AMSAT AO-E Project

Spring 2003 Status Report

Presented by
Richard M. Hambly, W2GPS

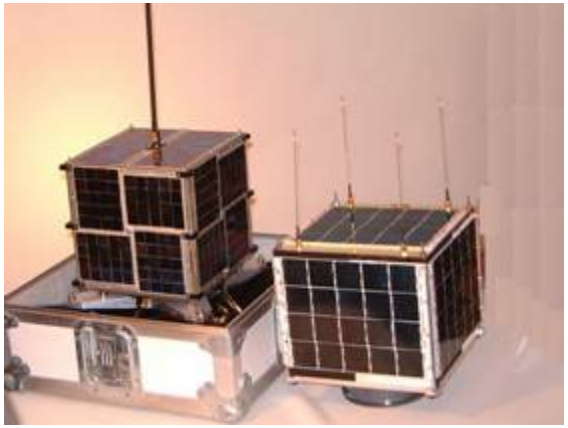
AMSAT Forum - Hamvention 2003

Saturday, May 17, 2003, 08:15 - 09:45 EDT
HARA Arena Complex, Room 1
Dayton, Ohio

In memory of the Space Shuttle Columbia and her crew, lost on February 1, 2003.

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
- Space and power are available for 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.

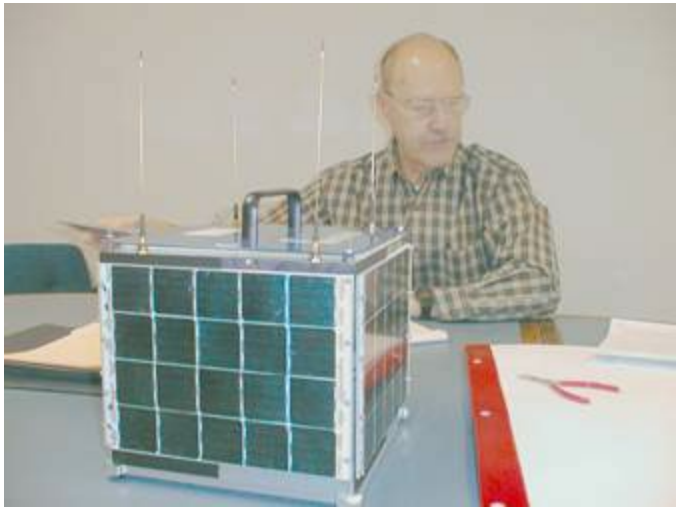
The AMSAT Board, Project Team and SpaceQuest personnel 20-Apr-02

AO-E Historical Background

- AMSAT Journal, May/June 2003
- Summer 2002 CQ/VHF magazine
- 7-Sep-02: Fall Fest 2002, Howard County Fairgrounds, MD presentation.
- 5-Oct-02: Project review at SpaceQuest.
- Sep/Oct AMSAT Journal
- 9-Nov-02: AMSAT-NA 20th Space Symposium presentation.
- Winter 2002 CQ/VHF magazine
- 04-May-03 Spring AMSAT-DC symposium presentation.
- 17-May-03: Dayton Hamvention presentation.

AO-E Introduction

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

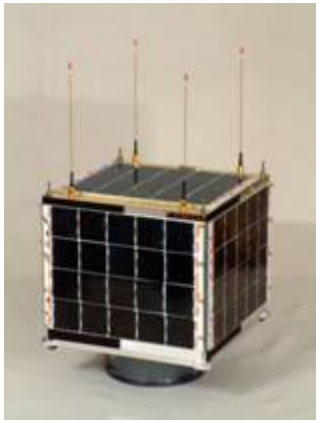


Dick Daniels W4PUJ at SpaceQuest 28_Feb-2002

- 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

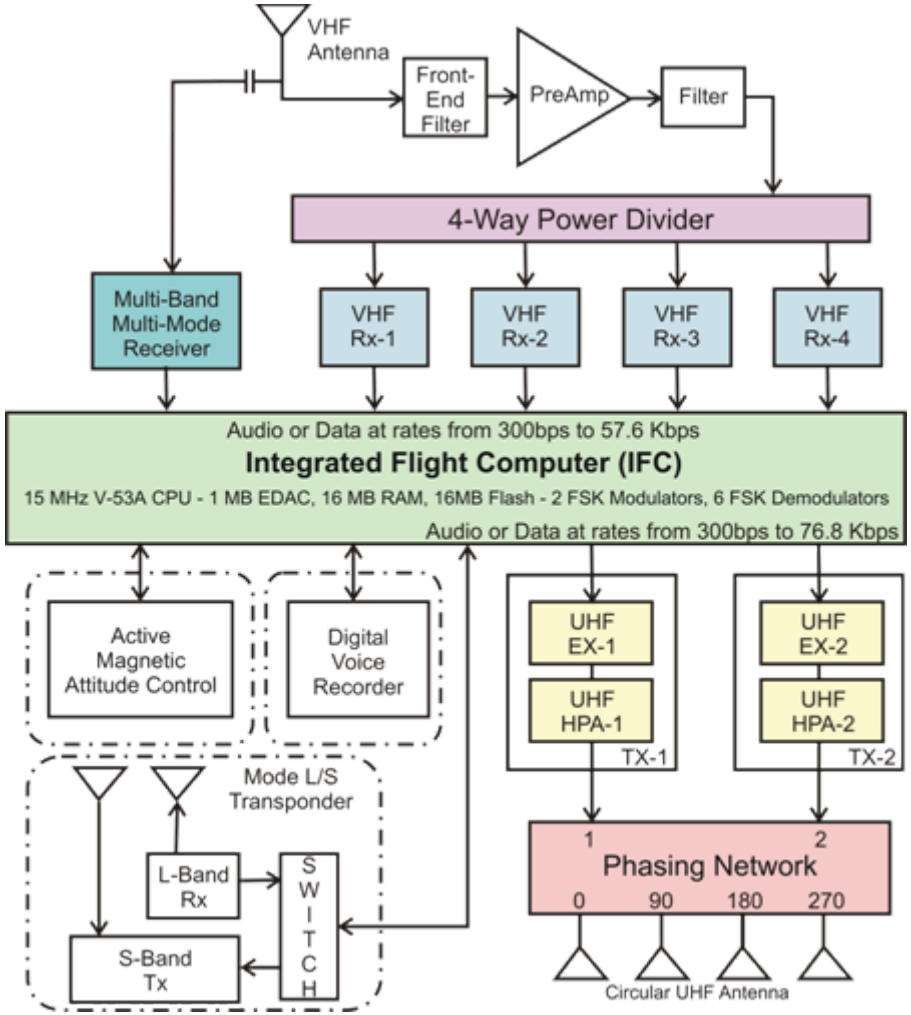
- Mode V/U, L/S and HF/U Operation
  - » V/S, L/U and HF/S are also possible
- Analog operation including FM voice.
- Digital operation
  - » Many speeds possible,
    9.6, 38.4 and 57.6Kbps most likely.
  - » Store and forward



- Four VHF Rx and two UHF high power Tx.
- 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.

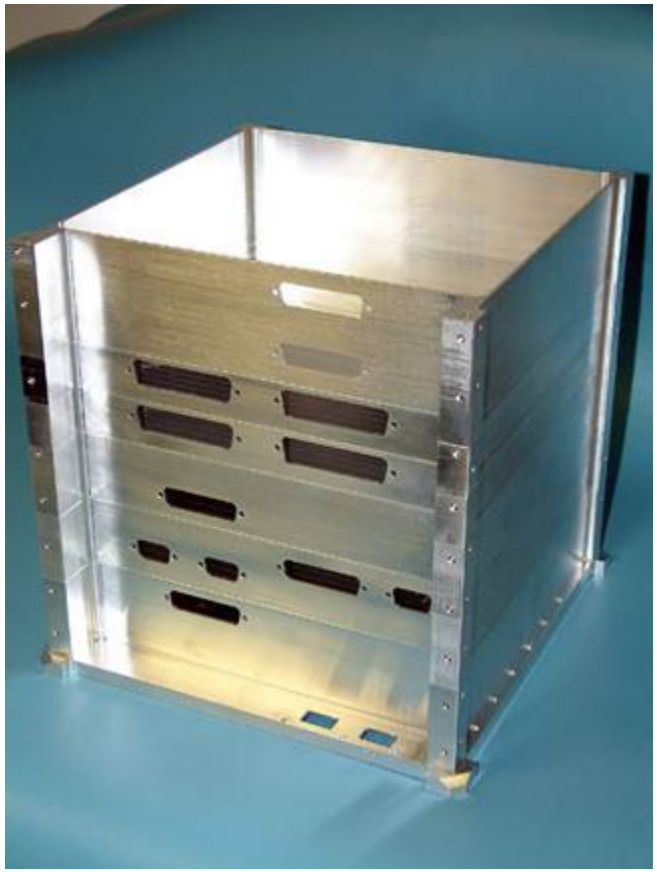
AO-E Block Diagram

- Four VHF receivers
- Multi-Band Multi-Mode Rx
- Two UHF transmitters
- Six modems
- Flight computer w/ RAM disk
- Batteries, BCR, Regulators
- Wiring harness, RF cabling
- RF switching and phasing networks
- 56 channels of telemetry
- Magnetic attitude control



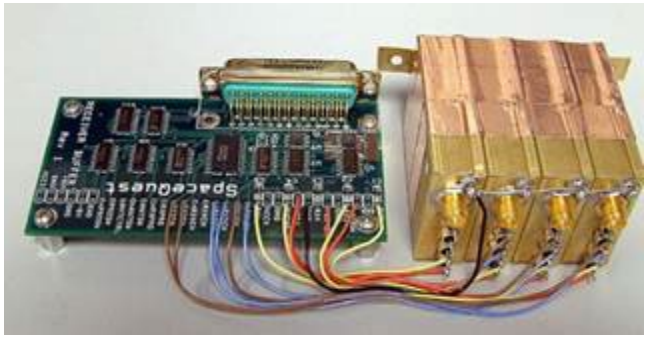
AO-E Status Update
Structure

- Trays are made from solid blocks of 6061-T6 aluminum, stacked with stainless steel sheer pins and 4 4-40 tie-down rods.
  - » 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.
- Overall 9.5” x 9.5” x 9.5”.

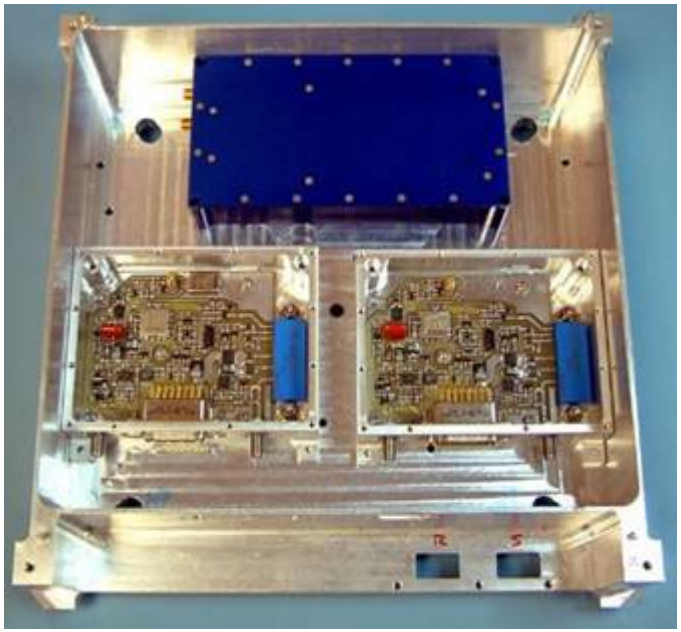


AO-E Status Update
RF Subsystems

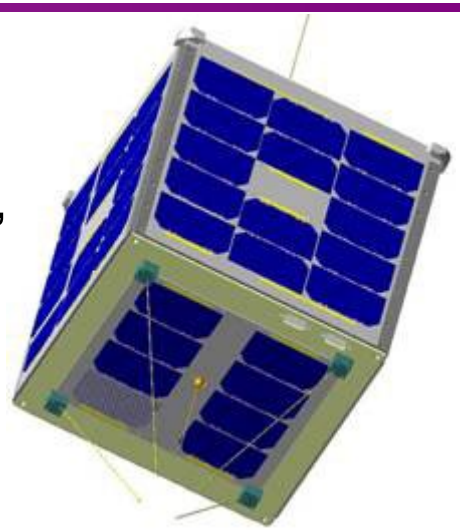
- Receivers
  - » Four miniature VHF FM receivers (<40 mW and <40 gm each).
  - » Each receiver has 2-channel capability.
  - » Sensitivity is -121dbm for 12db SINAD.



- Transmitters
  - » Two UHF FM transmitters that can be operated simultaneously.
  - » 0-8 watts output each.
  - » Frequency agile in 2.5KHz steps, tunable over about 20 MHz.
- Multi-band Receiver
  - » All-mode, 10m, 2m, 70cm and 23cm.
  - » Performance limited by broadband antenna.

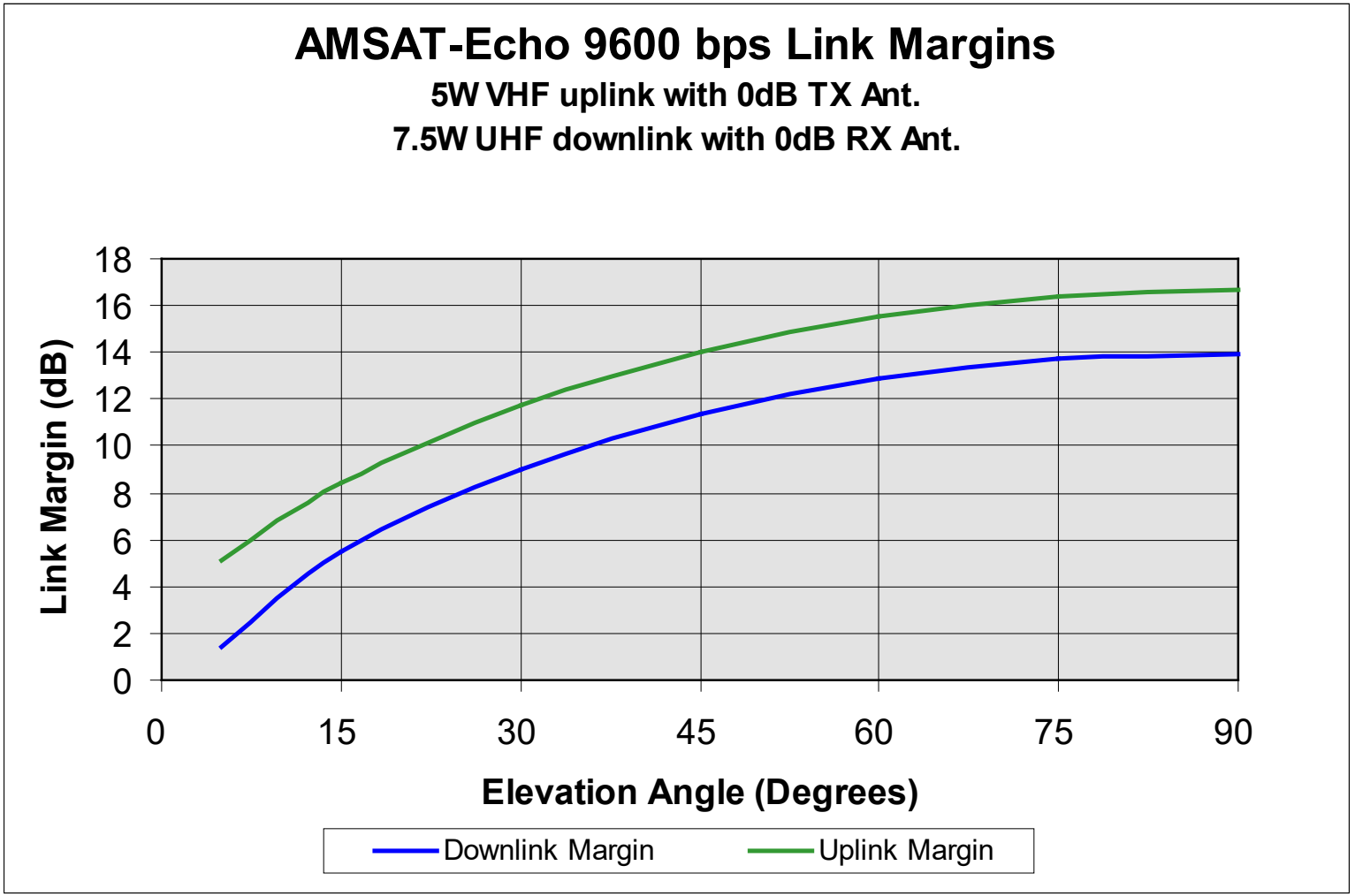


AO-E Status Update
RF Subsystems



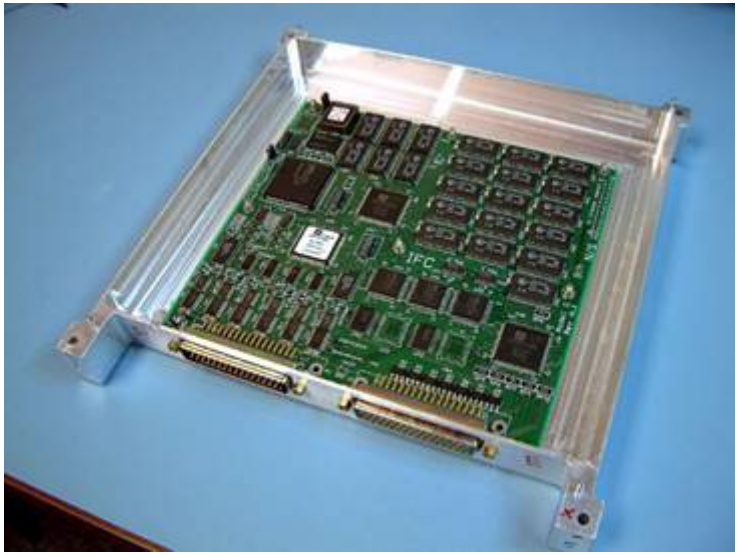
- Antennas.
  - VHF 18” whip on top.
  - UHF “Mary” Turnstile on bottom. One Tx RHCP, the other LHCP.
  - L+S band “open sleeve” antenna on the bottom.
  - Multi-band Multi-Mode Rx shares VHF whip.
- Link Budget
  - Tx’s adjustable from 1 to 8 Watts; max efficiency at 6 Watts.
  - Modulation is baseband shaped raised-cosine-in-time FSK. Many speeds possible, 9.6, 38.4 and 57.6Kbps most likely.
  - Antenna gain on the UHF is +2 dBic at +/- 45 degrees to -6 dBic at the backside of the spacecraft.
  - VHF ant feeds LNA with 0.7db NF and 20db gain, then BPF with 1.5db loss. Overall Rx perf. -125 dbm for 12db SINAD.

AO-E Status Update
Link Margins



AO-E Status Update
Central Processor

- Integrated Flight Computer (IFC)
  - » Developed by Lyle Johnson KK7P.
  - » Flight proven, low-power < 300 mW,
  - » 6 Rx and 6 Tx SCC channels
  - » 1 MB EDAC, 16 MB RAM,16MB flash
  - » 6 agile demodulators
  - » 2 agile modulators



- Spacecraft flight software
  - » The Spacecraft Operating System (SCOS) has been used on all of the Amateur Radio Microsat projects to date.
  - » Harold Price NK6K continues to allow AMSAT to use SCOS.
  - » Bob Diersing N5AHD has agreed to update the boot loader SW.

AO-E Status Update
Software Status Report

- SpaceQuest has provided hardware.
- Test version of boot loader complete.
  - » First step to enable the rest of the software effort. ~25% done.
- SCOS kernel port has started.
  - » Enhancements to drivers and supporting software being discussed.
- Windows command & telemetry program ~50% complete.
- Housekeeping task created and we are setting up to test it
- Windows based boot loader prototype done.
- Communication protocol for DVR-IFC is documented.

This is a summary of work by
- Bob Diersing, N5AHD
- Jim White, WD0E (Lab above)
- Harold Price, NK6K
- Lyle Johnson, KK7P
- Skip Hansen, WB6YMH

AO-E Status Update
Power Generation

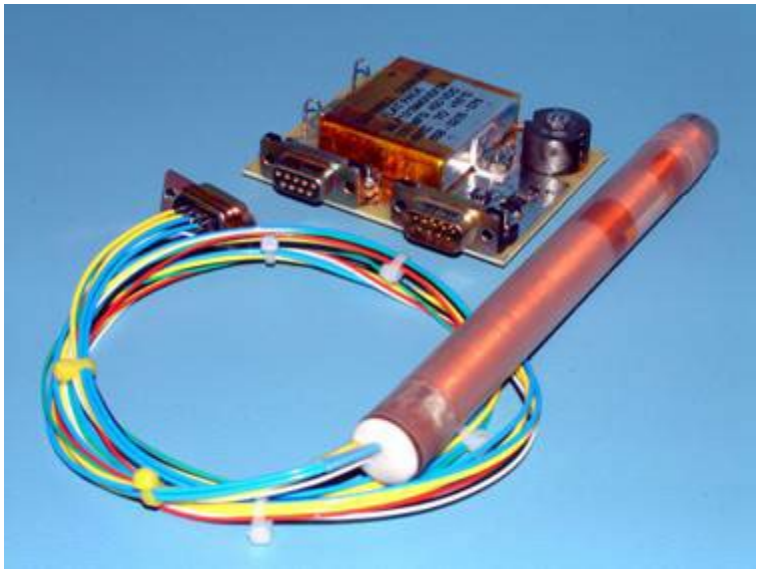
- Six high efficiency Solar Panels
  - » Triple junction MCORE GaAs cells (~27%).
  - » About 20 Watts when not in eclipse (12-14 Watts per side).

Mark Kanawati N4TPY carrying $20,000 worth of solar cells and sooo casually spreading glue all over ☺

AO-E Status Update
Power Distribution

- Battery Control Regulator (BCR)
  - » Autonomous, fail-safe.
  - » Operates at 50KHz with 89% efficiency.
  - » Keeps the spacecraft alive at all costs.
  - » Charges the battery using only solar panel power, so will charge a dead battery.
  - » Prevents the battery from overcharging or depleting completely at any temperature and provides the necessary voltages and telemetry.
- Matched set of six NiCd cells
  - » 4.4 Ah each, nominal 8 VDC.

AO-E Status Update
Other Subsystems



- Attitude control (Experimental)
  - » Active magnetic attitude control has replaced passive system.
  - » Doug Sinclair VA3DNS has implemented the torquer rod with electronics.
  - » Semi-permanent magnetic rods who's strength and polarity can be adjustable over a period of 15 seconds. (15 seconds give us maximum charge).
  - » It's possible to turn the satellite upside down.

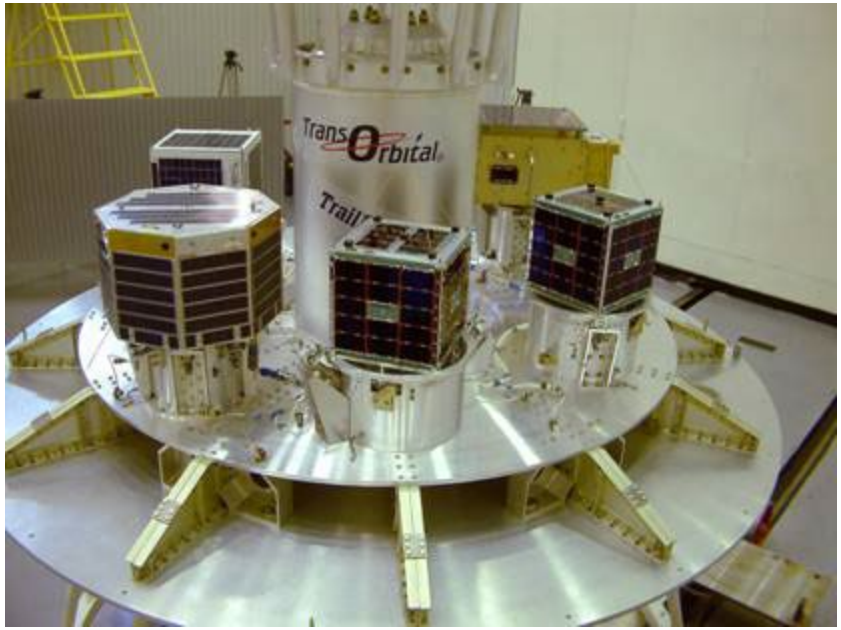
AO-E Status Update Integration

NASA Goddard Space Flight Center has returned the AMSAT Integration Lab to us!

- Thanks to Ron Parise WA4SIR and the GARC.
- Needs roof and floor repair.
- Furniture and test equipment will be provided.

AO-E Status Update
Launch

Launch planned for Oct 2003 or May 2004



Two AprizeStar satellites by SpaceQuest ready for launch. These are very similar to AO-E.

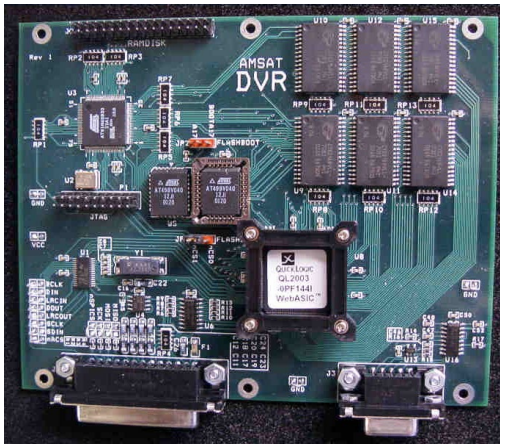
Dnepr LV (SS-18) launch from Baikonur Cosmodrome in Kazakhstan, Dec 2002

AO-E Space for Optional Payloads

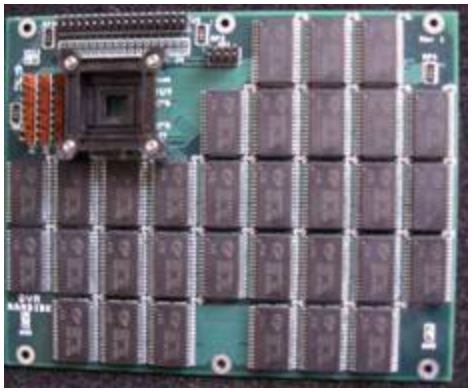
- Advanced Data Communications for the Amateur Radio Service (ADCARS)
- ☑ L-Band/S-Band Communications System
- Robust Telemetry Link
- GPS Receiver
- ☑ Active Magnetic Attitude Control
- ☑ Digital Voice Recorder (DVR)
- Low Frequency Receiver
- APRS
- ☑ PSK-31
- ☑ Multi-band Receiver/Antenna
- ☑ High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

Digital Voice Recorder (DVR)

- Multi-channel digital recorder.
- Samples audio from a selected receiver output at 16 bits/48 kHz.
- Can playback on either downlink.
- Has up to 64MB of RAMdisk storage, providing almost 12 minutes recording time.
- Based on the same ARM7 processor planned for use in the IHU3 for upcoming high-orbit missions.



CPU



1 of 4 RAMDISK Boards

Advanced Data Communications for the Amateur Radio Service (ADCARS)

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

- Multi-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

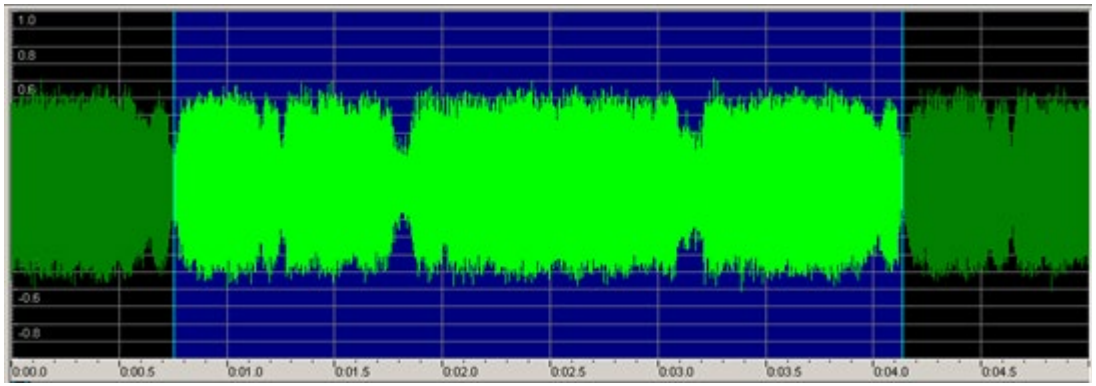
B = channel bandwidth, Hz

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.