AMSAT OSCAR-E Project
Spring 2004 Status Report

by Richard M. Hambly W2GPS

This status report about AMSAT-OSCAR-E ("Echo") is a companion article to the presentation given at the Maryland-DC area Annual AMSAT Meeting in March 2004 and the to the previous articles published in the AMSAT Journal[1,2,3], the AMSAT Proceedings[4] and CQ/VHF[5,6,7].

LATEST NEWS:

On December 8, 2003 a team led by Jim White WD0E and Mike Kingery KE4AZN arrived at SpaceQuest in Fairfax VA to begin the process of integrating Echo's various hardware and software subsystems. After two weeks of long hours and hard work the team had the core systems working and had successfully tested much of the experimental hardware.

During January and February the Echo integration team continued working with the designers of the flight and ground software and with the developers of the S-Band transmitter and the Digital Voice recorder to finalize Echo and get it ready for flight.

Figure 1: Project Manager Dick Daniels W4PUJ watching over Integration Team Leader Jim White WD0E at SpaceQuest on 18-Dec-03.

In mid-February we received the news that the primary payload for our launch was experiencing delays and so the launch window has been pushed back to a two month period beginning June 28, 2004. While disappointing, this will give us time to further refine the software and to get the experimental payloads installed and fully tested.

OPERATIONS and CAPABILITIES

As has been reported in previous articles, Echo will offer a wide range of capabilities that will support operations interests from "EasySat" operations to scientific experiments.

In anticipation of Echo's launch an operations committee has been formed to determine the initial operating schedule for Echo after commissioning is complete. The initial proposed schedule is as follows, but keep in mind that this is preliminary and subject to change any time.

FM voice repeater mode will be active all the time on one channel (except see experimenters' day below), 145.920 MHz uplink with 67 Hz PL tone and 435.225 MHz downlink, one Watt minimum. This mode will use CTCSS keyed mode, which means that the transmitter comes on only when it hears a 67 Hz PL for one second or more and stays on for up to ten seconds after the tone disappears. The transmitter power is controlled automatically by software and may be as high as six Watts output when sufficient DC power is available

Digital mode will also be active all the time on one channel (except see experimenters' day below), 145.860 MHz uplink at 9,600 baud, 435.150 MHz downlink also at 9,600 baud. The transmitter will be set to one Watt all the time. The software on the satellite will be set to run a store and forward bulletin board system (BBS) using the callsigns PACB-11 for broadcast and PACB-12 for the BBS. Echo's digital mode is just like that of UO-22; a store-and-forward BBS using the PACSAT Protocol Suite. The digital downlink will also contain periodic real-time telemetry and Echo's whole orbit data will be available in its file system for download. It is also possible that Echo will broadcast periodic APRS status messages.

Experimenters' day is every Wednesday (UTC). Any other mode that Echo is capable of implementing may be in use from Wednesday from about 0000 UTC to about 2359 UTC. Modes will be scheduled a week or more in advance. If no experiment is scheduled Echo will be in the default experimental mode which is digital operation using 1268.700 MHz uplink at 9,600 baud and 2401.200 MHz downlink at 38,400 baud. We expect the most common other experimental modes to be Mode L/S FM voice and Mode L/S with 9,600 baud uplink and 38,400 or 76,600 baud downlink.

There are many other possible modes that can be implemented by using Echo's various capabilities in creative combinations. As has been published before, Echo's capabilities include:

- Mode V/U, L/S and HF/U Operation. Modes V/S, L/U and HF/S are also possible.
- Analog operation including FM voice.
- Digital modes. Store and forward operation is planned. Many speeds are possible but 9.6K, 38.4K, 57.6K and 76.8K bps are the most likely.
- PSK31 repeater mode using 10-meter SSB uplink and UHF FM downlink.
- Four VHF receivers and two UHF high power 8-Watt transmitters.
- Can be configured for simultaneous voice and data.
- Has a multi-band, multi-mode receiver.
- Can be configured with geographical personalities.
- Advanced power management system.
- Digital Voice Recorder (DVR).
- Active magnetic attitude control.

TECHNICAL REVIEW

Echo's internal subsystems have received some refinements since they were described in the last article. Thanks to Michael Kingery KE4AZN we now have a really useful block diagram for Echo, shown as Figure 2. There you will see that Echo is made up of:

- Four VHF receivers.
- A Multi-Band Multi-Mode Receiver (SQRX).
- Two UHF transmitters.
- Six demodulators and 2 modulators.
- RF switching, RF cabling and phasing networks.

Not shown in this diagram are:

- Integrated Flight computer (IFC).
- Batteries, BCR, Regulators.
- Wiring harness.
- 56 channels of telemetry.
- Magnetic attitude control.

THE INTEGRATION PROCESS

Did you ever wonder what happens during one of these marathon integration sessions? What follows is an edited version of the summary report authored by Jim White WD0E describing the two week integration activity during December.

Jim White WD0E, Mike Kingery KE4AZN and Harold Price NK6K gathered at SpaceQuest in Fairfax, VA on Dec 8th to continue software development for Echo and to test the hardware. A great deal of the software had already been written but needed to be tested on the real hardware. Additional software had to be written while on site with the hardware.

Harold’s primary objective to was get the Spacecraft Operating System (SCOS), kernel and AX.25 protocol stack running, along with the file system that implements the PACSAT Protocol Suite. This was accomplished quickly on Monday. Testing on those components continued throughout the two week period but their early implementation enabled further software testing starting immediately after Harold departed Tuesday afternoon.

The primary objectives for the testing period, and the results achieved, were as follows.

Test all hardware. 90% of the hardware was tested. Two minor problems were found and corrected. Some hardware remains untested due to lack of time or lack of software.

Bring Mike up to speed on software generation and satellite operations. Accomplished.

Turn development of the ground command and telemetry software over to Mike. Accomplished.

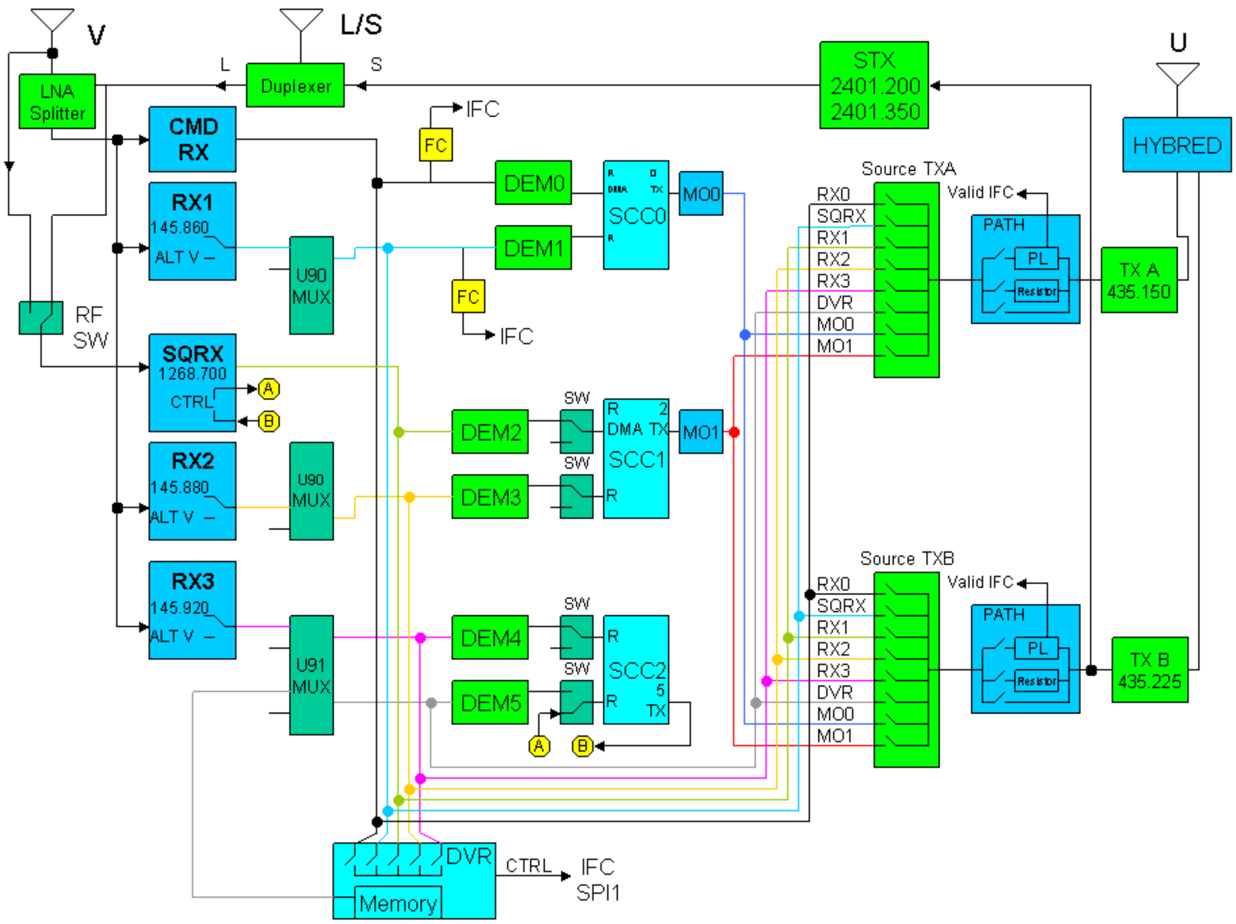

Figure 2: Echo Block Diagram by Michael Kingery KE4AZN

Get the telemetry software in the housekeeping task (PHT) working. 90% done.

Calibrate all telemetry points. 95% completed.

Test over RF links. Some testing was accomplished but much more needs to be done.

Establish all initial settings for the hardware. Completed. 46 items must be initialized on startup.

Figure 3: Jim White WD0E, Harold Price NK6K, Bob Bruhns WA3WDR, John Teller N4NUN and Mike Kingery KE4AZN showing us that an integration team needs fuel too. Photo by Mark Kanawati N4TPY

Create a boot loader and initial housekeeping task, burn them into ROM. Completed.

Test all modes. All modes except high speed data were tested. Recordings were made of voice contacts through the satellite on both V/U and L/S modes.

Gather pre-launch telemetry for analysis. 90% completed.

Get the flash memory working. Not completed.

Establish, burn, test, solder in the fire codes. Completed.

Test the CTCSS filtering. Partially completed.

Develop and test a small portable ground station for remote testing. Partially completed.

Test the Windows version of the Ground Station program (ground end of the boot loader). Partially completed.

Important findings:

The two downlink frequencies we initially chose are too close together for some operational modes. New operational frequencies were chosen and have been submitted for coordination. [It is these new frequencies that are reflected in this paper.]

With the exception of two small problems found and corrected, the hardware was rock solid.

We were able to add two jumpers to the Integrated Flight Computer (IFC) board to connect the ‘valid’ tone signals from the CTCSS decoders to IFC I/O inputs. These can be sensed and used to activate the transmitters for FM repeater operation if desired.

We made modifications to the IFC to move the SQRX receiver to the second SCC port that is equipped with DMA. This will facilitate high speed digital uplinks, particularly on L-Band.

A large number of interrupts from receivers hearing noise continues to be a problem (as it has been on all 9k6 digital uplink satellites). A method was tested that completely solves this problem but precludes digipeating.

The amount of current drawn by the UHF transmitters falls off approximately linearly with the output power setting. However, even at a low setting the current is enough that judicious use of the transmitters will be necessary, including perhaps scheduling, CTCSS keying, low power, and/or power management software.

The Battery Control Regulator (BCR) function to reset the IFC when the battery voltage sags was not a good fit for this mission and was removed. The function that does a complete power cycle (including the IFC) when the battery is much lower was left in as a fail safe battery protection measure.

Issues:

The SSB uplink via the SQRX was garbled. This may be due to the close proximity of the transmitter. This will require further testing.

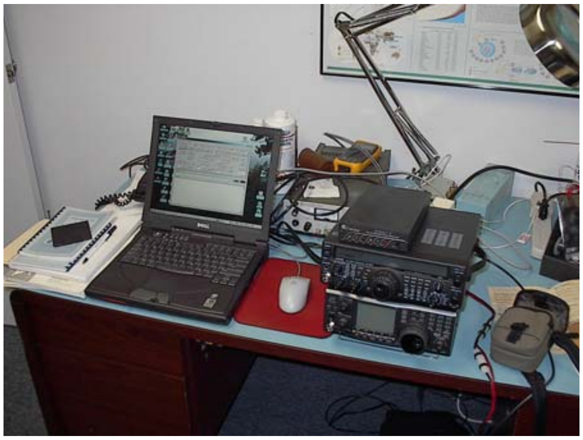

Figure 4: Photo by Mike Kingery KE4AZN's of his satellite station set up at SpaceQuest for RF testing with Echo. Great signals from across the room!

Some intermittent problems have shown up in transmitter power and CTCSS keyed operation when running in the boot loader.

Some false triggering of the CTCSS decoder was noted. It's unclear how that will effect operations or the power budget.

Action items:

Build the temperature decode software.

Test the RF links from a distance to get a more realistic test.

Perform calibration of torque rod feedback, transmitter power output, transmitter current draw, SQRX speaker and received signal strength indicator, BCR low voltage line current and 3.3V line current.

Fix the telemetry points that are not working.

Write and test torque rod automatic control.

Test and integrate final S-band transmitter hardware and test/calibrate telemetry points.

Test battery management flight software.

Write and test the transmitter CTCSS triggered keying software.

Test high speed data uplinks and downlinks.

Write and test BCR set point code.

Test SQRX 9,600 baud uplink.

Glue on reflector cubes. These are a new experiment that will facilitate laser tracking.

Test for reported variation in transmitter output power from boot loader.

Write and test battery current decode software.

Create the 'final' telemetry list and publish the results so all users can decode Echo's telemetry.

Create a free telemetry decoder program and make it available to the users.

Obtain and test a fully developed Ground Station program from Skip.

Get more time on all the hardware.

Finish the command software.

Complete and test a small portable digital ground station for remote testing.

Further test SSB up via SQRX.

Measure S-band power consumption.

Change the CTCSS decode tone, test.

Test the SQRX and VHF receiver-1 input lines and adjust the software (these lines had been switched).

Further test the digital uplinks without the frame search mode and with real antennas on the receivers.

An additional goal for Harold was to create software to utilize the flash memory for program storage.

POST INTEGRATION WORK

As this is written in mid-February work continues on the Echo satellite. Action items are getting resolved and the satellite is working very well.

The CTCSS tone has been changed to 67 Hz to make it the same as SO-50. Jim implemented software that samples the 'valid tone' line every second and keys the transmitter when it hears one. The hang time is 10 seconds. This is functionally equivalent to a terrestrial repeater with a kerchunk filter and a 10 second tail. This eliminates nearly all of the false triggering that was seen during integration testing. Among other advantages it will reduce power use.

Jim has found and eliminated several bugs in the flight software, mostly in the telemetry area.

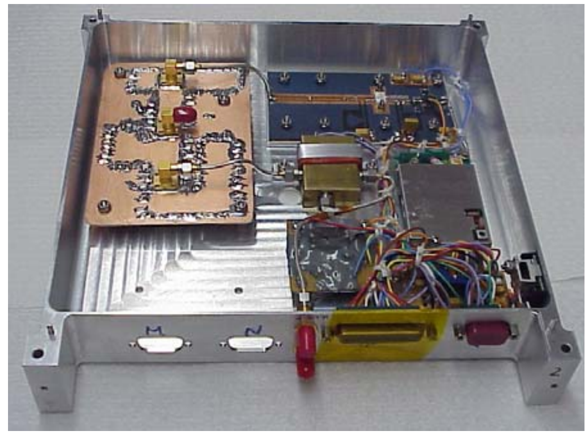

Figure 5: Echo's S-Band Flight Hardware. Chuck Schultz KE4NNF designed the exciter and Harold Sanderson KT4XK designed the power amplifier. Lou McFadin W5DID mounted wired the modules. Photo by Stan Wood WA4NFY.

An interaction between various modulator settings has been fixed. Each setting is now completely independent.

Mike has made significant improvements to the ground station command software and has started on the telemetry decoder. He added the tricky code for the temperature calculations and it works fine. We should be able to release the telemetry definition preliminary file soon, which will be done through the Echo Operations Committee.

Stan reports they are nearing completion on the final S-Band flight hardware.

Skip completed the last of the features in the Ground Station program.

The HF/2-meter signal splitter, RF switch and the active FET preamp have been finished and installed. These support the use of the SQRX on both L-Band and other bands, such as 10-meters.

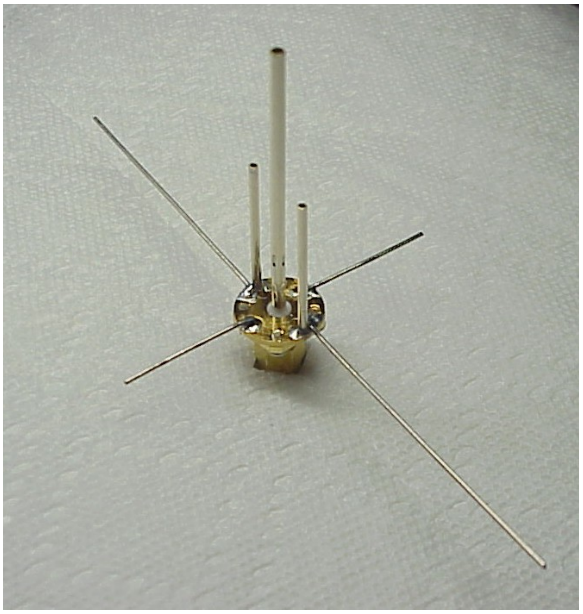

Figure 6: Dual band L-band and S-Band antenna designed by Stan Wood WA4NFY.

The dual band L/S antenna is finished. The L/S band antenna is shown in attachments. It is an open-sleeve design and works like a 1/4 wave stub on both bands. The center element works on L-band while the two stubs work on S-band. The entire antenna mounts on a male SMA flange mount connector. All parts are Gold or Silver plated brass. The screws are stainless steel. It looks like the radials on the L/S antenna will be 1/2 inch or more above the solar cells. As an additional precaution, SpaceQuest has decided to put cover glass on these cells.

LATE BREAKING NEWS

Stan has completed the design and construction of the splitter + preamplifier that will allow the 18 inch whip antenna to be shared by the SQRX multiband receiver as well as with the 2-meter uplink receivers. On Saturday February 14th an integration fit check was successfully performed to ensure that this new module will fit into the receiver tray, as it is mounted on the bottom of the Echo's top cover, directly above and extending into the receiver tray.

On Thursday, February 19th another fit check of the receiver tray was successfully performed, this time with all the modules including the splitter + preamplifier and the Digital Voice Recorder (DVR), which is a multi-board stack. This is the first time the DVR has been inside the receiver tray.

LAUNCH

Echo's launch is now planned for summer 2004. The launch will be on a Dnepr LV (SS-18) rocket from the Baikonur Cosmodrome in Kazakhstan.

VOLUNTEERS

Special recognition is due to the following for their contributions and support during the integration phase of the Echo project:

Jim White WD0E for his technical contributions, leadership skills and for the many hundreds of hours he has invested as the integration team leader. Jim's contribution cannot be overstated.

Mike Kingery KE4AZN for his on-site support of integration testing, including the loan of his satellite station, and for developing command and telemetry ground station software.

The SpaceQuest team has provided great support , especially Mark Kanawati N4TPY and Dr. Dino Lorenzini KC4YMG who are also AMSAT members and volunteers.

Harold Price NK6K, for his donation of the Spacecraft Operating System (SCOS) kernel and file system and for his on-site support during this effort.

Bob Diersing N5AHD, for his timely work on the boot loader.

Skip Hansen WB6YMH, for his efforts on the ground station software.

Chuck Schultz KE4NNF, Harold Sanderson KT4XK, Lou McFadin W5DID and Stan Wood WA4NFY for their work on the S-band transmitter and L/S band antenna system.

The AMSAT project management team for their help and assistance, especially Rick Hambly W2GPS and Dick Daniels W4PUJ.

David Bern W2LNX, for his assistance with the ground station hardware.

CONCLUSION

AMSAT OSCAR-E ("Echo") has continued to evolve and mature. Nearly all of its modules are built and undergoing testing. The software is working well and being refined. Initial system integration is complete and action items are being resolved.

By this summer the Echo satellite should be in orbit providing communications services to the Ham community and serving as a platform for testing new concepts in space communications.

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[1] "AMSAT OSCAR E, A New LEO Satellite from AMSAT-NA", AMSAT Journal, May/June 2002, pp5-11, Rick Hambly W2GPS

[2] "AMSAT OSCAR-E Project Status Update, A New LEO Satellite from AMSAT-NA", AMSAT Journal, November/December 2002, pp14-17, Richard M. Hambly W2GPS

[3] "AMSAT OSCAR-E Project Summer 2003 Status Report", AMSAT Journal, July/August 2003, pp11-14, Richard M. Hambly W2GPS

[4] "AMSAT OSCAR-E Project Fall 2003 Status Report", Proceedings of the AMSAT-NA 21st Space Symposium, October 2003, pp70-78, Richard M. Hambly W2GPS

[5] "AMSAT OSCAR E, A New LEO Satellite from AMSAT-NA", CQ/VHF, Summer 2002, pp13-20, Rick Hambly W2GPS

[6] "AMSAT OSCAR-E Project Status Update, A New LEO Satellite from AMSAT-NA", CQ/VHF, Winter 2003, pp12-13,72-74, Richard M. Hambly W2GPS

[7] "AMSAT OSCAR-E Project Summer 2003 Status Report", CQ/VHF, Summer 2003, pp14-16,80-82, Richard M. Hambly W2GPS