AMSAT OSCAR-E Project Status Update
A New LEO Satellite from AMSAT-NA
Richard M. Hambly (W2GPS)

This status report about AMSAT-OSCAR-E ("Echo") is an update to the presentation given at the Dayton Hamvention and the articles published in the AMSAT Journal (May/June 2002) and CQ/VHF Summer 2002.

BACKGROUND:

Following the 2001 Annual AMSAT-NA Meeting in Decatur GA, the Board of Directors met and asked Dick Daniels (W4PUJ), Tom Clark (W3IWI) and Rick Hambly (W2GPS) to review a proposal for "a new small satellite project." The team's report was presented to the Board during a teleconference on 17-Jan-02 and the Board unanimously approved the project.

AMSAT-NA built and launched the original Microsats in 1990. These were AO-16, DO-17, WO-18, and LO-19. The descendents of the Microsat legacy include IO-26, AO-27, MO-30, and SO-41. Each of these descendents has improved on the original design. The project team recommended that AMSAT-NA take full advantage of these improvements so, on 8-Feb-02, AMSAT-NA entered into an agreement with SpaceQuest, Ltd. of Fairfax, VA whereby SpaceQuest will provide AMSAT with the basic components of AO-E and leave it to AMSAT members to add any specialized payloads that may be desired. SpaceQuest is led by AMSAT members Dr. Dino Lorenzini (KC4YMG) and Mark Kanawati (N4TPY).

On 20-Apr-02 the AMSAT Board met at SpaceQuest to see firsthand that everything was going as planned. After the tour of SpaceQuest, the Board reconvened across the street in ARRL's DC area offices where there were presentations and an extensive review of the project. It was at this meeting that the Board agreed to postpone the launch until late 2003 to provide adequate time for the development of optional payloads.

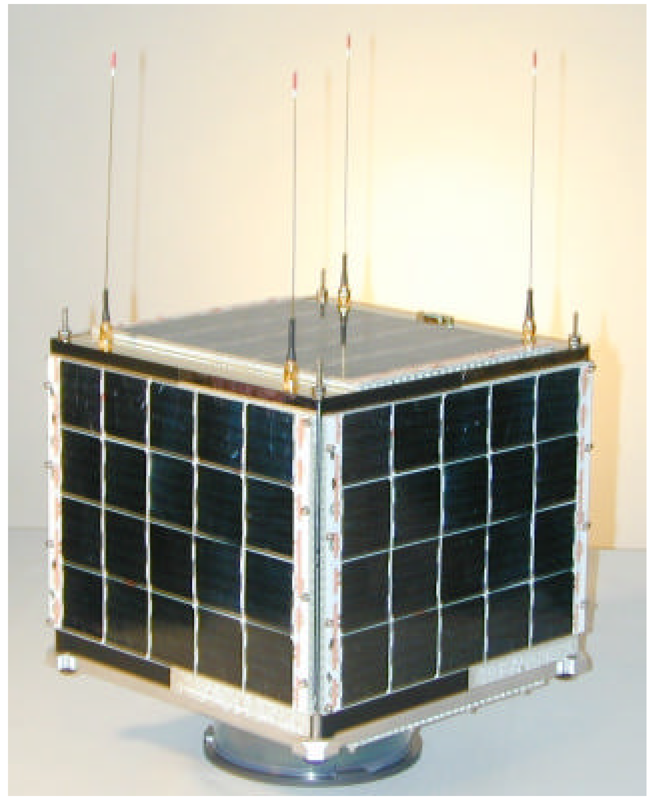

Figure 1: Mechanical Model of AO-E Class Microsat

The first public presentation on AO-E was at the annual spring AMSAT-DC symposium at NASA Goddard Space Flight Center on 5-May-02. The presentation was significantly compressed for the Dayton Hamvention AMSAT Forum on 18-May-02.

Full details of the project were published in the May/June AMSAT Journal. A reprint of the Journal article has appeared in the Summer 2002 issue of CQ/VHF magazine.

Figure 2: The AMSAT Board, Project Committee and SpaceQuest personnel at SpaceQuest 20-Apr-02

Throughout the year the AMSAT project team (W4PUJ, W3IWI, and W2GPS) has met on a regular basis with SpaceQuest and others to review the progress of AO-E and to discuss the various optional payloads that are under consideration.

FEATURES

The AMSAT OSCAR-E satellite will offer users a strong set of features even before optional payloads are added. These include:

- Analog operation including FM voice.
- Digital operation including APRS.
- High downlink power.
- Multiple channels using two transmitters.
- Simultaneous voice and data,
- Multi-band, multi-mode receiver.
- Geographically based personalities.
- True circular UHF antenna that maintains its circularity over a wide range of squint angles.

TECHNICAL

AMSAT OSCAR-E will be a step forward in the evolution of Microsat technology, with better receivers, higher power transmitters, and new operating modes.

The infrastructure of the satellite has many improvements over earlier generation Microsats, including:

- Faster and more capable IHU processor.
- Higher data rates on downlinks.
- Autonomous, self-healing, high efficiency power management system.
- Upgraded, highly capable, software package.
- Store and forward with continuous monitoring and geographically defined data forwarding.

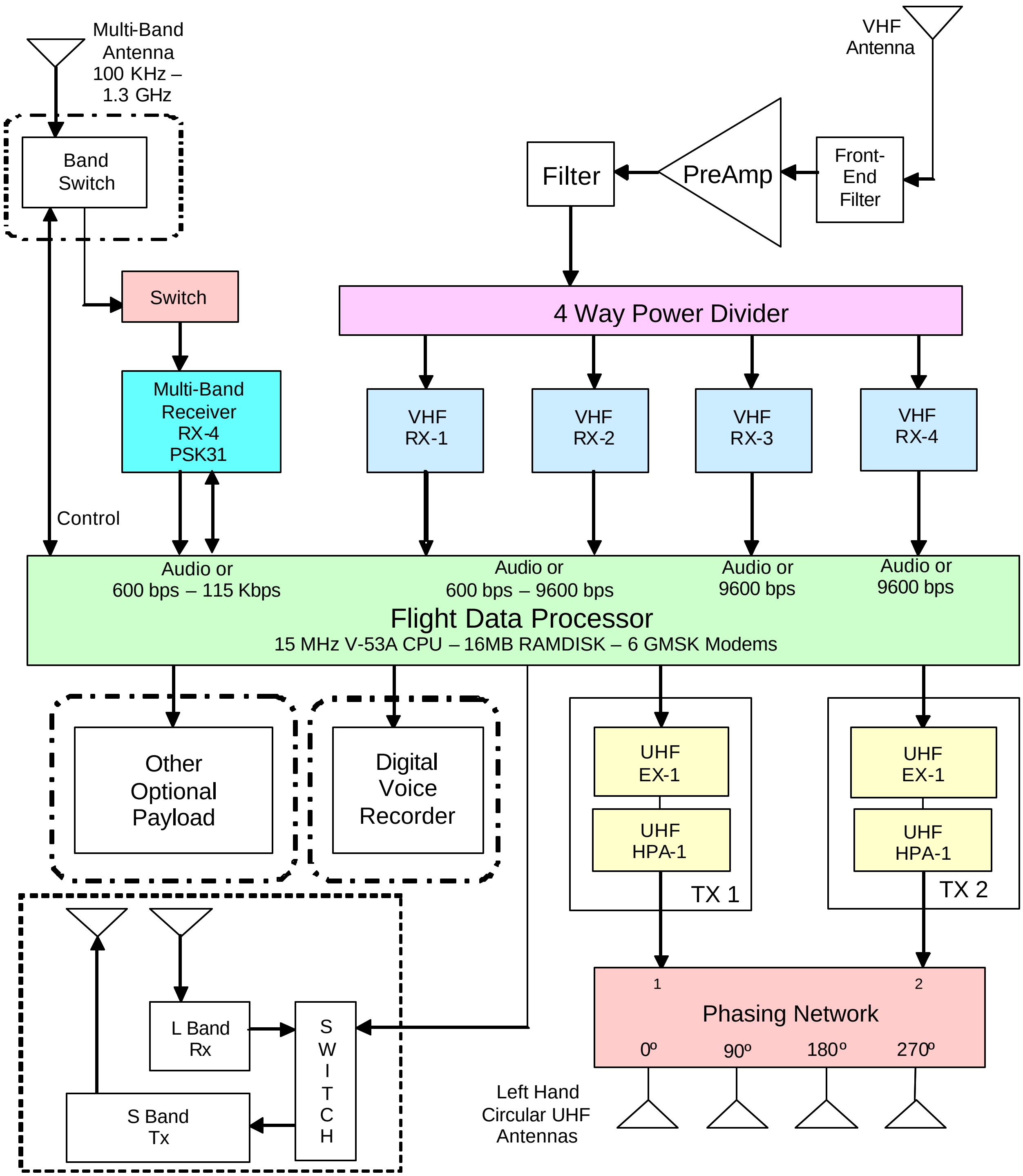

Figure 3: Conceptual Block Diagram of the AMSAT OSCAR-E Spacecraft

The internal subsystems have been described in detail in the AMSAT Journal article (May/June 2002) so only a summary is presented here.

The core elements of the AMSAT OSCAR-E satellite are being provided by SpaceQuest. This provides the basic platform on which AMSAT can build using optional payload trays and external modifications.

The subsystems that make up the core elements of AMSAT OSCAR-E are:

- The physical structure
- Attitude control
- Central processor hardware
- Spacecraft flight software
- Power generation and distribution
- Command and control
- A basic set of receivers, and transmitters
- Antennas.
- Space for optional payloads

Physical Structure

AMSAT OSCAR-E is made up of a stack of five machined aluminum modules each measuring 23.5mm x 23.5mm. The height of the stack is 24.5mm.

One module is empty and is to be used by an AMSAT supplied payload. Internal to the module there is 200mm x 220mm of space with rounded corners. The height is about 50mm.

Figure 4 shows a photo of a typical Microsat structure.

Active Magnetic Attitude Control

Originally an optional payload, the active magnetic attitude control has replaced the passive system as one of the core satellite subsystems. This will allow the spacecraft to be oriented to favor communications in the Northern or Southern Hemispheres at different times.

This attitude control system replaces the permanent rod magnets with semi-permanent electromagnets. Electronic circuits are required to polarize and condition the magnetic rods.

The Earth-pointing direction is on the order of ±20 degrees in the temperate zones, varying with orbital inclination.

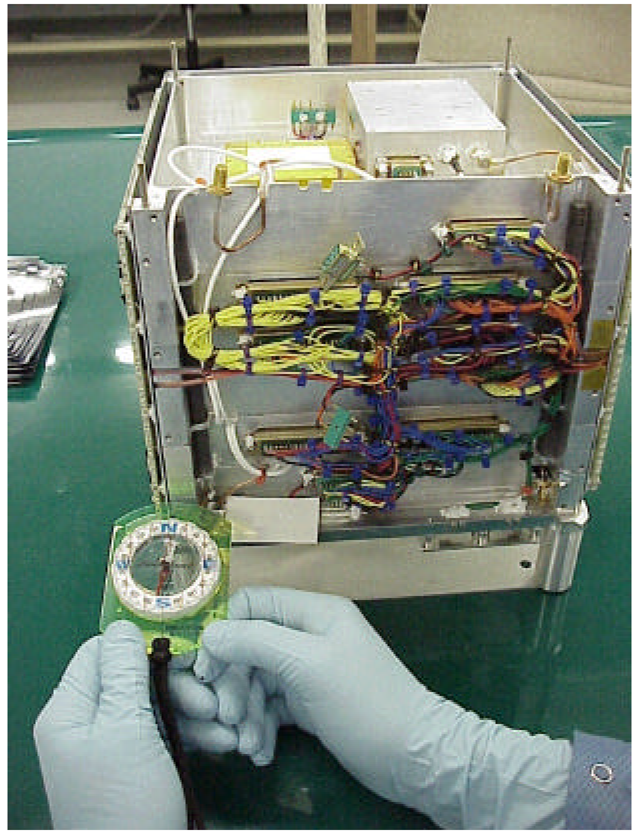

Figure 4: Typical Microsat Structure

As this is being written Lou McFadin W5DID has the stabilization rods for winding. Doug Sinclair is designing and building the electronics to control magnetization of the rods.

Central Processor Hardware

AMSAT OSCAR-E includes an improved Integrated Flight Computer (IFC) recently developed by Lyle Johnson WA7GXD.

The improved IFC used a new six layer circuit board and includes a flight-proven, low-power NEC V53A processor Central Processor Unit (CPU) that runs at 30MHz, 3x faster than the previous design. In addition to its 1Mb of error-detecting and correcting (EDAC) memory, it has 16Mb of RAM and 16Mb of Flash memory for mass storage.

The IFC board includes two GMSK modulators that can operate up to 115K Baud, and six

GMSK demodulators that can operate up to 14.4K baud. Also included is a PL tone decoder.

The Spacecraft Operating System (SCOS), also flight proven on numerous spacecraft.

Hardware and software development are facilitated through the use of the SpaceQuest "FlatSat" model, see Figure 5.

Spacecraft Flight Software

The boot loader provides the minimal set of functions required to verify the satellite health and load the operating system. The bootloader is being tweaked to improve the uplink.

The Spacecraft Operating System (SCOS) has been used on all of the Amateur Radio Microsat projects to date. Harold Price has agreed to allow AMSAT to use SCOS in AO-E without charge.

The Mission Software provides complete control over all aspects of the satellite, including experiments and attitude control. This software can be loaded into FLASH from the ground after launch.

Power Generation and Distribution

The AMSAT OSCAR-E Power Subsystem consists of a Battery Control Regulator (BCR), GaAs solar panels, matched flight cells, voltage regulators and a power activation switch.

The Battery Control Regulator (BCR) converts solar panel power to system power, and manages battery charge and protection. It is a switching design with a measured efficiency of 89 percent.

Six GaAs Solar Panels, which are mounted on all six sides of AMSAT OSCAR-E, produce a bus voltage of approximately 16 volts. The cells that have been purchased for AO-E are among the best available, with

Figure 5: Mark N4TPY with "FlatSat"

conversion efficiency of over 25%. Mark Kanawati will personally do the layout of the cells onto the panel. He proposes to fly without a glass cover on the cells, which requires more careful handling but gives an additional 1.5% in output.

The battery configuration is a matched set of six NiCd cells at 4.4 Ah each with a nominal battery voltage of 8 V dc.

The BCR provides multiple switched 8-V lines for both transmitters and other high power applications. There are also 3.3-V and 4.6-V switching regulators, capable of over 250 mA output each, with multiple switched and unswitched outputs.

Command and Control – Ground Station

The Bootloader application communicates with the satellite's bootloader upload code changes or to load and execute operating system tasks.

The Housekeeping program communicates with each of the tasks onboard the satellite.

The Telemetry Gathering and Reporting program downloads and displays satellite health information.

Each of these programs need to be written or re-written by AMSAT volunteers! This task has not yet been assigned.

Receivers and Transmitters

Four miniature VHF FM SpaceQuest receivers are used for both command & control and for user links. Each receiver consumes less than 40 mW and weighs less than 50 gm.

Two SpaceQuest UHF FM transmitters provide the downlinks and can be operated simultaneously. Nominal power output is 7 watts. The transmitter modules are being redesigned to reduce their overall height and to move the connectors to one end.

Antennas

The VHF antenna consists of a very thin quarter-wave (18-inch) vertical whip mounted in the center of the top surface of the spacecraft.

AO-E has a UHF Turnstile Antenna that is fed by a strip line hybrid antenna phasing network that provides the appropriate quadrature phase and amplitude to each of four output antenna ports to produce true circular polarization over a wide range of squint angles. As currently designed, the turnstile provides left hand circular polarization. SpceQuest is looking into redesigning the turnstile for right hand circular polarization but this may not be feasible.

Three additional antennas are provided in a cluster in the center of the bottom face of the satellite. One is an 18” whip with dual feed electronics to feed the LF/HF/VHF/UHF wideband receiver. This antenna is still under development. The other two are ¼ wave whips for L and S bands to support a proposed Mode L/s transponder.

Link Budget Data

The following data is approximate and is provided for those wishing to make preliminary link budget calculations.

Transmitter: 70cm band, fixed frequency crystal controlled. Power output is 12 Watts maximum and is adjustable over a range of 1 to 12 Watts. The best efficiency achieved at 7 Watts output. There are two transmitters that can be operated simultaneously.

Hybrid Coupler: The two transmitters are combined to feed one antenna. Loss in the hybrid coupler is about 0.5 db or less.

UHF Antenna: 1 to 2 dBic gain (2dBic at ±40 degree squint). See Figure 6.

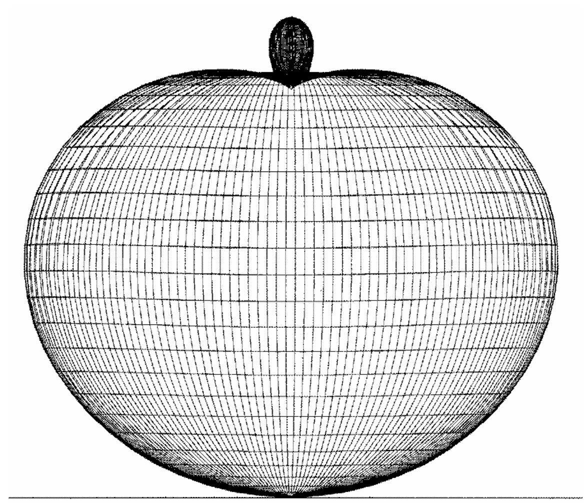

Figure 6: Turnstyle Antenna Radiation Pattern

Note that with these numbers it is possible to exceed the FCC recommended power flux density of -125dBw/m^2/4kHz.

When transmitting data the waveform is GMSK ("softened" FSK, not phase coherent like true GMSK). The data rate can be set to anything up to about 56K baud, limited primarily by the FCC channel bandwidth limit (100KHz).

Normal operation will probably be at 9600 baud to be compatible with all the radios and modem that are commonly available.

Receive Antenna: A 1/4 wave whip in the center on the face that normally looks up when over the Northern Hemisphere. It has about 1.5dBi (linear) gain.

Receive Cable and Filter assembly: 1dB loss.

LNA: 0.7dB Noise Figure. 18dB gain.

Receiver: 15KHz Bandwidth in voice or data (supports up to 9600 baud data).

OPTIONAL PAYLOADS

The optional payloads under consideration for the AMSAT OSCAR-E mission have been described previously so only status information is provided here.

Advanced Data Communications for the Amateur Radio Service (ADCARS)

A number of meetings and discussions have been held with KA9Q, W2GPS, SpaceQuest and others. This is a difficult and poorly understood project. Much more work will need to be done if AO-E is to provide meaningful support for the development of this new technology.

L-Band/S-Band Communications System

This project may be combined with ADCARS. A project leader with experience in wide band transmitter and receiver design is needed.

GPS Receiver

AMSAT, headed by W3IWI, is still looking for a suitable candidate for this. Power consumption, size and weight of available equipment are the limiting factors here.

Active Magnetic Attitude Control

This project has been embraced by SpaceQuest and is now a part of the core spacecraft design.

Audio Recorder Experiment

This experiment, proposed by KK7P, will provide the capability for recording and playing back any audio channel. The CPU is also needed to support ADCARS. There is no progress to report on this project at this time.

Low Frequency Receiver

To become feasible, a way must be found to share the single 18” wideband receive whip between low frequencies, using a new E-field antenna interface amplifier, and VHF/UHF frequencies, which use a more conventional interface.

APRS

APRS can be supported in various ways through software only solutions. While it would be best to develop the software while the satellite is still on the ground, it is not essential. A volunteer is needed to do the software development.

PSK-31

PSK-31 will be supported by operational control. No additional development is necessary.

Multi-band Receiver/Antenna

This receiver is now a part of the core satellite system. The capability is limited only by the antenna design, which must be finalized.

High Efficiency Solar Arrays

This is now a part of the core satellite system. Cells have been obtained that have conversion efficiency in excess of 25% and will produce over 7 Watts per panel when facing the sun.

Robust Telemetry Link

Discussions continue with KA9Q regarding implementation issues. This is another very valuable project that is now well understood.

CONCLUSION

The core elements of AMSAT OSCAR-E are under construction now by SpaceQuest.

The AMSAT OSCAR-E project team is still working to finalize plans for optional payloads. This is proving to be especially difficult.

It is hoped that AMSAT OSCAR-E will be the first in a series of new low-cost LEO satellites, each to carry optional payloads of interest to the AMSAT community.