The AMSAT® Journal

Editor:
**Ed Long, WA4SWJ**

Editorial Staff:
**John Bubbers, W1GYD**
**Bill Hook, W3QBC**

Volume 26, No. 6 November/December 2003

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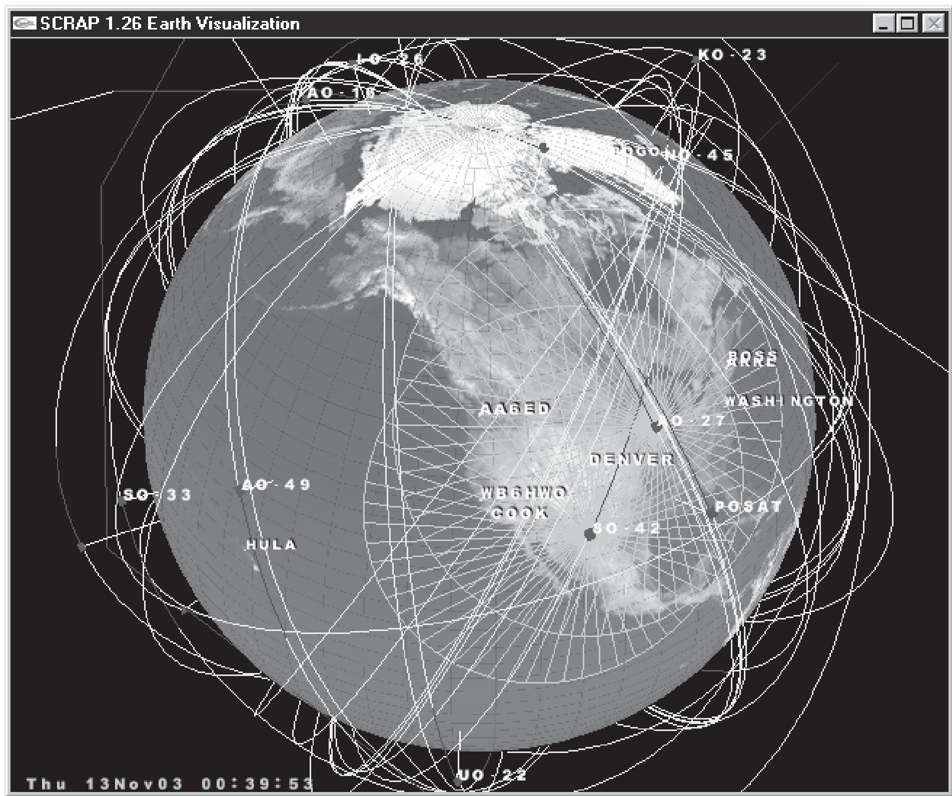


# SCRAP

**Satellite Contact Report Analysis & Prediction**

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**[You can find Bill's article on SCRAP on page 29 ...]**

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**AMSAT-NA website: *http://www.amsat.org***

***The AMSAT Journal Staff***
*Editor-in-Chief:* Ed Long, WA4SWJ

*Circulation:* Martha Saragovitz
(*martha@amsat.org*)
John Bubbers, W1GYD; Bill Hook, W3QBC



**Editorial Office: Ed Long, WA4SWJ, 550 Glenview Road, Williams Bay, WI, 53191, Internet: *journal@amsat.org*, telephone : 262-374-1349. Advertising Office: AMSAT-NA Headquarters, 850 Sligo Avenue, Suite 600, Silver Spring, MD 20910-4703.**

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*The AMSAT Journal* staff is always interested in article submissions. Whenever possible, submissions should be sent via e-mail to journal@amsat-na.org using plain text or word processor files; photos or figures in JPEG, GIF, or TIF formats. AMSAT-NA reserves the right to select material for *The AMSAT Journal* based on suitability of content and space considerations. The editors of this publications are volunteers giving freely of their talents, time, and efforts to produce *The AMSAT Journal*.

# Apogee View

We are now approaching the end of 2003 and the excitement of a launch is building!

Yes, Echo is on schedule to be launched at the end of March 2004 and we are almost ready to go! Final testing is underway and I am assured that the satellite is in great shape.

With 8 watts output on each of two UHF channels we should, under favorable circumstances, be able to work Echo on a handheld transceiver with only a rubber duck antenna. Please note I did say *favorable circumstances* and not with ground stations throwing out all sorts of excessive power, etc. May I suggest that for this satellite, every station give their AMSAT membership number in addition to their call sign? This will encourage membership in AMSAT and perhaps provide us with the extra revenue we need to meet your expectations.

AMSAT-NA, like most other AMSAT organizations, has traditionally raised its funding from the membership and will continue to do so for the foreseeable future. However AMSAT needs your direct involvement in raising funds for the launch campaign of Echo. At the 2003 Annual meeting I announced the start of the Echo Launch Fund Campaign. We have to raise $110,000 to cover the cost of Echo's launch and we need to raise this amount immediately or we cannot continue with the development of other satellites such as Eagle.

We need an average of about $22 US per member. In reality this is closer to $122/contributing member as some members contribute, some cannot contribute for personal financial reasons and, regrettably, some will not contribute. You can see the amount collected for the Launch campaign on the AMSAT Web page. Of course if all members of AMSAT were also donors to the Presidents Club at an appropriate level, then I would not ever have to ask for funds for building or launching satellites. Think of that and fill in the President's Club donor form. And if you live in the USA you will get a tax receipt for your contribution.

During the Board of Directors Meeting in Toronto, there were many discussions around "AMSAT should......." These discussions covered everything from satellites, information packages, education at universities and schools, to the latest communication techniques, but they all require your financial support. The AMSAT "Should List" is very long, almost as long as the "Satellite Should List."

As announced in Toronto, the anticipated launch date for Echo is 31 March 2004 and with the recent loss of both AO-27 and UO-14, we hope that this new bird will not only take their place but will add something extra to low earth orbit satellite operation. Echo combines a number of features of some previous satellites together with its own experiments all in one operation. For example, I am looking forward to being able to use 10 meters up (SSB) and 70 cm down (FM).

The digital voice recorder also offers some interesting thoughts, as does the Mode L/S transponder. But first things first. Let's get Echo into orbit and let's get the launch campaign paid.

Call Martha at 301-589-6062 or send your check or money order to AMSAT, 850 Sligo Avenue, Suite 600, Silver Spring, MD 20910-4703 USA. Please print your name, address and call sign so that your tax receipt may be sent to you.

Also, do not forget you can also assist in the campaign by ordering Echo golf shirts, T-shirts, hats, etc. Talk to Martha about them and she will be pleased to advise the sizes available and the long list of other items that she has.

In addition, we are studying a new membership system in which you may get a premium of your choice for the appropriate higher membership amounts. Personally I like my Echo golf shirts and Echo hat and I am always pleased when non-members ask me about them. It is one way of starting the conversation about AMSAT and introducing thoughts on their membership.

73,

Robin Haighton, VE3FRH
President AMSAT - NA

# What is AMSAT®?

AMSAT Members are a worldwide group of enthusiastic individuals designing, building, and operating amateur radio satellites as part of our program of space science education.The Radio Amateur Satellite Corporation (AMSAT or AMSAT-NA) is a non-profit scientific and educational organization chartered in Washington, DC, in 1969. Since then, AMSAT and colleague organizations around the world have built over 50 ham radio satellites. 15 of these satellites continue in operation.Joining AMSAT supports our current projects: Eagle, AMSAT-OSCAR-E (Echo), and ARISS. Eagle is a high orbit DX capable satellite planned for a 2007 launch; Echo is a low orbit FM and digital bird you will be able to use with simple equipment, planned for launch in 2004; and ARISS is our program on the International Space Station. You will keep up to date on the world of amateur radio satellites with 6 issues of the AMSAT Journal every year.

## We'd like to have you as a member!

AMSAT®, 850 Sligo Avenue, Suite 600 * Silver Spring, MD 20910-4703Phone (888) 322-6728 (Toll Free in USA) or 301-589-6062 * Fax 301-608-3410martha@amsat.org http://www.amsat.org/

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$1200, $600, $300, $120 per year ____________

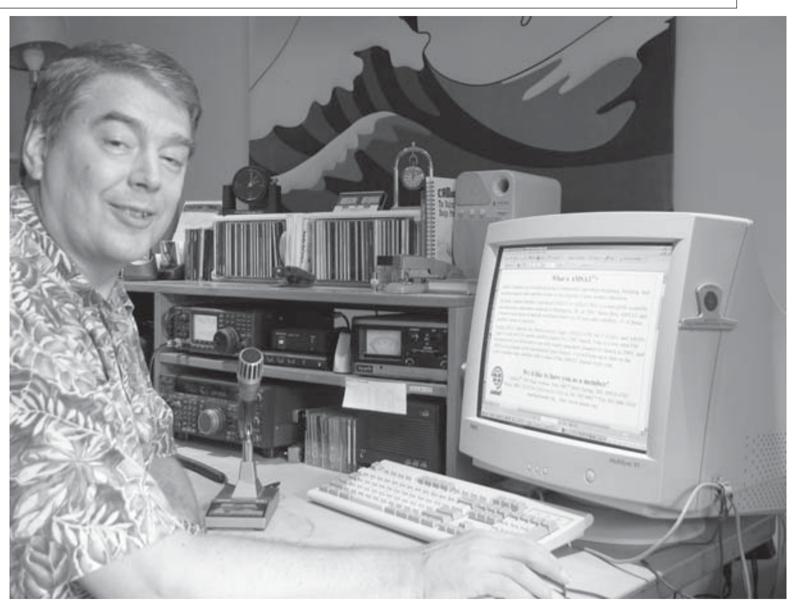
_____ Check here if you want to make 12 monthly Donations for the President's Club each 1/12 of the Presidents Club total (Credit Card only).

Other donation (such as $40, $70, $100, $250, $500) _________

Do you send QSL cards for satellite contacts? You can help AMSAT by inserting a form describing AMSAT and providing membership information. Put one of these inserts in every QSL mailing and you will help other hams find AMSAT and you will help AMSAT build new satellites.

Included at the amsat.org website are forms for single sided printing ... just print, cut and fold … and … for double sided printing.

You can find the QSL inserts on-line at **http://www.amsat.org/amsat/amsat-na/membership.html**



*(right) Rick Hambly, W2GPS, AMSAT Executive VP, shown viewing the AMSAT QSL insert.*

## New AMSAT-NA Appointments

Robin Haighton, VE3FRH, President of AMSAT has made the following announcement concerning new appointments to fill key positions within the AMSAT-NA organization:

*The AMSAT Journal* has a new Editor in Chief. He is **Ed Long**, WA4SWJ, of Peoria, AZ and Williams Bay, WI. Ed is a member of AMSAT and has been a licensed Amateur Radio operator since 1970 currently holding an Advanced Class license. He formerly held the callsigns WN8IKV and WB8IKV. A native of Charleston, WV, he holds a BSEE from West Virginia University and an MBA from Duke University. Ed can be reached at wa4swj@amsat.org . Article submissions for *The AMSAT Journal* can be sent to him or to journal@amsat-na.org . Ed is assuming editorial responsibility with the Nov/Dec issue of the Journal.

**Jim Jarvis**, N2EA, has been appointed as AMSAT Manager of Marketing. Jim, N2EA, is a multilingual (French, German, English) international business development executive, with over 20 years of experience in complex technologies. His work has principally focused on sales and marketing of research and test instrumentation, and automation systems for testing and handling semiconductors.

He holds an executive MBA from Rutgers University, Strategy Development training by the Boston Consulting Group and has attended New Product Development seminars at The Wharton School. Jim has rejuvenated and reorganized sales organizations, managed and developed products, started businesses and helped turn them around.

Jim was first licensed at the end of 1958, and has been interested in high speed CW, 40-meter gray line propagation, radio contesting, PSK31 and amateur satellites. He lived in Vermont for the past 8 years. Jim and his wife Peg recently relocated to Maryland and he's hoping to become active on AO-40 in the near future. All AMSAT marketing proposals should be sent to Jim for "synchronization and compliance with other AMSAT marketing efforts". Jim can be reached at n2ea@amsat.org .

On your behalf, I welcome Ed and Jim to their current positions. Ed is already working on the November/December issue of the Journal while Jim has started reviewing the "Echo Launch Fund Campaign".

Robin Haighton, VE3FRH

President AMSAT-NA

## Working the Easy-Sats - AO-40!

Hi friends, I am Pedro, EB4DKA. I am an AMSAT-EA member and I would like to share an interesting experience with you. I have operated AO-40 mobile from my car with a relatively simple setup. I have included two pictures of my mobile setup.

### NOVEMBER 15th

Today I worked AO-40 mobile from my car when the bird was 32,000 km from me and with 7.5º squint angle from IM78.

My setup:

**UPLINK:** Kenwood TM-455 with my Comet dual band mobile antenna (fixed on the roof of my car).

**DOWNLINK:** Kenwood TH-F7E HT with a pair of earbuds and a Wimo PA-13R-20 Flat Panel Antenna (33cm x 33cm) with a DB6NT converter.

My car was stopped on the side of the road and I was seated in the car with the flat antenna behind the window because it was raining (the antenna is smaller than the window) and the signals were very strong. I tried to uplink to the satellite and I could hear my own downlink very clearly. The only visible antenna from the outside of the car is the dual band whip! I worked only one station because when I started my mobile operation the bird was near MA230, and I had only a few minutes. I'll try to work mobile via AO-40 again because I travel a lot. I can work from the following grids: IM78, IM79, IN80, IM68 and a few more.

This was a very interesting experience for me. Thank you very much Peter, KC2HLI, for a very nice QSO!

### NOVEMBER 19th

I thought I would try my mobile setup from IM79. I was trying to work AO-40 from 8:00 UTC to 8:20 UTC (MA230). I worked Eduardo, KG6NDO (CM87) and Juan Antonio, EA4CYQ (IM78). Two minutes before MA230 (when the passband is turned off) I worked Emily, W0EEC (CM87). The bird was at 31,000 km range and about 7.5º squint. The downlink signals were very strong in my little TH-F7E HT. Not bad!

Best 73's from Spain,

Pedro Alvarez-Cienfuegos, EB4DKA

eb4dka@amsat.org

*EB4DKA Mobile on AO-40*

*Close-up of the Flat Panel Antenna*

# Field Ops Update: Celebrating Success and Looking Forward

**By Barry Baines, WD4ASW, wd4asw@amsat.org**
Vice President - Field Operations

One of the highlights of the AMSAT Symposium for me is the awards presentation that is given after the banquet dinner. I continue to be amazed by the depth and variety of volunteer work that is recognized by these presentations, such as implementing KA9Q's new Forward Error Correcting software on AO-40 telemetry, Amateur Radio on the International Space Station (ARISS), and development of Echo. AMSAT is blessed by both the technical and managerial skills of our members as well as the dedication of our volunteers to use their time and talents to help the organization.

This year we recognized seven individuals within Field Operations who covered a number of areas using a variety of skills and who made a difference for AMSAT. These volunteers serve as great examples of how each one of us can identify a need and fulfill it by using the skills and enthusiasm that we bring to AMSAT. Here are the citations that were presented to these individuals:

**Gould Smith, WA4SXM:** Many thanks for updating and enhancing AMSAT's premier book on satellite operations, "Getting Started with Amateur Satellites." Your labor of love fulfills a critical need in providing step-by-step guidance to newcomers interested in working the amateur satellites. Your latest publication is a continuation of a very successful technical writing career on behalf of AMSAT over the years. Thank you for keeping our publication offerings current.

**Keith Pugh, W5IU:** Once again, you provided critical support for AMSAT at the Dayton Hamvention and Hamcom. Your software demonstrations at the AMSAT booth played a critical role in generating interest in AMSAT and assisting our members to better utilize the software products offered by AMSAT. At Hamcom, you led the effort at the AMSAT booth and ensured that we were well represented at the 2003 ARRL National Convention. Thank you for continued strong support of AMSAT at these two major Amateur Radio events.

**Ed Collins, N8NUY:** Your willingness to coordinate a number of logistical issues for AMSAT in conjunction with the Dayton Hamvention on short notice is appreciated. In addition to managing the Friday evening banquet, you also served as a liaison with the Hamvention Committee and ensured that AMSAT's needs/requirements were met. You effectively managed AMSAT's presence at Hamvention and made a major contribution to AMSAT's overall success this year.

**Dee Interdonato, NB2F:** Your enthusiasm for 'showing the flag' for AMSAT at a number of hamfests and swap meets is both a great example as well as an inspiration for others to follow. You are currently one of the most active hamfest volunteers in AMSAT's Field Operations, having been willing to travel throughout New Jersey to create interest in the amateur satellite program. Thank you for your continued strong support of AMSAT.

**Mike Seguin, N1JEZ**: You play an important role within AMSAT, providing critical information to our membership concerning the current status of amateur satellites through the AMSAT News Service. This is a time consuming task requiring dedication throughout the year. These activities, coupled with maintaining and updating the AMSAT Frequency Chart (updated for Dayton Hamvention) is a reflection of your enthusiasm for AMSAT as well as your willingness to share information with others. Thank you for your continuing support of AMSAT.

**Art Feller, W4ART:** Thank you for stepping forward this year to help create some exciting new marketing and sales efforts for AMSAT. Your creativity in developing various ads, signs and announcements for new programs that you helped create, such as providing a premium to go along with a Membership (used, for example, at Charlotte and Dayton) as well as the membership recruitment drive which took place over the summer, resulted in significantly greater interest in AMSAT membership. Your willingness to volunteer to tackle opportunities outside your primary area of focus (finances) made a significant difference in addressing a primary concern within AMSAT – our membership levels. Thank you for stepping forward to address an issue that you recognized was important.

**Mark Kanawati, N4TPY and the SpaceQuest Team:** One of the AMSAT successes this year at the Dayton Hamvention was the enthusiastic interest in the AMSAT golf shirts that were offered that featured a design created by your team. We quickly sold out of the 75 shirts that were produced because the design struck a cord with the membership and others. Besides being an imaginative design that captured the essence of Project Echo, it also reflected the strong sense of pride that Echo is an Amateur Radio satellite. Thank you for taking the time away from your normal technical pursuits to create an outstanding logo design that was well received at Dayton.

Note that there are some common traits that were highlighted in each one of these citations:

- An AMSAT need was recognized by the individual;
- The individual figured out how to address that need;
- The individual dedicated their time and talent to handle the opportunity;
- Non-engineering skill sets were utilized to address the requirement (e.g. managing a process, creating teaching tools, working with newcomers, etc.);
- Typically, volunteers handled tasks outside their normal field of expertise (e.g. our treasurer volunteered to develop marketing programs while engineers at SpaceQuest created a graphics design); and
- In several cases, the recipients are not designated as Area Coordinators, but still fulfilled an important function and were recognized for their efforts.

Please take a moment to consider how you can help AMSAT by utilizing your time and talents to address an AMSAT need. Think about using your skills that you may not necessarily use at work or handle a situation that requires skills that you'd like to develop. AMSAT is 'us' – the membership. Each one of us has the potential to make a difference. Think about how your actions can reflect well on AMSAT – such as giving demos, serving as an Elmer and working with local organizations to build support for AMSAT. Publicize the fact that you're an AMSAT member and that you welcome people's questions and interest. For example, at a recent lecture delivered by Dr. Roger D. Launius, Chair of the Division of Space History at the National Air and Space Museum, Smithsonian Institution (and formerly the chief historian for NASA) at the University of North Florida, I made it a point to let him know about the accomplishments of AMSAT and to encourage him to check out our Web site (www.amsat.org). Unless we highlight AMSAT, we cannot assume that people will be aware of AMSAT.

When we recognize the accomplishments of these individuals, we also acknowledge the significant contributions of other Field Ops volunteers. The value in recognizing a few individuals at the AMSAT banquet is due in part to the opportunity to celebrate the overall achievements of the entire organization and to provide an inspiration for others to step forward to help AMSAT. This is not rocket science, but what our volunteers achieve is extremely important to the future health of AMSAT, as we must continue to build awareness and support.

**Looking Forward**

The AMSAT Symposium also includes the annual Field Ops Breakfast, which is held on Sunday morning. This year more than 20 individuals participated in our discussions of how we can better support AMSAT. We also distributed a beta version of the Area Coordinator Toolkit (version 3.1) edited by Gould Smith, WA4SXM that includes PowerPoint presentations, WAV files and other materials to support the efforts of our Area Coordinators to represent AMSAT in their local communities. Our expectation is that the final version will be available by January for distribution to the entire Field Ops Team. We also plan to have this same material posted on the AMSAT Web site for downloading.

One of the key goals for 2004 is to highlight the upcoming launch of our newest satellite, OSCAR-Echo. At this point, we expect a launch to occur in Spring 2004. Field Operations will support this program in several ways:

- Highlight the capabilities of the satellite to local hams
- Assist in providing information that can be given to local media outlets and amateur radio publications
- Encourage financial support of the Echo Launch Campaign
- Keep local amateurs aware of the status of the launch and resulting status of the satellite following placement in orbit.
- Teach hams how to use the satellite

Clearly, everyone within AMSAT can assist in this effort. The upcoming launch of a satellite provides a unique opportunity to highlight AMSAT. We should all think about how we can build support for AMSAT. Please work with your local Area Coordinator as launch approaches to build local awareness. Take the initiative to provide a positive image of AMSAT and build on the excitement that this launch opportunity provides.


Photo credit: Bruce McCaskie, N6THN

***The same weekend that AMSAT conducted its 21st Annual Symposium in Toronto, volunteers manned the AMSAT booth at Pacificon held in San Ramon, CA. Led by Emily Clarke, W0EEC (right) and assisted by Rick Fletcher, KG6IAL of Project OSCAR (left) and Bill Rausch, AA6PA (not in photo), AMSAT gained 8 new members and hosted about 300 visitors at the AMSAT booth.***

# The N3IYR AO-40 Antenna

## A venture into performance

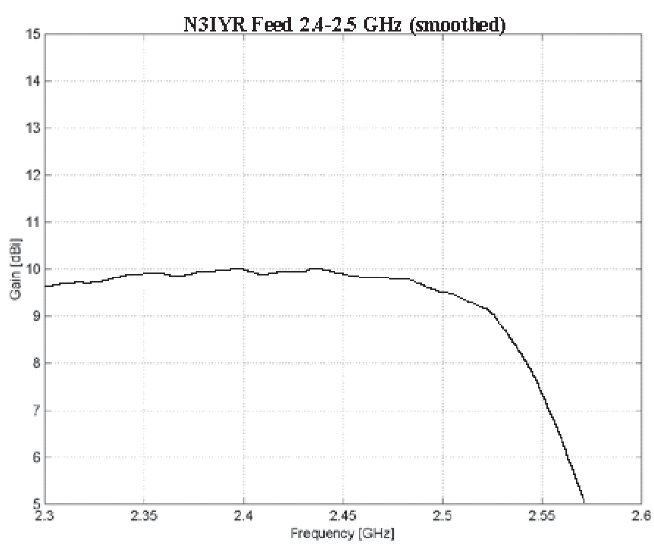
by Glenn Rollins, N3IYR, glennrollins@n3iyr.com

My interest in AO-40 began some years ago after working several LEO's and playing with the ISS seemed like child's play. I had read all about AO-40, and about the problems in flight that left the spaceship crippled, but still useable with limited transponder abilities. The thought of being able to use a satellite for hours at a time instead of one screaming from horizon to horizon in under 15 minutes was appealing. I already had a 40 element circularly-polarized Yagi for the uplink, but I needed an S-band downlink to effectively use AO-40. I also learned that I needed a downconverter to convert the 2.4 GHz signal to a 144 MHz signal useable with my 847.

I purchased a 3-foot barbeque grill type dish and downconverter combo. After assembly I noted that the antenna integrated the downconverter and a "dipole plate" feed into the grill. I found the noise figure good enough to be useable, but the signals from AO-40 were very weak. I could hear contacts being worked down near the noise level, but I could not make out the signals well enough to work them. I became frustrated with this approach and thought that there just HAD to be a better way of doing this. My thoughts were that if I could develop a way to get the signals to the downconverter more efficiently, it would greatly improve the reception of the weak signals I was forced to work with. I kept turning the design over in the back of my mind and until I came to a conclusion. My final decision was that I would need an offset parabolic dish approximately 3 feet in diameter. Further, I believed I could connect the downconverter directly to the feed antenna and eliminate line loss. That would enable me to connect anything I wanted to the feed and, because the dish was offset fed, the antenna/downconverter combination would not block any incoming signal. The next design element to improve efficiency would be to match the incoming signal polarity. Since I wanted an offset design I quickly discarded the notion of a patch feed because of the cost factor and the FD ratio.

I decided a helical feed antenna was the way to go. With a helical feed design and an offset parabolic type reflector in mind, I began my search for a manufacturer. I desired to bring this antenna to the amateur community since no one else was selling antennas with the performance I wanted. I used the Internet and contacted several parabolic dish manufacturers that were willing to produce the antenna, but I would have to buy at least 1,000 of them. I discovered a company that was willing to modify an existing product they were producing for point-to-point wireless Internet connections in the ISM band. Perfect! They produced an offset parabolic with a waterproof linear feed housed in an ABS enclosure. The 900X1000 mm dish produced 25 dBi of gain with 10.5 dBi in the linear feed. The trick was to make a LHCP helical of the same gain that would illuminate the antenna properly. LHCP is required because the signal from AO-40 would be reversed (like a mirror) when it was bounced off the reflector. I was sent a complete antenna to experiment with.

I really liked the dish design. The reflector is actually an oval, not a circle. But once tilted to the correct angle for signal refection, visually and as a reflector it becomes a circle. That is what is presented to the signal. Further improving the reflector's efficiency is the shape of the concave, deeper on one side than the other. Once again presenting a more perfect "lens" to the signal once tilted to the proper angle. I was later told that the entire shape of the reflector was computer designed in the proper proportions for reflecting ISM (S-band) specific signals. Fantastic!




For the feed, I began with a reflective plate and knowing the formulas for a helical design for this frequency, I started with 7 turns. I wound up trimming nearly two turns off the original design until no further noticeable difference was found in the antenna's performance. After working several stations on AO-40 with an ease I never dreamed of, I submitted my findings to the manufacturer of the dish. It turned out that the company is actually owned by engineers. I discovered that they had had a great time arguing among themselves whether or not my feed design would even work with their CAD designed reflector. I asked if they would like me to send them my prototype. After refusing my offer, they made their own helical feed and tested it on their own antenna range. My design for the feed with their dish produced 25 dBi of circular gain, with the feed alone producing just over 10 dBi. The great thing about this is that the helical feed fit in the originally supplied ABS housing. A finished prototype was shipped to me for testing. I could hardly believe it when the feed arrived.

I had to wait until daylight to test it! The benefits of no aperture blockage, matching the downlink signal polarity and a properly shaped reflector was apparent the first time I used the antenna on AO-40. I found the performance to be exceptional. I was completing armchair copy QSO's on the bird that I never thought were possible. I started my venture with an order for 50 antennas. An overseas import nightmare was avoided by my feeds being "piggybacked" in containers with their antennas to their stateside distributor. I began marketing the antenna in early 2001 and have over 200 of them in use worldwide. My antenna has survived A-B comparisons of antennas thought to be superior and I have many compliments from people all over the world. It has been a very interesting learning experience including everything from shipping methods (I used to make wooden crates) to logistics, paper-work and assembly. My antenna project has given me a great sense of accomplishment and I can now say I have left my mark (be it small) on furthering this hobby that I have held such great passion for all these years.

See http://www.n3iyr.com/

N3IYR Antenna is easily handled with a Yaesu G-5500 or equivalent. Elevation and azimuth has been successfully used by SatEL's AZ-EL

http://www.satelectronics.com/

**Sources:**

Helical antenna design:

http://www.wireless.org.au/~jhecker/

http://www.little.id.au/electronics/Radio/helical_antenna/helical_ant.html

http://www.tuc.nrao.edu/~demerson/helixgain/helix.htm

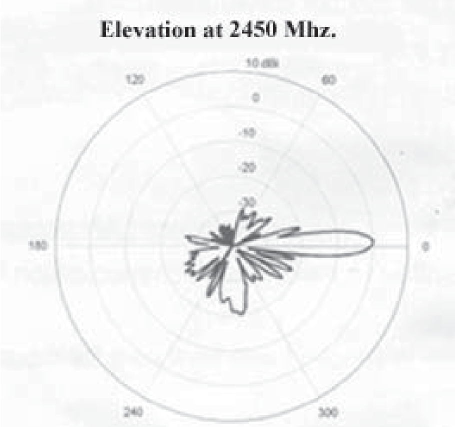
**AO-40 downconverters:**

SSB Electronics UEK-3000

AIDC 3731 (modified by K5GNA) k5gna@aol.com

Down East Microwave 2400-144RX

Norsat 2500


# Highlights of the AMSAT Annual Meeting and Space Symposium

## October 17 through October 20

### by Robin Haighton, VE3FRH

My apologies for writing this so late in the month, but I wanted to include some information from the AMSAT Annual Meeting, Board of Directors Meetings and Space Symposium that took place in Toronto on October 17 through October 20. My other excuse is that with three computer crashes I am now typing it for the fourth time!

When the AGM is held it is natural for those who worked to put it on to feel apprehensive until the reviews start coming in. Well, I am pleased to tell you that we had a great time and I must thank the Toronto Airport Marriott Hotel together with Barry Delong, VA3BJD, and the crew of hams who worked hard to put the show on. I was able to sit in on all the presentations at the Space Symposium and found them to be both stimulating and inventive. A copy of the majority of the papers can be obtained from the AMSAT office, just ask Martha. The cost is $20 plus mailing cost to other countries and they are worth every penny. If AMSAT were a profit making organization we would be charging at least $400 US to attend such a symposium due to the quality of the papers and the work in putting the organization together. What a bargain at $30! Next year we will visit Washington, DC, the original home of AMSAT, on our 35th birthday and I look forward to being there with you.

Our recent membership competition ended up in a tie, both people having 10 new AMSAT members. The two winners were Steve Diggs, W4EPI, and Drew Glasbrenner, KO4MA. With only one prize available the toss of a coin settled the matter and Steve won the VX7R, which was kindly donated by Vertex Standard/Yaesu. However, Drew did not go home empty handed, as he was awarded 3 years membership in AMSAT. My congratulations go out to both Steve and Drew and to the many others who brought in a total of 64 new members to our organization.

During the meeting in Toronto, I announced the start of the "Echo Launch Fund Campaign". Echo will be launched around the end of March 2004 (scheduled March 31) and the total launch cost will be $110,000 US. We have to raise that amount before we can think of any further activity on Eagle or other satellites. Every member of AMSAT-NA will be receiving a letter from me in the next few weeks requesting participation in the launch campaign. With AO-27 and UO-14 no longer in service, Echo will be fulfilling that operation as a LEO satellite. In addition, there are a number of other things that Echo can do, and we will be developing a schedule of initial operations for Echo in November. Remember, there are three transmitters on Echo and we have the opportunity to possibly run two of them at any one time. I look forward to trying to work Echo with my handheld and a whip antenna – it should be possible under the right conditions, perhaps even with a rubber duck!

One request from me, for your benefit lets encourage the use and exchange of AMSAT membership numbers in satellite communications. This will, I hope, encourage more people to join AMSAT and thus produce more revenue for more satellites.

One final thought, the "new" Board of Directors met in Toronto (for details see the minutes to be published later) and the three new members of the Board were present. I was delighted to see the skills that they bring to the board and I am sure that Rick Hambly, W2GPS, Gunther Miesse, W8GSM and Lou McFadden, W5DID, will serve you well over their terms on the Board.

The Board did re-elect me as President; however, this will be my last term as your President after serving in this role for four years and previously as Executive Vice-President for two more years. I feel that next October will be the right time to retire and let others with new ideas take over the leadership of the organization.

73,

Robin Haighton VE3FRH
President AMSAT-NA

ve3frh@amsat.org

# Satellite DX by Wayne Estes, W9AE, W9AE@AMSAT.ORG

Operating activity on AO40 has declined recently as AO40 enters its seasonal dormant period. And the loss of UO14 makes it difficult for casual FM satellite operations. But AO40 will be back at the end of the year and hopefully Echo will provide DX opportunities in 2004.

Hardy, DC8TS, was the first person to report working 100 DXCC entities on AO40. Hardy is the "king" of satellite DXers having worked 270 of the 335 DXCC entities on satellite since 1977.

## HEARD ON THE AIR

EI4HT & EI3DP (Ireland)
SV9FMB (Crete)
SV1AWE (Greece)
A71AW (Qatar)
EX8MLT (Kyrgystan)

## RECENT DXPEDITIONS

**VK9XW** (Christmas Island) Oct. 4-11
This German HF/satellite DXpedition made 133 AO40 contacts using portable antennas loaned by Rolf DK2ZF.

**VK9CD** (Cocos-Keeling Is.) Oct. 11-23.
The team also made 160 AO40 contacts from Cocos-Keeling as the operating windows steadily shrunk due to advancing ALON. They didn't make very many contacts with the U.S. due to the difficult range and inconvenient pass times.

**4W4W** (Timor Leste) Oct. 22-28
A Japanese group activated Timor Leste on AO40 satellite for the first time. Unfortunately the short operating windows made contacts difficult with North America, especially the eastern part of North America.

**EA6/DK2ZF** (Balearic Is.) Oct. 3-17
Rolf DK2ZF used his new portable AO40 antenna on the island of Mallorca to make sure everything would work for his upcoming Pacific islands expedition. His 110cm dish is cut into 4 pieces and is used for both downlink and L-band uplink.

**V55V** (Namibia) Oct. 27
With the help of South African AO40 operators, V55V was on AO40 for a couple of hours after the CQWW Phone contest. Hopefully they will activate other rare countries in southern Africa.

**FY/F6CBC** (French Guiana) October.
Jean F6CBC was occasionally active on AO40 while on business in French Guiana. He used the same 1.2m Inmarsat umbrella dish that he had successfully used in Martinique earlier this year.

**TY/LZ3XV** (Benin) Nov. 7-9
Vladi 5N0EVR planned to operate two weekends there before AO40 goes into its dormant phase.

## FUTURE DXPEDITIONS

AO40 DXpedition activity starts with a bang when AO40 comes out of hibernation.

**FT5Z** (Amsterdam Island)
A new ham named Sabastien plans to be active on AO40 from Amsterdam Island (grid MF81tx) for the entire year of 2004. AMSAT-France is preparing training and equipment. Only the eastern and far northwestern parts of the U.S. will have windows.

**K7ASU/KH9** (Wake Island) Jan-Feb.
Terry K7ASU will be stationed on Wake Island in January and February. He plans to be active on AO40 using a 1.8m Teksharp dish. So, he should hear the weakest stations and have an excellent uplink.

**KH2GR** (Guan) Feb. 11-16
Yoshi JF6BCC will be active on AO40 once again from Guam.

**3B9C** (Rodrigues Island) Mar.29-Apr.15
G0MRF will operate AO40 with the 3B9C team. There is no window for those west of the Rocky Mountains.

**T33C** (Ocean Island) Apr. 4-16
Doug N6TQS will be the satellite operator for this large international DXpedition.

Please send reports of planned future DXpeditions to w9ae@amsat.org. Feel free to contact the author if you are interested in satellite operation from a rare country and want operating tips or loaner equipment.

*Jean, F6CBC, operating AO-40 Mode L/S from French Guiana using a 1.2 meter Inmarsat umbrella dish*

# Doing More with Fewer Wires in the Harness: A New Approach to Spacecraft On-Board Command and Telemetry Interfacing

by

Bdale Garbee, KB0G, Chuck Green, N0ADI, Lyle Johnson, KK7P, and Stephen Moraco, KC0FTQ

## Introduction

*The new approach to handling on-board command and telemetry described here replaces much of a traditional spacecraft wiring harness with a CAN bus connecting standard module interface boards. Using this approach reduces mass and integration complexity, provides flexibility, and simplifies and facilitates testing of individual spacecraft modules and groups of modules before full satellite integration.*

*A new, lightweight protocol designed to take advantage of unique features of the CAN bus architecture delivers a simple, robust, and powerful solution for multiplexing large numbers of control signals and telemetry channels on a single twisted-pair in the wiring harness. A flexible module interface board and associated spacecraft bus interface connector become standard components, simplifying module design and allowing payload experimenters to concentrate on their payloads, not spacecraft interfaces.*

*The hardware and software detailed in this paper are scheduled to fly on the AMSAT-NA Eagle spacecraft intended for high-altitude elliptical Earth orbit. While the initial focus is on meeting all of Eagle's requirements, components and protocols designed for this system have wide applicability to other spacecraft of similar complexity.*

*Prototypes of the module interface boards have passed radiation and other relevant tests. Final module circuit board designs and flight software are nearing completion.*

## Background

Traditionally, most satellites used a point-to-point wiring harness to connect all of the onboard electrical and electronic components. As spacecraft become larger and advances in technology allow more features to be packed into each module, the complexity of this wiring harness increases. As the complexity increases so does the mass and the administrative burden of keeping track of which wires go where in the wiring harness design.

One of the successful innovations in the original AMSAT Microsat design was the use of a multi-drop serial bus for command and telemetry. The Microsat bus was based on an obsolete Motorola part called the AART, which provided a modest number of modules in close proximity with a modest number of control and telemetry points. More recent micro-satellites have employed other serial bus technologies like SPI with similar success.

Early in the Phase 3D program that resulted in AO-40, CAN bus was proposed as an alternative to the traditional wiring harness. The CAN (Controller Area Network) bus was originally designed primarily for use in automotive electronics. While it has grown in popularity and is fairly widely used within the embedded systems community today, in the early days of the Phase 3D program it was brand new with no real track record. To manage risks, the decision was taken to build AO-40 with a traditional wiring harness, which turned out to be the most complex such harness ever built for an AMSAT spacecraft! However, a CAN bus was flown as an experimental interconnect, and serves as the primary communications path between RUDAK and all of the scientific experiments. This CAN experiment on AO-40 was highly successful, and CAN bus technology has also now flown on a number of other small satellites including several built by SSTL.

## The Idea

For the AMSAT-NA Eagle project the size and complexity of the spacecraft suggested to us that it might be a good time to revisit the idea of replacing at least part of the wiring harness with a modern, robust multi-drop serial bus design. After considering various alternatives, CAN bus was selected as the base technology.

Drawing from the design of the AART boards in the Microsats and the CAN SmartNode boards on AO-40, we have designed and are building a number of identical small circuit boards, one of which will be placed in each module to provide a standard interface between the spacecraft bus and the module's electronics. These circuit boards contain an Atmel microcontroller with CAN interface, power switch, temperature and current sensors, connectors for the spacecraft and module interfaces and signal conditioning circuitry for all of the inputs and outputs.

The Eagle team intends to use a new housekeeping computer design called IHU-3. This IHU is derived from the designs flown on previous Phase 3 spacecraft including AO-10, AO-13 and AO-40 and is intended to reuse much of the software developed for those missions. Thus, one of the design constraints for this project was to provide a conceptual equivalent to the I/O multiplexer that was associated with previous AMSAT IHU designs. In effect, what we have done is to design a system for distributing the I/O multiplexing among the various modules instead of centralizing it in the IHU. Fortunately, this turns out to be an excellent match to what CAN bus does best.

We also realized during the Phase 3D project that having each module use a different set of connectors and pinouts for attaching to the wiring harness made bench testing of modules difficult. Special test boxes and wiring harnesses had to be developed for each module or set of modules, and these were hard to keep up with in the AMSAT lab environment. A major benefit of this project is that key interfaces between each module and the spacecraft harness are identical for every module, and a single test harness can be used to test many individual modules or groups of modules.

As we surveyed the needs of the satellite module builders it quickly became apparent that there were at least three classes of *consumers* for the CAN module. Three main operating modes are implemented that are easily selectable by the module builder. We refer to these as normal, multiplexed and byte-pipe modes.

## Electrical Design

There are two components to the hardware in this system. The first is inclusion of a CAN interface on the IHU(s) on the spacecraft, which is left to the IHU-3 team to document.

The second is implementation of the small circuit boards that will be included in each payload module and we describe here.

The core component on the *widget board* is an Atmel T89C51CC01 microcontroller. This part is a derivative of the venerable Intel 8051 architecture including a number of digital input and output lines, an integrated analog to digital converter, a CAN interface, onboard Flash program memory and data RAM.

Jumper locations on the board allow for six bits of address selection allowing up to 64 modules and two bits of mode selection. Currently we implement three of the four possible modes - normal mode, a *multiplexed* mode supporting expansion of the digital control and telemetry line count and a byte pipe mode for communication with a processor in the module's electronics.

In normal mode the features provided by the widget board include a power switch, current sensor, temperature sensor, 12 digital output lines, 8 digital input lines and 5 user-defined analog sensor channels.

In multiplexed mode the digital output and input lines from normal mode are replaced by support for up to 8 banks of external multiplexers. The output lines are allocated as 8 for the mux data bus, 3 for mux select and one for a strobe. The input lines are converted to a mux data bus using the same select and strobe lines as the outputs. Thus, in this mode the widget board provides a power switch, current sensor, temperature sensor, up to 63 lines of digital output, 64 lines of digital input and 5 user-defined analog sensor channels.

In byte-pipe mode the widget implements distinct 8-bit input and output busses with simple handshaking. The feature set in this mode includes the power switch, current sensor, temperature sensor, 8-bit input and output busses each with strobe/ack handshake lines, two independent output lines and three user-defined analog sensor channels.

Various ideas have been discussed for other modes we might support including various flavors of serial byte pipes. There are also proposals for reusing this hardware with fully custom firmware for some special sensor applications. No commitments have yet been made by the team to support any of these other applications.

**Circuit Description**

Please refer to the schematics on pages 16 and 17 for this discussion.

A 15-pin male D-sub connector (P1) interfaces to the spacecraft and brings in nominal 14V power, provides CAN connections and passes through up to five user-definable signal lines which connect directly to the associated module. Redundant CAN connections are provided so the spacecraft wiring harness can *loop through* the module without splicing wires. An *EB* line is provided passed through to the user module, which allows tapping the IHU engineering beacon data stream if required by the module.

A 40-pin connector (J5) organized as 2 rows of 20 pins all on 2.00 mm centers attaches to the module and brings all available signals to the module.

Incoming power is fused, filtered and applied to a power switch (FET Q2 and associated electronics) and to a switching regulator (U7) which provides the required +5V to run the CAN module.

Analog circuitry includes a temperature sensor (U12) and a means to monitor the current consumption of the attached module (U8). Remaining analog circuitry conditions the ADC inputs with filtering and clamping. Analog signals are then applied to the eight ADC inputs of the microcontroller (U5).

CAN signals are filtered by U3 and applied to U4, which converts from the CAN physical layer-signaling scheme to standard CMOS 5V logic levels. U4 has its own power supply filtering to minimize noise effects from the CAN bus. The CMOS signals are interfaced directly to U5.

U5 includes clock circuitry and is set to 8 MHz by crystal Y1. U6 provides a regulated analog voltage reference independent of the accuracy of the 5V supply.

Shift register U2 allows the microcontroller to read the jumpers at reset or on command. The jumpers set the widget address as well as its operating mode.

Schottky diodes and current limiting resistors isolate the U5 digital outputs. The user module must provide pull-ups to not more than +5V and the pull-up value should be at least 10K ohms.

**Radiation Testing Results**

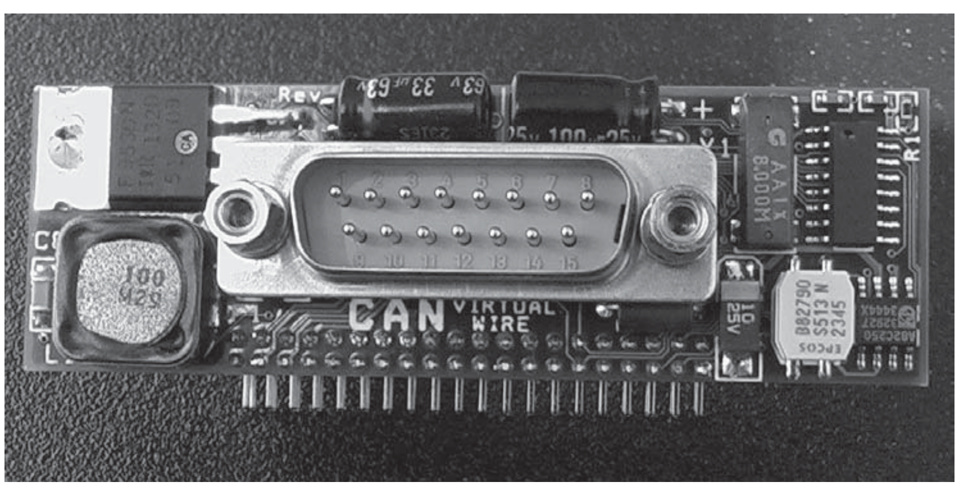
We were pleasantly surprised by how well the Atmel microcontroller survived our radiation testing. By arrangement with the University of Virginia Medical Center, prototype CAN widgets were exposed to a calibrated radioactive source in controlled dosages. The module was then evaluated for power consumption and functionality. These tests were repeated until failure, which occurred at some 60 kRads.

In addition to the confidence this testing provided, we were able to directly apply some of its results to the circuit design. For example, the use of the clock oscillator on the microcontroller, which saves tens of milliwatts of continuous power consumption, was only decided upon after evaluation of the radiation results. This may result in a power savings of a watt or so in a moderately complex spacecraft like Eagle.

To further enhance reliability in the radiation intense GTO orbit environment AMSAT will continue our traditional practice of applying additional shielding material to critical ICs. This shielding will likely be implemented with 1mm of Lead affixed to the relevant components.

**Mechanical Design**

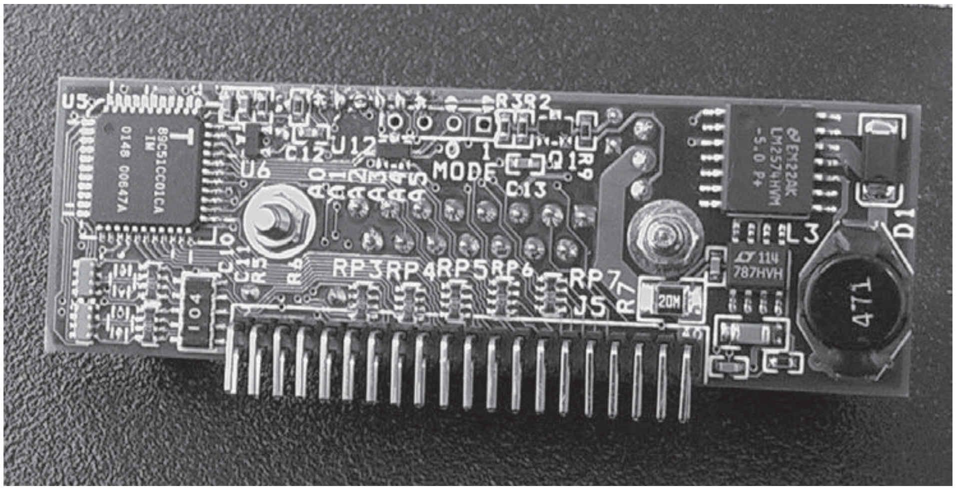
As usual, the process of laying out the PCB was more an exercise in mechanical engineering than electrical engineering. The mechanical objectives were simple to state but a bit more difficult to implement. Keep it as small as possible while maintaining a form factor that would fit into any size box available to the module developers. And provision for mounting the board must be adequate to




***Circuit Board Showing Sub-D Connector***

withstand vibration levels anticipated during launch.

Throughout this section we freely mix metric and imperial units. When working with electronic components any attempt to standardize is futile. And trying to standardize on a single set of dimensional units will only lead to errors.




PCB with Downward Facing Plug

The minimum box thickness is one inch so a board height of 24mm was chosen. The width would be whatever was necessary to contain all the parts. There are a total of 67 parts on the board (not counting radiation shields) with sizes ranging from 0603 resistors to the 15-pin Sub-D connector. The width turned out to be 74mm.

Efficient use of volumetric space was also desirable. The 15-pin Sub-D connector established the space needed between the PCB and the inside edge of the box it is mounted in to about 1/4 inch. So all high-profile parts should be on this side of the PCB to make maximum use of this space. Only low profile parts can go on the backside of the PCB. The tallest part on the back of the PCB stands out about 3.5mm with the exception of the 40-pin connector that plugs into the PCB containing the module function.

In some cases it may be desired by the module developer to extend their PCB all the way to the connector side of the box. If the box height is sufficient this can be done by inverting the orientation of the 40-pin connector so that the right angle pins point down rather than up. This connector is located at the bottom edge of the PCB to accommodate this choice and centered left-to-right along this edge.

The 15-pin Sub-D connector is located in the geometric center of the PCB. It is mounted to the PCB by stand-offs so that when the connector is secured to the side of the box the PCB is also securely held in place.

When a part requiring a radiation shield (IC's and FET transistors) is located on the PCB a similar part should be located on the opposite side of the PCB. This way, a radiation shield attached to the top of one part can also shield the bottom of another part thereby reducing the total number of shields needed.

The FET module power switch should be mounted on the side of the PCB facing the box edge to maximize heat radiation coupling to the side of the box rather than back into the module contained in the box. Similarly, the thermistor should be on the backside of the PCB facing the application module.

The above requirements made component placement challenging. But an even bigger challenge was connecting everything properly. Some traces needed to be wide to allow for significant currents. Other traces could be very narrow. However, if you make them too narrow the PCB manufacturer will experience manufacturing problems. The narrowest traces on the PCB are 0.006 inches wide and the smallest spacing between traces is also 0.006 inches. This is a four-layer board.

Most components are SMD and these units will likely be assembled by hand.

### Protocol Design

Our protocol design is based on a simple transaction model that takes full advantage of the unique characteristics of the CAN bus. We use the 11-bit addressing mode on the CAN bus instead of the longer 29-bit mode to reduce packet size since the shorter addresses used in the 11-bit mode are more than sufficient. Modules generally do not speak unless spoken to (input packets from a module in byte pipe mode are the exception), and the transaction model is as close to stateless between transactions as possible.

CAN is a message oriented bus so each packet contains a single message or stream address. The data payload of each packet is small - a maximum of eight bytes. All of the low-level packet handling is implemented in the CAN controller hardware, including error checking and retransmission.

The design of the CAN bus encodes packet priority in message addresses. When two CAN devices try to transmit at the same time the higher priority packet succeeds and the lower priority packet is deferred until it is the highest priority packet. Our allocation of address bits makes the module address less significant than the stream type, which reflects our sense of priorities in the spacecraft environment. For example, an IHU can be confident of always being able to write output state vectors to all modules even if some modules are responding oddly or not at all.

In normal operation an IHU sends a single CAN packet to each module that contains a complete state vector to be written to the module's outputs. Each module then responds with a short burst of packets that contain a state vector representing the complete input state of the analog and digital inputs to from the module. In this way each transaction completely refreshes all of the control lines and gathers a complete set of telemetry points from a module.

In normal and multiplexed modes the output state is contained in a single CAN packet and the input state requires two or three CAN packets for normal or multiplexed mode respectively. In byte pipe mode the output state, other than data for the byte pipe, is contained in a single CAN packet and the inputs require two reply packets. The data to be piped is sent and received in single CAN packets of eight data bytes each that are separate and at a lower bus priority than the command/telemetry packets.

For maximum compatibility with IPS software expectations the protocol is designed around the idea that each module might be asked to engage in a command/telemetry transaction as often as 50 times per second. At this repetition rate it is not possible to interact with a full set of modules all in multiplexed mode on a 800 kbit/sec CAN bus. However, all reasonable configurations of modules for all spacecraft currently contemplating use of this design are easily handled with bandwidth to spare.

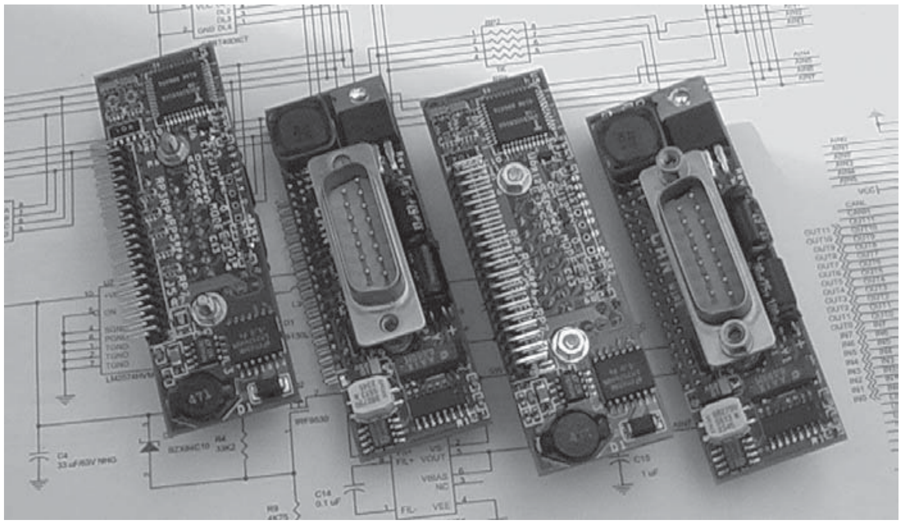
## Firmware Design

From the onset of this project, we intended to release the entire design as Open Source. This has guided many aspects of the firmware development from the choice of tools we use to our internal documentation style. All of our tools are themselves Open Source. Where one did not exist, we created it and are releasing it as Open Source. The tools we found are an 8051 family assembler and a disassembler. We created our own flash utility for reprogramming the microcontroller as we were not able to find an Open Source tool for this purpose. Our internal documentation is quite descriptive, perhaps more than typical for a project of this type. The reason, in addition to this design being open, will be described shortly.

Other philosophies guide our implementation. This device implements our spacecraft wiring harness. As such the expectation is that it *just works*. In fact, it must or we can easily lose our spacecraft. To meet this expectation we adopted a philosophy seen elsewhere in AMSAT designs - what is not flown in orbit will not break in orbit. To a firmware designer this means keep the amount of code to a minimum. Make each routine simple yet efficient. Use only the features within the microcontroller we need to accomplish our function.

Another constraint on our firmware design is that we want this to work in the traditional AMSAT spacecraft environment. The currently selected IHU is the master controller of the CAN bus. Modules speak only when spoken to. Our firmware design supports all modules on the CAN bus being spoken to 50 times per second. The only exception to this "speak when spoken to" policy is the byte-pipe traffic. Byte pipe traffic is implemented using lower priority messages so that it will not interfere with the high priority effort of writing state vectors and reading telemetry from the modules. It consumes bus bandwidth not used by the higher priority traffic.

Delving a little deeper into the firmware implementation, the Atmel T89C51CC01 part is rich in onboard devices. Our current firmware makes use of the 256 Bytes of on-chip RAM, 32K Bytes of on-chip Flash Memory, two of the three 16-bit timers/counters, one of the channels of the 5 channel 16-bit programmable counter array, the hardware watchdog timer, the 10-bit resolution Analog to Digital Converter with 8 multiplexed inputs, all four I/O ports and the onboard CAN controller. While this seems like quite a list there remain more capabilities which we don't use such as the 2K Byte on-chip EEPROM or a 1K Byte on-chip XRAM. Again, we only use what we actually need.



***Circuit Board Group***

The onboard CAN controller handles all CAN bus interaction. The CAN controller provides 15 independent message objects each of which can be configured for either transmit or receive. The firmware uses only a couple of the 15. Each type of message is allocated a receiver object. The CAN controller handles the entire CAN protocol (receiving, acknowledging, retransmission, etc.) and notifies the firmware when a message has been completely received. The firmware then copies the incoming message to RAM, performs whatever actions are indicated by the message and then tells the CAN controller that it can start listening for that type of message again.

On the transmit side firmware hands the entire message off to the CAN controller and tells it to start sending. The firmware is then later told that the transmission has completed.

We clock the T89C51CC01 at 8MHz, well below the 20 MHz maximum for the part. Instructions are executed in a minimum of a single machine cycle, which is 6 or 12 clock periods long. We run the part in what's called X2 mode that selects the 6 clock period machine cycle. The resulting machine cycle time is 750 nanoseconds. The instruction set contains a mix of 1, 2 and 4 machine cycle instructions and, by rough calculation, our code can be running anywhere from 650,000 to 1.3 million instructions per second.

For the standard and multiplex modes the firmware copies the state vector bits from each incoming message to the output ports including turning on/off the power as requested in the message. It then reads all the digital inputs, digitizes the analog inputs, places all these telemetry values into packets and initiates transmission of the telemetry packets over the CAN bus.

The act of digitizing the analog values is the only place that we use any of the special reduced power modes of the microcontroller. When the firmware samples the analog channels it follows an Atmel recommendation to instruct the microcontroller to power itself down during the conversion and reawaken once the conversion is complete. This reduces digital noise during the conversion and increases the precision of the analog readings.

In the unlikely event that our firmware stops working as expected a hardware watchdog will reset the microcontroller. Since the firmware is effectively stateless between transactions the watchdog allows the firmware to restart and continue operating with only the loss of the transaction underway at the time of the lockup. Each watchdog event resets the CPU putting all of the output lines in a default state. To speed overall system recovery the firmware keeps multiple copies of the last output state vectors received in RAM. Upon restart these copies are evaluated and if there are at least two copies that agree, these are immediately written to the output lines. This means that it is likely that the firmware can endure a watchdog restart and still be able to restore the last known output state if memory is not entirely corrupted.

In byte-pipe mode the firmware processes CAN messages for all functions other than the pipe normally. In addition, it accepts output CAN messages and transfers those bytes to the associated module electronics and simultaneously can accept bytes from the module to be sent over the CAN bus. To prevent lockups if something goes wrong in the module electronics our firmware enforces a minimum transfer rate for the module developers to meet. We implement a timer to make sure each transfer completes in the allotted time. If this timer runs out the current transfer is abandoned. Any practical use of the byte-pipe mode will involve an end-to-end protocol between the IHU and module involved so this defensive approach makes good sense.

Even though we use hardware watchdogs and timers to watch over the system we still want to do our best to ensure that these mechanisms only come into play under extreme circumstances. To help ensure this all of our firmware is written in handcrafted assembly language because we want to know exactly what the code is doing. Before flight experienced software engineers in the AMSAT community will be invited to review our work. We fully expect this code review effort to find ways we can improve the firmware. One of the key benefits of the Open Source approach is the notion that with enough eyeballs looking at the code, all problems become visible. The high level of internal firmware documentation mentioned earlier is intended to facilitate these inspections by rapidly communicating the intent and desired effect of each routine in the code.

Finally, we use our firmware in these *widget boards* on the ground before the satellite is even assembled. The module designers are given the widget boards to be incorporated into their module, CAN bus interfaces for their PC's and software that mimics the way an IHU will interact with the modules on board the satellite. This means that all of the module implementers will be testing the behavior of these widget boards throughout the development of their components of the satellite. Any issues the module developers point out which could affect flight will be addressed in the firmware before it is flown.

### Conclusions

The project is nearing completion at the time of this writing. Prototype modules have passed functional and radiation tests. Flight firmware is nearing completion and enough PC software exists to allow functional testing of new modules and rudimentary control of the modules by satellite module builders. Still remaining are improvements to the ground software, implementation of the required software in IPS to enable IHU interaction with the modules and completion of the documentation package for satellite builders.

Several other AMSAT projects involving spacecraft of similar complexity are expected to adopt this design for their onboard command and telemetry systems, and at least one small satellite company has expressed interest.

Additional information about this project will be published on the web at: **http://www.amsat.org/amsat/projects/can-do/**

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## Support AMSAT-NA!

AMSAT®

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## Bird Watchers

IT'S A HAWK! IT'S A MAN!
IT'S MIKE, N1JEZ!

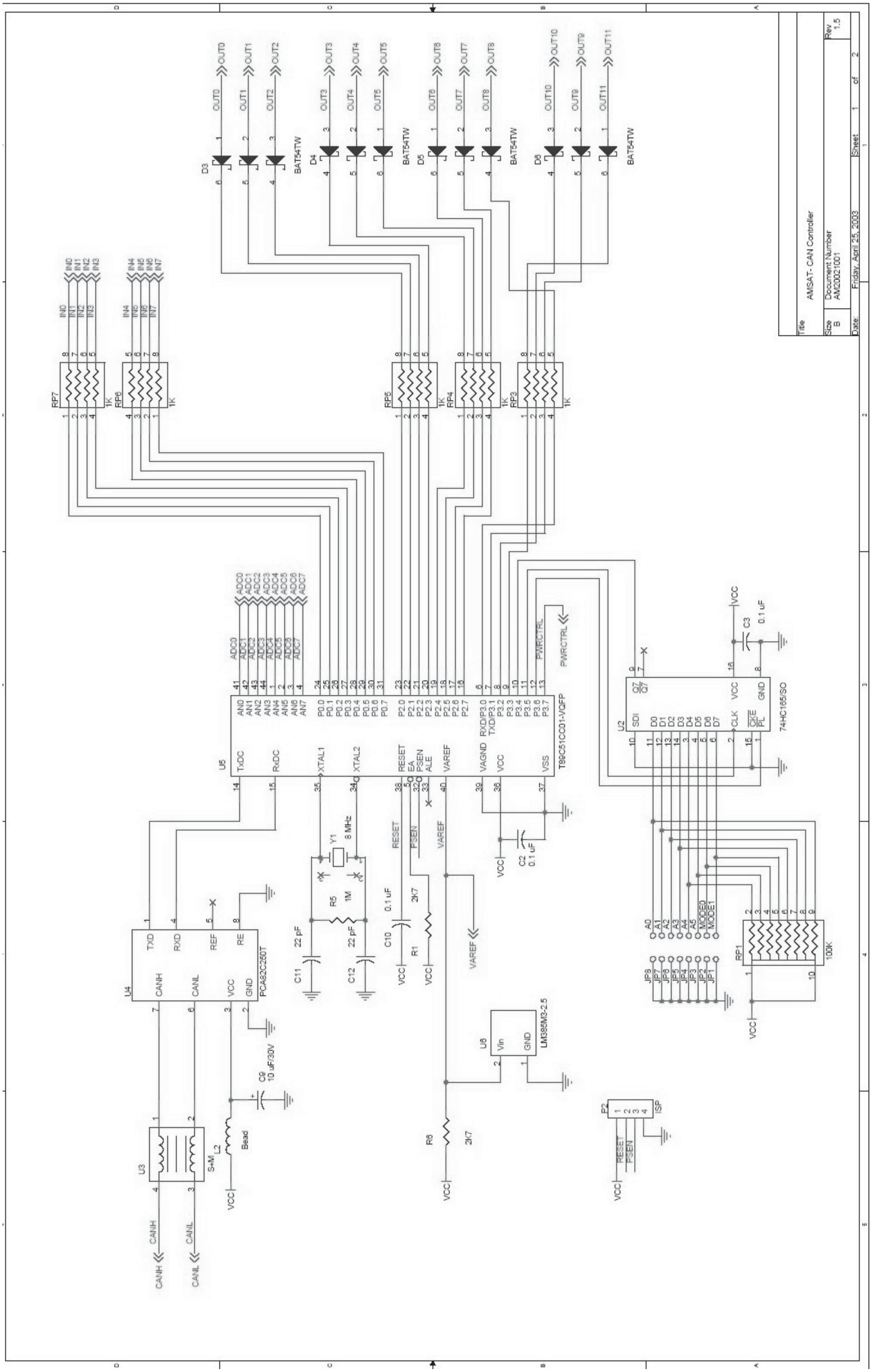
Last Sunday Dave, (N9PVF), his charming wife and I went to the top of Mt. Wachusetts, MA to watch the Hawk population migrating to the south as they do every year. We had expected to see many of them following the air currents. The hilltop was filled with many other bird watchers with their telescopes and binoculars of all different makes and models. Many of them had come from many miles away just to see this event.

I noticed one with a microwave dish jumping back and forth from his antenna and his car. I stood along side him for a moment and heard him say FN41 you are acknowledged. Somehow or other I knew this was not a bird watcher. Then I heard him say this is N1JEZ FN42BL. I froze in my tracks and said to him "Hello Mike" I am N1ORC, Arthur, and he replied I knew your voice the moment I heard you speak. Previously we had conversations on the Mt. Washington, NH repeater (146.655) and on UO-14. Mike had driven four hours from his home in Burlington, VT to reach this location to participate in the Microwave contesting that took place on Sept. 21, 2003. All I can add is that you never know whom you will meet in any part of this small world.

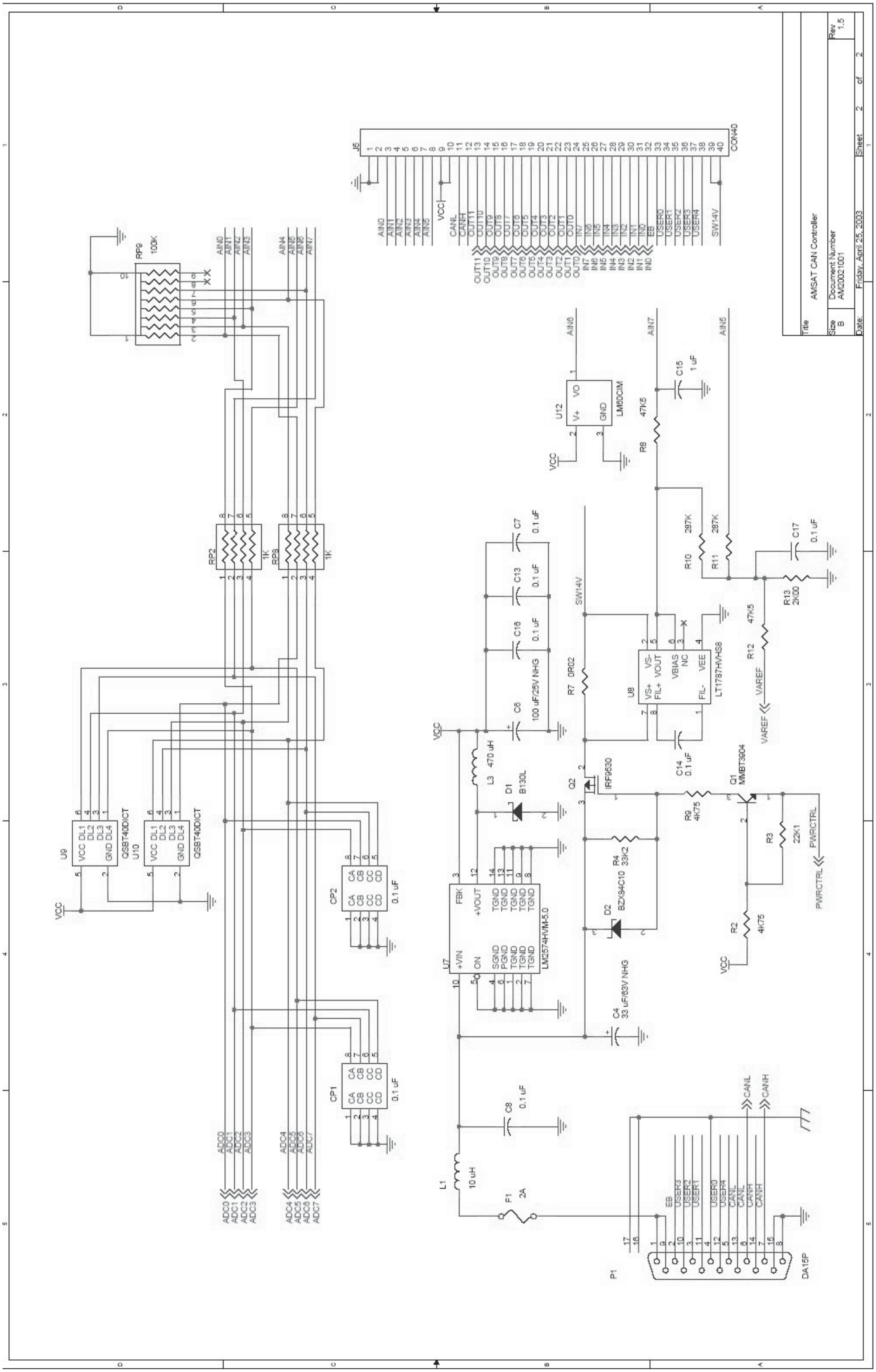
Arthur, N1ORC

P.S. I guess we were too early to see any Hawks but we did see several Sea Gulls.

(Ed. Note - See Mike's article on page 25.)




**Can-Do!**
**Processor Schematic**




**Can-Do!**
**Power Supply and Interface Schematic**

# Amateur Radio on the International Space Station (ARISS)

## The First Educational Outreach Program on ISS

**Carolynn Lee Conley; Frank H. Bauer, KA3HDO; Deborah A. Brown; Rosalie White, K1STO**

**Used with Permission: Presented at the 53rd World Space Congress, October 2002, Houston, Texas**

Amateur Radio on the InternationalSpace Station (ARISS) represents the first educational outreach program that is flying on the International Space Station (ISS). The astronauts and cosmonauts will work hard on the International Space Station, but they plan to take some time off for educational activities with schools. The National Aeronautics and Space Administration's (NASA's) Education Division is a major supporter and sponsor of this student outreach activity on the ISS. This meets NASA's educational mission objective: "To inspire the next generation of explorers…as only NASA can." The Amateur Radio community is helping to enrich the experience of those visiting and living on the station as well as the students on Earth. Through ARISS sponsored hardware and activities, students on Earth have a once-in-a-lifetime opportunity — to talk to the crew on-board ISS. Using Amateur Radio equipment set up in their classroom, the students get a first-hand feel of what it is like to live and work in space. This paper will discuss the educational outreach accomplishments of ARISS, the school contact process, the ARISS international cooperation and volunteers, and ISS ham radio plans for the future.

### History of Amateur Radio in Space

Amateur Radio has had a significant human presence in space starting with a flight on-board the space shuttle Columbia on the STS-9 mission late in 1983. At that time, astronaut Owen Garriott provided an unprecedented level of excitement in the Amateur Radio community by talking to ham radio operators on the ground using a 2-meter FM transceiver. These modest beginnings 19 years ago have led to a significant, nearly continuous presence of ham radio in human-tended space vehicles today.

In the U.S. the human spaceflight Amateur Radio activities are sponsored by the American Radio Relay League (ARRL), the Radio Amateur Satellite Corporation (AMSAT), and NASA. Several international Amateur Radio organizations have worked with the U.S. team for nearly two decades to maintain a constant Amateur Radio presence in space. Members of the international consortium of Amateur Radio teams include:

· **Germany** – The Amateur Radio (called SAFEX) team successfully operated Amateur Radio hardware on two shuttle missions and on the space station *Mir*.

· **Russia** — Since 1987, Russia operated Amateur Radio hardware on the space station Mir. The current ISS Amateur Radio hardware is located in the Russian Segment of the ISS.

· **United States**— Since 1983, the Space/Shuttle Amateur Radio EXperiment (SAREX) team successfully flew Amateur Radio hardware on 25 shuttle missions & supported astronaut Amateur Radio operations on the Russian space station Mir.

This combined team pioneered several new and exciting communications capabilities on U.S. and Russian-based human spaceflight vehicles. Some of the accomplishments include:

• The first human tended Amateur Radio in space (1983)

• The first communications between astronauts and people outside official NASA channels (1983)

• The first pictures uplinked and downlinked to Shuttle (1985)

• The first astronaut-student interviews (1990)

• The first computer-to-computer e-mails from the Shuttle (1990)

• The first television uplink to the Shuttle (1991)

• The first backup communications during a NASA satellite (TDRSS) outage (1992)

### ARISS—The International Space Station Connection

More than 40 space flight missions over five years will be required to assemble the ISS. The astronauts and cosmonauts will work hard on these missions, but have committed some of their free time to talk with schools. ARISS represents the first Educational Outreach program that is flying on ISS. In the U.S., NASA's Education Division and Office of Space Flight are the primary supporters and sponsors of this student outreach activity on the International Space Station. This meets NASA's educational mission objective: "To inspire the next generation of explorers…as only NASA can."

As the International Space Station takes its place in the heavens, the Amateur Radio community is doing its part by helping to enrich the experience of those visiting and living on the station as well as the students on Earth. Through ARISS activities, students on Earth have a once in a lifetime opportunity—to talk to the crew on-board ISS. Using Amateur Radio equipment set up in their school, students get a first-hand feel of what it is like to live and work in space. Each school gets a 10-minute question and answer interview with the on-orbit crew using a ground station located in their classroom or through a remote ground station. Through ARISS, students learn about orbit dynamics, wave transmission, radio communications, and working with the press. Since its inception, thousands of students and their families have participated in an ARISS event.

### ARISS—A program and an International team

The first organizing meeting was held in August 1996 to leverage successful, independent, international Amateur Radio teams to develop an Amateur Radio station plan for ISS. The NASA Education Division required the amateur community to commit to the development and operation of a single, coordinated Amateur Radio system on ISS. The ARISS team was formed consisting of nine international partners—Belgium, Canada, France, Germany, Italy, Netherlands, Japan, Russia and United States. A joint agreement was signed committing to the development and operations of a single, coordinated Amateur Radio system for ISS. International ARISS meetings are held about twice per year. To date these have been in Canada, England, the Netherlands, and the United States. The team also has executive-level teleconferences once a month and numerous committee teleconferences throughout the month.

## ARISS Objectives

The primary goals of the ARISS program are fourfold. These include:

1.Educational outreach - Through school contacts, ten or more students at each school ask the orbiting ISS crews questions and hundreds of students and family members participate. The nature of these contacts embodies the primary goal of the ARISS program — to excite students' interest in science, mathematics, technology and Amateur Radio.

2.Crew psychological factors - Contacts are scheduled with the astronauts' friends and families. Random contacts with the Amateur Radio public provide a unique opportunity for casual conversations with non-project related individuals. These boost the crew's morale by reducing the sense of isolation. This gives the crews more freedom in talking with family and friends.

3.ISS-based Communications Experimentation - ISS provides a testbed for development of new communications techniques which can be used to develop new educational projects.

4.International Good Will - Astronaut contacts to schools and the amateur community fosters international good will. Joint hardware development provides a forum to enable international technical partnerships.

## Volunteerism

Community involvement and volunteers are critical to the success of this program. Taking on a volunteer project that must meet the stringent requirements of a human spaceflight mission is a monumental task, to say the least. Literally hundreds of volunteers from numerous organizations worldwide have helped to make ARISS the outstanding success that it has become. The success of ARISS is, and will continue to be, predicated on the dedication and sacrifices made by those that have a desire to share Amateur Radio and the human spaceflight program with students and the general public.

## Current ARISS On-Board Hardware

The ARISS team has developed various hardware elements for the ISS Amateur Radio station. These hardware elements have flown to ISS on three Shuttle flights and one Progress flight. The initial educational outreach system consists of an FM radio system attached to some externally mounted antennas. The radio system is located in the Functional Cargo Block, named Zarya. This system supports FM voice operations and packet radio (computer-to-computer radio link) capabilities. Packet radio has several capabilities including an Instant Messaging-type system and a Bulletin Board System that allows radio amateurs to store and forward messages and allows the orbiting crew to send e-mail to all hams or to individuals.

## School Contacts

### School Contact Process

Individual schools submit an application to the ARISS program to hold a ten minute interview with a crew member on the International Space Station (ISS). After initial screening, these applications are processed on a first-come-first-served basis. An ARISS internationally based school committee reviews and prioritizes all applications for incorporation into the flight queue. The school group committee then forwards all completed applications with their priorities to the ARISS international operations team. This team assigns an operations mentor to each school. The schools have several months to prepare for their contacts. The operations team recruits volunteer Amateur Radio operators that are cognizant in Amateur Radio satellite operations and are near the school to support the local school group contact. A school may have its own radio club or station, but it is not required. The local Amateur Radio volunteers support the school with the technical know-how to make the ARISS contact successful. They also provide the required antennas, radios, computers and software to establish an effective ground station at the school.

The classroom teacher needs on the order of six months to plan and prepare the school for the 10-minute Amateur Radio interview. Actually, the contact is just the pinnacle of a substantial educational program that centers around Amateur Radio in space. Grades K-12 are encouraged to participate. However, other educational institutions, including colleges and museums, may also participate.

Contacts are available year round, but depend on the work schedule of the crews on the ISS. The operations team attempts to schedule one to two contacts per week. During weeks involving extravehicular activity (EVA) or visiting Soyuz or Shuttle crews, the ISS crew is usually not available for school contacts.

The operations mentor works closely with the local Amateur Radio volunteers and the school teacher to ensure they are prepared for the contact. This includes the preparation of the questions to be asked. Since the operations mentor has performed numerous

*Figure 1: Merivale Public School child reading her question to Commander William Sheperd, Expedition 1. (Photo Credit - Michelle Rickard, courtesy of Nepean This Week, Ontario, Canada)*

ARISS contacts, the mentor knows many tips to maximize the success of the contact. One important decision that is made early on is whether the contact will be made through a radio station that is installed at the school (a direct contact) or through a remote ground station (a telebridge contact).

Approximately 4-6 weeks prior to the ARISS event, several contact opportunities are generated by the operations team. This information is shared with the school group to arrive at a prioritization of contact times. These priorities, as well as specific information about the school and the questions to be asked by the students is forwarded to the ISS mission control team. These contact opportunities usually fall within a specific week for that particular school. Approximately one week prior to the event, the ISS mission control team provides the rise and set time for the event and the crew member that will participate in the event.

During contact day, the operations mentor and the school team are in constant communication, sharing and confirming orbital data, synchronizing timing, sharing information on contact success and compiling metrics from the contact.

Once the contact is complete, the school is asked to fill out a NASA educational survey form called EDCATS. This helps NASA compile its own statistics on the educational benefit of this and other programs.

## Direct Contact Ground Station Requirements

The mentors that have supported the Shuttle, Mir and Space Station programs have spent years developing and honing the optimal Amateur Radio station configuration to be installed at the school. This station will ensure a solid, 10 minute horizon-to-horizon contact for the school. Specifically, the station should include:

- · A 2-meter FM radio system with the ability to memorize multiple odd split pairs of frequencies,
- · Output power at least 75 to 100 watts
- · A receive pre-amplifier
- · OSCAR style circular polarized crossed yagi antenna,
- · Azimuth/elevation rotation control of the antenna system
- · Computer with current satellite tracking software.
- · Battery backup power supply
- · A redundant radio system that supports 75-100 watts of power output. This should be attached to a simple, vertical antenna

The redundant radio system and the backup power supply are included to minimize the effects of "Murphy's Law" where things can and will go wrong at the worst possible time.

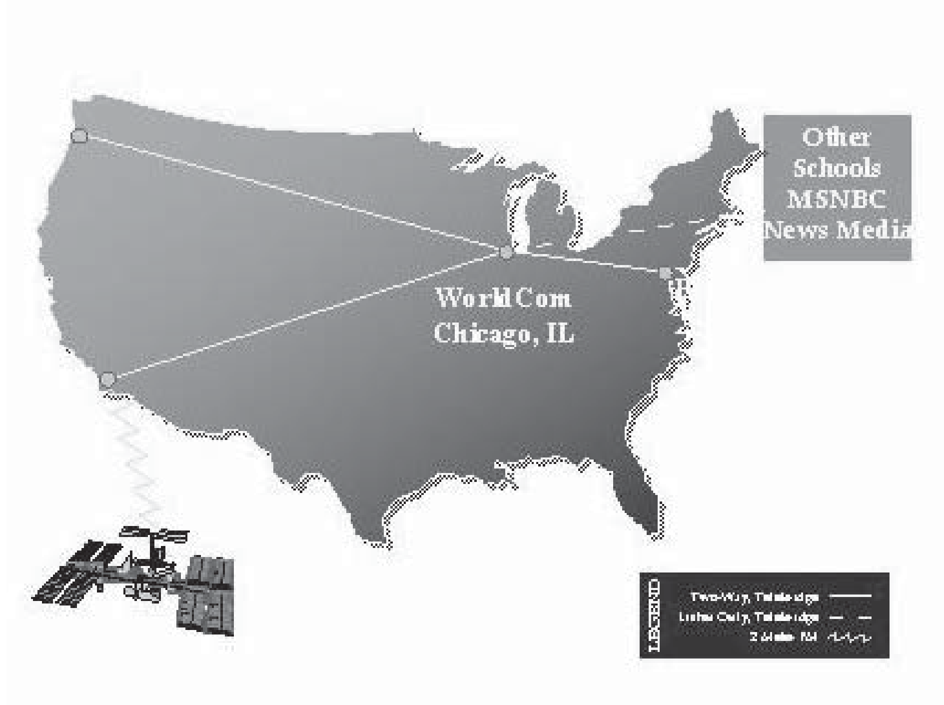



*Figure 2: The WorldCom Telebridge Network*

## Worldwide Telebridge Facilities

The telebridge system is used when direct ISS communications is impractical, either due to visibility or timing constraints, (e.g. low elevation passes at school location, late night passes), national rules on unlicensed persons using an Amateur Radio, or technical concerns at the school. The telebridge system consists of an international network of ISS ground station volunteers that can be linked to school groups using a telephone conferencing system. See figures 2 and 3. This system is similar to NASA's system of tracking stations which were used extensively during the 1960's, 1970's and early 1980's to track human space flights. One school is interactively linked to the bridge with one ground station for the entire 10 minute pass. However, several school groups can be interactively connected to the bridge with several ground stations providing a direct link to the ISS for periods of up to 20 minutes. The school groups usually talk to the astronauts through a local radio system which is patched to the telebridge. If this is not practical, a speaker phone can be used; however this is not encouraged since it is not in the spirit of Amateur Radio activity.

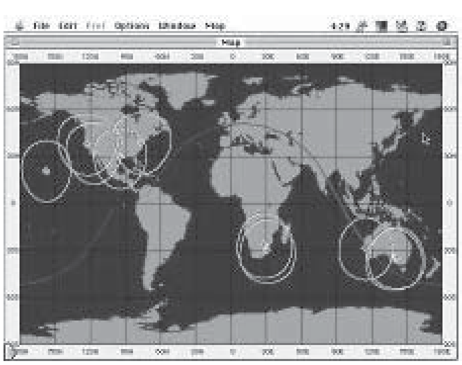


*Figure 3: Telebridge Network Ground Station Locations*

Figure 2 depicts the telebridge communications links for a hypothetical school group in Seattle, Washington. As shown, the primary bridging service is graciously donated by Worldcom. During the contact, an ARISS bridge coordinator is on-line with the technical staff at Worldcom to ensure that the voice levels are appropriate and that the bridge is working well. Other groups tied into the bridge as listen-only participants include MSNBC, specific press sites that coordinate with the team prior to the contact, and other schools interested in witnessing the event. Figure 3 illustrates the specific ground stations around the world that support this activity. ARISS telebridge ground stations are located in Australia, South Africa, California, Hawaii, Maryland, and Texas. To date, over 30 ARISS schools have been linked via telebridge.

## Application Information

Applications are available at:
www.arrl.org/ARISS/ariss-ap.html

Applications are accepted continually, but because of worldwide interest, there is a one to two year waiting list for ISS contacts. The program's official website is at: ariss.gsfc.nasa.gov

## On-Orbit Operations Metrics

To date, over 70 school contacts have been performed through ARISS. These include contacts in thirteen countries and over 26 states in the U.S. Table 1 illustrates the specific number of contacts performed by each expedition crew and by the Soyuz Taxis crew members. As shown, Frank Culbertson performed the highest number of ARISS school group contacts. He averaged approximately 1.2 schools per week during his stay on ISS.

## School Contact Metrics

Other educational events that the crew supported included contacts during the 2001 and 2002 Amateur Radio field day by Expeditions 2 and 5 respectively and the Boy Scout Jamboree-on-the-Air in 2001 by Expedition 3 Commander Frank Culbertson.

| Crew Expedition | School Contacts |
|---|---|
| 1 | 7 |
| 2 | 14 |
| 3 | 22 |
| 4 | 17 |
| 5 | 10 |
| Tourists/Taxi Flights | 5 |

*Table 1: School Contact Metrics*

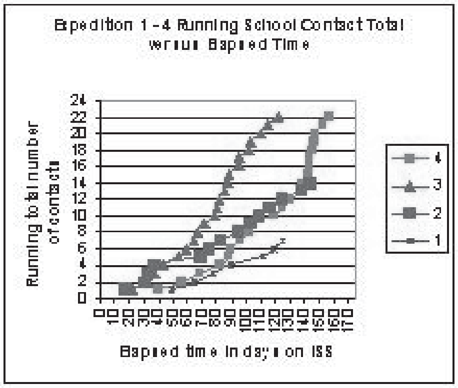



*Figure 4: School Contacts Illustrated*

The above graph (Figure 4) illustrates the consistent participation in school contacts by the ISS crews.

Early in the ISS Expeditions, the crew relied almost exclusively on the ISS ham radio system for friends and family contacts. For example, up to 5 friends and family members were contacted per week by the Expedition 1 crew. With the introduction of the IP Phone on ISS, the U.S. friends and family contacts have curtailed but the Russian friends and family contacts continue. In addition, the use of the equipment for general, worldwide communications have increased, particularly with commander Valery Korzun on Expedition 5.

The ISS ham radio system also supports packet (computer-to-computer radio link) capabilities. Packet radio has several capabilities including an Instant Messaging-type system and a Bulletin Board System that allows radio amateurs to store and forward messages and allows the orbiting crew to send e-mail to all hams or to individuals. The Instant Messaging capabilities have been operational since April 2001 on Expedition 2. Valery Korzun from Expedition 5 enabled the Bulletin Board System in February 2002. Since that time, hundreds of e-mail messages have been sent by the ISS crew and forwarded between radio amateurs on the ground.

## International Outreach

Thirteen countries have had school contacts to date—Australia, Belgium, Canada, Finland, France, Germany, Italy, Israel, Japan, Russia, South Africa, United Kingdom, and the United States. Some of the more exciting international contacts are described below:

Japan — A school contact was organized for a Saturday morning that had the entire school and community involved. During this contact, the astronaut's answers were simultaneously translated into Japanese and projected on a screen in the auditorium. All the Japan television stations attended this historic event and either broadcast the contact live or replayed it on the evening news.

Newfoundland, Canada — A special request was made by the Canadian Space Agency to support a school contact at Signal Hill, Newfoundland to commemorate the 100th Anniversary celebration of the first Marconi radio transmission.

South Africa – Space tourist Mark Shuttleworth conducted four school contacts during his stay on ISS. These contacts were transmitted over national television and retransmitted to 38 countries in the continent of Africa.

## Estimated Outreach

NASA maintains an educational database, called EDCATS, to track the success of all the ARISS school contacts. With over 70 schools contact since its inception in late 2000, over 15,000 school children have participated in an ARISS event. In addition to classroom activities, the ARISS program requires that each school involve the local community. The teachers are encouraged to include in their planning and lessons, interactions with their local media. All of the 70+ schools have had local, state, and/or national news coverage reaching a minimum of another 12 million people worldwide. At least one-third of all school contacts are broadcast live on the Internet via MSNBC.com. Several school contacts are archived on the Internet by MSNBC and others. Clearly, ARISS is ***inspiring the next generation of space explorers***.

## IMAX "Space Station 3D" and ARISS

ARISS successfully supported the IMAX team in their production of the first film documenting the construction of the ISS. The IMAX "Space Station 3D" film includes two scenes with students on the radio talking to the crew. As of late June 2002, the "Space Station 3D" film is showing in 104 IMAX theatres in approximately 26 US cities and nine countries. Twenty-four more theatres in seven additional countries will open later in 2002 and in 2003. Countries initially showing in 2002 included Australia, Canada, Denmark, England, Germany, Japan, Norway, Sweden, and the USA. Upcoming countries include Ireland, Kuwait, Netherlands, New Zealand, South Africa, Taiwan, and Thailand. There are currently 226 IMAX theatres in 30 countries worldwide; additional theatres may decide to show the film over the next few years.

*Figure 5: Frank Culbertson at the ARISS Station during Jamboree on the Air*

## School Contacts—A Once in a Lifetime Event

The radio contact is the culmination of a long series of classroom projects, space science and engineering activities, community involvement, and public relations that produce a spirit of teamwork. There is a sense of accomplishment that results from the school and the students setting up and conducting the ISS ham contact themselves. The students better understand how NASA and the other international space agencies conduct science on ISS. The unique, hands-on nature of the Amateur Radio contact provides the incentive to learn about orbital mechanics, space flight, and radio operations. This is the "best educational outreach program at NASA," says one of our NASA Headquarters sponsors. In addition, the ISS Ham educational activities support the National Education Standards in Math, Science & Technology.

A coordinating teacher said, "To see the kids' eyes light up, it was worth everything we've done to see that. This is something they will remember for the rest of their lives."

### The Future

The ARISS team will be expanding the program with new communications capabilities such as television, image e-mails sent automatically to schools and other communications projects. This past year, the team has installed 4 antenna systems on the outside of the Russian Service Module. These antenna systems will support future operations within this module. Additional hardware systems to exploit these antennas are currently under development. These systems will allow the crew to support multiple activities at the same time (e.g. voice, e-mail, and television) with higher power radio systems. This will enable a more comprehensive school contact event.

Each school contact performed allows additional schools to network into the program. New lesson plans are under development and additional material will be available for the schools and for the general public on the ARISS Web pages.

## Conclusions

The ARISS program represents the first Educational Outreach Payload on-board the ISS. The ISS ham radio activity is one of the most exciting and stimulating educational outreach programs in space, providing students a once in a lifetime opportunity to talk to a crew member on-board ISS and learn what it is like to live and work on ISS. In less than two years, this program has enabled tens of thousands of students to participate and learn about science, technology, and amateur radio. Through ARISS, the space agencies and Amateur Radio community is inspiring the next generation of space explorers.

## Comments about ARISS from the NASA EDCATS Educational Database

"I believe strongly in ARISS as an educational tool- I cannot express briefly the impact it made on our entire student body!" … a classroom teacher.

"My future contacts are waiting, some of the schools on my list see this project as the best way to turn children on to science and technology - they are right !!"
… an educational administrator.

## Author Information

Carolynn Lee Conley
ISS Ham Integration Manager, Muniz Engineering, Inc., Houston, Texas, 77058, USA, Phone: 281-244-8150,
carolynn.conley1@jsc.nasa.gov

Frank H. Bauer
Chief, Guidance, Navigation and Control Division, National Aeronautics and Space Administration, Goddard Space Flight Center, Greenbelt, Maryland, 20771, USA, Phone: 301-286-8496,
frank.bauer@gsfc.nasa.gov

Deborah A. Brown
Education Specialist, Teaching From Space Program, Washington, D. C., 20024, USA, Phone: 202-554-4380,
dbrown4@hq.nasa.gov

Rosalie White
Field and Educational Services Manager, American Radio Relay League, Newington, Connecticut, 06111, USA,
Phone: 860-594-0237,
rwhite@arrl.org

# New AMSAT Board of Directors

*L-R, Tom Clark, W3IWI; Lou McFaddin, W5DID; Barry Baines, WD4ASW; Rick Hambly, W2GPS; Gunther Meisse, W8GSM; Robin Haighton, VE3FRH. Not shown is Lee McLamb, KU4OS (First Alternate)*

## AMSAT-NA Dues Increase in January

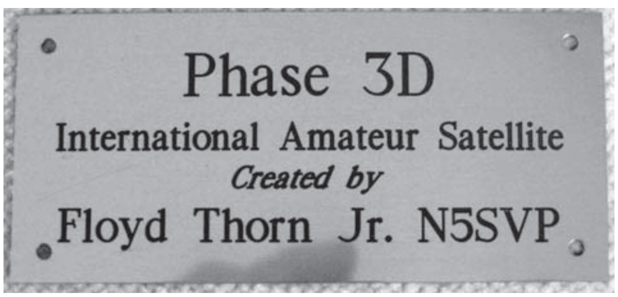
There is No Such Thing as a Free Launch .....

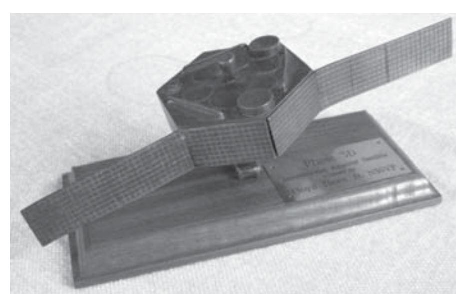
Everything costs more, but not much more for AMSAT Members. AMSAT membership dues are going up only three dollars a year. Beginning in January 2004, dues will be $39 a year in the USA; $45 in Canada and Mexico and $50 elsewhere. The increases are needed to cover extra printing and postage costs. Thanks for supporting AMSAT-NA!

### AMSAT-NA Auction

How would you like to own a handmade, bronze model of PHASE 3D - only one of 4 ever made? The model (shown below, with nameplate detail shown at left) was created in bronze by Floyd Thorn (SK), N5SVP. Floyd made only four castings using drawings supplied by Bill Tynan, W3XO. The casting measures 11 inches tip to tip and 3-1/4 inches above its base. The piece has been donated by Floyd's estate as a contribution to help support the launch of Echo.

This beautiful bronze model will be auctioned to the highest bidder, with proceeds going to support the launch of Echo. The auction will be held on E-Bay. A link to the auction will be provided on the AMSAT-NA Web site so that visitors can easily find the correct location. Final details will be announced on the AMSAT-NA Web site shortly. We expect the auction to run from mid-January until the end of the month. Larger color pictures of the casting will be available showing the details of this beautiful model. Check the AMSAT-NA Web site at http://www.amsat.org for more details. Don't miss out on a rare opportunity to own a highly unique part of AMSAT history!



## JD1YAB DXpedition on AO-40

**By Masahiro Arai, JN1GKZ**

jn1gkz@qsl.net

http://www.ne.jp/asahi/m-arai/gkz/

JD1YAB (IOTAAS-031, Grid QL17CB) was a special events station operating during the 35th anniversary of the reversion of the Ogasawara Islands. JD1YAB was set up on Chihi-jima Island from June 15 to August 31, 2003. The station used the same callsign used for the first Ogasawara DXpedition 34 years ago.

JA0EOK, JK1NAF, JL1BFC and JL1SAM arrived from the Japanese mainland on Chihi-jima Island to operate JD1YAB on June 26-29, 2003. They were the first crew to operate AO-40 from JD1YAB. They operated AO-40 on only two passes and made 54 QSO's. After June 29, Aki, JD1AMA, who lives on Chichi-jima Island and the other guest operators, continued to operate on AO-40 and made multiple contacts.

The JD1YAB AO-40 station equipment included:

- IC-910D (uplink: 1.2 GHz, 10W)
- 2.4GHz Maki-Denki down-converter
- Dual feed Dish Antenna

Some photographs from the operation may be seen below. Congratulations to the team for a great operation.

***The JD1YAB crew, 26-29 June 2003 Left to right: Hiro, JK1NAF; Aki, JD1AMA; Kazu, JL1BFC; Tosy, JL1SAM; Tack, JA0EOK***

*Photos continued on page 31 ....*



## Worth Noting: Awards Costs

As it has been well over 5 years since AMSAT has adjusted the cost of awards. Effective January 1, 2004, the awards fee for AMSAT members will be $5 and for non-AMSAT members $10. The cost for the Communicator Club for your first satellite QSO will remain at $1 for members and $2 for non-members.

Bruce Paige, KK5DO
AMSAT VP-User Services & Awards Manager

# K Band on AO-40 by Mike Seguin, N1JEZ, n1jez@amsat.org
## Presented to 2003 AMSAT Symposium, October 17 - 18, 2003
## Toronto, Canada

One of the most significant challenges for satellite operators is K Band reception from Oscar 40. The center downlink frequency is 24.048035 GHz. The transponder is 50 kHz wide. What follows are my experiences as I went from conception to full operation on Oscar 40's highest operating downlink frequency. (We're all still waiting for laser!)

I will purposely include references to terrestrial 24 GHz microwave operation. One should consider building for this frequency as well. Not a lot of changes are necessary and 24 GHz is becoming more popular among the microwave community.

### In the Beginning

I first became interested in K Band during the 2001 AMSAT Symposium in Georgia. At that time, I was just beginning my microwave experimentation using 10 GHz equipment. It all seemed like an immense uphill battle to first understand the equipment requirements and then to secure the necessary pieces to complete a working system. Unlike the relative simplicity of Mode S, K Band seemed very complex. I suppose the lack of "Elmers" made the task seem huge.

I came away from the "K Band Working Breakfast" presentation with lots of ideas. Over the next few weeks, I re-read the material and slowly began to formulate a plan. My microwave experience, using 10 GHz narrow band gear, was beginning to help shed light on the various obstacles to overcome.

The Oscar 40 K Band transponder transmits with only 800 mW into a 23 dBi linear horn. This was going to be a true weak signal mode.

### The Equipment

Over time, I developed a list of equipment that I would have to acquire to attempt to hear AO-40 on K Band. This included:

1. Dish and Feed
2. Receive Preamp
3. Waveguide Filter
4. Mixer
5. Local Oscillator (LO)
6. IF
7. Mount and Pointing System

Early on, I decided that I wanted to be able to operate both satellite and terrestrial on 24 GHz. The frequencies are different. Satellite is receive only on 24.048 GHz while terrestrial is on 24.192 GHz. This added more parts and pieces to my list of equipment. I now was in need of a second LO, waveguide filter, waveguide switch and power amp.

Please bear in mind that I was designing a high-end portable system and I was looking for very good performance. Two factors led to this decision. First, because of the 'incident' with AO-40, the minimum requirements for successful reception had been elevated somewhat. Most notably, we're looking at an additional 10,000 km of path loss. Range for me is typically 60,000 km+. Also, for terrestrial operation, I wanted more power than just a bare mixer could provide. This is also a totally portable system, which creates additional requirements that I'll discuss further.

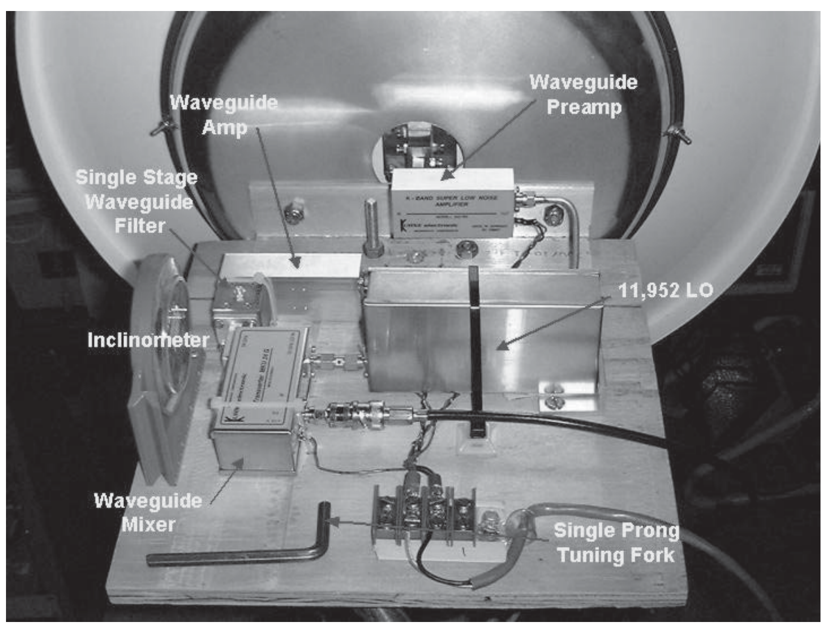
One of the biggest decisions that I made was whether to try to build or buy most of the assemblies. My decision was to buy. The rationale was really quite simple. Without at least some test gear at these frequencies, I would really have no way to test or optimize anything I built. I was slowly acquiring test gear for 10 GHz and knew I could extend that to 24 GHz in time, but for now I wanted to go with a known quantity.

At this frequency, we try to use waveguide whenever possible to minimize losses. The standard for 24 GHz is WR-42. You will see it mentioned numerous times in the text.

All of this led to the decisions I made on equipment:

1. Dish and Feed - Procom[1], 0.5 meter, Linear Feed
2. Receive Preamp - DB6NT/Kuhne Electronic GmbH[2], < 2 dB NF
3. Waveguide Filters (2) - MikroMechanik[3] & SSB Electronic USA[4]
4. Mixer - DB6NT Subharmonic
5. LO – 2 units, DB6NT 11.880 GHz & 11.952 GHz
6. IF – 2 units, FT-290 & FT-790

The Dish and Feed were chosen because of previous experience with Procom at 10 GHz. While they are not the most efficient performers, they are a known quantity. The size of dish was a tradeoff between gain, beamwidth and portability. The decision to go with a linear feed was based primarily on terrestrial operation where we use horizontal polarization for narrow band operation. I was aware that AO-40 has a linear horn antenna and is spinning. I knew using a linear feed would cause deep fades due to polarity mismatch. In fact, I was told that I wouldn't be able to make a contact because of the QSB. This really surprised me! I looked at the spin rate and determined that it shouldn't be a huge problem. Yes, there would be fades, but it wouldn't be insurmountable. I predicted that I would see approximately 7 to 8 seconds of good signal, followed by 3 to 4 seconds of fade. I knew I could trade callsigns/grids/reports in that time. However, carrying on an extended QSO would be easier with circular polarization to minimize the fades.




*Rear view of 24 GHz receiver showing individual components*

A receive preamp was an absolute necessity. I chose a DB6NT preamp. They are state of the art. I chose a waveguide (WR-42) input and SMA output. Waveguide input was chosen to be able to attach directly to the feed on the dish. This was to minimize losses to maintain a good receive noise figure. SMA was used on the output to couple to an amplifier I use for terrestrial operation.

I needed two WR-42 waveguide filters; one for each segment of the band I planned to operate. Waveguide filters were chosen because of tight filter requirements due to the use of a 2m and 432 MHz IF. It turned out that SSB Electronic had a terrestrial waveguide filter that was less expensive than MikroMechanik, so I ended up with one from each company.

The mixer was a subharmonic design by DB6NT. The input/output was WR-42 waveguide. SMA connectors are used for both LO input and IF.

The Local Oscillators (LO) are DB6NT. For AO-40, I chose 11.952 GHz. This results in a low side injected 2 m IF frequency. The LO frequency is doubled in the mixer.

**(11.952 GHz x 2) + 144 MHz = 24.048 GHz**

For terrestrial operation, I chose 11.880 GHz. This results in a low side injected 432 MHz IF frequency. The LO frequency is doubled in the mixer.

**(11.880 GHz x 2) + 432 MHz = 24.192 GHz**

The terrestrial LO frequency of 11.880 GHz turned out to be a good choice because it can also be used at 47.088 GHz with a high side injected 432 MHz IF frequency. This LO frequency is quadrupled in a DB6NT mixer I have for 47 GHz operation.

**(11.880 GHz x 4) - 432 MHz = 47.088 GHz**

The IF rigs chosen were the Yaesu FT-290/790 portable series. I had the FT-290 2M IF and picked up the FT-790 432 IF surplus. The Yaesu FT-817 was not an option at the time. It would have been a good choice as well.

For mounting, I used my QuickSet[5] Hercules tripod. This is the same one I use for mountaintop microwave activity. It's extremely rugged, being designed for a large format camera. It will easily handle a 150-pound top load. I can attest that it is stable even in 50+ mph winds having operated with it on top of Mt. Washington in NH. With a dish that needs to be accurately aimed within a few degrees, stability is important.

For pointing, I use a combination of compass rose for azimuth and inclinometer to set elevation.

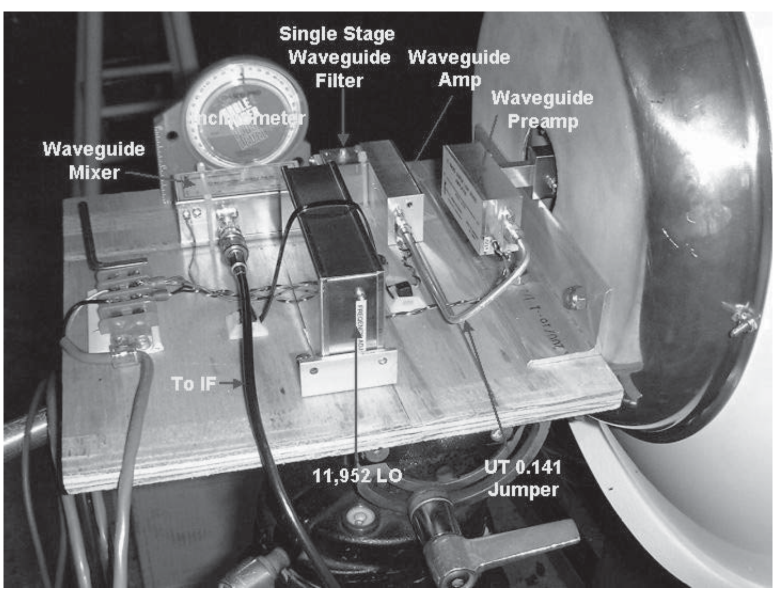
## The System

The first receive only system I built is pictured at left and below:

For dish mounting, I've adopted the use of frying pans. Mirro makes a series of frying pans that have a lip that makes them easy to drill and ideal for this purpose.

In the pictures above, you'll notice a second amplifier between the preamp and filter. I had the amplifier and put it inline, but it isn't necessary. It was actually used in place of a transition. At the time, I was missing a WR-42 to SMA transition and ended up using the amp in its place.

A block diagram of a typical signal flow without the additional amplifier is on the next page.




***Side view - receiver***

## The Challenge

Portable satellite operation is always a challenge. K Band operation is no different from any other operation except higher precision is required. There are a series of major variables you will need to deal with.

1. Tracking.
2. Pointing – both azimuth and elevation.
3. Frequencies – Doppler shift and LO drift.

If you are able to eliminate or minimize the error in any of these variables, your chances of success increase significantly.

## Tracking

For most of us, tracking is relatively easy. We do it all the time with our satellites. The only difference here is the need for more precision. There's not much room for error. One degree can be the difference between success and failure. Operators who use large dishes for S Band reception can begin to appreciate the precision required. However, they have the advantage of listening for loud signals.

I use Nova for Windows(R) for tracking. As well as giving me the usual azimuth and elevation data I need, I also make use of the scheduling feature to input the MA versus transponder modes for AO-40. This way I can easily see when the K Band window will be available.

## Pointing

I can't over emphasize the importance of having an accurate means of pointing the dish both with respect to azimuth and elevation. A 0.5-meter dish on 24 GHz has a little over 2 degrees beam width. This is both in the vertical and horizontal plane. In a portable situation you must have some way to determine where you're pointed or, unless you're very lucky, you're doomed from the start.

First, for azimuth, I have an accurate compass rose mounted on my tripod. My favorite source for these is Oregon Rule Company[6]. For elevation, I use a simple inclinometer. An inexpensive device that works well is the "Angle Finder" from Dasco[7]. They are available at hardware stores. To set the compass rose, I use sun alignment. I'm sure some are thinking of sun alignment as trying to peak a receive signal while pointed at the sun. This is not how I do it. This method involves using the sun to cast a shadow from the feed on the face of the dish. Using this method, I can usually set the compass rose within 1 degree. It works as shown at the lower right on page 27.

To determine the position to set the compass rose, I use Stacey Mills', W4SM, wonderful little program TrakSM[8].

This method of alignment obviously requires the sun. If it's cloudy, a compass can be used, but it's far from accurate.

### What's the Frequency Kenneth?

By the time I had gotten to assemble my system, I had the means to measure frequency to beyond 12 GHz. This proved to be very helpful in setting the LO as close to 11.952 GHz as possible. In microwave operation, frequency drift is a way of life. We're getting better at minimizing it, especially with the introduction of GPS disciplined oscillators and phase lock systems.

Usually our systems start with a basic crystal oscillator in the 100 MHz range that is multiplied up. This is the case for my 24 GHz system. The fundamental oscillator is at 124.5 MHz. This is multiplied 96 times to reach 11,952 MHz and then doubled again in the mixer. As you can imagine, there's quite a bit of room for error. The crystal does have a thermistor heater attached, but even with this, you will see a slow drift up and down of 4-5 KHz as the crystal heats and cools. The bottom line is to be ready to tune to find the beacon.

### K Band Doppler

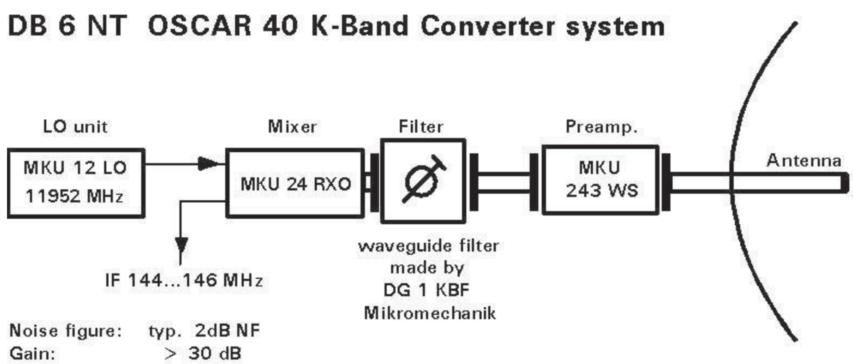
During a typical K Band operating window, you should expect to see up to 60 KHz of Doppler shift plus LO drift. I use the frequency display in Nova for Windows(R) to help determine the beacon frequency. I have it set for 24,048.035 MHz. It's reasonably accurate and gives a good indication of where to begin listening. Even so, be prepared to tune.

### The Next Step – Listen for the Beacon

Armed with a working system, I set out to first hear the beacon. Since trees surround my house, I chose an operating location not far away that had good line of sight down to the elevation in the 2 prime directions that I needed to look for AO-40 during the K Band windows. You must have an unobstructed view for K Band operation otherwise you won't hear it.

*What can you expect for a signal level with a system such as mine?*

About the strongest signal I've heard is S5 on peaks. A more typical signal is only about 3 S units above the noise. With a linear feed, I see maximum signal when the polarity matches the satellite. If you convert to circular, it will minimize the fades at the expense of about 3 dB in signal level.




***Antenna/Downconverter Block Diagram***

K band windows are scheduled to minimize the squint angle. Charlie, G3WDG made the graph on page 28 of squint vs. signal level.

As you can see, with my system I really need to have a squint below about 5 degrees or copy starts to get rough. Remember, 3 S units is a peak level.

A typical K Band window is about 10 MA long. Usually the first few minutes (2 MA) are dedicated to "beacon only" operation. The uplink receivers are shut down. This is significant because the transponder is hard limited. This means that normally the beacon and any uplinks share the transponder downlink power. If there is a very loud signal in the passband, it will rob power from the beacon, to the point that it's sometimes very hard to detect. Having a set amount of time where the beacon has full transponder power makes detection easier.

On April 14, 2002, I set up about an hour before the scheduled K Band beacon activation. One reason I set up early was to allow my LO to temperature stabilize to minimize drift. Right on schedule, the K Band beacon was fired up and I began to search. Within about 5 minutes of searching I found the beacon! The QSB was as predicted. A big temptation was to tune or move the dish as the signal faded. I soon learned this was a bad thing to do as I lost the signal more than once. In the coming days, I made several more successful attempts. Finally satisfied with my ability to find the beacon and track AO-40 consistently, it was time to try a QSO.

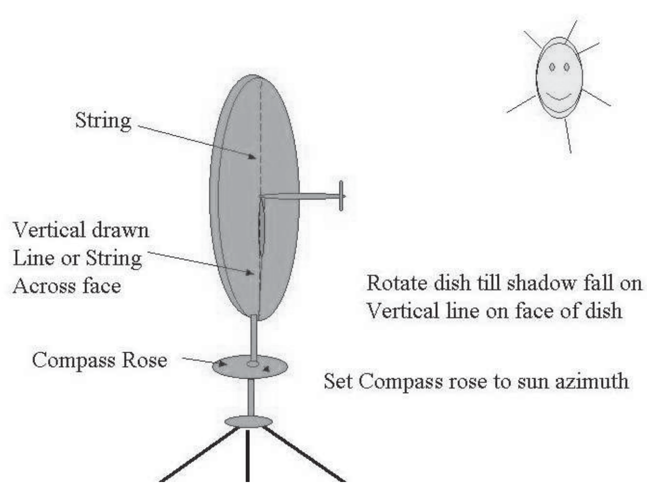
### The First Voice QSO

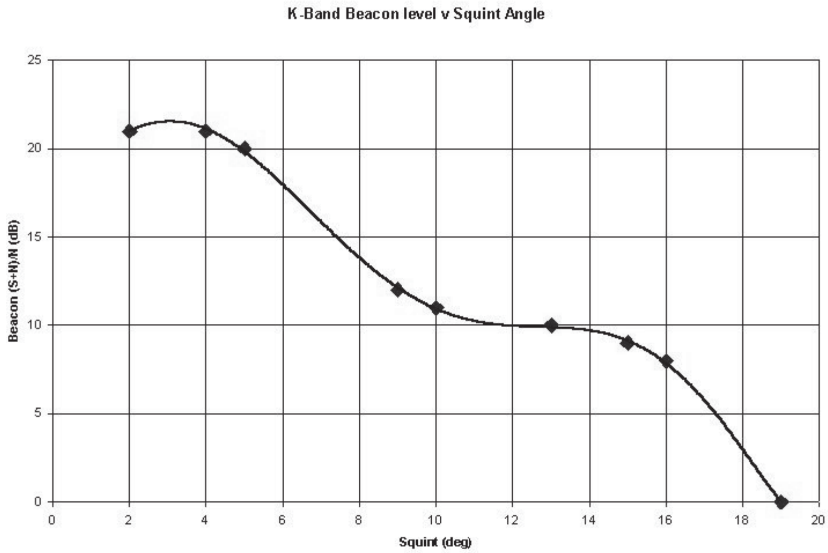
I sent email to Jerry, K5OE to see if he would be interested in trying to work me. On April 20, 2002 Jerry and I exchanged calls and reports. I was using L band up and K band down. Jerry used U band up and S band down. The following day, I also worked Steve, KB8VAO.

One trick I learned when I first began to operate satellites was to load the beacon frequency of the bird I was operating into the second VFO on my radio. That way at any time, I could switch to the beacon to see the downlink level. This is a tremendous aid in K Band operation. You do have to compensate quite often for Doppler on the beacon, but being able to quickly shift to the beacon and verify transponder signal level is a big help.

Up until my success, the only other ham with K Band capability in the U.S. was Al, W5LUA. I contacted Al to see if he'd like to try a K Band to K Band contact, but found out he couldn't elevate his dish enough so we could

***Setting the compass rose***





*Beacon signal strength vs. squint angle plot*

work during a mutual window.

Shortly there after, I contacted Charlie, G3WDG to see if he'd like to try. I figured as well as this being my first K Band to K Band contact, it would also be the first ever trans-atlantic one as well. On May 7, 2002 Charlie and I had a successful QSO both using K Band down.

Audio of these contacts is available at: http://members.aol.com/mike73.

### The Box Score

Since that time, I've made quite a few contacts. Here's a list as of July 2003:

| | |
|---|---|
| G3WDG * | K5OE |
| F6GBQ * | KB8VAO |
| OE1VKW * | KO4MA |
| I8CVS | K5AXW |
| DK2ZF | WC9C |
| OM3WAN | K2IYQ |
| HB3YEV | UU9JJ |

* Indicates K Band equipped station.

All contacts were made using SSB. Typical distance was 60,000 km+. Most contacts were made at about 20 kHz below the beacon. Care must be taken to not go too low because the transponder is only 50 kHz wide (± 25 kHz of the beacon). Sadly, as I write this, there has yet to be a successful K Band to K Band contact between two US operators. Hopefully that will change soon.

### Recommendations

1. **Find an Elmer!**
   More importantly, find an Elmer with test gear! It will make your life a lot easier.
2. **Work with as big a dish as you can.**
   With these small signal levels, bigger is better. It is a tradeoff. Bigger is harder to point.
3. **Use Circular Polarization.**
   If you can use a bigger dish, by all means try circular polarization. It makes it a lot easier to not have to deal with the fades.
4. **Build a Weak Signal Source/ Marker.**
   I recently built one of these and it's a great tool to help verify system performance. My system is based on a Qualcomm 3036 synthesizer programmed for 2672 MHz. The ninth harmonic is loud on 24.048 GHz. It's not real expensive to build. The synthesizer can be programmed for numerous frequencies. I have mine switch selectable for use at 24.048, 24.192 and 47.088 GHz. If you'd like details, please email me. n1jez@amsat.org

### The Future

I'm currently in the process of building a dedicated K Band receive only system. This one will be based on a P-Com receive mixer. It will initially utilize a slightly larger 24" dish and circular feed. If it all works out, I hope to increase the dish size once again to 1.2 meters also with a circular feed.

I'm also working on Phase Locking my LO to address the frequency drift issue. I will be using either a 10 MHz or 1 pps GPS reference in conjunction with a CT1DMK board for locking.

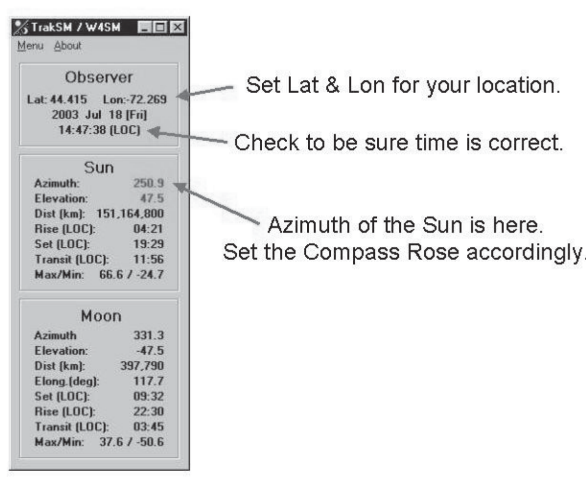
On February 23, 2003 the S1 receiver was successfully tested. To utilize this receiver, the S transmitter must be shut down so the only operating downlink is K Band. We will hopefully be given more S1/k windows in the future. I look forward to operating this mode!

I'm currently writing this paper in July for submission in early August. K Band will be re-activated in mid August. I hope to report more findings of my experimentation at the Toronto AMSAT Symposium in October.

Good Luck! I hope to work you via the K Band downlink on AO-40!

### References


1. **Procom:** **http://www.procom-dk.com**
2. **Kuhne Electronic GmbH - DB6NT** **http://www.kuhne-electronic.de/english/frameset.htm**
3. **MikroMechanik DG1KBF available through Kuhne Electronic GmbH**
4. **SSB Electronic USA** **http://www.ssbusa.com**
5. **QuickSet** **http://www.tripods.com/index.html**
6. **Oregon Rule Company** **http://www.oregonruleco.com**
7. **Dasco** **http://www.tools-plus.com/das.html**
8. **Stacey Mills, W4SM** **http://www.keplerian.com/**

*TrakSM Sun Azimuth Screen*

# Satellite Contact Report Analysis & Prediction (SCRAP)

William H. Bytheway, K7TTY
k7tty@arrl.net

## What is SCRAP?

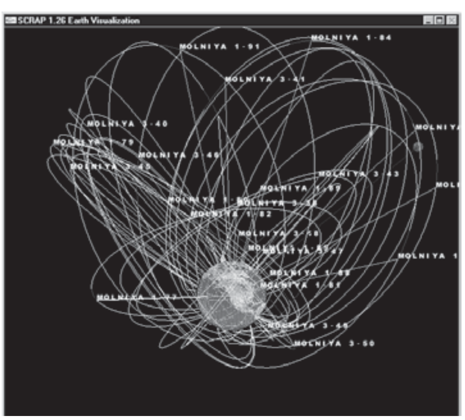
Satellite Contact Report Analysis & Prediction (SCRAP) is a tracking, report, analysis, prediction and 3-D real time display program. It tracks and predicts passes of satellites based on the geographical location of the ground station, the current date and time and Keplerian orbital data for the satellites of interest to the ground station. The software is capable of tracking over 2000 satellites in real-time as well as producing contact reports. In addition to the satellites, it provides ground labeling for over 260 countries and 2265 cities. The user is able to pick from 27 different map textures, and apply islands, lakes, rivers, US states, coastal lines and national boundaries lines.

The project started as a challenge to integrate satellite-tracking technology into a 3-D display of the Earth. Additional features were later added for fun. I've invested many hours in the development and test already. The satellite tracking technology has proven to be quite a challenge to me, but the results are impressive. Therefore SCRAP is what Amateur Radio operators would consider a goldmine in satellite viewing. It's being made available for distribution through AMSAT for a small donation.

SCRAP is similar to Analytic Graphics STK, Aerospace SOAP, Predict and InstantTrac software. Software was developed using Microsoft Visual C++, OpenGL and a modified version of Glut DLL. The executable has been packaged in a zip file and placed in the public domain. It has been tested on Windows 95, 98, 2000 and ME.

## Supported Computer Platforms

SCRAP is not for the underpowered computer. To propagate ephemeris for each of the satellites it displays and reports on, it performs millions of floating-point calculations every second. Therefore, the minimum recommended platform is Windows 98 or better running a Pentium Processor 500 MHz or greater, 256 Mbytes RAM and a graphics accelerator card with OpenGL support. Of course it helps to have at least 1024x768 resolution.




*Molniya Orbits*

For example, test results on a Windows 98 500 MHZ Pentium show that it takes about 5 seconds to calculate 200 satellite vehicle positions and display the results. If your processor does not meet the minimum recommended horsepower it is suggested you should keep the number of satellites displayed to a minimum. This can be done at run-time via a command-line entry.

SCRAP does not access the Windows registry or place any hidden files on your system. It does have TCP/IP code for downloading TLE and APRS data from the Internet.

## Display and Control

The display is organized into panels as shown in the picture below, allowing the user to control SCRAP's features. The current panel shows the Multi-Track display option.

In summary these functions are:

| | |
|---|---|
| Initialize | Allows the user to load the variousTLE filesand to download new TLE files from the Internet. |
| Earth View | Selection of viewpoint to include country, satellite, QTH, etc. and to select the Earth Orthographic projection overlay map and display option. |
| Target QTH | Select the QTH to be used for pass predictions and reports. |
| Sim Time | Define a simulation and setup time other than current UST time. |
| Ephemeris | Set the SGP propagation model and view the position and velocity of satellites. |
| TLE Viewer | View the decoded TLE parameter in classic Orbital Elements. |
| Pass Reports | Produce predicted orbit pass reports, visible passes and solar illuminations. |
| APRS | Download APRS stations via the Internet. Locations can be used for prediction and display. |
| Multi Track | Display current and upcoming passes in real time. |
| Antenna | Future enhancement for AZ/EL rotor control. This option is still being developed. |

## Two Line Orbital Elements

To give SCRAP the best performance one should download the latest TLE files from the Internet using the "Initialize" panel. SCRAP extracts valid NASA format 2-line Keplerian element (TLE) sets from the TLE input file, which may contain other text of various kinds. It removes the miscellaneous text commonly added by network e-mail and bulletin transmissions. It can remove lines of text before, after or between element sets, but not between the lines of a single element set. It can remove text on the same lines as the element sets or before or after the element sets provided that the three lines of the element set all begin in the same column.

In addition, SCRAP allows you to append additional TLE sets from input files to the existing set. Keep in mind that it does not check for redundant satellites in the load.

TLE data is downloaded using a pre-built script file. Pressing the download button initiates TCP/IP connections to the TLE source and in a matter of a minute or so you have downloaded the latest files set.

## Ephemeris Propagation Model

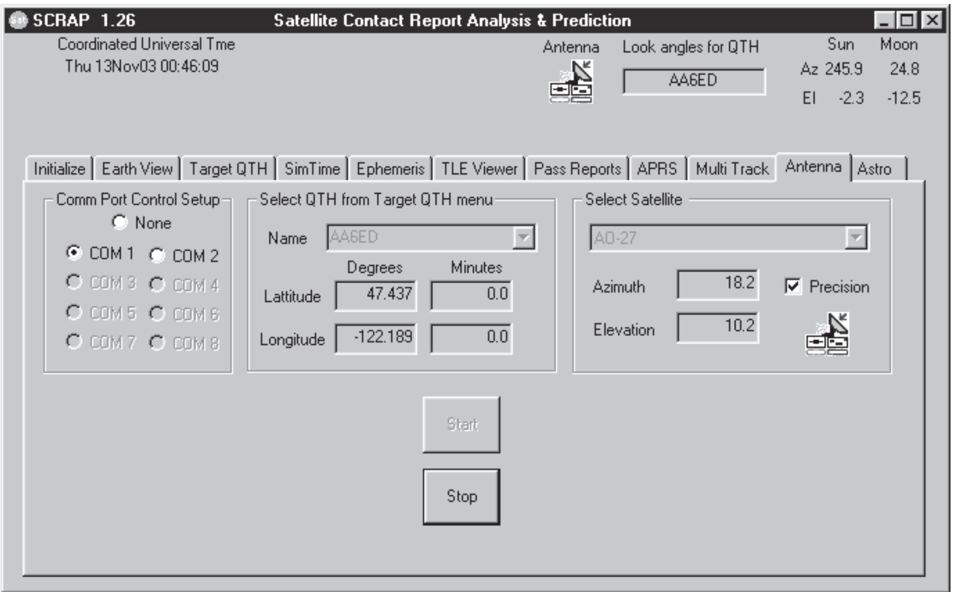
The main ephemeris engine is Dr. T. Kelso's Pascal's SGP, SGP4, SGP8, SDP4 and SDP8 satellite ephemeris propagation routines. These models were borrowed from SPACETRACK REPORT NO. 3, Models for Propagation of NORAD Element Sets, Felix R. Hoots, Ronald L. Roehrich, December 1980.

## Satellite Pass Reports

Satellite contacts in the program's database are calculated at a once/second rate. Separate windows are used to display current passes and upcoming passes. SCRAP also can create text-format reports of predicted passes. The satellite pass report options were originally developed and used in the PREDICT tool written by John A. Magliacane, KD2BD. John's report format was rewritten and integrated into SCRAP with some minor modifications.

Tracking data is also displayed for satellites in contact range. The name, azimuth heading, elevation, sub-satellite point latitude (in degrees North) and longitude (in degrees West) positions are provided along with the slant range distance between the satellite and the ground station (in kilometers).

The Visible Passes report option displays the satellites in sunlight where the ground




***Antenna AZ-EL Rotor Control***

station is under the cover of darkness.

Solar illumination prediction report indicates how much sunlight a particular satellite will receive in a 24-hour period. This information is especially valuable to spacecraft designers and satellite ground station controllers who must monitor spacecraft power budgets or thermal conditions on-board their spacecraft due to sunlight and eclipse periods. It can even be used to predict the optimum times for astronauts to perform extra-vehicular activities in space.

### Automatic Packet Reporting System

The project takes an interesting twist with this addition. The Automatic Position Reporting System (APRS) developed by Bob Bruninga, WB4APR, is used for tracking and digital communications with mobile GPS equipped stations with two-way radio (ref. http://www.aprs.org). SCRAP provides an Internet access that downloads APRS station information residing on multiple Web servers as defined by the APRS Protocol published by the Tucson Amateur Packet Radio Corporation.

The APRS protocol is not a very straightforward design as multiple vendors have added their own unique twists. SCRAP in its current form can only decode the simple latitude, longitude and altitude of most stations and attempts to display the broadcasted comments. Compressed APRS data fields are not supported.

To use the Internet download feature, select the desired WEB server and press "Internet Download". If the counter does not increment try another server. Not all servers in my current list provide the proper protocol. Most servers will never disconnect so the SCRAP design lets you determine when enough stations have been added to the list. You can go to multiple servers and add more stations as desired.

A file import option has been added that allows the user to import a text file dump of the Internet APRS servers. This is useful for displaying locations without the need for an Internet connection.

### Earth 3-D Simulation Display Control

The Earth-Simulation 3-D model was written by Ohad Eder Pressman in 2001 and placed in the public domain. The program is based on a large sphere with a selected Earth map texture overlaid on the surface. You can rotate the Earth, zoom-in, etc. using the mouse and control key. Map textures of the Earth can be changed at any time during the run.

The GLUT extension to OpenGL is required for the 3-D display window controls. Since multiple processing threads are used for ephemeris prediction and display control, a modified version is provided that is SCRAP friendly. GLUT source code is in the public domain.

### Simulation Time Control

The ability to control simulated time is provided to allow you to fast forward the simulation to get a perspective in fast motion of what the satellites are doing. You can also set a negative step time and run the simulation in reverse. The various time formats were provided for flexibility in setting up the simulation. All displayed times are in UST (GMT) but the user has the option of specifying times in GPS, MJD, JD or calendar formats.

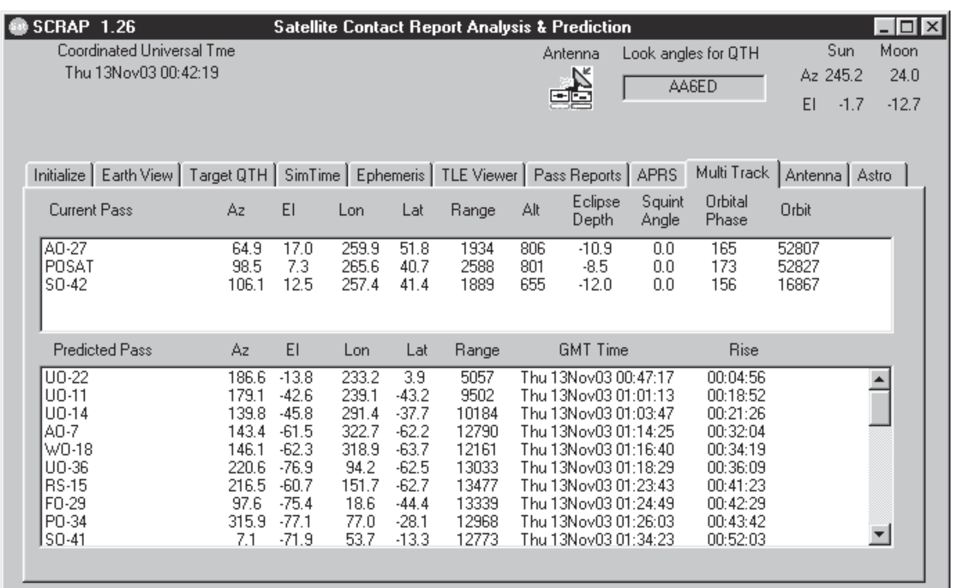
### Target Definitions

The original PREDICT tool performed all of its predictions based on a user input QTH. I've modified it so that the user can specify multiple QTH locations. This panel allows you to change the default QTH location to any city, country or QTH of your choice. The QTH control file stored in "UserData' is called qth.lst and has the format of callsign, longitude, latitude, elevation and GMT offset in hours.

I've also added the capability for the user to assign any country, city or APRS station to be the new QTH. You can easily move from location to location to predict and display satellite contacts for any location.

### How to Obtain SCRAP

AMSAT-NA will be distributing the SCRAP




***Real-Time Satellite Tracking Display***

software. Although final details of the distribution method are being resolved, the suggested contribution to AMSAT is $50 for members and $60 for non-members. Final details should be resolved by the time you read this. This is a large program and will be distributed on CD-ROM. Updates and additional downloads will be available via the Internet.

The author would like to thank his wife, Eva Bytheway, KC7WOI, for putting up with him while he labored many hours preparing SCRAP.

### Public Domain Sources

1. PREDICT written by John A. Magliacane, KD2BD kd2bd@amsat.org , http://www.qsl.net/kd2bd/predict.html .

2. The C source code ported from NORAD's Spacetrack report #3, which included FORTRAN source for SGP, SGP4, SDP4, SGP8 and SDP8. A statement in that report states that the document is free of copyrights and is open to unlimited public distribution. Information can be found at: http://www.projectpluto.com/sat_code.htm .

3. Two line orbital elements (TLE) are posted daily from Dr. TS. Kelso's CelesTrack website at: http://www.celestrack.com/ .

4. The OpenGL Utility Toolkit (GLUT) Programming Interface API Version 3 Mark J. Kilgard Silicon Graphics, Inc. November 13, 1996, can be downloaded at: http://www.opengl.org/developers/documentation/glut/ .

5. NASAWASH NASA-Format Keplerian Element Set File Cleanup, updated 8 Mar 2002, Copyright 1995 Paul Williamson, KB5MU. All Rights Reserved, permission given for non-commercial purposes. Source and description can be found at: http://www.mustbeart.com/software/nasawash.html .

6. 3-D Earth-Simulation, Ohad Eder Pressman, 2001. Source code that creates the Earth sphere and map textures with rotation, zoom-in, etc. control can be found here: http://ohad.visual-i.com/exper/exper.htm#earth .

7. Equidistant Cylindrical maps from NASA/GSFC are copyright-free by Dave Pape, pape@evl.uic.edu . Maps can be found at: http://www.evl.uic.edu/pape/data/Earth/ .

8. The GNU General Public license for software distribution can be found at: http://www.gnu.org/copyleft/gpl.html .

Bill Bytheway, K7TTY, is a principal embedded software/systems engineer with the Boeing Company and is primarily interested in developing software in support of digital communications (RTTY, PSK31, TCP/IP). Other software development projects can be reviewed at http://www.rtty.com/bytheway.

## OPERATING NOTES: Straight Key Night on OSCAR

### by Ray Soifer, W2RS

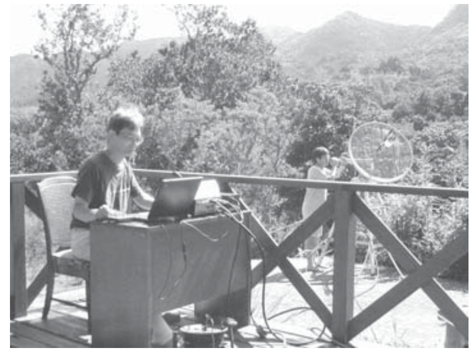
You are cordially invited to participate in the 31st annual Straight Key Night on OSCAR, conducted by AMSAT-NA for radio amateurs throughout the world. There are no rules, no scoring and no logs required. Just operate CW on any OSCAR satellite, using a straight hand key, from 0000 UTC to 2400 UTC on 1 January 2004, working as many SKN stations as you can. The moon (OSCAR Zero) counts too!

In keeping with the friendly nature of this event, please nominate one of the operators you worked for "Best Fist". It is not necessary that your nominee have the best fist of anyone you heard, just of those you worked. Please send your nomination to W2RS via e-mail at w2rs@amsat.org , via packet at W2RS@WA2SNA.NJ.USA.NA , or by mail.

Those nominated will be recognized in an ANS Bulletin to be published in early February, and in *The AMSAT Journal*. Soapbox comments can be sent to *The AMSAT Journal* Editor at wa4swj@amsat.org.

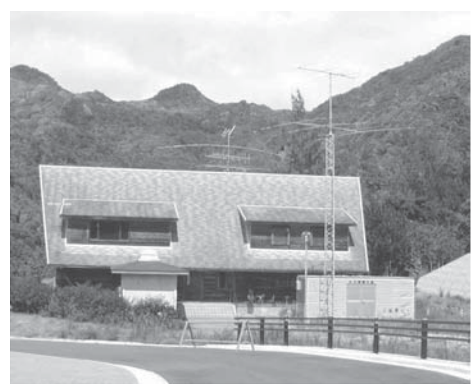
## JD1YAB DXpedition on AO-40

(continued from page 24)



*AO-40 operation: JA0EOK is operating AO-40 and JK1NAF is adjusting the antenna direction.*

*The S-Band Antenna*



*JD1YAB shack and antennas.*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## AG-2400

Downlink Receive Converter

Converts a 2400MHz RF signal to a 144MHz IF signal, allowing US mode operation. When used with optional UX-910, LS mode operation is also available.

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