Microsat Design
What Do People Want?
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As AMSAT-NA returns to the business of satellite construction it appears that the world around us has changed significantly. But in some very important ways our world has not changed much at all. The following are my observations and suggestions.

PROBLEMS I SEE

After months of searching for qualified and motivated leaders and developers for AO-E's optional payloads without much success, I observed these same types of people joining up with AMSAT-DL's Mars program and flocking to build CubeSats.

BACKGROUND

In January 2001 KA9Q presented a radical new proposal for a wideband digital communications pipe that would finally allow for practical use of the bands above 1GHz on LEO satellites, without the need for high performance Doppler tracking. The AMSAT-NA Board endorsed the concept and encouraged further.

In July 2001 AMSAT-NA hosted a meeting of the new Project Committee in Denver CO. The goal was to decide on the design parameters for "Eagle" and discuss emerging technologies. The result was a conservative design with spin stabilization, Mode U-L/S linear transponder, Mode L/S wideband digital transponder, and a GTO orbit requiring no (or very little) propulsion.

In January 2002 AMSAT-NA also approved building a Microsat class LEO satellite. This satellite could be launched much sooner that "Eagle" and would provide a successor to AO-27. To get a reliable design built on a rapid schedule AMSAT-NA approved having the satellite built by our friends at SpaceQuest. This also provided a tray for our builders to add whatever new feature they desired and a variety of proposals were evaluated.

In April 2002 the AMSAT-NA Board voted to extend the AO-E launch schedule to late 2003. This was done, in part, to give the builders more time to get an optional payload on the satellite.

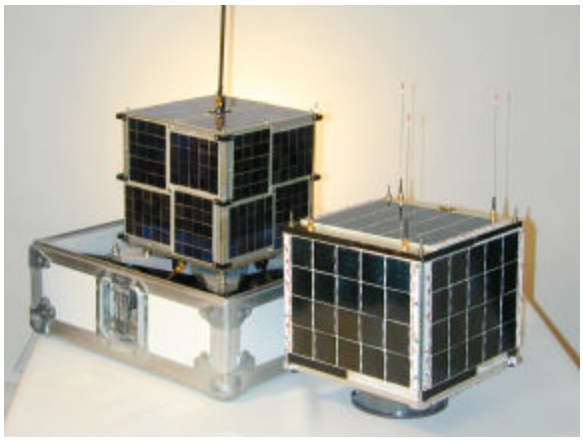

Figure 1: Microsat and AO-E

THE USER COMMUNITY

As soon as they were announced, users began expressing their opinions about the features they want to see in the new satellites. These users tend to fall into a few broad groups with different perceived needs.

EasySat Users

EasySat users are generally categorized by those with simple antennas and one or two HandieTalkies operating FM voice on the 2-meter and 70-cm bands.

Figure 2: EasySat User

For the most part these users seem quite pleased by AO-E's core design, which can support two simultaneous high power Mode V/U FM voice channels.

Linear Transponder Users

Linear transponder users are generally characterized by base stations with computer tracking, 2-meter and 70-cm beams on a Yaesu Az-El rotor with computer steering. Many of these stations have added Mode-S receive antennas and some have added Mode-L transmit antennas to their antenna arrays.

Some of these users have expressed disappointment in AO-E because the core package offers nothing of interest to them and none of the optional payloads offer a traditional Mode-B or Mode-J linear transponder.

These users who are waiting for "Eagle" and many of them see AO-E as an irritant that will only serve to delay the launch of "Eagle".

APRS Users

APRS users are generally characterized by 2-meter mobile and portable operation using 1200 or 9600 baud AFSK. A few of these stations are dedicated base stations with sophisticated software to monitor the various LEO satellites as they pass over and route any APRS packets they hear to the Internet (IGATE stations).

These users see nothing interesting in the "Eagle" project. They are generally dissatisfied with AO-E because they want to reverse transmit and receive bands (Mode-B instead of Mode-J). This would improve the link budget for these stations that usually have plenty of power but have marginal receive capability. It would also eliminate desensitization of their 70-cm receivers by the harmonics of their 2-meter transmitters.

Users with Limited Capabilities

These are users that generally cannot set up home stations because of restrictive covenants, living in rental property, apartments and condominium dwellers, etc. These users sometimes belong to AMSAT just so they can receive the Journal and support AMSAT. Many of these users compensate by becoming part of the builders group or by operating in one of the mobile/portable categories.

Many of these users would benefit from implementation of the wideband Mode L/S communications system proposed by KA9Q but, surprisingly, there has not been a groundswell of support from this group yet. Many simply don't understand the concept.

BUILDERS

AMSAT's builders group includes those that design, construct, test, launch, control and experiment with the satellites. AMSAT's builders have traditionally been an independent

group of scientists, engineers technicians and others who build what they want, each using their own personal style. Builders, as defined here, don't actually have to build anything. Some are idea people, others do conceptual design and others do post-launch analysis.

Many of these people do not even have a satellite station at home but when they do the stations tend to be very sophisticated.

The builders tend to work behind the scenes. Most don't check into nets, operate DX on the satellites or send messages on AMSAT-BB. They are most visible at events like Board meetings and the AMSAT Annual Meeting and Space Symposium.

Most of the builders view their involvement as "professional" even though they are volunteers. Some of the most prolific have used their amateur satellite involvement as a springboard for real professional activities.

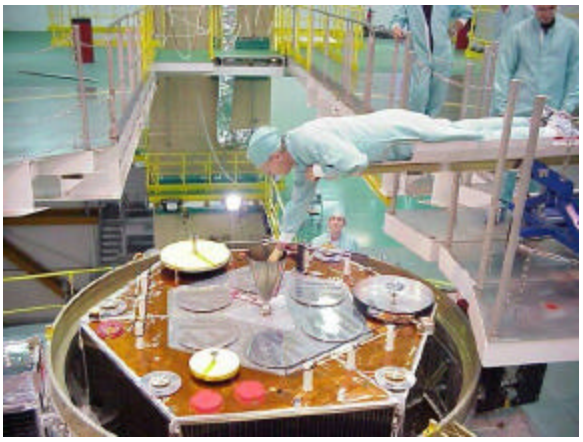

Figure 3: Motivation

So what do the builders want? The two things that seem to be of greatest importance are technical challenge and/or recognition. For example, when AMSAT-DL proposed a mission to Mars AMSAT-NA builders started lining up to get on the team. It matters not that none of the people in the users groups will ever hear the signals from this spacecraft. It is a huge and worthy challenge, and that's enough!

I have not observed that same level of enthusiasm for AO-E and "Eagle". Why? Perhaps it is because these satellites pose few interesting new challenges.

Another characteristic common to many of our builders is that they are an aging group. They are a decade older than when they built the original Microsats. Certain of their skills show signs of age, too, especially in areas like software and wideband communications techniques. There are very few new young builders in AMSAT but there are young builders out there, as has recently become evident at the 16th Annual AIAA/USU Conference on Small Satellites held in August 2002 at Utah State University. Many of them just haven't been introduced to Ham Radio. Unfortunately many of these people don't fit the mold of classical amateur radio at all. They maybe get a license just to be able to fly their satellite. Thus, the interest shown by some universities in building and launching satellites can be both a challenge and an opportunity for AMSAT.

I have also learned that some builders place a high value on AMSAT's Area Coordinators and "Elmers" as an interface with the general membership and others, allowing the builders to focus on their tasks.

GENERAL MEMBERSHIP

The one characteristic common to the general membership and other onlookers is their demand for a complete, honest, and timely flow of information. This is especially true if the news is bad.

When there is even a slight delay, the result is a perception that "they" are keeping something important from "us". This attitude is infectious and invariably negative.

The advent of the Internet has enabled everyone to become an instant critic. Some feedback is good, some degerates into tangents, some is downright counterproductive and some even exhibits blatant violations of the laws of physics. Most of the builders ignore the feedback because S/N is so poor.

It has been noticed that many of those who complain the loudest are not even AMSAT members.

TECHNICAL CONSTRAINTS AND OTHER CHALLENGES

Every year the advances in technology have enhanced our ability to put more features in less space than ever before. Unfortunately, commercial interests have discovered the same thing and what was once a free ride as ballast replacement is now a muti-million dollar cost driver for our projects.

Software is becoming more important than ever. We can now implement modems using sound cards and DSP software, which is driving TNC manufacturers out of business. But how many of us understand modern techniques of software development or the mathematics needed to grasp DSP and coding theory?

Colleges and universities around the world have recognized these facts and have changed their curriculums to accommodate. For example, Cornell University first started a small Computer Science department as a joint venture between the Engineering and Liberal Arts Colleges. Now the Computer Science department has merged with the Electrical Engineering School to become the School of Electrical and Computer Engineering. But traditional skills essential to developing a satellite like RF, analog and digital design, are getting harder to find.

WHAT'S WRONG?

AMSAT-NA is trying to be responsive to the perceived needs of the average user while being realistic about what it will take to get at least one satellite launched soon. This is considered essential to rebuild our image and membership roles following the problems with AO-40.

These goals, while well motivated, overlook two realities that have, in the past, driven the development of our satellites – a real launch opportunity with a fixed schedule and the desire of the builders to build. All AMSAT-NA's past successful missions have grown from a launch capability and opportunity. Because of commercialization, launches for small satellites have become more and more rare and costly, and we compete with DoD, Universities and commercial entities for launch opportunities.

In the case of AO-E we believe we have that launch opportunity but it needs to be firmed up. In the case of "Eagle" we don't know how and when it will get launched.

Providing motivation to the builders is much more difficult. I am hoping that by reconsidering some of our design parameters for both AO-E and "Eagle" we can create the kind of technical challenges that will bring the builders to the design table.

In addition we face challenges to our frequency spectrum from commercial, industrial, defense and other scientific users. We also face challenges on the regulatory front, especially in the area of space debris mitigation, that could drive the cost of launching satellites beyond our reach.

MY RECOMMENDATIONS FOR AO-E

The following changes to the AO-E design are proposed with the goal of creating a LEO platform that is an ideal transition between the past, present and future technologies. The core

platform being built by SpaceQuest is already well suited for this mission and all of these changes can be accommodated by this platform if AMSAT can provide motivated builders to make it happen.

A) Reinstate the gravity gradient boom stabilization. Find a way to ensure that it stabilizes right side up. This will make it so AO-E will always point down with an accuracy of about 5 degrees.

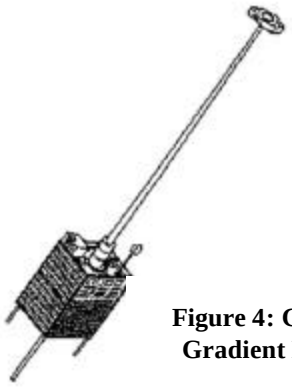

Figure 4: Gravity Gradient Boom

With this improvement the satellite will be equally effective in either hemisphere and will be able to support high gain antennas creating a potentially huge savings in power consumption.

B) Design new FM transmitter and receiver modules so we can switch to UHF uplinks and VHF downlinks.

In this configuration the transmitters could be optimized for 1-2 watts instead of the current 7-12 watts, improving our power profile.

While this frees the users from most cross band interference and desensitization issues, it creates those issues for the satellite designer. Perhaps it's best to solve these issues once on the satellite rather than forcing every user to solve them individually.

C) Add a Mode B Linear transponder sharing antennas with the FM receivers and transmitters.

This capability would give support to the traditional SSB/CW user. This mode will support the most simultaneous users in the near term and will provide some real opportunity for chasing DX.

D) Build the Mode L/S transponder and a high speed modem to support development of the wide band technology as proposed by KA9Q.

Wide band technology is needed to support practical use of the microwave bands on LEOs. There are many challenging issues here that could be the subject of an entire paper. This is truly the future for LEOs.

E) Implement encoding for AO-E's digital downlink channels. The coding should be optimized to compensate for the various types of noise and fading that can occur on a satellite link, for both normal and abnormal conditions. If possible, the coding should also enhance the link margin through coding gain. The solution will likely be some combination of Forward Error-correcting Codes (FEC) and interleaving.

Use AO-E to prove that all telemetry and command downlink channels on all future satellites should be encoded for maximum performance at minimum power.

MY RECOMMENDATIONS FOR "EAGLE"

The most significant challenge for "Eagle" is to achieve a favorable orbit regardless of the launch opportunity. To optimize the usefulness of this high flying satellite this is probably not a GTO orbit.

1) Plan to go to a useful and interesting orbit. I propose that we consider one of three interesting orbits, the standard Molnya orbit, a geosynchronous orbit, or a high Molnya orbit now used by the Sirius system[1].

The high Molnya orbit would keep “Eagle” above the Van Allen radiation belts. Admittedly, it takes lots of energy to get there, but I didn't say it would be easy.

2) Put a motor on "Eagle" that is sufficient to achieve the goal or reaching the desirable orbit. There are a variety of technology choices, some involving one or two tanks of liquid fuel and others using solid fuel.

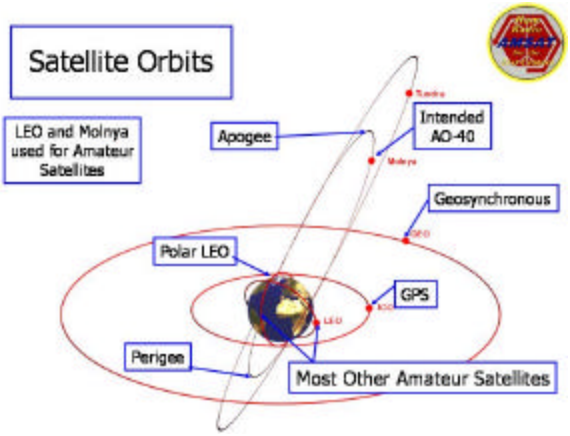

Figure 5: Orbits

Implementation of these suggestions would probably have a significant impact on the size, weight, and cost of “Eagle” and would raise significant launch issues.

COST

Many of the questions and thoughts in this paper are influenced by a lack of available funding. If AMSAT is to remain as the leading amateur radio satellite entity, then the membership must be prepared to provide sufficient funding to meet their requirements from the organization. We as members of the Amateur Radio community willingly spend a great deal on our equipment. Some of us even spend a dollar or more a day on coffee. But many of us don't or won't spend even 30 cents a day on supporting AMSAT.

If you want AMSAT to produce the goods - then you must support AMSAT. Most of the above suggestions, although very desirable, are expensive and funding to carry them out is necessary - what can you do?

CONCLUSION

If AMSAT-NA is going to build its own satellites again, it must fire up the imaginations of the builders. No amount of user satisfaction or fund raising will substitute for this!

Our builders must be replaced! We need to cultivate a crop of new, younger, builders and ask our experienced builders to act as mentors. With the shrinking rolls of Ham Radio, propped up somewhat through the new no-code licenses, we will probably have to look outside Ham Radio for these people. The colleges and universities are our best hope. AMSAT will need to work hard to get talented young people into Ham Radio and into AMSAT.

Finally, AMSAT-NA needs to serve the broad user community through education, information, and activities that promote the feeling of belonging. AMSAT-NA also needs to restore its membership rolls to the levels of a decade ago to help maintain its financial vitality.

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[1] Sirius Press Release: Sept 5, 2000 09:43 GMT. Nation: USA. Launch Site: Baikonur . Launch Complex: LC81L. Launch Vehicle: Proton 8K82K / DM3. Sirius 2 Class: Communications. Spacecraft: FS-1300. Agency: Sirius R. Manufacturer: Space Systems/Loral, Palo Alto. Perigee: 24,521 km. Apogee: 47,051 km. Inclination: 63.4 deg.

Sirius Radio's Sirius 2 was launched into a 144 x 168 km x 64.8 deg parking orbit. The Blok DM3 stage then made two burns to deliver Sirius 2 to an elliptical 6192 x 47057 km x 63.4 deg orbit. The was to provide digital radio broadcasts to mobile users in North America. Stationed at 64 deg W. Last known longitude (31 August 2001) 64.56 deg W drifting at 0.003 deg W per day.