AMSAT OSCAR-E

AMSAT AO-E Project Team
Dick Daniels, W4PUJ – Project Manager
Rick Hambly, W2GPS
Tom Clark. W3IWI

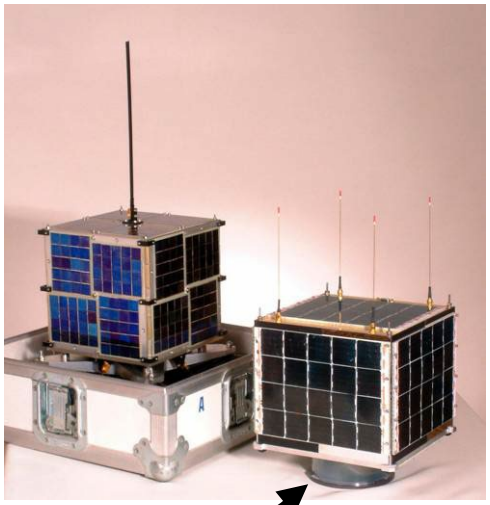
Report Presented by
Richard M. Hambly, W2GPS

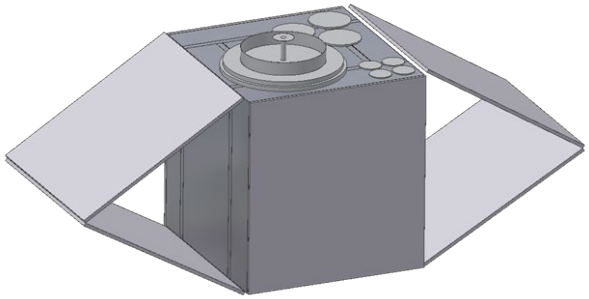
20th Space Symposium and AMSAT-NA Annual Meeting

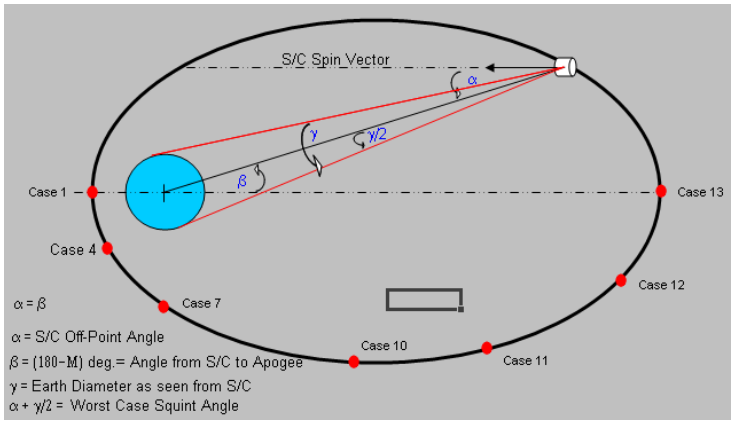
Saturday, November 9, 2002, 08:15 - 09:00 CST
Lockheed Martin Recreation Area (LMRA), Bryant Irvin Road, Fort Worth, TX

AMSAT OSCAR-E and "Eagle"

- **AMSAT OSCAR-E** is a new LEO satellite from AMSAT-NA.
- **"Eagle"** is a new HEO satellite being developed by AMSAT-NA.







AMSAT OSCAR-E (AO-E)

- AMSAT-NA is back in the satellite business!
  - » 12 years since AMSAT-NA built and launched the original Microsats, AO-16, DO-17, WO-18, and LO-19 in 1990.
  - » 8 years since AMRAD-sponsored AO-27 was launched in 1993.

- AMSAT OSCAR-E is a new Low Earth Orbit (LEO) satellite
  - » AMSAT is returning to the practice of designating LEO satellites by sequential characters. This was last done for AMSAT OSCAR-D, which became AMSAT OSCAR-8.
- Space and power are available for one or more optional payloads that will be provided by AMSAT volunteers.

AO-E Historical Background

- 08-Oct-01 BOD initiated review of “a new small satellite project.”
- 17-Jan-02: BOD unanimously approved the project. Project team is W4PUJ, W3IWI, and W2GPS.
- 08-Feb-02: AMSAT-NA entered into agreement with SpaceQuest.
- 20-Apr-02: BOD review at SpaceQuest. Launch set late ‘03.
- 05-May-02 Spring AMSAT-DC symposium - AO-E presentation.
- 18-May-02: Presentation at Dayton Hamvention AMSAT Forum.

The AMSAT Board, Project Team and SpaceQuest personnel 20-Apr-02

AO-E Historical Background

- May/June AMSAT Journal - Full details of the project.
- Summer 2002 CQ/VHF magazine – Full reprint of the Journal article.
- 7-Sep-02: Presentation at AMSAT Forum at Fall Fest 2002, Howard County Fairgrounds, West Friendship, MD.
- 5-Oct-02: Project review at SpaceQuest.
- Sep/Oct AMSAT Journal – Project update.
- 9-Nov-02: Presentation at AMSAT-NA 20th Space Symposium.
- Winter 2002 CQ/VHF magazine – Full reprint of the Journal article.

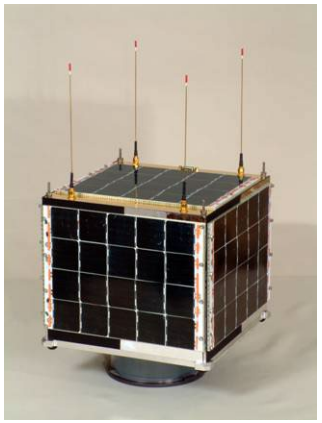
AO-E Introduction

- Microsat class spacecraft (~10 kg).
- Six (was five) solid aluminum trays stacked to form a 9.5-inch cube structure.
- Six solar panels, one on each side.

Dick Daniels W4PUJ at SpaceQuest 28_Feb-2002

- Antennas on top and bottom.
- Similar to original Microsats
  - » AO-16, DO-17, WO-18, LO-19
- Similar to the descendents of that legacy
  - » IO-26, AO-27, MO-30, SO-41.

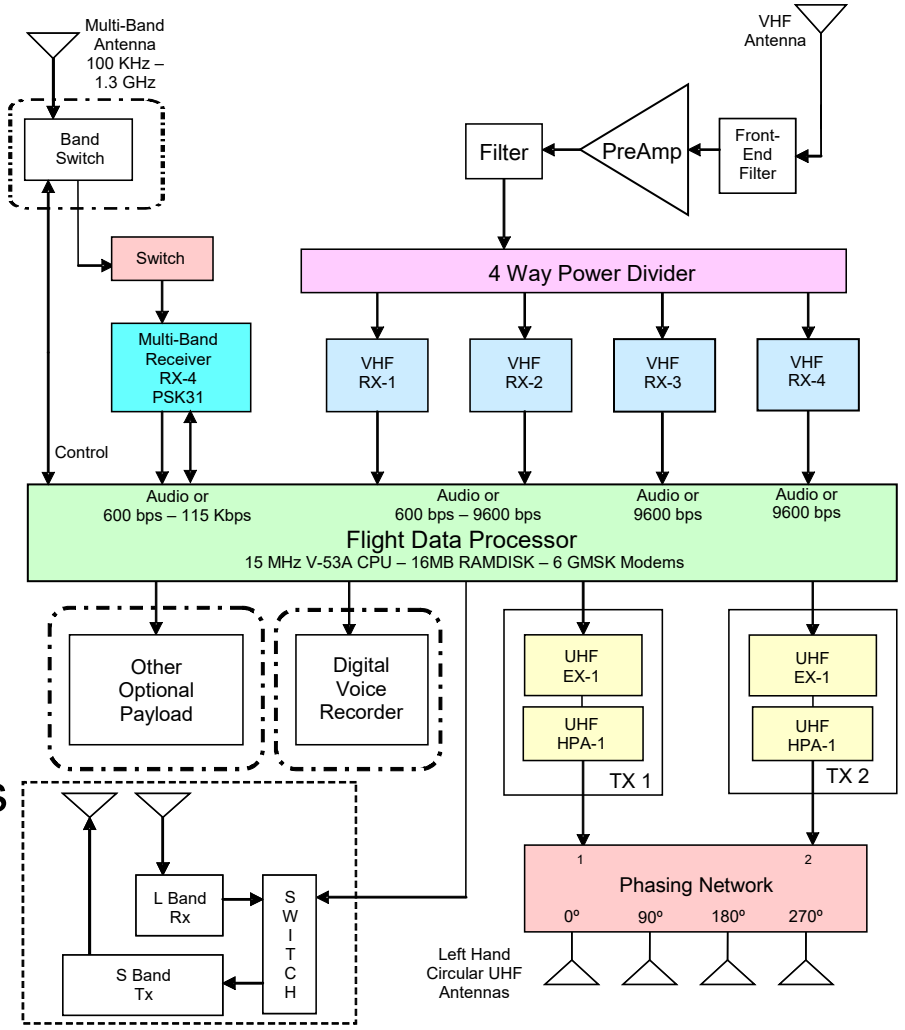
AMSAT OSCAR-E (AO-E) Summary



- Analog operation including FM voice.
- Digital operation including high speed APRS.
- High downlink power.
- Multiple channels using four Rx and two Tx.
- Can be configured for simultaneous voice and data.
- Has a multi-band, multi-mode receiver.
- Can be configured with geographically based personalities.
- Has a true circular UHF antenna
  - » Maintains its circularity over a wide range of squint angles.
- High data rates on downlinks, up to at least 56Kbps.
- Advanced power management system.
  - » Autonomous, self-healing, high efficiency.
- Store and forward
  - » Continuous monitoring and geographically defined data forwarding.

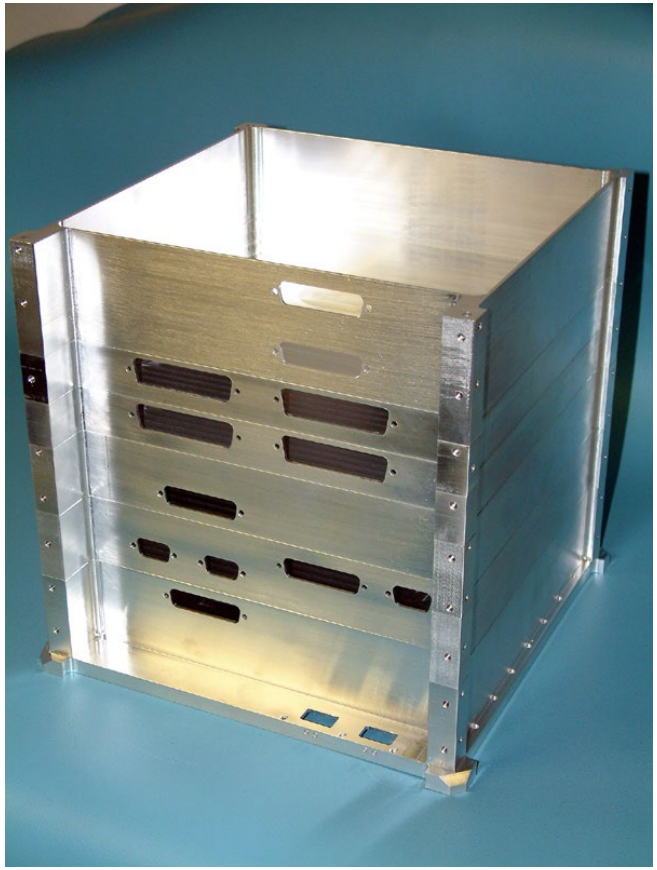
AO-E Block Diagram

- Four VHF receivers
- One Multi-Band Multi-Mode Rx
- Two UHF transmitters
- Six modems
- Flight computer
- RAM disk
- Batteries
- Battery charger and regulators
- Wiring harness
- RF cabling
- RF switching and phasing networks
- 56 channels of telemetry
- Magnetic attitude control



AO-E Status Update
Structure

- The physical structure
  - Receiver tray: 58mm with 2mm base.
  - CPU tray: 24.8mm with 2mm base.
  - Charger tray: 24.8mm with 2mm base.
  - Battery tray: 38mm with 2mm base.
  - Payload tray: 58mm with 2mm base.
  - Transmitter tray: 39mm with 9mm base.
- One empty module for AMSAT payload. 200 x 220 x 56mm.
  - Trays available by end of year.
  - This will allow AMSAT to do payload integration at that time.



AO-E Status Update
RF Subsystems

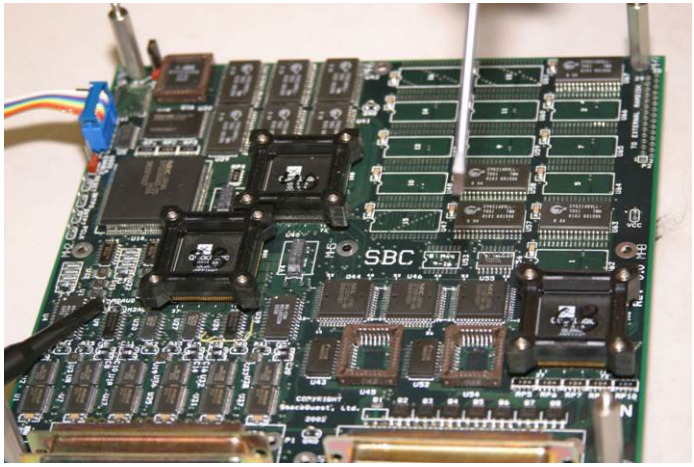
- Receivers
  - » Four miniature VHF FM receivers (<40 mW and <50 gm each).
  - » Each receiver has 2-channel capability.
  - » Sensitivity is -121dbm for 12db SINAD.
- Transmitters
  - » Two UHF FM transmitters that can be operated simultaneously.
  - » 7-12 watts output each.
  - » Frequency agile in 20 or 35 KHz steps, tunable over about 20 MHz.
- Wideband Receiver
  - » All-mode, “DC to Light”. Performance limited by broadband antenna.

AO-E Status Update
RF Subsystems

- Antennas.
  - VHF 18” whip on top.
  - UHF Turnstile on bottom. Currently LHCP. Might change.
  - L and S band whips on bottom.
  - Broadband HF/VHF/UHF 18” whip on bottom. Design issues remain.
  - The design is still open within the constraints of the solar panel layout. It is now possible to put antennas in any corner or in the center of any panel on the satellite.
- Link Budget
  - Tx’s adjustable from 1 to 12 Watts with max efficiency at 8 Watts.
  - Modulation is GMSK at any speed from 300 to 56K baud.
  - Antenna gains average about 0dbi. (-10dbi to +2dbi).
  - VHF antenna feeds a BPF with 1.5db loss, then an LNA with 1db NF. Thus, overall Rx performance is -123 dbm for 12db SINAD.

AO-E Status Update
Central Processor

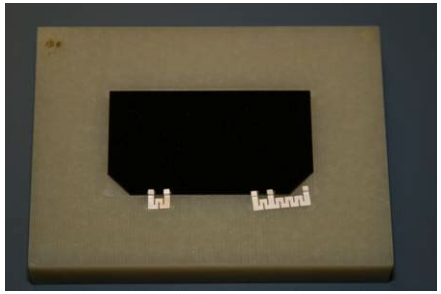
- Central processor hardware
  - » Will have improved Integrated Flight Computer (IFC) recently developed by Lyle Johnson KK7P.
  - » Two CTCSS decoders.
  - » Audio recorder for WB Rx.
  - » Available for AMSAT testing by Jan.
  - » A prototype CPU is running now.

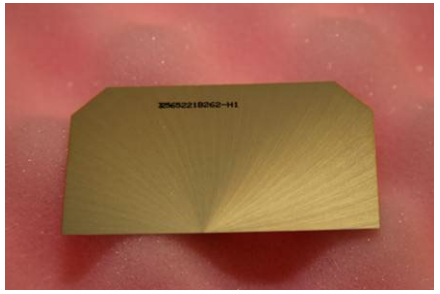


- Spacecraft flight software
  - » The Spacecraft Operating System (SCOS) has been used on all of the Amateur Radio Microsat projects to date.
  - » Harold Price continues to allow AMSAT to use SCOS in AO-E.
  - » Bob Diersing N5AHD has agreed to update the boot loader SW.

AO-E Status Update
Power generation and distribution

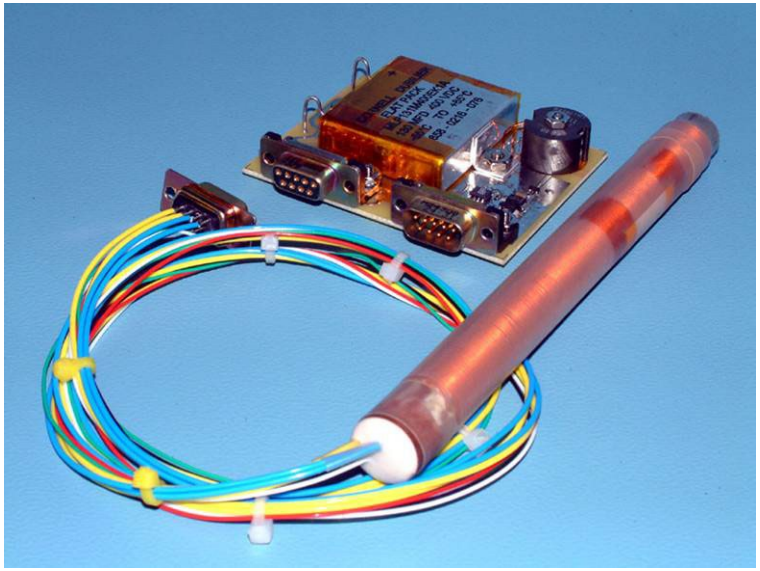
- Six high efficiency Solar Panels
  - » Triple junction MCORE GaAs cells (~27%).
  - » Total power about 20 Watts when not in eclipse (12-14 Watts per side).
- Battery Control Regulator (BCR)
  - » autonomous, fail-safe.
  - » Operates at 50KHz with 89% efficiency.
- Matched set of six NiCd cells, 4.4 Ah each, nominal 8 VDC.





AO-E Status Update
Other Subsystems

- Attitude control
  - » Active magnetic attitude control has replaced passive system.
  - » Doug Sinclair VA3DNS has implemented the torquer rod with electronics.
  - » Subsystem is at SpaceQuest for testing.



- Ground Control Software
  - » Bootloader
  - » Housekeeping program
  - » Telemetry Gathering and Reporting program.
  - » All need to be written or re-written by AMSAT volunteers!

AO-E Space for Optional Payloads

- Advanced Data Communications for the Amateur Radio Service (ADCARS)
- L-Band/S-Band Communications System
- Robust Telemetry Link
- GPS Receiver
- ☑ Active Magnetic Attitude Control
- ☑ Audio Recorder Experiment
- Low Frequency Receiver
- APRS
- PSK-31
- Multi-band Receiver/Antenna
- ☑ High Efficiency Solar Arrays

Advanced Data Communications for the Amateur Radio Service (ADCARS)

Apply digital encoding techniques to improve communication links and bandwidth utilization.

- Wide-band TDMA single frequency data link for multiple simultaneous users and modes.
  - » voice, data, video, telemetry, etc.
- S-band downlink, due to bandwidth requirements.
- L-band uplink.
- Optional signal regeneration.
- Optional integration with on-board systems.
  - » File transfer
  - » Telemetry
  - » Data communication
  - » MPEG recordings

Channel capacity:

$$C = B\log_2\left(1+\frac{S}{N}\right)$$

where:

C = channel capacity, bits/sec

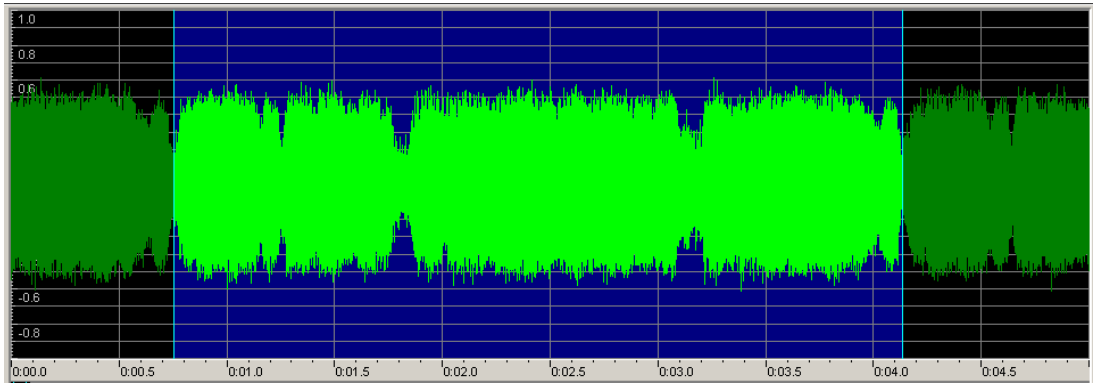
B = channel bandwidth, Hz

S = signal power, W

N = noise power, W

Robust Telemetry Link
Proposal for a FEC-Coded Telemetry Link

With FEC the bits corrupted in a fade can be regenerated from the others that are received. It doesn't matter how deep the fades are, as long as most of the frame gets through



AO-40 S-band telemetry as received by W2GPS and WB4APR using the 12-meter dish at the US Naval Academy on January 18, 2001. The time span is 3.38 seconds, the spin period at that time.

A short, deep fade that causes a single bit error is enough to destroy an entire frame even if the average Eb/No is high. AO-40's 11-second frame has multiple deep fades when the antennas are not earth-pointing so every frame is almost guaranteed to have at least one bit error.