yo.com/

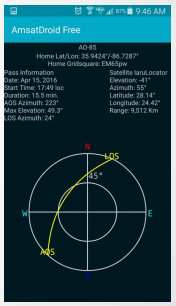
Android Tracking Apps

AmsatDroid FREE
By Dave Johnson, G4DPZ, one of the members of the AO-73 team, created this application.

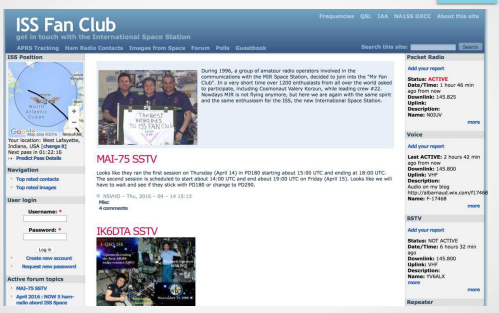
Heavens-Above
Free if you'll live with the advertising, or $5 for an ad-free version.

PocketSat3
Sells for $24.99.

Track Sats
Free in the Play Store. Tracks all amateur satellites.



Web Tracking - https://www.issfanclub.com/



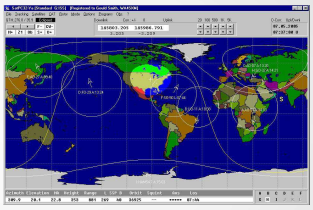
Tracking Software

Nova for Windows – The "latest" copy of Nova for Windows is free at
http://www.nlsa.com/uploads/nfw2.2c/Full/setup.exe

You should also download and install this patch for compatibility with later (post-XP)
http://www.nlsa.com/uploads/nfw2.2c/Patch/Patch.exe

Ham Radio Deluxe

Gpredict – for Windows, MacOSX, and Linux
http://gpredict.oz9aec.net/

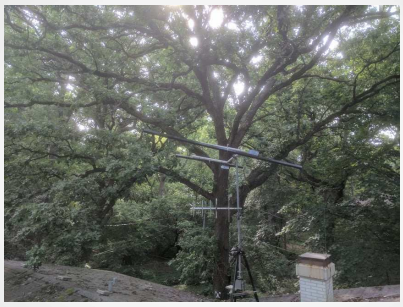


SatPC32 – Free to try, on sale at:
http:www.amsat.org select 'Store'

MacDopplerPro -in the AMSAT Store

Thoughts on building a satellite station …

LEO Antenna Configuration at K9JKM

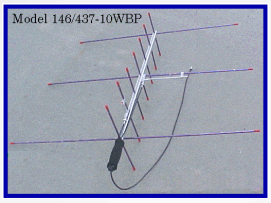


- 6 elements VHF yagi tuned to 145.900 MHz
- 8 elements UHF yagi tuned to 437,000 MHz
- Homebrew: www.wa5vjb.com/yagi-pdf/cheapyagi.pdf

… another random thought ...

Gear at K9JKM

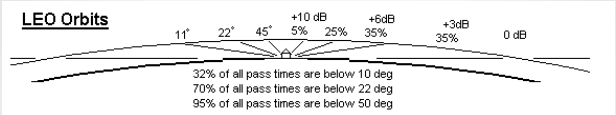
Arrow Antenna



Yaesu FT-857D

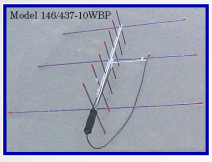
ADI AT-600 dual-band handheld

Fixed Elevation Works OK for LEO



- **Directional Antenna**
  - 3 to 6 elements on 2 meters
  - 4 to 7 elements on 70 cm
- **Omnidirectional Antenna**
  - Actually does work
  - Usually need to wait until the satellite gets closer to your QTH
- **Easier configuration**
  - Antennas on a short mast on TV rotor for azimuth adjustment
  - Fixed 15° to 25° elevation covers 95% of most passes

Connecting VHF & UHF to the Radio



Arrow Antenna has duplexer rated for 10 watts built into the handle

Duplexer with higher power rating used with my FT-857D

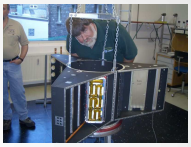
- **Port 1 – 1.3-225 MHz**
- **Port 2 – 350-540 MHz**
- **200 watts**
- **0.2 dB insertion loss**
- **<1.2 VSWR**
- **55 dB isolation between the ports**

$30 to Experiment

- Super cheap Chinese radios have been made to work by some
  - Baofeng UV-5R on Amazon for $30 or less
- Need to buy 2 radios for full-duplex operating
- Hear the downlink when you transmit to make sure you aren't stepping on someone else
- Desense problem when operating VHF up and UHF down.
  - 3rd harmonic of 2M desenses the UHF receiver
  - Separate antennas or duplexor for isolation have proved beneficial

Looking to the Future

- Phase 3 Rideshare – proposal with Virginia Tech and an unnamed government agency to include an amateur transponder. Not funded in this fiscal year.
- Phase 4 GEO - proposal with Virginia Tech and an unnamed government agency to include an amateur transponder aboard Millennium Space Systems Aquila M8 surveillance satellite . Not funded in this fiscal year.
- NASA Cubequest Challenge
  - 6U CubeSat to either lunar orbit or deep space >4 million KM
  - AMSAT communication package aboard Ragnorak Industries Lunar flight – on the waiting list.



Tuning for Doppler Shift

- Tuning the receiving side
- Start higher than the center frequency and tune DOWN
- VHF start 3-5 KHz high and tune down as satellite approaches
- Keep tuning down 3-5 KHz as satellite passes
- UHF start 10 KHz high and tune down as the satellite approaches
- Keep tuning down 10KHz as satellite passes
- See next example for combination of tuning the receive side and transmitter side

Bunch of Links

- AMSAT-NA https://www.amsat.org
- http://www.amsat.org/status/
- https://www.amsat.org/two-way-satellites/
- https://www.amsat.org/station-and-operating-hints/
- AMSAT-UK https://amsat-uk.org/
- https://amsat-uk.org/beginners/
- ARISS http://www.ariss.org/
- http://www.ariss.org/contact-the-iss.html

UHF Doppler Tuning Example

Channel	Receive(MHz)	Transmit(MHz)	Location
1	437.560	437.540	AOS
2	437.555	437.545	Approaching
3	437.550	437.550	TCA
4	437.545	437.555	Departing
5	437.540	437.560	LOS

- **Transmit start LOW and track UP**
- **Receive start HIGH and track DOWN**

Get Some Gear for Satellites?

Questions?