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CORPORATION

PROCEEDINGS OF THE
AMSAT-NA

13th Space Symposium,
and **AMSAT** Annual Meeting
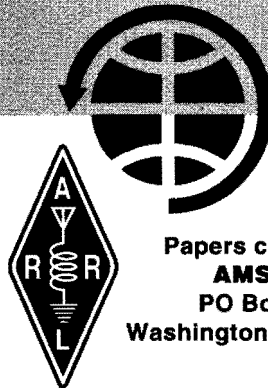
October 6-8
1995
Orlando, Florida

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Table of Contents

WELCOME

I am glad that so many of you have been able to attend the 1995 AMSAT Annual Meeting and Space Symposium. As we did last year, the site of our meeting is but a few miles from the Phase 3D Integration Laboratory. I know that is one of the factors which has prompted so many of you to attend. And, it was one of the factors which led us to return to Orlando this year.

Those who were here last year had the opportunity of seeing the Phase 3D spaceframe not long after it arrived. It is only natural that they will make comparisons of what they saw last year and what is presently apparent. The comment may be made that, "not a lot has changed." That may appear to be the case on the surface, but I can assure you that a great deal has happened in the intervening year. First, and very important, the SBS has been completed and is ready for shipment to Orlando. The SBS (Specific Bearing Structure) is the cylindrical container in which Phase 3D will ride on the Ariane rocket. A decision was made to use the materials and people available to build a second SBS. This should be complete by the time of this Space Symposium. This was done for two reasons. One has to do with certain tests the European Space Agency may require of us, involving sending an SBS to Europe. We did not want to send our only SBS. The other has to do with insurance. That insurance consists of a "policy" we are writing ourselves and involves having as much spare hardware, with which to build a replacement spacecraft, as possible. The SBS is one of those large and expensive pieces we would need in the event that we would want, or need, to produce a second spacecraft. We also have a second spaceframe which is currently on display at Weber State University. Of course, a spaceframe and an SBS do not a satellite make, but they *do* represent two of the largest and most expensive pieces. I will remind you that OSCAR 10 was built from spare pieces after the loss of the first Phase 3 satellite in 1980. That event demonstrated that everything does not always go right in the space business. That fact was re-emphasized again this year by the very unfortunate loss of UNAMSAT and TECHSAT in an unsuccessful launch attempt aboard a Russian launch vehicle.

There is progress on Phase 3D in other areas. Much of the propulsion system plumbing is installed on the spaceframe and the Propellant Flow Assembly is essentially complete. The spacecraft central computer, the IHU, is complete and checked out. The RUDAK computer is almost complete, as is the computer to support the GPS experiment. The power wiring is in place, as is the coaxial cabling to connect the IF Matrix with the various receivers and transmitters. Most of these units are in the final stages of construction and checkout in Europe and some may actually have been delivered by the this time. The signal wiring is now well underway and should be compete and installed in a few weeks. Designs for the spacecraft's antennas have been completed and some flight units are awaiting installation.

Yes, there has been significant progress since our last Space Symposium, however, the fact remains that the satellite is not as far along as we had envisioned at this time last year. But, there have been some changes in ESA's schedule as well, so we are not in bad shape at all. Such schedule slips are frequent occurrences in any development program, and this one has proven to be no exception.

The important thing is that we all must stay focused on the objective of completing the Phase 3D spacecraft and seeing it launched. This means those actually doing the work, those looking after the management and business end of the Project and those who are so generously donating the money needed to make this most ambitious and capable Amateur Radio satellite, to date, a success. There are several opportunities to contribute funds to the Phase 3D Project. One, announced several months ago, is a

campaign sponsored by AMSAT-UK. Those giving 150 Pounds Sterling or more directly to AMSAT-UK will have their names and call signs inscribed in the spacecraft and sent off into space with it. Naturally, we all know about the ARRL's current Phase 3D Campaign. Contributions to this fund are being matched by the League up to $150,000. With this campaign certain to bring in over $300,000, coupled with the approximately $200,000 raised in their previous campaign; the ARRL's financial backing of Phase 3D amounts to a **HALF MILLION DOLLARS!** Of course, there is the effort mounted by AMSAT-NA. Since its inception in late 1991, our members have also generously contributed nearly **HALF MILLION DOLLARS** . I was informed, early in the summer, that a West Coast based foundation will be matching all Phase 3D contributions made directly to AMSAT-NA during that last half of 1995 up to $50,000. We have been submitting monthly statements to this foundation and have already received several installments of matching funds. It is very important that we take full advantage of this kind offer. In addition, I am announcing, at this meeting, the inauguration of a new AMSAT-NA sponsored Phase 3D fundraising campaign. This effort is aimed at securing large individual and corporate donations. Those contributing increments of $2,500 will receive a large plaque depicting Phase 3D, complete with all of its solar cells. Each individual plaque will carry a plate acknowledging the name of the contributor and the specific solar cell, or cells, dedicated to that contributor. In order to encourage those who have already contributed to Phase 3D through AMSAT-NA, we will credit those contributions already made toward the $2,500 needed to qualify for one of these plaques. Thus, if you have already given $1,000, you need only contribute $1,500 more to receive this beautiful commemoration of your generous support of Phase 3D. Naturally, those who have already contributed $2,500 have already qualified. On behalf of all of Amateur Radio, I want to extend thanks to every individual and organization that has contributed to this project. I believe that Phase 3D is destined to bring substantial benefit to our hobby. for years to come, and your help will prove crucial in assuring its success..

Although almost one-hundred per-cent of our energies have been devoted to Phase 3D, we have taken steps to examine what kinds of projects our organization might embark on following the successful launch of that most ambitious amateur satellite. To that end, several articles and editorials have appeared in the AMSAT Journal and a survey of a sample of somewhat over ten per-cent of AMSAT-NA members was conducted. The Board of Directors will use data from this survey, and various other inputs from our members, to begin to chart our course into the next century. One of the prime factors that must be considered is what can reasonably be expected to be accomplished by an organization not associated with a large commercial concern or government agency. One approach being actively investigated is seeking the cooperation of one or more colleges or universities much as we did with Weber State University in Ogden, Utah in the MICROSAT and Phase 3D Projects. Several "feelers" have already gone out to schools which might be expected to interested in participating in some kind of joint venture with the amateur space community. If you know of such an institution, please let one of the officers or Board members know. Furthermore, please, take advantage of the opportunity afforded by this gathering to discuss, with these people, any thoughts or ideas you might have for the future of our organization.

I hope you enjoy this 1995 AMSAT-NA Annual Meeting and Space Symposium, and that your attendance will prove to be educational and rewarding for both you, and our organization.

73,

Bill Tynan W3XO

Keplerian Element Estimation for Radio Sputnik 15 (RS-15)
Ken Ernandes, N2WWD

INTRODUCTION

The pre-launch estimation of Keplerian elements for Radio Sputnik 15 (RS-15) was the first live test of a modeling technique that provides interim elements for new amateur radio satellites. While the technique was found to generate useful Keplerian elements, its success was overshadowed by an unexpected sequence of events that resulted in a long delay in the availability of the official elements. Therefore the estimation process continued for several weeks, refining the Keplerian elements in order to accommodate amateur operators during the period in which the official elements were not available.

PRE-LAUNCH ESTIMATION

This section provides an overview of the pre-launch modeling process and element estimation. The mathematical details are omitted in favor of conceptual illustrations.

The flight to orbit was modeled based on the pre-launch orbital parameters and the launch site information provided by the Russian amateurs. This information was not sufficient to define the intermediate orbit(s) and sequence of events (i.e., the mission profile) necessary for RS-15 to achieve its final orbit. Therefore, part of the orbital estimation process was to use reasonable values for the unknown parameters and to presume the simplest possible mission profile for the satellite to achieve its intended orbit.

The Russian amateurs provided unofficial information for RS-15 that indicated a circular orbit 2300 km in altitude with a 67 degree orbital inclination. An altitude of 2300 km is too high for an efficient direct orbital injection with contemporary booster technology. The simplest [reasonable] mission profile to achieve such an orbit is for the booster to inject the satellite (and the attached upper stage) into an elliptical "transfer" orbit (see figure 1). The upper stage and attached satellite then coast in unpowered flight to apogee (the highest altitude) of the transfer orbit. The apogee of the transfer orbit was targeted to be equal to the final orbital altitude (in this case 2300 km). The perigee (the lowest altitude) of the transfer orbit must be within a reasonable injection altitude for the launch booster. For both simplicity and efficiency, injection at perigee was presumed.

To achieve the final orbit, the upper stage re-fires at apogee of the transfer orbit increasing the spacecraft's speed. The thrust cutoff is selected so that the velocity increase establishes a circular orbit at the apogee altitude.
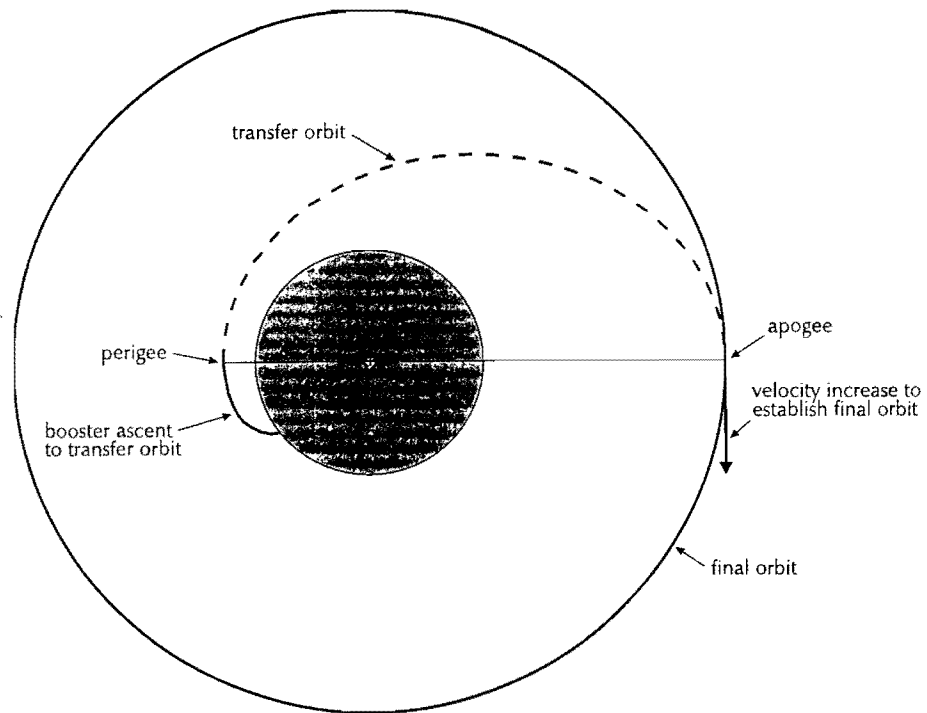
Figure 1., Presumed RS-15 Mission Profile for a Circular Orbit

A few days before the launch, a new bulletin was posted by UA3CR of AMSAT-Russia with revised information for RS-15. The orbit was revised from circular to elliptical with altitudes of 1946 km for apogee and 1809 km for perigee. The inclination was also adjusted to 64.2 degrees. The planned launch date / time was listed as 26-DEC-94 / 03:00 UTC.

The switch from a circular to an elliptical final orbit required yet another assumption to be made: the orientation of the apsidal (apogee-perigee) line. The most likely scenario was for the perigee of the final orbit to be the apogee of the transfer orbit (see figure 2). This assumption did not require any major adjustment to the basic mission profile; the transfer orbit's apogee altitude and its post-burn velocity just needed to be adjusted to establish the final orbit's apogee and perigee altitudes.
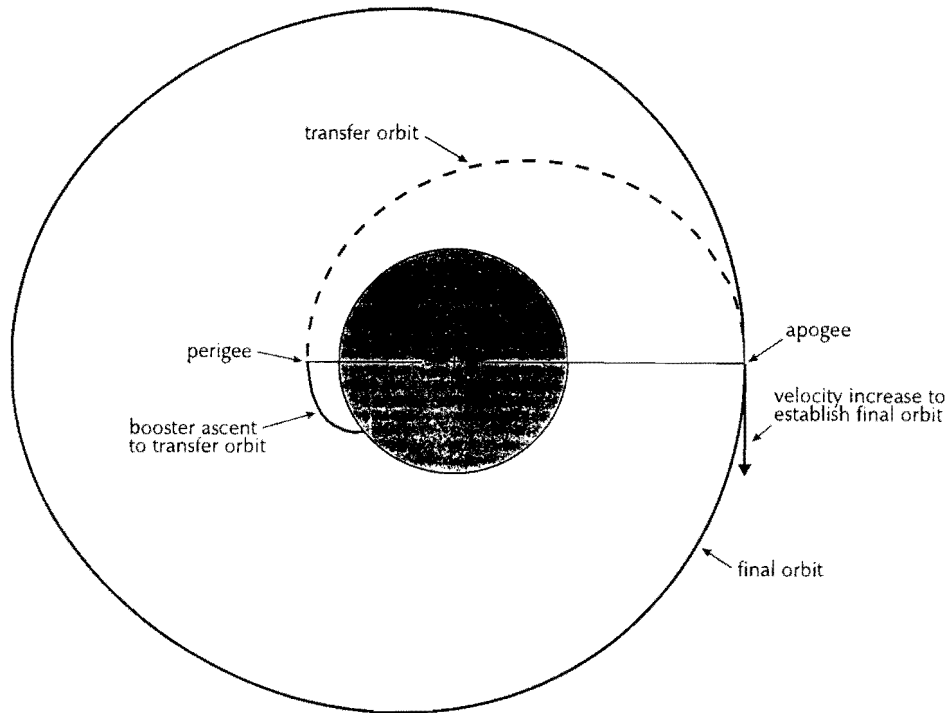
Figure 2., Presumed RS-15 Mission Profile for an Elliptical Orbit

The mission profile begins with the powered flight of the booster (the ascent profile) originating at the launch site (Baiknour for RS-15). The ascent profile of the "Rokot" booster (composed of an SS-19 ballistic missile and a "Briz" 3rd stage) was unknown. In the absence of specifications for the booster, a high fidelity simulation could not be performed. Therefore a "typical" profile was presumed in which: (1) the time from launch to transfer orbit injection, (2) the injection altitude, and (3) the downrange Earth-central angle (along the great circle) were selected as: 6 minutes, 150 km, and 6 degrees respectively (see figure 3).

The ascent profile was projected into the *inertial* azimuth plane required to establish the 64.2 degree inclination from the Baikonur launch site within the range safety constraints (a northerly azimuth). The transfer orbit injection occurs at booster cutoff (at the end of the ascent profile). Note that some error was introduced by modeling an inertial boost plane. While the induced error is probably small when compared with other the errors, plans are to correct for the Coriolis (Earth rotational) effects during boost in future applications.
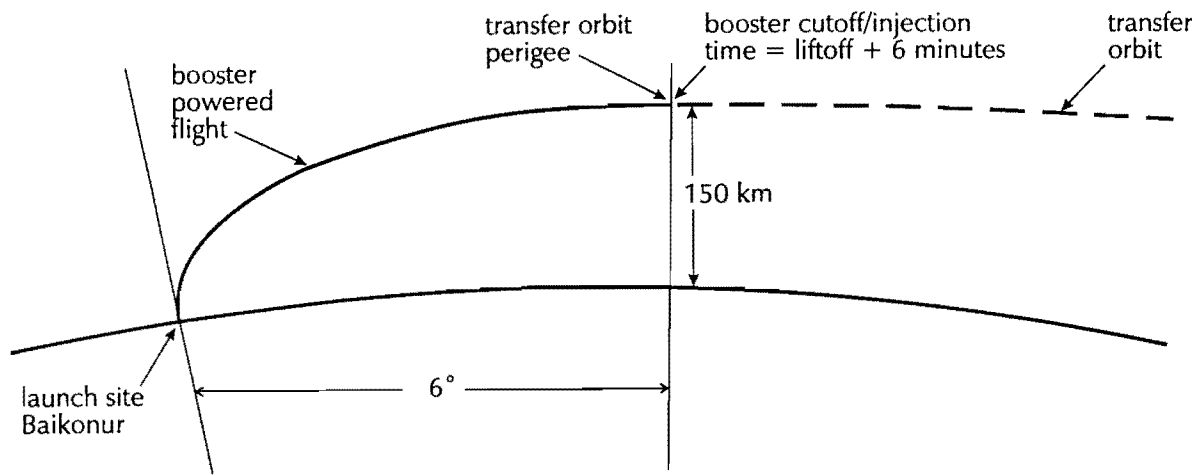
Figure 3., Presumed Ascent Profile for the Rokot Booster

The end of the booster ascent profile is the time and the position of the transfer orbit injection. The injection velocity is computed using basic orbital mechanics equations. The velocity is computed to achieve the desired apogee, which occurs one half a revolution after transfer orbit injection. Since injection is modeled at perigee, there is no radial component of velocity. Therefore, velocity is directed horizontally in the azimuth plane.

The transfer orbit is determined by the injection time and the injection position and velocity vectors. A set of Keplerian elements is computed by entering these parameters into the Vector to two-line Elements (VEC2TLE) software. The first apogee of the transfer orbit is the time

and position of final orbit insertion (as indicated by figures 1 and 2). An impulsive thruster firing maneuver is modeled at transfer orbit apogee to establish the final orbit with the specified apogee and perigee altitudes. The time and the position and velocity vectors of the final orbit insertion are then entered into VEC2TLE to compute the corresponding Keplerian elements for the final orbit.

Even though the scheduled launch time was provided for RS-15, launches do not always occur on the scheduled date or at the scheduled time. A change in launch time results in a change to the Keplerian elements. To accommodate launch time flexibility, the orbital injection times were referenced to Mission Elapsed Time

6

(MET) and the vectors were generated in the Earth-Fixed Greenwich (EFG) [a.k.a. True of Day Rotating (TDR)] reference frame. The EFG reference frame rotates with the Earth. Therefore position and velocity vectors in this reference frame remain the same, regardless of launch date or time.

The rationale for choosing the time-independent EFG reference frame was to make the position and velocity vectors useful to the amateur satellite operator. The MET-referenced EFG state vector was released along with the Keplerian elements (corresponding to the planned launch time). Providing the EFG state vector allowed the user to enter any updated launch date and time into VEC2TLE and immediately compute the corresponding [updated] Keplerian elements.

The time-independent MET/EFG state vector estimated for RS-15's final orbit was:

```
Vector format = 10107
Satellite Name:         RS-15
Catalog Number:         99915
Epoch MET:                   0.03931712963
                        0/00:56:37.000 MET
EFG E:                      -3623.178002 km
    F:                      -4408.622502 km
    G:                      -5870.758751 km
    Edot:                    5.550164511 km/s
    Fdot:                    0.518089209 km/s
    Gdot:                   -3.814378116 km/s
ndot/2 (drag):           0.00000000682 rev/day^2
nddt/6:                     0.00000E+00 rev/day^3
Bstar:                      1.40330E-05 1/Earth Radii
Elset #:                              2
Rev @ Epoch:             1.64664923167
```

The corresponding Keplerian elements based on the nominal launch date / time of 26-DEC-94 / 03:00 UTC are:

```
Satellite: RS-15
Catalog number: 99915
Epoch time:     94360.16431713
Element set:    2
Inclination:      64.2029 deg
RA of node:      174.3271 deg
Eccentricity:   0.0093331
Arg of perigee:  234.2744 deg
Mean anomaly:    358.4925 deg
Mean motion:   11.56772041 rev/day
Decay rate:    6.82000e-09 rev/day^2
Epoch rev:               1
```

FEEDBACK AND CORRECTION

It should be clear by now that a lot of approximation and "educated guessing" was used for the pre-launch estimation of the Keplerian elements. In the absence of more definitive information, it would be too optimistic to expect these elements to predict the position and motion of RS-15 *perfectly* from the onset. What is very realistic, however, is to expect the estimated elements to provide good "ballpark" predictions of pass times. Once a series of observations is made and compared with the predictions of the estimated elements, a trend analysis can be performed which can indicate where to make logical adjustments to the mission profile and/or estimated state vectors. These adjustments are then translated into new Keplerian elements.

The first orbital "feedback" that I received for RS-15 was from Andy Thomas, G0SFJ who posted a message on the Internet AMSAT-BB with the times he observed the satellite's beacon. G0SFJ's first observations, made well within the first day after launch, indicated that RS-15 was lagging approximately seven (7) minutes behind the pre-launch elliptical (1946 x 1809 km) Keplerian elements estimate. With no additional information, I presumed the apogee and perigee altitudes to be correct and computed a new set of Keplerian elements with a 7 minute launch delay. This was accomplished with the above pre-launch MET/EFG state vector, by re-setting the launch date/time in VEC2TLE to 26-DEC-94 / 03:07 UTC.

Observations of subsequent RS-15 passes revealed a drift of the AOS/LOS times when compared with the predictions made by the latest Keplerian elements. The recorded differences in the observed AOS/LOS times showed RS-15 getting progressively later than predicted on each pass. This very *linear* trend indicated that RS-15 was in a higher altitude orbit than that dictated by the pre-launch 1946 x 1809 km apogee and perigee information. The measured difference in orbital period translated directly into an adjustment in mean orbital altitude. Since there was no indication of where the orbital altitude increase should be applied (apogee, perigee, or both), an interim circular orbit was estimated based on the measured orbital period.

Predictions from the interim [circular] Keplerian elements turned out to be lagging RS-15's actual AOS/LOS times by a few minutes. These observations were independently confirmed by Jim Mollican, N2NRD and John Gordon, KD2JF.

On 27-DEC-94, an RS-15 launch report was issued by Leo Maksakov, RA3AT relaying post-launch information from the RS-Group (RS3A). The report confirmed the launch time of RS-15 on 26-DEC-94 / 03:00 UTC. The apogee and perigee altitudes were listed as 2165 km and 1885 km respectively. The inclination was also slightly different from the pre-launch information, now at 64.59 degrees.

The RS-15 launch report provided a far more complete picture than was previously available. Still missing were the details of the booster ascent profile and the transfer orbit. The result was that there was still some uncertainty in the final orbit injection time and location, which in turn resulted in some ambiguity as to the orientation of the line of apsides (apogee-perigee line) within the orbital plane. The original presumptions were used to fill in the missing information.

Based on the updated information, the following set of updated Keplerian elements were generated:

```
Satellite: RS-15
Catalog number: 99915
Epoch time:        94360.16459491
Element set:       3
Inclination:        64.5927 deg
RA of node:        174.9040 deg
Eccentricity:      0.0173416
Arg of perigee:    233.4418 deg
Mean anomaly:        0.0000 deg
Mean motion:      11.27220920 rev/day
Decay rate:        4.74000e-09 rev/day^2
Epoch rev:                 1
```

Because of the missing information, I sent a message to RA3AT (at the Internet address provided in his message -- rsgroup@olymp.msk.su) requesting additional orbital information in whatever form he might be able to provide. His response (about a week later) was that they, unfortunately, have a very difficult time obtaining official orbital information. In fact, the orbital information they were using was coming from NASA Bulletins, Internet, and Packet Radio. In response, I provided RA3AT with my estimated elements for RS-15.

Several days after launch, Keplerian elements for RS-15 began appearing on the OIG RAID RBBS release point at NASA Goddard Space Flight Center (GSFC). The elements appearing for satellite #23439 were a very close match to my estimated elements (set #3). At this point, I believed I was finished with the RS-15 orbital estimation process.

Within a day of the NASA/GSFC release of Keplerian elements for satellite #23439, the orbital periods of the subsequently-released element sets began to increase. Dennis Dinga, N6DD noted that the new elements represented much too high an orbit because their predictions were lagging well behind the observed passes of RS-15. Since the orbit for satellite #23439 did appear to originate from the RS-15 launch, I searched the GSFC OIG RAID RBBS database and found satellite #23440 to be a much better match to above element set #3. However, actual tracking of RS-15 indicated slightly late AOS/LOS predictions for these elements and they were drifting progressively later on each successive pass.

The inability of the Keplerian elements for either satellite #23439 or #23440 to accurately predict the pass times for RS-15 indicated that neither represented the orbit of this satellite. Since it was apparent that both objects originated from the RS-15 launch, the orbits of satellites #23439 and #23440 were traced back to their Point of Closest Approach (PCA) with respect to each other. The Time of Closest Approach (TCA) for these two objects was computed at approximately 3.5 hours after launch; a few degrees after perigee for both orbits.

The computed PCA conjunction information is listed below:

```
Relative Minimum Geometry         26-DEC-94 / 06:30:49.023 UTC
Primary:          23439                Secondary:           23440
       Geo:    Lat (deg)      Lon (deg)             Ht (km)
(1)             -43.2488       316.3269            1883.9718
(2)             -43.2448       316.3271            1884.1723


       ECI:       X (km)         Y (km)              Z (km)
(1)            -5148.6200      3147.6412          -5638.5125
(2)            -5149.0919      3147.9066          -5638.2318


Delta-V:    intrack (m/s)  crosstrack (m/s)       radial (m/s)
(1 v 2)            15.68             -6.09             -27.34


      View:    azimuth (deg)  elevation (deg)       range (km)
(1 v 2)           33.6295           19.5063            0.6099
```

Because satellites #23439 and #23440 converged well to a PCA very close to their perigees, it was concluded that the two satellites were indeed pieces from the RS-15 launch. Since the pre-launch information provided in the December 1994 edition of QST made reference to a "parent satellite," it seemed logical that satellite #23439 was probably that primary payload and that satellite #23440 was the upper stage "Briz" rocket body from the Rokot booster. The PCA of the two orbits, occurring at 26-DEC-94 / 06:30:49 UTC, would then correspond to the deployment of satellite #23439 from the upper stage. If true, this would represent a bad assumption in the presumed mission profile, since deployment would have occurred at the second apogee of the transfer orbit.

The most disturbing aspect to the PCA information was the relative velocity (Delta-V) between the two objects. The total delta-V magnitude (approximately 32 meters per second) is very large. Moreover, deployments are generally made with delta-V in the intrack direction; the delta-V computed for the above PCA is directed rather randomly.

This suggested that an anomalous situation occurred at or near the presumed deployment point.

A very encouraging fact about the PCA, however, was that its 1884 km altitude corresponded nearly exactly with the 1885 km perigee altitude provided by RA3AT for RS-15. With the altitudes aligning so conveniently, it seemed logical to presume that the separation of RS-15 from the upper stage occurred at or near the PCA and TCA of satellites #23439 and #23440. Since #23440 was presumed to be the rocket body, its position vector at the TCA was used as the presumed deployment position of RS-15. The velocity vector was computed (as described earlier) to establish the 2165 km apogee at the opposite side of the orbit from the deployment position. The only change made was that the velocity vector was projected in the same (64.83 degree inclination) orbital plane as satellites #23439 and #23440, rather than the 64.59 degree inclination provided by RA3AT.

The orbital estimation algorithm was also enhanced, modeling the Earth's surface using the World Geodetic Survey of 1984 (WGS-84) ellipsoid. This was done to compute the Earth-centered radii corresponding to the given apogee and perigee altitudes.

The Keplerian elements resulting from the latest refinements were:

```
Satellite: RS-15
Catalog number: 99915
Epoch time:        94360.27140046
Element set:       4
Inclination:        64.8314 deg
RA of node:        174.6168 deg
Eccentricity:      0.0175780
Arg of perigee:    310.1310 deg
Mean anomaly:        0.9271 deg
Mean motion:      11.27503470 rev/day
Decay rate:        4.77000e-09 rev/day^2
Epoch rev:                  2
```

Three observations were made after tracking RS-15 for several days using estimated element set #4: (1) the apogee and perigee altitudes provided by RA3AT were an excellent match to the orbit of the presumed upper stage (satellite #23440), but did not exactly match the observed orbital period of RS-15; (2) the estimated elements for RS-15 had perigee occurring approximately 20 degrees forward of (later than) perigee for satellites #23439 and #23440; and (3) software Doppler shift compensation (based on the estimated elements) had a tuning bias in one direction for the first "half" of the pass that changed to a different tuning bias for the second "half" of the pass.

These observations indicated that the estimated elements for RS-15 were still not quite correct. Since the AOS/LOS times were reasonably accurate, the conclusion was that the error was primarily with the line of apsides. This could be manifested by an error in the orientation of the apogee/perigee line (consistent with observation #2) and/or errors in the actual apogee/perigee altitudes (consistent with observation #1).

Because of the close match in perigee altitude between satellites #23439 and #23440, this was retained as RS-15's estimated perigee altitude. Adjustments were made to the estimated apogee altitude in order to fine tune the orbital period to the actual pass times of the satellite. The actual perigee time of satellite #23440 was 26-DEC-94 / 06:23:52 UTC, approximately 7 minutes before the conjunction between it and satellite #23439. A new set of Keplerian elements was estimated from this adjusted deployment time and position.

The new Keplerian elements, based on the adjusted deployment time and position were:

```
Satellite: RS-15
Catalog number: 99915
Epoch time:        94360.26657407
Element set:        5
Inclination:        64.8377 deg
RA of node:        174.6064 deg
Eccentricity:      0.0181234
Arg of perigee:    290.3947 deg
Mean anomaly:        0.3861 deg
Mean motion:      11.27538755 rev/day
Decay rate:        4.77000e-09 rev/day^2
Epoch rev:              2
```

COORDINATION WITH SPACE COMMAND

It was clear from the beginning that the lack of: (1) precise tracking data and (2) least-squares differential correction software, that the estimated Keplerian elements for RS-15 could not indefinitely predict the satellite's position and motion. Hence the heavy reliance of the amateur satellite community on the Space Command Keplerian elements released by NASA GSFC.

I discussed the matter of the unavailability of official Keplerian elements with Keith Baker, KB1SF, the AMSAT-NA Executive Vice President. Agreeing with his recommendation, I contacted Mr. Ron Roehrich, the Deputy Director for Space Analysis at United States Space Command (USSPACECOM). While not specific as to the nature of the difficulty with the RS-15 launch, Ron gave indications that there were multiple significant pieces on orbit with RS-15 and its upper stage. Since USSPACECOM's primary sensor's usually only provide radar tracking data, it can be difficult to distinguish one payload from another or from another piece such as a rocket body.

I provided Ron Roehrich with my estimated element sets #4 and #5 so that the Space Command Orbital Analysts could compare them with the pieces they were tracking, and thus identify RS-15. After Space Command compared my elements with the pieces they were tracking, Ron telephoned me and indicated that the N2WWD-derived elements matched a piece they had tentatively identified as the "rocket body." I explained to him that our only tracking capability was the active beacons and transponders on the "payload" (RS-15) and that we were blind to all other pieces. He accepted this as very encouraging news and indicated that we should expect an answer within the next few days. Shortly after coordinating with Ron, the official RS-15 elements released at NASA GSFC OIG RAID RBBS began matching both the estimated elements and the AOS/LOS pass times for RS-15.

In the meantime, Walt Daniel (KE3HP) posted a message on the Internet AMSAT-BB regarding RS-15. Quoting an article from the 16 January 1995 edition of *Aviation Week and Space Technology*, Walt announced that RS-15's upper stage rocket body exploded approximately 3.5

hours after liftoff. The explosion scattered a debris cloud in orbit around RS-15. Clearly, the PCA computed between the Keplerian elements for satellites #23439 and #23440 (3.5 hours after launch) was actually the computation of the time and location of the *upper stage explosion*.

The *Aviation Week and Space Technology* article provided the most reasonable explanation for the mis-identification of RS-15. As mentioned earlier, Space Command's primary sensors are radar's that echo their signal off the satellites they are tracking. In routine operations, it's somewhat difficult to distinguish an active payload (such as RS-15) from a rocket body or other piece of debris. Thus while Space Command had precise orbits determined for RS-15 and the pieces in the debris cloud, the piece identification was only tentative.

Since amateur satellite operators only track active signals (satellite beacons and transponders), we were "blind" to the ambiguity or confusion caused by the debris cloud. Therefore, identification of RS-15 by these active signals was trivial using amateur radio equipment.

Coordinating RS-15 orbital data with Space Command was a significant milestone. Space Command used the N2WWD-derived Keplerian elements as an inexpensive, but complementary resource in the piece identification process. The amateur radio "estimated elements" were compared by Space Command against the orbits of the pieces they were tracking. This helped them in identifying RS-15 from the other pieces. Since this process brought about a flow of regular updates to RS-15's Keplerian elements, amateur satellite operators ultimately received the greatest benefit.

CONCLUSION

The estimation of Keplerian elements for RS-15 served not only to provide interim Keplerian elements for amateur satellite operators, but it also provided Space Command a convenient means of discriminating the RS-15 satellite from the upper stage debris cloud. This cooperative exchange provided positive identification of RS-15, which in turn initiated updates of high quality Space Command Keplerian elements.

The modeling technique used for RS-15 orbit estimation was an extension of the process that provides time-independent pre-launch orbital information to the amateur satellite operator. The successful use of this process for RS-15 orbit determination means that this type of pre-launch orbital data will be made available for future amateur radio satellite launches. Future directions, including improvements to this process, will depend on feedback and initiative from the amateur satellite community.

BY

W5IU

INTRODUCTION -

The time has come for an operations status of all of the "Birds" in our flock and a report on the nets and operating events related to the Amateur Satellites. Over the past year, the Amateur Radio Satellite Community has been busy building, launching, and operating on the flock. We have also been busy operating HF and other AMSAT nets. There have been some high points and some low points; successes and failures. This report will attempt to bring you up to date on all of the "Birds" and nets with a little bit of news from the AMSAT-UK Colloquium thrown in for good measure. The reports will be grouped into the following categories: High Altitude, Educational, Low Earth Orbit (LEO) Analog, LEO 1200 PSK, LEO 9600 FSK, Manned, Unsuccessful Launch, Phase 3D, HF Nets, and Operations Nets.

High Altitude - AO-10, AO-13

Our oldest active "Bird," AO-10 has had a good year, but has been under utilized. Launched in 1983, AO-10 has suffered some degradation over the years but it is still ticking. Similar to some humans I know, AO-10's memory was the first to go leaving us with no control over its attitude and mode. This event also dropped an already weak mode "L" out of the schedule. AO-10 has been operating in this status for about the last seven years. It has good spells and bad spells depending on its attitude relative to the Sun. During the past year, it appears that the batteries no longer hold a significant charge. Even with this handicap, it still works fine when in good Sunlight. Don't cross it off of the list yet, it may outlive AO-13. Check its passband for activity and use it to the end.

The other high altitude "Bird," AO-13, continues to operate well but its days are numbered. Launched in 1988, AO-13 has also suffered some setbacks but it still responds to full control. The first major setback was the loss of the 70 cm transmitter rendering modes "J" and "L" useless. However, this loss was the shot in the arm needed to make mode "S" popular. AO-13 continues today with a full schedule of modes "B, BS, and S." Due to long term orbital geometry changes, the latitude of Apogee has moved further and further South converting AO-13 from a Northern

Hemisphere "Bird" to a Southern Hemisphere "Bird." Coupled with seasonal variations in the geometry relative to the Sun, we now suffer from long periods (three months) of marginal off-pointing of AO-13's antennas to keep the batteries in good health. The final blow to AO-13 is becoming more apparent each day with the decay of Perigee altitude. Perigee altitude is following the predictions almost exactly as small perturbations of the orbit due to the Sun and the Moon cause the decay. James Miller, G3RUH, is now predicting mid December 1996 for the final decay and re-entry of AO-13. Smart money will go with James. At the AMSAT-UK Colloquium this year, James also made predictions for visual sighting of AO-13 during Perigee. Coincidentally, one of these opportunities occurred immediately after the Saturday Night Banquet and annual "Fun Junk Sale." No one saw the "Bird;" however, James was reportedly seen lying on the Lake Bank with his binoculars (antenna) and stop watch waiting for the event.

Educational - UO-11, DO-17, WO-18

Launched in 1984, UO-11 is our second oldest satellite and it is still operating well. It currently transmits a full schedule of Whole Orbit Data, telemetry, and weekly UoSat bulletins from AMSAT-UK. Its 1200 baud ASCII signals are easy to copy with the proper demodulator and a quiet two meter environment. Occasionally the digitalker is still heard. At the AMSAT-UK Colloquium, Doug Loughmiller, KO5I/G0SYX, UoSat Ground Station Manager, reported that the watch dog timer occasionally resets early and the transmitter drops off line before the command station catches the problem. Don't be surprised when this happens. Wait a day or two and it should be back on the air.

Better known as DOVE, DO-17, has recently passed the 400 day mark in continuous operation. As discussed before, DOVE is not up to its full potential due to some equipment problems that have plagued it from launch in 1990 but it is at least on the air and stable. It is currently running only the 1200 baud AFSK Packet Telemetry and Text. The duty cycle has been reduced to about once every 30 seconds, so you may have to wait a short time to hear the Packet. This has been done to keep the transmit power high. The "S" band beacon is off at the present time. Earlier this past year, DOVE was transmitting a computer generated voice repeating the phrase "HI THIS IS DOVE IN SPACE" and a series of audio tones along with the Packet telemetry. The digital voice from a voice chip started degrading further and was taken off line before it failed entirely. Work is progressing on an alternate voice capability using software generation of voice through voice synthesis techniques. The test tones were the early manifestations of that technique. Keep listening and don't

give up.

After five years in Space, WeberSat, WO-18, continues to take pictures and spectrum samples on a regular basis and provide this data along with telemetry on the 1200 baud PSK downlink for analysis. Its PSK downlink has suffered recently from some carrier creeping back in causing some difficulty in recovering data. The alternate transmitter has been used and appears to work better. In general, WeberSat is working OK but the data recovery rate is lower than it was early in its career due to the carrier problem.

LEO Analog - RS-10, RS-12, RS-15, FO-20, AO-27

Three "Radio Sputniks," RS-10, RS-12, and RS-15 account for most of the activity on the LEO Analog "Birds." RS-10 continues to operate very well in mode "A," two meters up and ten meters down, and is one of the primary "Easy Birds." RS-12 continues to operate very successfully in mode "K," 15 meters up and ten meters down. Many people have now worked WAS through this "Easy Bird" using only an HF rig with dual VFOs and a simple antenna. At least two DXCCs have now been awarded for operations through RS-12. RS-15 was our Christmas present in 1994 from the Russians and has been gaining in popularity as a mode "A" Bird. It is unique among the LEO Analog "Birds" in that its altitude is approximately twice as high as its competition, RS-10 and RS-12. The signals are not quite as strong and stable as RS-10 but it has frequent 6 to 10 minute windows to Western Europe from the center of the USA. RS-15 periodically suffers from insufficient battery charge when significant portions of its time is spent in eclipse.

Fuji OSCAR-20, FO-20, started the year as a hybrid digital and analog satellite; however, its digital side suffered a problem and it is now doing duty as our only mode "J," two meters up and 70 cm down, SSB and CW "Bird." Like AO-10 it suffers from not enough use so crank up the station and work it. Doppler tracking on this "Bird" takes a little getting used to, but the rewards are good strong signals and easy access.

Our only FM voice "Bird" at the moment is AO-27. This Microsat is capable of other modes, but has been utilized, when in amateur radio service, as a mode "J" FM voice repeater. In general, it is only available when it is in Sunlight and not being interfered with on the uplink. Unfortunately, there are un-licensed operations on its uplink, 145.850 Mhz, in some parts of the world. AO-21 popularized the FM voice mode until its untimely demise and AO-27 is picking up the pieces. Watch out for Doppler

on the downlink.

LEO 1200 PSK - AO-16, LO-19, IO-26

Pacsat, AO-16, is the leader of this flock with well over a year
of un-interrupted service as a store and forward relay "Bird."
Launched in 1990, AO-16 is gaining in popularity again now that
the "queue" has gotten so long on the 9600 baud "Birds." LuSat,
LO-19, suffered a computer crash about three months ago and it
has taken until now, early August 1995, to get it reloaded and
back into BBS service. Thanks to the Argentina command team for
their tireless efforts. ItAMSAT, IO-26, has been in-active most
of the past year due to several computer crashes and an apparent
power shortage. Command has changed hands to another team in
Italy and the learning curve hasn't helped. We hope to welcome
IO-26 back into the flock soon.

LEO 9600 FSK - UO-22, KO-23, KO-25

These three "Birds" do the Lions share of the digital work these
days with their high speed data links. Over the last three or
four years, the routine has settled into UO-22 for international
message relay or Gateway operation and the others for individual
point to point operations. Earlier this year, UO-22 suffered a
mysterious computer crash that apparently locked up the CPU
requiring that power be removed to effect a recovery. The UoSat
Command Team figured out a course of action and 24 hours later
the "Bird" was back in service. KO-23 and KO-25 are operated by
the Koreans and are the most popular "Birds" with individual
operators. KO-23 has the highest altitude and consequently the
longest windows. Pictures are excellent. Judging from the
"queue" these birds are getting nearly overloaded with individual
activities. Fortunately all of the "Birds" are working well
except for problems getting into the "queue." There have been
some short outages on all of these "Birds" but, in general, it
has been a good year. The introduction of programs like WISP and
SATSKED for complete automation of digital satellite ground
stations has contributed heavily to the popularity of these
"Birds."

Manned Space - MIR, Space Shuttle (SAREX)

The Russian Space Station, MIR, launched in 1986, continues to
provide many contacts via its Packet Bulletin Board and FM voice.
First Amateur Radio operations were in 1988. The most popular
operation from MIR in recent months were from Dr. Norman Thagard
during his long stay aboard MIR. Norm enjoyed ragchewing and

many operators had the chance to have meaningful QSOs with him from horizon to horizon. During the busy times leading to the first docking with the Shuttle, both voice and packet capabilities were utilized for backup communications with the Russian and American command stations.

Three Space Shuttle SAREX missions have flown this calendar year: STS-67, STS-71, and STS-70 in that order. STS-67 set another new record for number of school contacts and made many general contacts as well. STS-71 was the first MIR docking mission and the first test of the MIR rendezvous radio. Five school contacts were completed, but few general contacts were made. Limited time was the biggest problem. SAREX operations occurred at the end of the mission after un-docking with MIR. Only about two days were left for SAREX operations and the Packet Robot was not available on this mission. STS-70 did much better for general contacts. Many times the Astronauts were heard calling CQ in voice with less than normal response. Two more missions are scheduled before the end of the year so "stay tuned."

Unsuccessful Launches - TechSat-1, UNAMSAT-1

Two new "Birds," TechSat-1 and UNAMSAT-1, with the hopes of two nations, Israel and Mexico, were launched on a Russian modified ICBM in March. Unfortunately, the fourth stage had a short burn coupled with no burn of the fifth stage and the payloads failed to achieve orbit. Of course this was a great disappointment for the builders and the rest of the Amateur Radio Community; however, both builder groups are re-building and looking for new launch opportunities. Let's wish them luck and offer any assistance possible.

Phase 3D - The Satellite for All Amateurs

The most ambitious Amateur Satellite Project ever is showing good progress at builders sites around the world and at the integration site in Orlando, FL. The launch has been slipped two months by Arianespace from April 3 to May 29, 1996. Several of the packages are complete with others nearing completion. Peter Guelzow, DB2OS, gave a complete status at the AMSAT-UK Colloquium. The 24 GHz transmitter was shown and discussed by Danny Orban, ON4AOD. Complete definition of the wiring harness for the entire "Bird" has recently been received and work is in full swing in Florida making up the harness. Propulsion system plumbing is complete, and most of the antennas have been fabricated and tested on a full scale mockup on the antenna range at the integration facility. The Integrated Housekeeping Computer and the CAN bus along with other digital items were

demonstrated recently in Tucson, AZ, during a ten day meeting between Lyle Johnson, WA7GXD, Chuck Green, N0ADI, and Peter Guelzow, DB2OS. These items are now ready for integration.

Operations on the new "Bird" are now being discussed by the operating committee, made up of member societies that have contributed heavily to the building and funding of Phase 3D. Detailed initial plans will be announced before launch, but, with the flexibility inherent in the Phase 3D design, these plans can be expected to change to adjust to the needs and desires of the users. Plans for control of the new "Bird" are now being formulated.

Fund raising received a real shot in the arm recently with the matching funds program provided by the ARRL. The $150,000 available for matching has now been fully subscribed. Other ideas are forth coming. AMSAT-UK is sponsoring a "your call in space" campaign. For a 200 Pound Sterling donation, you can have your call etched on a small plaque that will fly in Phase 3D. Contact AMSAT-UK for further details. Lets keep up the good work and raise the rest of the funds necessary for the launch. We have enough to finish building the "Bird," now lets complete the launch funds.

The Nets -

Over the years, AMSAT HF nets have operated on the 75, 20, 17, 15, and 10 meter bands. Operations nets have been held on the AO-10 and AO-13 as well. As propagation changes with the Sunspot Cycle, so do the nets. Currently, the 17 and 15 meter nets have been discontinued until the return of better propagation, but their Net Control Stations are still active in support of the remaining nets. The 10 meter net has not operated for several years due to variations in propagation and lack of a Net Control Station. Operations nets are only conducted during favorable pointing periods of AO-13.

75 Meters - Sometimes frustrating in Summer, but a delight in Winter, this regional net provides the most consistent operation of all of the nets. To cover the whole country, this Tuesday evening net is broken into three nets all operating on 3840 KHz. The East Coast Net meets at 2100 Eastern time and is "chaired" by Ron Long, W8GUS, in Columbus, OH. At 2100 Central, net control is passed to Jim McKim, W0CY, in Salina, KS, for the Mid-America Net. Last, but not least, the West Coast Net starts at 2000 Pacific led by Jim Shepherd, K6OYY, in Santa Barbara, CA. Before the days of digital communications, the AMSAT News items usually originated on the East Coast and were passed from region to

region live on this net.

20 Meters - Called the "International AMSAT Net," this net meets
Sunday afternoons on 14.282 MHz. starting at 1800 UTC with the
"pre-net warmup." At 1900 UTC the AMSAT News Service bulletins
are read to the East and at 1930 a repeat is done to the West.
Directions are from the QTH of Keith Pugh, W5IU, in Fort Worth,
TX, net control. The "pre-net warmup" is an informal session for
questions, answers, requests for data, and general discussion of
Amateur Radio Satellites. Wray Dudley, W8GQW, of Tubac, AZ,
participates in the "pre-net warmup" and acts as backup NCS. As
time permits, additional questions, etc., are taken at the end of
each of the bulletin sessions. Depending upon propagation,
international visitors frequently participate. Pat Gowen, G3IOR,
regularly checks in and provides the "News from Across the Pond."
Currently, the AMSAT News Service bulletins, generated by Dave
Cowdin, WD0HHU, are read first on this net and then are
distributed throughout the world via the digital media.

17 Meters - Since the acquisition of the WARC bands, John Shew,
N4QQ, has hosted the 17 meter net on 18.155 MHz. each Sunday
evening at 2300 UTC. Until recently placed on hold for poor
propagation, this net provided excellent coverage to the Midwest
and Western portions of the US and the Caribbean. Other
countries participated on occasion. This net will resume
operation when the Sunspot cycle improves.

15 Meters - Also known as the "International AMSAT Net," this net
was held, until recently, on 21.280 Mhz. every Sunday afternoon
at 1900 UTC. Wray Dudley, W8GQW, of Tubac, AZ, has been net
control for many years and also "simulcasts" this net on AO-10 or
AO-13 whenever a "Bird" is in view at net time. Another victim
of the current slump in the Sunspot cycle, this net will also
resume operation when propagation improves. During prime
propagation, international check-ins were frequent. Wray is
regularly assisted in his NCS activities by Jack Butler, KB7UZ,
of Great Falls, MT. Wray and Jack are instrumental in
establishing the frequency and coordination for the 20 Meter Net
and the 15 Meter Net each Sunday.

Operations Nets - Operations nets are held periodically on AO-13,
during periods of good pointing, to demonstrate net operations
for a wide area via the satellites. During the last two "good"
cycles, nets have been scheduled every weekend at the best times
for operation. Unfortunately, these good operating times do not
always occur at favorable times for operators. Attendance has
been spotty with some very good turnouts and some short
operations. Guest speakers have been predominately from the

Phase 3D Integration Team. On at least two occasions, operators have stepped in voluntarily, on short notice, and performed very well. This is in the true spirit of Amateur Radio, and it is good to see people taking a more active part. We need more of this to bring forth new ideas and to prevent "burn out" in the regular volunteers.

Summary -

As you can tell, it has been a busy year in Amateur Radio Satellites and we have a lot of capability for everyone to use. There has never been a better time to get involved in Amateur Radio Satellites. The biggest challenge we have facing us in the future is the successful launch and operation of Phase 3D. Let's do it right and avoid some of the past controversy we have experienced with AO-13. See you on the "Birds" in '96.

Keith Pugh, W5IU
AMSAT VP of Operations

The World Wide Web Amateur Satellite Ground Station

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Introduction

The *World Wide Web Amateur Satellite Ground Station* (http://gndstn.sp.nps.navy.mil) (Figure 1) provides a glimpse into the world of digital communications Amateur Satellites through the Internet's World Wide Web. The *Web* is the fastest growing facet of the Internet today. It is characterized by its intuitive and easy to use graphical user interface client program, sometimes called a *browser* or *navigator*, which is available for a variety of computing platforms. The World Wide Web was conceived at the European Particle Physics Laboratory, CERN, in Geneva, Switzerland. The *Web*'s designers sought to combine information from related projects through hypertext [1]. Eventually, the University of Illinois' National Center for Supercomputer Applications (NCSA) took the idea one step further and created the popular *NCSA Mosaic* browser program [2]. Since the introduction of the World Wide Web in 1990, its popularity has surpassed everyone's expectations. Prospective users can access the World Wide Web from work and school and through major information providers such as CompuServe® or America Online® as well as many local Internet Access Providers.

The *Web Ground Station* is located at the Naval Postgraduate School in Monterey, CA. It is part of the Satellite Development Program in the Space Systems Academic Group. The *Web Ground Station* is an outgrowth of the Amateur Satellite ground station that is provided for students to learn about the operation of low earth orbit digital communications satellites. The *Web Ground Station* is an experiment in combining two dissimilar networks via a gateway computer.

The Amateur Satellite Ground Station

The *World Wide Web Amateur Satellite Ground Station* starts with an Amateur Satellite ground station. At the center is an ICOM IC-970H dual band, multimode UHF/VHF transceiver. The antenna system is the Cushcraft AOP-1, Yaesu G-5400B azimuth/elevation rotors, and an ICOM AG-45 low noise preamplifier for the downlink. The terminal node controller (TNC) is an Advanced Electronics Applications, Inc. DSP-2232.

Figure 1. The Home Page of the WWW Amateur Satellite Ground Station

The computer is a 486DX-33 MHz with 8 Megabytes of RAM and 240 Megabyte hard drive. A L. L. Grace Kansas City Tracker/Tuner (KCT/T) card is plugged into an expansion slot. The KCT/T provides the interface between computer and the antenna rotor controller (for tracking) and transceiver (for tuning). An Ethernet Network Interface Card (NIC) is plugged into another expansion slot and provides the ground station's interface to the campus network and Internet. Figure 2 shows a system block diagram of the equipment for the *Web Ground Station.*
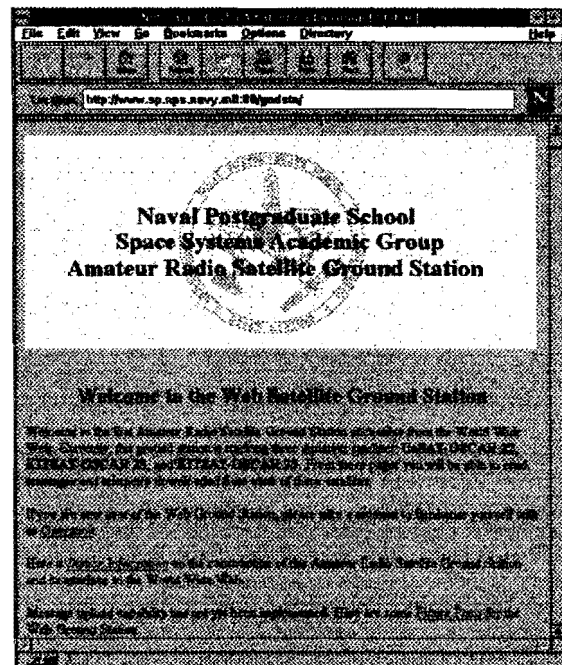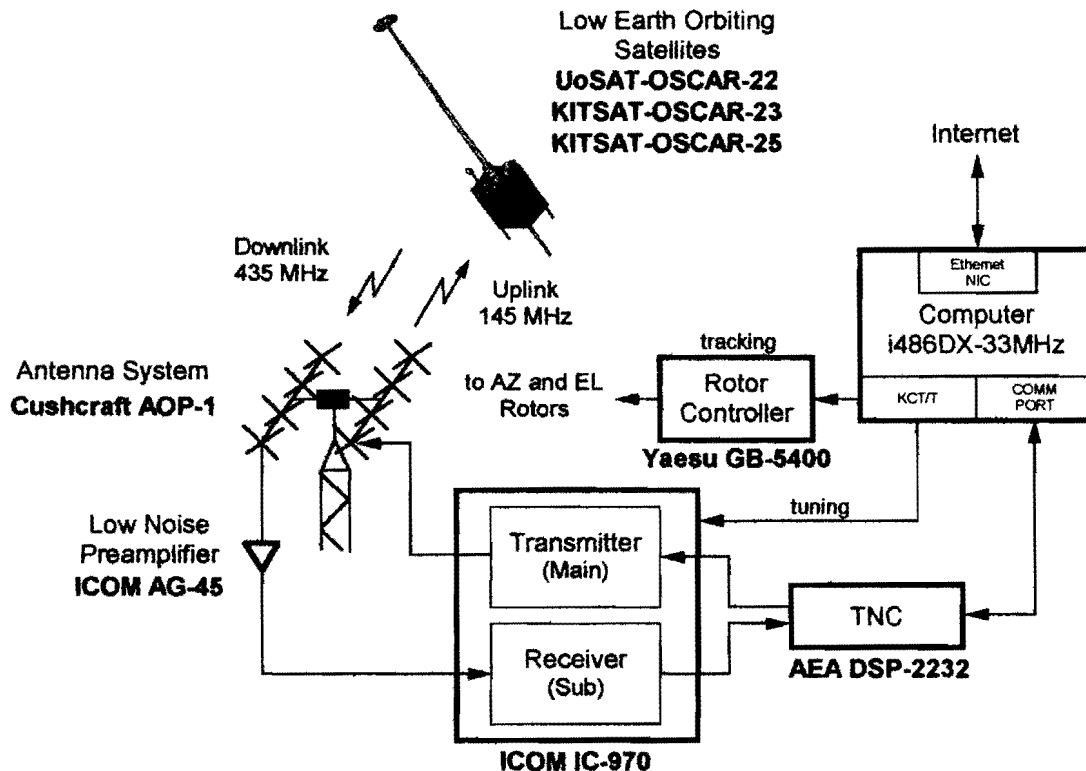
Figure 2. System Block Diagram of the Web Ground Station

Various softwares are loaded on the computer. The operating system is Microsoft® Windows™ for Workgroups Version 3.11 with 32-bit extensions (Win32s) and TCP/IP protocol stack (Wolverine)[1]. Controlling the satellite tracking and upload/download functions is Chris Jackson's, G7UPN/ZL2TPO, Windows Satellite Program (WiSP)[2] and David Hoatson's, KC6WYG, KCT/T Windows driver program. WiSP is an integrated suite of seven programs that schedules, tracks, tunes, composes and views messages, and transfers files to and from the satellites. The KCT/T driver program interfaces WiSP with the KCT/T card.

The World Wide Web server program is Windows httpd V1.4c written by Robert Denny[3]. The program runs under Windows 3.1 or Windows for Workgroups 3.11 and serves requests by the browser program for pages on the *Web Ground Station*. This combination of equipment and software creates an Amateur Satellite ground station that can track multiple satellites, unattended, 24 hours a day and serve documents to the World Wide Web.

Packet Satellites (PACSATs)

The *World Wide Web Amateur Satellite Ground Station* tracks and exchanges files with three amateur low earth orbit, digital communications, store-and-forward satellites: UoSAT-OSCAR-22, KITSAT-OSCAR-23, and KITSAT-OSCAR-25. These satellites communicate via 9600 bps FSK full duplex up and downlinks using the PACSAT Protocol Suite [3]. To better understand the inner workings of the *Web Ground Station*, a little background on how these digital communications satellites work is in order.

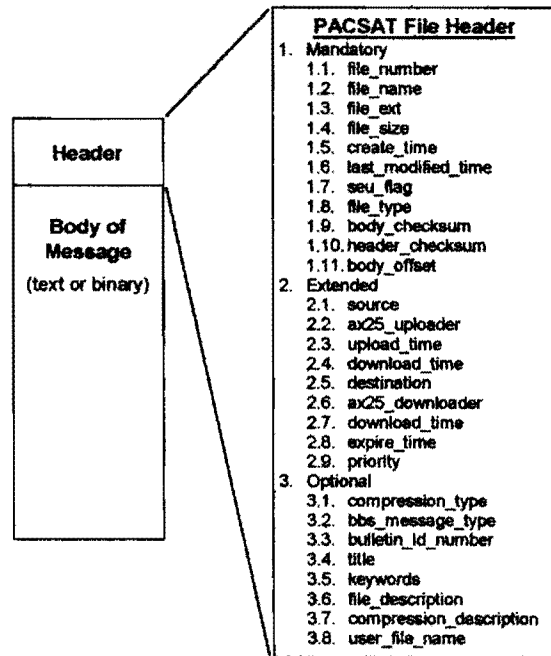[1] Win32s and Wolverine are available from Microsoft's anonymous ftp site ftp.microsoft.com.

[2] WiSP is available from AMSAT NA, 850 Sligo Avenue, Silver Spring, MD 20910-4703; Phone: (301) 589-6062.

[3] For more information about Windows httpd V1.4c see http://www.city.net/win-httpd/.

Messages uploaded to the satellites are prepared by the ground station software. The body of the message can be either text or binary information. The body is appended to a header which contains such information as the callsigns of the originating and receiving stations, title of the message, date and time of upload, and keywords. There are 28 possible fields in the header, divided into mandatory, extended, and optional categories [4] (Figure 3). When messages are uploaded to the satellite, the header information is removed and stored in the satellite's directory. The body of the message is assigned a sequential hexadecimal file number and stored in the satellite's memory.

The satellites transmit their directory listings separately from messages and files. This method facilitates a large number of ground based users each contending for resources on the satellite. Ground stations receive directory information from the satellite and scan it for messages that meet download criteria. If any messages are addressed to the callsign of the station or to ALL, the ground station transmits to the satellite and signals it to transmit the message.

Since the directory is transmitted separately from messages and files, the ground station maintains a listing of all the messages that reside on the satellite. When a message is transmitted to the ground station, only the body of the message is sent and the identity of the message is only known by its hexadecimal file number. Therefore, the ground station computer only maintains those messages addressed to it, to ALL, or messages overheard when broadcast to another ground station within the footprint of the satellite. When using WiSP's Message View program to read messages, the directory files are used to associate header information with the body of the message.

When directory listings, messages, or telemetry are downloaded, WiSP places them in their respective

PACSAT File Header
1. Mandatory
1.1. file_number
1.2. file_name
1.3. file_ext
1.4. file_size
1.5. create_time
1.6. last_modified_time
1.7. seu_flag
1.8. file_type
1.9. body_checksum
1.10. header_checksum
1.11. body_offset
2. Extended
2.1. source
2.2. ax25_uploader
2.3. upload_time
2.4. download_time
2.5. destination
2.6. ax25_downloader
2.7. download_time
2.8. expire_time
2.9. priority
3. Optional
3.1. compression_type
3.2. bbs_message_type
3.3. bulletin_id_number
3.4. title
3.5. keywords
3.6. file_description
3.7. compression_description
3.8. user_file_name

Figure 3. PACSAT messages are made up of the header and body

directories on the ground station computer. Directory listings have the filename MSPExxxx.PFH. The prefix MSPE stands for the MicroSat Protocol Engine, the program responsible for decoding information to and from the satellites. The xxxx is a sequential number assigned by WiSP. The PFH extension identifies the file as written in the PACSAT File Header (PFH) format. WiSP stores messages downloaded from the satellites in their original form: text for messages and binary for files. Text messages are stored in the MSGS subdirectory with the hexadecimal file number and MSG extension. Binary files are stored in the BIN subdirectory. Telemetry is captured by WiSP and labeled with a time stamp in the form of YYMMDDHH and an extension of TLM. Figure 4 summarizes the information flow from the satellite to the ground station computer.
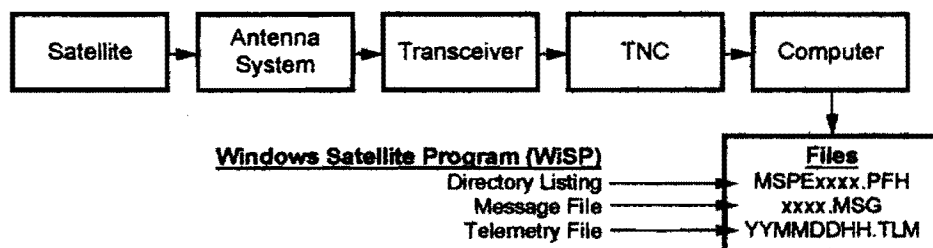
Figure 4. Information flow from the satellite to the ground station computer

The World Wide Web Interface

24

Once WiSP tracks the satellites and stores satellite directory information, messages, and telemetry on the ground station computer, the *Web* interface takes over. A few minutes after the satellite pass, WiSP schedules two custom programs to run. The first converts the directory listing into Hypertext Markup Language (HTML), the language of the World Wide Web, and the second decodes the captured telemetry and formats it into a text file.

The first custom program is called PFH2HTML.EXE. It reads the MSPExxxx.PFH file, parses it according to the PFH protocol, and writes a text file in HTML format. First the *Web* user clicks on the appropriate hypertext that requests the directory listing from the satellite of interest. From here the user can see a listing of all messages that are resident on the satellite. As mentioned before, not all messages are downloaded to the ground station. Therefore, when PFH2HTML parses the directory listing, it sees if the corresponding message is resident on the ground station computer. If it is, a hyperlink is made to the message. If the message is not resident, it is listed as normal text. Figure 5 shows a directory listing from KO-23. Hypertext is indicated by the underlined titles of the message. This indicates that the message is available to be read. By clicking on the associated hypertext the message is presented to the user. Hyperlinks allow the user to see at a glance which messages are available to read. This is an elegant interface and a fantastic demonstration of the power of hyperlinks. The interface is intuitive, easy to use, and does not distract the user.

The telemetry files are converted in the same fashion as the directory listings. The second custom program, called TLM.EXE, reads the raw telemetry and writes a text file. The user can choose to read the decoded telemetry or download the raw telemetry for later decoding with their own program.

The *Web Ground Station* tracks the satellites individually, downloads directory listings, messages,

Figure 5. The KO-23 directory listing. Hypertext indicates messages that are available to read.

and telemetry, all while unattended. WiSP takes care of the tracking and placing of files into their appropriate directories and the custom programs PFH2HTML and TLM convert the files into HTML format for the *Web*. But the custom programs could not do their job if it were not for WiSP's unique feature of scheduling programs. PFH2HTML and TLM are scheduled to run 2 minutes after each satellite pass, so files are kept up to date. Anytime a user browses the *Web Ground Station* they are viewing the latest files available from the station's location. Figure 6 summarizes the flow of information between the files WiSP writes to the ground station computer and the custom programs that format them into their HTML counterparts for the *Web* server.

Figure 6. Web Server Information Flow

A Virtual Classroom

The previous sections describe the heart of the *World Wide Web Amateur Satellite Ground Station*, the ability to read directories, messages, and telemetry in near real time. The *Web Ground Station* also has pages that describe how to operate the *Web Ground Station* for first time user and hardware and software descriptions complete with graphics (Figure 7). There are also hyperlinks to other associated sites on the World Wide Web for those interested in exploring information provided by The Radio Amateur Satellite Corporation (AMSAT) and Tucson Amateur Packet Radio (TAPR) organizations.

Something Borrowed

PFH2HTML.EXE and TLM.EXE were written using a technique called "code reuse." Source code was borrowed and modified from the microsat programs for the Linux operating system. John Melton, GØORX/N6LYT, the author, released the programs through the GNU General Public License[4], making them freely available. It is John's generosity that made the Web Ground Station possible. Thanks John!

Summary

Judging by the enthusiastic response and the many thousands of accesses, *The World Wide Web Amateur Satellite Ground Station* has been a resounding success. It has been accessed by Amateurs and non-Amateurs from all around the world. Even educators are finding the *Web Ground Station* useful for classroom demonstrations and it has given beginning satellite enthusiasts and seasoned Amateurs alike a glimpse into the world of Amateur digital communications satellites.
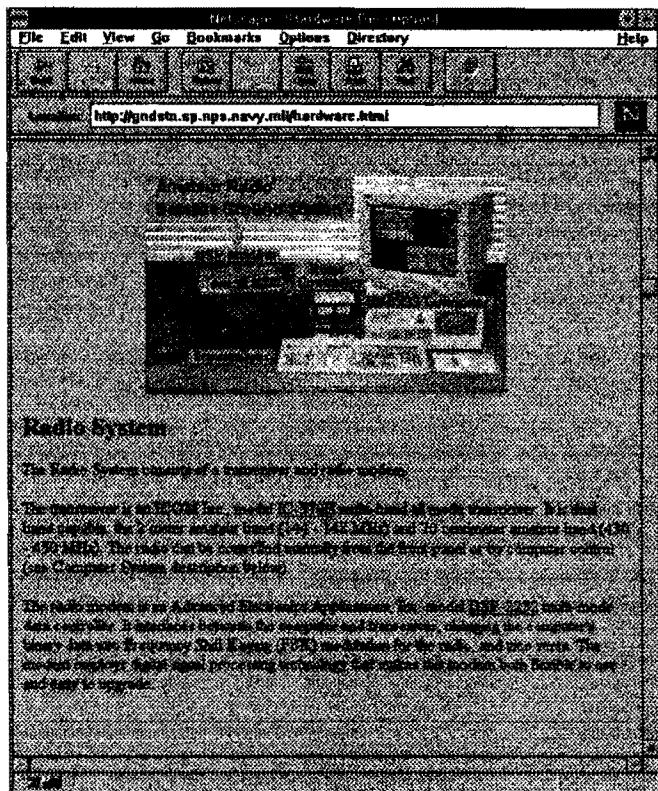
Figure 7. Hardware Description Page

Acknowledgments

26

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[3]   H. E. Price and J. Ward, "PACSAT Protocol Suite - An Overview," *ARRL Seventh Computer Networking Conference*, Oct. 1, 1988, pp. 203-206.

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The Phase 3 D Integrated Housekeeping Unit

by Lyle Johnson, WA7GXD

Phase 3D, the most complex amateur satellite ever constructed, will have a multitude of advanced microprocessors and microcomputers among its various experimental payloads.

For example, the digital communications system (RUDAK) will employ a pair of x86 processors as well as sixteen (16) digital signal processor (DSP) chips. The GPS system will be based on a 32-bit RISC processor from AMD. The SCOPE cameras will employ 68000-based controllers. A number of 68HC11 family processors will be networked via the CAN-bus to provide distributed sensing and control functions.

Buried in the midst of all these high-technology parts is the Integrated Housekeeping Unit (IHU), based on the humble, 1970's technology COSMAC 1802 microprocessor. Oddly enough, the IHU is responsible for the overall management of the spacecraft...

IHU - A Brief Background

When the Phase 3 satellites were conceived in the mid 1970s, AMSAT engineers recognized that a microprocessor-based flight computer would be necessary to manage the spacecraft. Earlier OSCARs had been designed before the microprocessor era had begun, and their mission profiles were straightforward. The Phase 3 spacecraft, with their complex navigation requirements and variable payload management needs, required a more complex control system. Unfortunately, complexity often leads to reduced reliability of a system. With the advent of the microprocessor in the early 1970s, a workable solution appeared and one more piece of the Phase 3 puzzle came into being.

A lot of effort went into defining the computer architecture, I/O requirements, command and telemetry formats and modulation/demodulation methods, operating system and efficient programming development system. Remember, we are talking about an era when an 8-bit processor was the best available, 64K bytes of memory was breathtaking, and small computer mass storage requirements were met with audio tape cassette decks at 300 bits/second. A computer with an 8" floppy disk drive required a significant investment. Most hobbyists wrote directly in machine code, an assembler was a luxury and the closest thing anyone had to a high-level language generally available was an interpreter called Microsoft BASIC by students Paul Allen and Bill Gates - if you had the 4k to 8k bytes of memory necessary to use it and the patience required to load it from your cassette recorder...

The early processors, like the 8080, 6502, 6800 and Z80, were made with NMOS technology, consumed a lot of power for what they did and were very simple by today's standards. For example, today's Pentium has a few million transistors; a 6502 had a couple tens of thousands.

In the mid-1970s, RCA introduced a microprocessor called the COSMAC 1802. This processor shared most of the limitations of microprocessors of its era. But, it was made from very low-power CMOS technology and it had a few unconventional features that made it ideal for spaceborne applications. This processor formed the basis for the Phase 3 IHU hardware.

In the late 1960s, an astronomer was dealing with the limited computational power of the minicomputers used to control and operate the sophisticated telescopes of the time. Charles Moore developed a new computer language, called FORTH (because FOURTH was too many characters for his computer to recognize). FORTH was unconventional in its structure, but boasted of extreme memory efficiency and reasonable computational speed. For the small, memory-limited control systems of the day, its advantages were many. The concepts of FORTH were incorporated into a multi-tasking language called IPS, which formed the software basis for the Phase 3 IHU.

The 1802

The COSMAC 1802 processor is in some ways typical of early 8-bit microprocessors. It has a 64K-byte memory addressing capability, deals with 8-bit quantities well, and runs slowly. It has a separate I/O space of 15 locations.

It is also atypical in many ways. It has one output pin (Q) and four input pins (EF1..4) on the processor itself. It has status outputs that can be used to tell the processor's current state. It uses an internal array of sixteen (16) 16-bit general purpose registers. And, it has a direct memory access (DMA) mode!

Finally, being built with large-geometry cells, it can operate from power supply voltages as high as 10.5 VDC. This higher voltage operation enhances the processor's ability to resist radiation poisoning by increasing the threshold shift that must occur before a given cell no longer switches.

Apart from its low-power CMOS construction and high-voltage operation, the two features most attractive on this part are the register architecture and the DMA facility.

The register architecture of the 1802 is similar, though on a smaller scale, to that of today's RISC processors. This regular architecture also lends itself to very efficient implementations of high-level languages, such as FORTH or IPS.

The DMA facility is used by the command decoder hardware to enable command stations to upload operating software to the IHU. A big advantage here is that absolutely no fixed memory storage (ROM) is needed to "boot" the computer. Dependable ROMs for use in a radiation environment are problematical even today. In the late 1970s, they simply did not exist. This feature of the 1802 allowed simple, reliable hardware to dependably load the operating software into the IHU.

Of course there are downsides to everything. In the case of the 1802, one of its major shortcomings is its very slow operation. In the IHU, it is clocked at 1.6 MHz. This means it can only execute about 100,000 native instructions per second.

IPS

FORTH is an "extensible" language. This means that new functions, operators, etc., can be defined and then immediately used. FORTH maintains "words" in a "dictionary"; conventional languages do similar things but claim to maintain "procedures" in "libraries." The effect is much the same.

FORTH, however, runs as an interpreter while executing code. It can compile new words on the fly. The new words contain addresses of already known words, "threaded" together to create the new word.

IPS is very like FORTH. Its notable extension is that it is a multi-tasking environment, rather than a single-tasking environment. It uses a simple, round-robin method of executing these tasks.

Phase 3A/B IHU

The Phase 3 satellites required much more in the way of digital I/O control and status lines than the few 8-bit ports offered by the 1802. In addition, there was a need to measure analog signals (e.g., battery voltages, solar array currents, module temperatures, etc.).

Significantly more memory would be required than could be provided by the simple 1k-bit (and smaller!) memory parts developed by RCA for use with the COSMAC.

A reliable means of starting the IHU and loading software into it had to be developed.

The IHU design that evolved was based on the extensive use of RCA 4000-series and Motorola 14500-series CMOS logic. Housed in dual-in-line (DIP) packages ranging from 14 to 24 pins, these components had the advantages of extremely low power dissipation (measured in microwatts when signals weren't changing), large gate geometries and availability as military-rated components. The low power was necessary due to the limited power available from the solar panels. The large geometries helped improve the yield of the part in the fab lines of the day. The military versions of the part were rated for operation over an extremely wide temperature range and were packaged in rugged ceramic housings capable of withstanding a lot of abuse. In the 1970s, plastic-packaged ICs were often subject to "purple plague" due to poor sealing and other problems, so ceramic packages were a big advantage.

The digital I/O port expansion was handled by a multiplexing scheme. A value to be sent to another part of the spacecraft (e.g., turn on MODE B transponder, or arm the rocket ignition system) would be stored in a register (or latch) at a specific I/O location. An "address" of the destination system would be written to another I/O register. Finally, a third I/O location would be written to, resulting in a pulse to signal the remote system that there was information for it to receive, and provide the proper timing signals for it to be properly received. This technique greatly expanded the I/O capacity of the 1802, and only inserted one additional component in the chain of parts, thus having minimal impact on reliability.

The analog monitoring system was handled by building an on-board analog-to-digital converter (A/D or ADC) on the IHU PC board. This was constructed of op-amps, gates, counters and latches along with a few discrete components. The resulting ADC had 8-bits of resolution and was linear in its response except for the first few counts at the low end. It had a range from near zero to about +2.5-volts, and a conversion time not greater than 20 mSec.

To handle the necessary channels, and external analog multiplexer was constructed with thirty-two (32) inputs. A number of the inputs were specialized to handle the YSI thermistors to be used for temperature measurements. Others were simply multiplexed inputs. Using the I/O multiplexing scheme described above, the 1802 was able to select the desired analog input channel, read it, then store it, process it or simply report it as telemetry.

The memory system used in these early IHUs was based on a 16K-bit dynamic RAM (DRAM). Contrast this with today's commonly used memory chips of 16 megabits, or three orders of magnitude greater capacity!

Experiments determined that 16K memory chips from MOSTEK (now a part of SGS-Thomson) could be operated with a +10-volt supply, making them compatible with the voltages in use elsewhere in the IHU. The memory system for Phase 3A and Phase 3B was built using these parts.

To synchronize events and provide real-time operation, the IHU fundamentally divides time into 20 mSec intervals. This means that no task can take longer than 20 mSec to complete. There is only time to execute about 100,000*0.02=2,000 native 1802 instructions per time period.

The command decoder, an external module, was designed to take advantage of the DMA facility of the 1802 to load new software. It also had the ability to reset the IHU on command from the ground.

Physically, the IHU was in a standard Phase 3 module box, used a pair of PC boards measuring 100mm by 300mm, and used a pair of D-sub 50-pin connectors. The board layout was done by hand, and the boards were double-sided (e.g., traces on both sides of the PC boards). The boards were wired together using turret-style posts and individual wires. Similarly, the D-sub connectors were hand wired to the PC boards.

Phase 3C IHU

The requirements for the IHU on Phase 3C (AO-13) were much the same as for the previous Phase 3 spacecraft. However, the memory subsystem needed to be redesigned for better radiation tolerance if long-life operation of the spacecraft was to be achieved..

In the early 1980s, Harris Corporation developed a series of low-density 4K-bit CMOS static RAMs (SRAMs). They assembled some of these chips into modules (HM-6564) built on ceramic substrates and configurable in their organization as 8K-by-8-bit or 16K-by-4-bit arrays. They also developed radiation-hardened versions of these memory chips.

The IHU design physically had the memory subsystem on a separate 100mm x 300mm PC board, so revising the memory system had little or no impact on the rest of the IHU. The designers of the Phase 3C IHU created a new memory module based on the Harris radiation-hardened SRAMs. The IHU memory capacity was doubled from 16Kx12 to 32Kx12.

In all other respects, the IHU flying aboard AO-13 is the same as the previous models.

Phase 3D IHU

The requirements of the IHU for Phase 3D are more intense. There is a lot more I/O, more payloads, more complex switching of the payloads, a more complex navigation system, etc.

In light of these requirements, various options were considered for the IHU. Different processors, different technology, higher levels of integration and so on.

In the end, a few pieces of radiation-hardened COSMAC 1802 CPUs were located. The software flying on AO-10 and AO-13 had been flight-proven in the harsh environment of the Phase 3 orbit. It was determined that the 1802 could in fact handle the anticipated computational and control loads needed by Phase 3D. The hardware design had also logged a lot of time safely and reliably performing its duties on AO-10 and later AO-13. Since the entire P3D mission depended on the IHU, there was considerable reluctance to abandon the existing design in favor of something unproven.

Early on, it appeared there might be a serial bus that could be toggled between processors to allow an old-style IHU and a newer, higher-technology IHU to be simultaneously flown. It turned out that the obstacles to this, and the reliability risk, dictated use of standard, parallel wiring instead of the serial bus for primary payload control and spacecraft navigation.

Two major problems still remained, however.

One was regarding physical size. The Phase 3D module boxes are smaller than the earlier Phase 3 module boxes. The largest Phase 3D module footprint is 200mm x 270mm. This would mean somehow shaving 30mm off of the existing IHU PC boards, or massaging other things to fit the larger module box into the spaceframe.

The other and more serious problem had to do with memory. The Harris HM-6564 modules were obsolete and none were found. Fortunately, Plessey agreed to donate sufficient pieces of a different, larger radiation hardened memory chip to the project to build one (1) IHU.

After some discussions in early 1994, it was decided that a new IHU would be designed based heavily on the earlier IHUs. It would still use the COSMAC 1802 processor. In fact, the only changes that would occur would be those necessary to accommodate the new memory chips, and such minor changes as were required to allow for expanded I/O. The command, control and telemetry systems would be based on the earlier, successful versions already flown.

The resultant Phase 3D IHU differs from earlier designs in some major and many minor respects.

- The memory space has been increased from 32K bytes on AO-13 to just under 64K bytes.
- A four-layer PC board is being utilized, with line geometries reduced to those successfully employed on the MicroSats.
- The CPU board and memory board have been consolidated onto a single 200mm by 270mm PC board.
- The command decoder has been integrated onto the same PC board.
- An serial-bus has been integrated onto the IHU for communicating with secondary (i.e., not spacecraft survival dependent) experiments.
- PC board mounted connectors are used, completely eliminating internal wiring harnesses within the IHU.

The increased memory space may prove useful. On the other hand, IPS is very compact and the upper 16K bytes of memory on AO-13 have not yet been utilized. With the limited speed of the processor, it is not practical to code and use long program sequences.

The denser PC board results in a very quiet system. Two inner layers of metal are used for power and ground planes. 10 mil (0.25mm) tracewidths along with 10 mil spacing between traces allows much tighter packing of the components than was possible using earlier design rules.

Combining three (3) PC boards from earlier missions onto a single, smaller PC board contributes to mass reduction of the spacecraft, an important Phase 3D constraint.

The Controller Area Network (CAN) bus is an international automotive standard. Incorporating it onto the IHU allows it to be validated for possible critical applications on future AMSAT spacecraft. Such validation may be important for mass reduction, as well as man-hour reduction in time spent wiring future spacecraft.

Eliminating the internal wiring harnesses results in reduced mass. Perhaps more importantly, it dramatically reduces the man-hours needed to build flight and engineering model IHUs, and eliminates the possibility of errors in wiring the module connectors. With three (3) connectors totaling 109 pins, there is plenty of opportunity for errors to occur!

Like its predecessors, Phase 3D's IHU will send telemetry frames at 400 bit/sec using Differential Binary Phase Shift Keying. Existing demodulators for watching the telemetry from AO-13 will be suitable for observing the conditions aboard Phase 3D. The IHU similarly has the capability to send Baudot RTTY and CW formats.

Acknowledgments

If you were involved in the design or construction of any of the Phase 3 IHUs and are not listed above, or if you know of anyone who was and isn't listed here, please let me know. Any omissions are purely unintentional.

RUDAK-U

by Lyle Johnson, WA7GXD, for the RUDAK Team

RUDAK-U is a digital communications system currently slated to fly aboard Phase 3D. RUDAK-U will bring real-time digital communications with global coverage to the world Amateur Satellite community.

Presently, your packet traffic is typically handled on VHF/UHF channels at 1200 bps or 9600 bps data rates. The station you directly communicate with is usually less than 25 miles (40 km) away. Most of your traffic is in the form of electronic mail, bulletins and programs or data files. This is store-and-forward communications -- like talking to your neighbor's telephone answering machine...

You've been conditioned to believe that packet is for non-real-time communications, and you've exploited this limitation. Some of you may have tried to use packet for keyboard-to-keyboard QSOs and have been informed by the local "experts" tell you are clogging up important file transfer channels, and that packet isn't intended for such communications.

Existing packet satellites have been optimized to exploit their low earth orbits and are, in effect, flying mailboxes.

"So?" you may ask. "We've already got a terrestrial packet network, and several low earth orbit (LEO) packet satellites. I've had my fill of packet, anyway. What's so special about this?"

RUDAK - WHAT IS IT?

Being a part of P3D, RUDAK-U will be able to see half the world at a time, and from almost any location on the planet you'll have access to almost all of the rest of it over a 48-hour period. Like the systems you may already be accustomed to, RUDAK will have file store-and-forward capability.

Unlike existing satellites, RUDAK will utilize ground-based servers rather than on-board memory to implement most of its storage facilities. The 32 megabytes or so of on-board memory will act like a cache, holding only the most recently used or needed data along with its own programs, local data and so forth.

But let's look at the real-time opportunities.

RUDAK may have as many as ten (10) communications channels operational at a time. During these times, multiple QSOs may be carried out using, say, digital voice. At other times, only a few channels will be operating. Some of these channels will likely be "scheduled" to minimize QRM.

RUDAK-U will be the primary communications path for images from the SCOPE earth-imaging cameras on Phase 3D. It will also be a source of precise information from the on-board Global Positioning Satellite (GPS) experiment.

Some of the time, RUDAK-U will have only one or two downlinks running on a particular downlink transmitter. At these times, a simple ground station similar to that required to work UO-22 or KO-23 is all that will be required. At other times, when more downlinks are on or high-speed links are in use, a more powerful ground station transmitter and better receiving system will be required.

SOME DESIGN DETAILS

RUDAK will carry two (2) independent computers.

CPU-A will be based on the NEC V53 processor. This processor is a superset of the V40 flying aboard the MicroSats (AO-16 through LO-19). The V53 is flying now as part of AO-27. It will have 16 megabytes of error correcting memory, and sixteen (16) DMA-based communications ports.

CPU-B will be based on the Intel i386EX processor. This is a high-end controller and is being investigated for use on future Amateur spacecraft as well. Like CPU-A, this one will have 16 megabytes of memory, with error correction to help protect against the hazards of radiation upsets. It will also have 16 DMA channels. In the event that this CPU doesn't work as expected, the design of the experiment is such that a second V53 can fly in this position.

For comparison, the MicroSats have 256 kilobytes of error-correcting memory (1/64th the amount of either CPU on RUDAK-U) and a total of 8-1/4 megabytes of memory (about 1/2 the amount of either CPU on RUDAK). They have only six (6) DMA ports.

The CPUs will be tied together by a high-speed first-in first-out (FIFO) buffer. This will effectively enable each CPU to have access to much of the other CPU's memory resources.

The modems for RUDAK will interface to the IF switching matrix on P3D. This means a different kind of interface (similar to that pioneered by RUDAK-II aboard RS-14/AO-21) and the ability to operate on multiple frequency bands along with the analog transponders.

One of the design goals of RUDAK-U is to be compatible with existing packet users. Another goal is to be flexible for future operations. Since we expect P3D to be operational for more than ten (10) years, we don't want people to have to use today's (obsolete) technology. This means flexible modem technology.

Each CPU will connect to the modem PC board. Each will have access to one-half of the available modems. The modem board will have:

(1) Four 9600 bps FSK uplink/downlink for "typical" operation. This ensures compatibility with the present 9600 bit/sec satellites. These will be fixed frequency, hardware modems.

(2) Eight DSP-based modems. These will allow operation at reasonable data rates (we are looking at making them capable of 56 kbps operation) as well as more complex modulation schemes. They will of course be able to provide compatibility with today's satellite standards.

These modems will be based on Analog Devices ADSP-2171 DSP chips. There will be a total of sixteen DSP chips used, eight for uplink for eight for downlink.

The downlink DSPs will drive Analog Devices AD7008 direct digital synthesizer (DDS) chips operating at the I.F. This enables the channel frequency and power so be changed under software control, and also allows extreme flexibility in modulation formats.

The uplink DSPs will each sample a Harris HSP50016 digital downconverter (DDC) chip. These are very flexible, I- and Q-channel oscillator/mixer/filter chips. Like the uplink, they can be tuned to different frequencies and tailored for various modulation schemes under software control.

Thus, these modems can be used to implement more or fewer channels, and use evolving modulation techniques to tailor RUDAK to the needs of the Amateur Satellite digital community throughout the life of the P3D mission.

LINK MARGINS

Unlike the current Packet Satellites, P3D will be in a very high altitude orbit. As a result, even though it will use higher gain antennas and a more powerful transmitter, a ground station for effective use of

RUDAK's advanced capabilities must have a more powerful transmitter and a better receiving system than is needed for the low earth orbit spacecraft. A station currently capable of effective operation of AO-13 will do well, provided of course that it has the proper modems and other digital communications gear necessary. The following tables summarize the expected RF needs. Since these are pre-launch numbers, be sure to add several dB for safety if you are planning on building your station now.

(see the Microsoft Excel Tables included in the ZIP file that contains this article).

As you can see, when RUDAK is operating multiple downlinks, you will need a very good receiver. When it is operating only one or two downlinks at 9600 bit/sec and allowed a full 20 watts for its downlink power, a modest station will perform well.

As can also be seen, it will be more difficult for your station to hear RUDAK than for RUDAK to hear your station in many cases. You may notice, for example, that if RUDAK is only putting 33 dBm into a 70 cm downlink, you'll need an 18 dB gain ground station antenna to hear a 9600 bit/sec FSK downlink at apogee! However, if RUDAK has only two downlinks operating at 70cm, it can increase its downlink power to 40 dBm, reducing your ground station antenna requirement by 7 dB. In this case, an AO-13 class 13 dB gain receiving antenna will probably suffice. If only one downlink is in operation, an additional 3 dB can be put to work, making reception even easier.

The case is less clear at 13cm (S band) because the transmitter power is more limited than at 70cm.

FREQUENCIES

The fixed-frequency 9600 bit/sec modems are planned for the following frequencies, depending on transponder mode:

UPLINKS:

2m:	145.810 MHz	145.830 MHz

The other two fixed uplink frequencies may be published at a later time.

DOWNLINKS:

70cm:	436.000 MHz	436.050 MHz	436.100 MHz	436.150 MHz
13cm:	2400.750 MHz	2400.800 MHz	2400.850 MHz	2400.900 MHz
3cm:	10451.550 MHz	10451.600 MHz	10451.650 MHz	10451.700 MHz
1.5cm:	24048.550 MHz	24048.600 MHz	24048.650 MHz	24048.700 MHz

The other DSP-Uplink/Downlink frequencies will be in the frequency range of the P3-D bandplan for digital modes. The exact frequencies will be completely under software control and published at a later time.

STATUS

As of this writing, some of the PC boards for RUDAK-U are being fabricated. Others are in layout. Nearly all of the component parts are in hand. Thus, RUDAK is on-time and behind schedule!

WHO IS MAKING RUDAK?

Major players in the RUDAK experiment include:

Lyle Johnson, WA7GXD, Project Manager

Chuck Green N0ADI
Peter Guelzow, DB2OS
James Miller, G3RUH
Harold Price, NK6K
Jeff Ward, K8KA/G0

RUDAK 13cm Uplink Calculations			1200/PSK	1200/PSK	9600/FSK	9600/FSK	56K/MSK	56K/MSK
Frequency, MHz			2401	2401	2401	2401	2401	2401
Ground Station								
Transmitter Power, dBm			30	36	30	36	36	36
Line Losses, dB			1	1	1	1	1	1
Antenna Gain, dBic			20	20	20	30	30	36
Path								
Sat Altitude, km			43800	43800	43800	43800	43800	43800
Max Distance, km			49765	49765	49765	49765	49765	49765
Polarization Loss, dB			0	0	0	0	0	0
Atmospheric Loss, dB			0.1	0.1	0.1	0.1	0.1	0.1
Spacecraft								
Isotropic Signal at Spacecraft, dBm			-145.0	-139.0	-145.0	-129.0	-129.0	-123.0
Antenna Gain, dBic			18	18	18	18	18	18
Sky Temperature, K			300	300	300	300	300	300
Feedline Loss, dB			0.7	0.7	0.7	0.7	0.7	0.7
Receiver NF, dB			0.5	0.5	0.5	1	1	1
Bandwidth, kHz			2.4	2.4	15	15	100	100
Data Rate, symbols/sec			1200	1200	9600	9600	56000	56000
Receiver Noise Temperature, K			392.3	392.3	392.3	438.9	438.9	438.9
Receiver Noise Power, dBm			-138.9	-138.9	-130.9	-130.4	-122.2	-122.2
User S/N, dB			11.8	17.8	3.9	19.4	11.1	17.1
User Eb/N0, dB			14.8	20.8	5.8	21.3	13.6	19.6
User C/N0, dB-Hz			45.6	51.6	45.6	61.1	61.1	67.1
Link Margin								
Required S/N for BER=10^-5, dB								
Non-coherent FSK		13.5	-1.7	4.3	-9.6	5.9	-2.4	3.6
Coherent FSK		12	-0.2	5.8	-8.1	7.4	-0.9	5.1
PSK, Coherent		9	2.8	8.8	-5.1	10.4	2.1	8.1
DPSK, Coherent		10	1.8	7.8	-6.1	9.4	1.1	7.1
			yagi	yagi	yagi	1m dish	1m dish	2m dish

$\mathcal{DSP}$-93 Update:
The TAPR/AMSAT Joint DSP Project

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Abstract

This paper discusses the geniuses of the TAPR/AMSAT Joint DSP project. The end result was the TAPR/AMSAT DSP-93. As of July 1995, 300 units have been made available to amateurs for construction. Items to be covered include: a history of the project, history of the DSP-93, DSP-93 design, current software suite, code development, and comments on the successful use of Internet for project support.

Introduction

In 1987, DSP-based modems were seen as the coming amateur trend [1,2]. Digital signal processing techniques have been a promise of improved reliability and lower cost since 1986. In July 1988, TAPR and AMSAT entered into the Joint DSP Program, in order to fund the development of an eventual DSP unit for amateur usage. The hope was to fulfill the dream of having a low-cost, flexible amateur kit. The DSP-1 was based on a TI TMS320C15 at 25Mhz, with 4K of program memory. In addition, a GPP board (NEC V40 with 72001 serial I/O chip) was developed to interface the DSP-1 to a PC for programming. Progress was made during the early stages of the project [3,4], but later trailed off as other projects appeared. The articles in the reference provide a good snapshot for those early days. The DSP-1 platform, along with experience gained from the earlier Delanco Spry boards, while never reaching a final kit, proved invaluable in the learning process. These early developments are reflected to some degree in the final DSP-93 project.

In 1993, the TAPR/AMSAT co-management team made the deliberate decision to stop work on the DSP-1 project and to proceed with a proposal by Bob Stricklin, N5BRG, in Dallas, Texas that focused on a modular, stand alone DSP system. The Stricklin KISS design [5], later renamed DSP-93, offered many of the elements that the initial design goals of the project had specified. Seven years into the joint project and fifteen months after the decision was made to proceed with the DSP-93 development, TAPR and AMSAT shipped the first 110 units of the project. In July of 1995, a second batch of 180 units was produced and shipping began — an end to a long journey.

39

The history of DSP-93 can be traced back to 1991 when development began on the KISS DSP. The KISS DSP was a single board DSP engine designed around the Texas Instruments TMS320C25. The KISS DSP board, as described in an earlier AMSAT publication [5], included the DSP, memory, serial I/O, and a limited audio interface. The KISS DSP was designed as a stand alone box to interface between the computer and radio. In some cases, a TNC was needed to process the HDLC digital data. To simplify the computer interface, a monitor routine (DSP BIOS) was developed which included functions to download DSP programs from a computer, view and change program memory, data memory, and DSP registers. To make software development possible, work was undertaken with Thomas Anderson of Speech Technology in Issaquah, Washington to produce a TMS320C25 assembly table for his assembler. The result was an inexpensive assembler for the a TMS320C25-based DSP.

Several amateurs obtained and built the KISS DSP boards and placed them in operation. The KISS DSP experiments served as an excellent initial platform to develop and understand the realities of developing DSP software and hardware for amateur applications. Areas which needed work were the radio interface circuitry and understanding how to match the hardware with the particular application. A single 'do all' DSP box is not a practical solution to all amateur DSP applications. It is not "Only Software." It is a combination of selecting the best hardware for the particular application and developing the software around the selected hardware. Since most amateurs are looking for a cost effective solution, you can sacrifice some of the capability and provide them as future additions.

Based on the KISS DSP lessons, DSP-93 was designed in a modular fashion with multiple four-layer boards which include the interconnecting bus structure. The boards include a DSP engine board and a radio and computer interface board. Any of these boards can be replaced with a future board designed for any number of unique applications. It's sort of like adding a new application card to a PC without redesigning the complete PC. Figure 1 shows the basic hardware black diagram. Figure 2 shows overall structure of the assembled unit with enclosure.

The bottom board (DSP Engine) contains the TMS320C25 DSP, 64K by 16 bits of program and data memory, the clock circuitry and programmable array logic (PALS) for system I/O. All the DSP lines are connected to the backplane bus. This was intended to make it easier to add additional features on additional DSP-93 boards. The floating input lines all have 100K pull up resistors. The clock circuit for driving the DSP is also included on the DSP Engine board. Since slower EPROMs are used to boot the system, the clock is designed to shift between half the maximum rate and full speed. Clock shifts are software controlled and will be transparent to the application. The target clock speed is 40 MHz; however, we have demonstrated that 26 MHz is adequate for most amateur applications. Additional testing of the Beta boards will be required to establish the final clock rate.

The top board (Radio Interface Board) contains two eight pin mini-DIN connectors for the radio interface. Incoming radio signals pass through a voltage divider to establish the initial levels, then through an eight channel multiplex chip. The multiplex

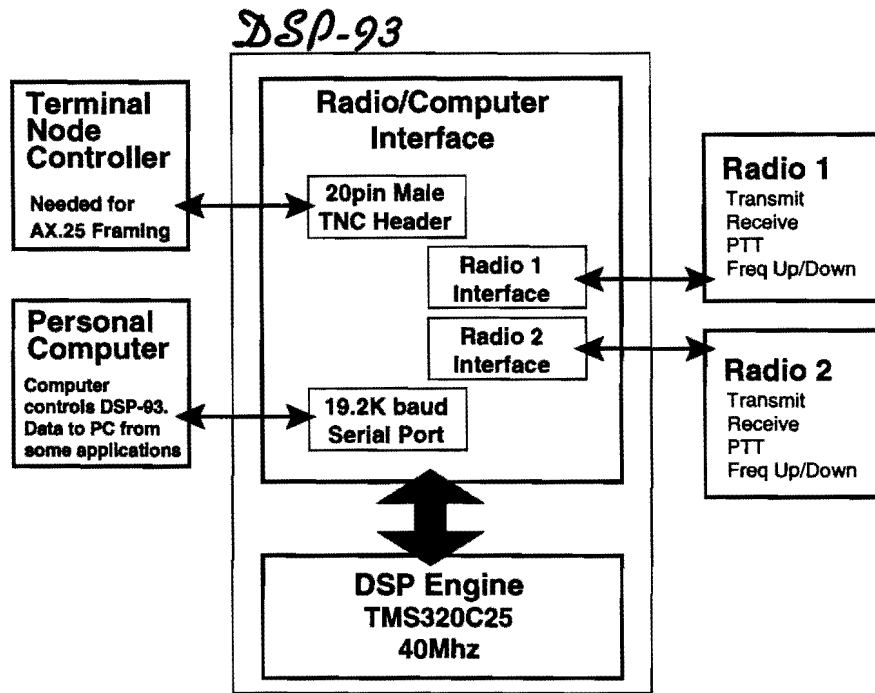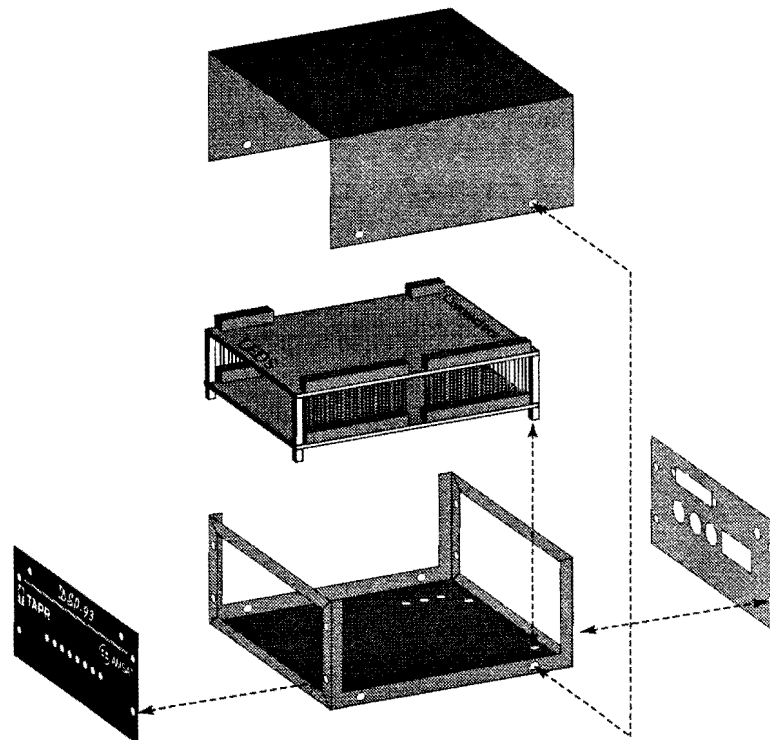**Figure 1: Basic hardware black diagram.**

Figure 2: Overall structure of the assembled unit with enclosure.

chip will feed the single A/D input with either of the radio inputs or one of the six auxiliary inputs. Before reaching the A/D, the signal is conditioned by an OP-AMP whose gain is software selectable. Gain options include; 1X, 2X, 5X, 10X, 20X, 100X, 1000X and a comparator mode with ground being the reference voltage. Once again this is all software controlled and it should make for some nice adaptive signal conditioning algorithms. The Texas Instruments TLC32047 Analog I/O chip is used on board two. This chip samples and updates at a rate of 45K operations per second and it includes aliasing filters. The chip communicates with the DSP using a 5 MHz serial interface. The 5 MHz interface is routed through a selection PAL to allow the user to disable this serial device in favor of another.

Code Development

A low cost shareware assembler is available for code development. Thomas Anderson of Speech Technology in Issaquah, Washington has worked with the DSP-92 development group to produce a TMS320C25 assembly table for his assembler. All the details needed to write DSP code is supplied with the kits. An in-depth programming guide has been developed and is available for DSP-93 developers.

Project Team

Much of the development and current success of the DSP-93 project can be contributed to the designers, developers, and testers. Designer: Bob Stricklin, N5BRG. Project Managers: Bob Stricklin, N5BRG and Greg Jones, WD5IVD. Joint DSP Project Officers: Robert Diersing, N5AHD (AMSAT) and Greg Jones, WD5IVD (TAPR). The Alpha-Team: Bob Stricklin, N5BRG, Frank Perkins, WB5IPM, Jon Bloom, KE3Z, Lon Cecil, WB5PKJ, Tom McDermott, N5EG, Robert Diersing, N5AHD, UoSAT/ Doug Loughmiller, K05I/G0SYX, John Conner, WD0FHG, Greg Jones, WD5IVD, and Bill Reed, WD0ETZ. The Beta-Team: Jack Davis, WA4EJR, Paul Beckmann, WA0RSE, Scott Zehr, K9GKC, Ron Parsons, W5RKN, Jim Tittsler, 7J1AJH/AI8A, Michael Zingman, N4IRR, Stan Salek, KD6CVL, Mark Hammond, KC4EBR, Marcel Losekoot, Bill Beech, NJ7P, Gould Smith, WA4SXM, Roy Welch, W0SL, Greg Ratcliff, NZ8R, Brian Straup, NQ9Q, Doug Howard, KG5OA, and Robert Greenfield, VE3DSC.

The current DSP-93 development group consists of: Bob Stricklin, N5BRG, Frank Perkins, WB5IPM, Tom McDermott, N5EG, Ron Parsons, W5RKN, Scott Zehr, K9GKC, Stan Salek, KD6CVL, Mark Hammond, KC4EBR, Gould Smith, WA4SXM, Roy Welch, W0SL, Brian Straup, NQ9Q, Michael Zingman, N4IRR, Lon Cecil, WB5PKJ, and Robert Diersing, N5AHD.

Basic Software Suite

As of June 1995, the DSP-93 had the following software available. Some modems have multiple versions to accommodate various radios and are not shown.

9600 bps Modems

FSK93U1/2	Half or full duplex operation, active DCD	WB5IPM/W5RKN/W0SL
FSK93U1/2B	Weak signal optimized FSK93U1/2	WB5IPM/W5RKN/W0SL
FSK93K1/2	ISI comp. for KO-23/25, active DCD	WB5IPM/W5RKN/W0SL
TPRS931/2	TPRS with NRZI in/out, active DCD	WB5IPM

1200 bps Modems

PKT931/2	Standard AFSK, active DCD	WB5IPM
PSK93R1/2J	Satellite PSK, active DCD, SmartTune	WB5IPM
PSK93R1/2Y	Sat. PSK, active DCD, SmartTune, YAESU	WB5IPM

HF Modems

HOT_HF93	RTTY modem, Viterbi soft detection	W3HCF
HF_93HT1/2	300 bps FSK, active DCD, adpt. threshold	WB5IPM
HF_93U1/2	AMTOR using TOR.EXE, adpt. threshold	WB5IPM

Sat. Pic/Telem

APT_93HX1/2	Carrier-sync. pixels eliminate doppler bow	WB5IPM
P3C93T1/2	AO-13 400 bps telemetry, P3C.EXE comp.	WB5IPM
UO11	UO-11 telemetry decode.	WB5IPM

Noise Processing

W9GR_93	Adpt. carrier null, channel enh., BP filters	N4IIR/K9GKC/W9GR
CW93_D	CW filter	WB5IPM

Instrumentation

D93WE (PC)	Control Loader, audio oscilloscope, function generator and spectrum analyzer (Figure 3)	N5EG
DSP-93 (Mac)	Control Loader, audio oscilloscope (Figure 4), function generator and spectrum analyzer	W5RKN

Diagnostics

Monitor	Basic DSP-93 Monitor and SW utilities	N5BRG
DSP-93 tests	Check-out of all DSP-93 functions	WB5PKJ/N5EG/W5RKN

Software is being distributed on Internet, the Amateur Satellites, as well as being made available on disk as part of the TAPR software library. The idea of software for the DSP-93 is to make it as easy as possible to get and upgrade software in the future.

Figure 3 - Spectrum Analyzer Display from DSP93WE Windows [10]
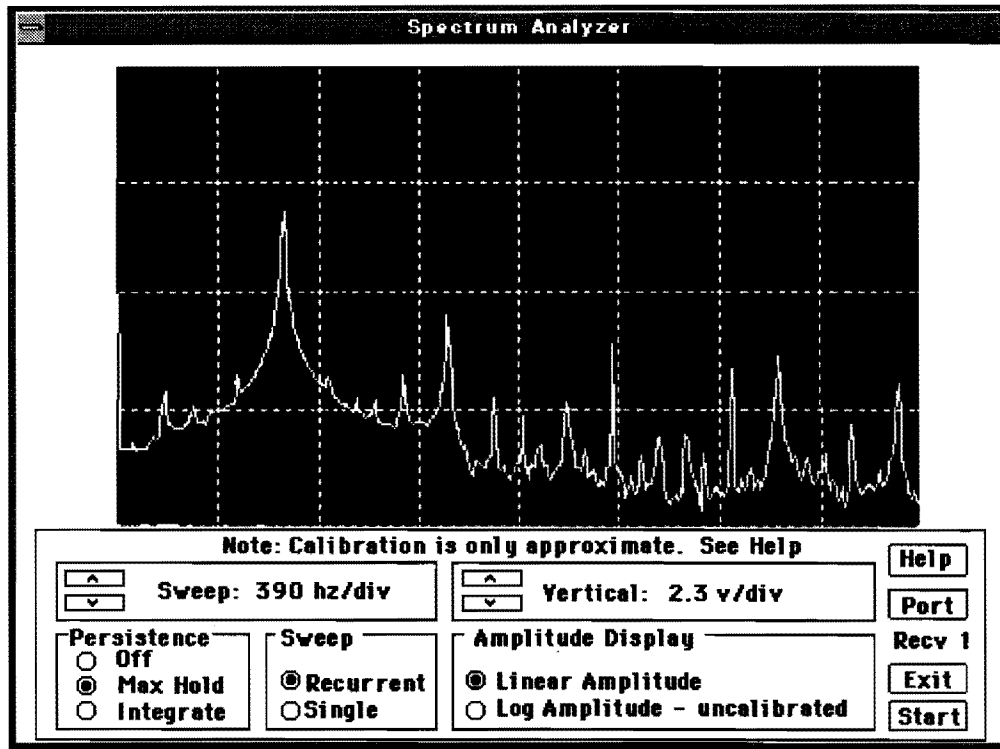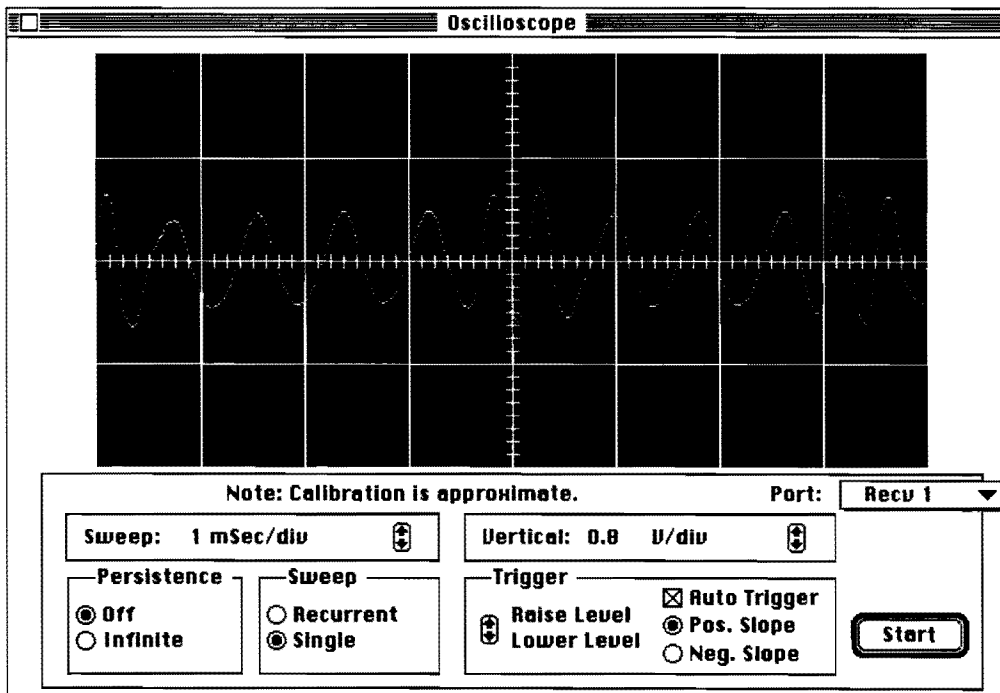

Figure 4 - Sampling Oscilloscope from DSP93 Mac [11]

Oscilloscope: The display shows a 1200 bps packet audio signal. Note the two different periods of the waveform corresponding to different binary digits.

Success of Internet Support

The project, from the beginning, has been supported using only the Internet. Internet and satellite communications have been a major key to the success of the project. Internet e-mail allowed one of the few TAPR projects to include small groups of individuals outside of the main development group located in the Dallas area. We felt that the development group still had to be in a local geographical area or the development process would have been retarded. Much of the initial development required personal visits during the prototyping and initial alpha testing.

TAPR maintains an ftp site at ftp.tapr.org. Updates and archive material relevant to the DSP-93 can be obtained via anonymous ftp from the directory /tapr/dsp93. Copies of all past messages distributed on the dsp-93@tapr.org list by sending mail to 'listserv@tapr.org', subject of 'list', message of 'index dsp-93'. Recently a web page has been created with links to manuals, software, and quicktime movies of various modes. http://www.tapr.org/tapr

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Introduction to Programming
the TAPR/AMSAT $\mathcal{DSP}$-93

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Abstract

The purpose of this paper is to give a brief overview to assist potential programmers, new to the TAPR/AMSAT DSP-93 environment, insight into the tools and techniques available when developing for the DSP-93. The full developers/programming guide is available from TAPR [1].

Introduction

Any introduction regarding DSP-93 programming must begin with discussing how to locate and secure reference materials. The first step is to locate your local Texas Instruments distributor and call them. Local distributors have been known to give free access to their literature room. Books that you should be looking for include:

• **TMS320C2x User's Guide By Texas Instruments; Document # SPRU014C**
This book covers the TMS320C25 DSP chip used in the DSP-93. It covers the chip's electrical properties, memory models, interrupt processing, and, of course, the instruction set.

• **Linear Circuits; Data Conversion, DSP Analog Interface, and Video Interface; Data Book Volume 2 By Texas Instruments; Document # SLYD004A.**
This book covers the TLC32044CN AIO chip used in the DSP-93. It covers the chip's electrical properties, configuration, etc.

• **Digital Signal Processing Applications with the TMS320 Family; Theory, Algorithms, and Implementations**
Volume 1 Document # SPRA012A
Volume 2 Document # SPRA016
Volume 3 Document # SPRA017
These books cover various DSP algorithms which may or may not be useful to you.

• **Digital signal processing with the TMS320C25** Chassaing, Rulph, published 1990 by Wiley, New York 464 pg
ISBN 0471510661

• **Digital Signal Processing: A laboratory approach using PC-DSP.** Alkin, Oktay, published 1994 by Prentice-Hall, Inc.
ISBN 0-13-328139-6
An introduction to Digital Signal Processing techniques. Comes with a DOS program which can compute FIR coefficients, among other things..

The next basic step is to get a good feel for the basic architecture of the DSP-93. Spend some time examing the schematics and get a good look at the interconnect lines. The basic system includes a DSP engine board and a radio/computer interface board. The DSP Engine, contains the TMS320C25 DSP, 32K by 16 bits of program and data memory - upgradable to 64K, the clock circuitry (40MHz) and some programmable array logic for system I/O. The Radio/Computer Interface Board, top board, contains two eight pin female mini-DIN connectors for radio interfacing. Incoming radio signals pass through a voltage divider to establish the initial levels, then through an eight channel multiplex chip. The multiplex chip then feeds the single A/D input with either of the radio inputs or one of the six auxiliary inputs. The Texas Instruments TLC32044 Analog I/O chip is used to sample and update the input signal at a rate of up to 45K operations per second and includes aliasing filters. This board also communicates with your computer at speeds up to 19.2K baud using a serial connection and, with special programming, this can be increased to the maximum rate attainable by a 16C550 and your computer. [2,3]

The next step is to begin to get comfortable with either of the development systems (Mac [5] or Windows [4]) and play with assembling available source. A low cost shareware assembler, TASM TMS320-25 Assembler, is available for code development and both the Mac and Windows interfaces provide near seamless use of the assembler. Code development and testing can become a quick task.

What follows is a basic overview of various areas needed, when developing for the DSP-93.

Memory Map

The following memory map exists after you have entered a 'G' command from the Monitor. The 'G' command is executed after a program download using DSPLOAD.EXE or the windows program D93WE. The unit is operating entirely in static RAM and in the high speed mode at this point.

```
PROGRAM                      DATA

0000  Interrupts       0000  TMS320C25
      and                    MEMORY MAPPED
      Reserved               REGISTERS
001F  ———            0005  ———
                            Reserved
                      0060  ———
                            On DSP Block B2
                      007F  ———
      Reserved
      For Monitor     01FF  ———
                      0200  ———
                            On DSP Block B0
                      02FF  ———
                      0300  ———
                            On DSP Block B1
                      03FF  ———
                      0400  ———
                            Page 8 Data
                                   Memory
0FFF  ———
1000  TINT
1002  RINT
1004  XINT
1006  TRAP
1008  ———

      User Program           User Data
      Memory Space           Memory Space

FFFF  ———            FFFF  ———
```

The Harvard architecture used in the TMS320 is quite different from the typical microprocessor. There are two memories utilized during one instruction—data and program. Until experience is gained working with this architecture, it is easy to forget this basic principle. There are two memories active at the same time. By having two memories, a single instruction can load a word out of program memory and do something with a word out of data memory, all within the same cycle. It facilitates implementing filters and other digital signal processing algorithms. For example, stepping down a table of constants, such as filter coefficients and doing a multiply and add to accumulator with a data array of signal values can be accomplished at full machine cycle speed with no overhead for instruction fetches, nor double accessing of a single memory.

47

Program and data memory can change, and keeping track of "what is which" is needed. How this is done is largely a function of how the DSP-93 design uses the TMS320. Therefore, the TMS literature will not give the whole story necessary to understand the DSP-93.

The DSP-93 has a number of physical memories. Some memory is internal to the TMS320C25 chip and other is external. The tables below outline the physical memories, as well as the conditions which determine whether they are used by the TMS320C25 as program or data.

Internal memory (TMS320C25)

Label	Can be configured as	Size
B0	Data or program *	0100h
B1	Data only	0100h
B2	Data only	0010h

* B0 is in data mode after a hardware reset, Monitor reset, or CNFD instruction. It is program memory after a Monitor 'G' command, or CNFP instruction.

External memory

How the external memories are configured depends on the state of the XF bit. Hardware reset turns the XF bit ON, as will the SXF instruction. RXF turns it OFF. SRAM U104, U105, U110, and U111 come with the basic kit and provide two 32K memories (one program and one data). Four more SRAM IC's will raise the amount to 64K for both program and data memory.

(1) - XF line/bit is ON after a hardware reset, after a Monitor reset command ('R'), or after a SXF instruction. RXF turns the bit off, and it is also turned off after a Monitor 'G' command.

(2) - Data addresses below 0400h access internal memory in the TMS320 and therefore are not available for use in the external memory.

(3) - Addresses FF00h - FFFFh access internal memory, B0, when B0 has been configured as program memory (normally after a Monitor 'G' command).

Note that all memory is organized as 16 bit words, and not 8 bit bytes. Along the same lines remember that the accumulator is 32 bits long so be careful about unintended sign extension.

Internal memory, B0, is configured to the data mode after a hard reset. Also, the Monitor in EPROM configures B0 to data when a 'R' (reset) command is executed, and to program when a 'G' command is executed. Switching B0 modes is done with the instructions CNFP and CNFD, (set program, and set data, respectively), or the hardware reset that switches it to data.

External memory is switched via the XF line out of the TMS320. This line is controlled by the XF bit. A hardware reset sets this bit high. The bit can be set/reset by the instructions SXF/RXF, respectively.

IC number	XF = ON(1) "Slow speed"		XF = OFF(0) "Fast speed"	
SRAM				
U104, U105	Data	0000 - 7FFF(2)	Prog	0000 - 7FFF(2)
U106, U107	Data	8000 - FFFF	Prog	8000 - FFFF(3)
U108, U109	N.A.	.... -	Data	0000 - 7FFF(2)
U110, U111	N.A.	.... -	Data	8000 - FFFF
EPROM				
U102, U103	Prog	0000 - 7FFF(2)	N.A.	.... - ....

When the XF bit is high, such as after power-up reset, the EPROM, which contains the Monitor programs, is active as program memory. This makes it possible to get the machine running with something intelligent. XF also selects a low speed mode, so that the processor is slow enough to accommodate the EPROM. XF also makes external memories U104,5,6,7 switch to data mode and U108,9,10,11 not accessible. This arrangement allows the EPROM Monitor to load program into data memory (U104,5,6,7 and B0). This switching is necessary since the TMS320 does not execute instructions which store anything into program memory; the downloaded program is placed into the DSP-93 as data.

With the Monitor program executing out of EPROM, the usual step is to download a program from a general purpose computer. The program being downloaded is stored as data, in data memory, which is U104,5,6,7 at this time. Upon completion of the downloading, the general purpose computer issues a 'G' command which causes the DSP-93 Monitor to turn off the XF bit. This switches U104,5,6,7 from data memory to program memory. The Monitor also jumps to location 1008h (of program memory) to start the program that was just loaded (into what was data memory).

With XF low, program normally runs out of external SRAM, U104,5,6,7, using U108,9,10,11 for data storage. B0, B1, and B2 can also be used. B0 as stated before can be configured either as data or program, though remember that the Monitor sets it to program after the loading process completes and a 'G' command is given. Operating out of internal memory is somewhat faster than external memory and may be needed for time critical operations. The TMS320C2x User's Guide shows timings for instructions according to the memory combination being used.

Since B0 can be switched between data and program, it can be loaded with a program which can be executed. During the normal program downloading process, B0 is configured as data, so it can be loaded with program no differently than U104,5,6,7. When the loading process completes, the Monitor does a 'G' command and jumps to 1008h. The program at 1008h can then jump to B0 and execute the code which was loaded. When B0 is configured as program, it is no longer at locations 0200h - 02FFh, but occupies FF00 - FFFFh. Therefore, the code assembled at 0200h - 02FFh must be capable of executing properly when moved to locations FF00h - FFFFh. The jump from the program in U104,5,6,7 will be to FFxyh, if the beginning of the code loaded into B0 is 02xyh.

External memory is not accessed for data addresses below 0400h, as these are reserved for the TMS320. Also, FF00h - FFFFh of program memory is not accessed when B0 is configured as program.

Note that some addresses are really registers within the TMS320, such as locations 0 and 1 which are used to load/receive the serial shift register data to/from the AIO chip. The TMS manual covers these in detail.

External memory, (prog, fast), 0400h - 1000h holds the Monitor which is used when in the fast mode. If these locations are blasted, such as with a Monitor Fill command, the Monitor is lost and a hard reset is required.

The TMS320 cannot load and store (i.e. move) data from program memory to program memory. Data-to-data memory can be accomplished, as well as program-to-data and data-to-program. Therefore, it is not likely that a runaway program will blast the Monitor stored in 0400h - 1000h.

The Monitor uses B0 during the transition from EPROM to the SRAM or from low speed operation to high speed. Therefore, it is not possible to load the entire 256 words with program, or Fill it via the Monitor. If a reset command is executed by the Monitor, locations 0200h - 0275h are overwritten with "stuff" from the Monitor, wrecking what might have been downloaded into B0. As long as a Monitor reset does not occur between the loading of B0 and utilization of B0 (either as data or program), then the full page can be used. Otherwise, only those locations not used by the Monitor can be used (0276h - 02FFh).

DSP-93 Firmware - Monitor Operation

When the DSP-93 is powered up, the firmware Monitor takes control of the unit. The Monitor conditions the TMS320C25 and then begins polling the serial data link looking for single character instructions to execute. The action taken by the Monitor during each operation will be explained in more detail here.

After initialization is complete, the Monitor enters a polling loop checking the serial port for an input character. The Monitor is not case sensitive and an entry of '?' will bring a listing of the Monitor version and the commands. The commands available in the monitor are as follows:

A-AR REGISTERS
This command displays the value contained in the eight 16 bit registers on the TMS320C25. The first register is used by the Monitor and so the value in register zero will normally be 0400 hex. This is what you should see when you enter 'A' after power up.

D-DUMP MEMORY
The dump memory command displays the specified block of program or data memory. You must specify whether you want to use program or data memory. Then, enter the hex starting address and the ending address of the memory block. The memory contents will then be presented in block form with one 16 bit data address and eight 16 bit data values on each line.

F-FILL MEMORY
The Fill memory command works like the data dump command except it is filling memory with a 16 bit hex value. If you write over any program areas, you will kill the Monitor.

G-FLIP & RUN PROGRAM @ 1008h
The 'G' command is used after you have loaded a program and you are ready to run it. The Flip referred to here means that the Monitor is flipping from the EPROM over into the static RAM.

H-INTEL LOADER HIGH BITS
This is an Intel style hex loader for placing bits in data memory. To execute properly, the DSP-93 must be in the LOW speed state. The data is expected in the following sequence; count (8 bits), byte address (16 bits) (the byte address is twice the word address), Intel hex code command (8 bits), some quantity (count) of data (8 bits) and finally an 8 bit checksum. If no checksum errors are found, the data is placed into memory in the address locations specified. If an error occurs, a checksum error message is transmitted via the serial port. When the loader is finished, control is returned to the Monitor.

J-JUMP TO XXXX & RUN
JUMP and run executes in the same manner as the 'G' command except execution begins at the specified address. The interrupt vectors must still be in place if you are going to allow interrupts to occur.

L-INTEL LOADER LOW BITS
The 'L' command works exactly like the 'H' command except it deals with the lower 8 bits of the 16 bit words.

M-MODIFY WORD
This command is used to change the contents of a 16 bit memory location in program or data memory. The command can be used to force the D/A output of the TLC3204X to a particular value. This can be done by modifying location 0001. D/A changes will only occur if the AIO chip is active.

P-PROGRAM
This command is used to launch one of the firmware programs located in the DSP-93 EPROM. '?' will list all programs available.

R-RESET
Entering an 'R' will cause the DSP-93 to go through a soft reset. The results of this should be equivalent to a hardware reset. If you have entered the 'G' command and you are working in static RAM, the DSP-93 will bounce back to the EPROMs just as if you hit the reset button. Some of the areas in data RAM are initialized during a reset cycle.

S-SHOW WORD
This command is used to display the contents of a particular memory location.

T-MEMORY TEST

This command tests the current data memory for errors. The memory is tested by writing 0000h, 5555h, and 0FFFFh into every location and reading it back. The test will loop through all locations and give a '*' prompt if no errors occur. If an error occurs, the location of the error will be reported along with the value written and the value returned. Both RAM banks can be tested by issuing the 'T' command in slow mode (i.e., after a reset) and again in fast mode (i.e., after a 'G' command).

Sine/Cosine table

In versions of the Monitor prior to Version 2.17, the sine/cosine table located in EPROM was copied to RAM memory when the 'G' command was issued. Beginning with Version 2.17, although the table is still in EPROM, it is no longer copied to RAM. This 1) frees up some Monitor code area 2) eliminates the possibility the sin table will write over code the user loads, and 3) allows user to locate the sin table in data memory which is the place he will really need it.

The table in EPROM is a 540 degree, 0.25 degree step, sine/cosine table is located in EPROM from 767Fh to 7EEFh and is scaled by 2^15. Sine begins at 767Fh; cosine begins at 77E7h.

The Parts of a DSP-93 Program

One of the best ways to learn DSP-93 programming is to read, study, and understand existing programs. A lot of source code is provided on the system diskettes. Use this valuable resource. Not every program will use all these parts, and not all that do use them will use them exactly as shown. If they did, there would be only one program!

Header (Instructions, Copyrights, Disclaimers)

It's a good idea to have a header that tells what the program is, how to assemble and execute it, who wrote it and a Copyright and Disclaimer statement. See the sample program for more examples.

The Include Files

There are currently five include files that define most of the constants that you will use when programming the DSP-93. It is *strongly* encouraged that all programs include these files and use the constants therein. This will make your program easier to understand and will reduce programming errors. These files are:

MACROS.INC

Purpose: This macro defines the origin in the code segment that the initialized data is to begin. This macro defines storage in the code segment while also creating a symbol representing the location the data will reside in data memory after an initialization block move.

MONITOR.INC

Purpose: This file defines the DSP-93 Monitor functions and addresses. Symbolic names for all of the entry points have been assigned. This file should be used instead of the absolute addresses since a linker does not exist. The file may also contain any macros defined in the future that can help in using the Monitor functions.

PORTS.INC

Purpose: This file defines the DSP-93 I/O ports and I/O bits. The file assigns symbolic names for each of the ports and bits. The user should make use of the TASM bitwise AND (&) and OR (|) operators to manipulate the bits. The programmer is discouraged from using hex values in programs, as other users may have to read the listings, and the symbolic names assign greater meaning to the code.

SERIAL.INC

Purpose: Define symbols used in configuring the serial port for the DSP-93. The symbols in this file describe the 16550 UART. Programmers should use this file instead of using magic numbers in their programs.

REGS.INC

Purpose: This file defines the register replacements for the TASM assembler. The register file AR0 through AR7 are defined as well as the memory mapped registers defined, by the processor.

The following lines of code should be in your source after the header:

```
            .NOLIST
#include    "MACROS.INC"
#include    "REGS.INC"
#include    "PORTS.INC"
#include    "MONITOR.INC"
#include    "SERIAL.INC"
            .LIST
```

Memory Location Equates

Storage variable locations in internal and/or external memory must be defined in your program. These variables are defined using an .EQU directive to assign values to labels. For example:

```
;   global variables
BUFI    .EQU    060h    ;AIO input buffer
BUFO    .EQU    061h    ;AIO output buffer
DO      .EQU    062h    ;data output buffer
```

Program Constant Equates

Constants used in your program should be assigned a label and that label be given a value using an .EQU directive. It is *strongly* encouraged that all programs use labels for constants rather than using constants in the body of the program.

Program Origin

The TASM assembler does not, by default, set the DSP-93 starting address of 1000h. So be sure to include the directive: .ORG 1000h

Interrupt Vectors

The first four instructions of the program handle the various interrupt vectors and must branch to the appropriate labels. The Timer and Trap interrupts will not occur in the DSP-93 programs, so they branch to the program starting label GO. Program execution begins at 1008h, just following the TRAP interrupt vector.

```
                ;Define Vectors
        B   GO      ;branch to program
                    ;   start (TINT) Timer
        B   RINT    ;AIO receive interrupt
                    ;   service routine
        B   XINT    ;AIO transmit interrupt
                    ;   service routine
        B   GO      ;branch to program
                    ;   start (TRAP)
GO      DINT        ;program starts here
```

Initialization of the Math, Serial and Memory Model

There are various parameters for specifying how mathematical operations, the DSP chip serial IO, and memory models will be handled. Your program should set these values at the beginning of the program.

Initialization of the AIO

The initialization of the AIO chip is probably the most confusing aspect of DSP-93 programming. However, using the recipes written by the development group should enable you to start the chip sampling at the rate you desire without problem.

The AIO chip is reset and enabled by manipulating the IO data lines D15 and D14. In doing so, the variable CFG in which the value to be output to the RADIO_GAIN port must be in external memory, i.e. page 8 or greater.

Immediately after resetting and enabling the AIO chip, it must be configured to specify the AIO gain, sync, filters and the values of RA/TA and RB/TB which set the sample conversion frequency. See "AIO Port Programming, Setting the AIO conversion frequency" [1].

Initialization of the DSP

The initialization of the DSP consists of initializing of any program values your program may use. For example:

```
DSP_INI ZAC             ;   zero A

        SACL    DO  ;   zero buffer
        SACL    SO  ;   zero buffer
```

Handling Interrupts

The transmit and receive interrupts, generated by the AIO chip, must be handled by your code. This requires two functions RINT and XINT, pointed to by the interrupt vectors at the beginning of your program. Data received from the AIO are stored in the variable BUFI and processed, in this example, by the function DSP. Data to be sent to the AIO is stored in the variable BUFO and will be processed when a transmit interrupt occurs. TINT and TRAP interrupts can be handled in the same way.

Serial Port IO and Exiting to the Monitor

If your program is to read the DSP-93's Serial Port while executing, code is available that provides that capability. The function should be called from someplace in your code that is executed repeatedly. The character read is returned in the variable CHARREAD. If no character were available, ACC will be zero upon return. In any case, to be a user-friendly DSP-93 program, include this function always. If an upper- or lower-case R is sent to the DSP-93 Serial Port, the program will exit to the Monitor.

Wait Functions

There are two "wait" routines in the Monitor (See MONITOR.INC). There are also three "wait" functions that are commonly included in DSP-93 programs. These have delays of:

```
WAIT4   104 msec
WAIT2   52 msec
WAIT1   26 msec
```

Defining Data Tables

Tables of data such as filter coefficients, strings, etc. may be defined within your program.

Using Pre-defined Data Tables
There are two tables of waveforms provided with the DSP-93 source code. One table is the Sin/Cos table:

```
0..511 is Sin(theta), 512 words = 2 PI
64..639 is Cos(theta), 512 words = 2 PI

512 words long for each table, total
640 words long.  The table is scaled by
2^11
```

the other is the general waveform table:

```
Table 0 = Sine(theta) scaled by 2^15
Table 1 = Triangle(theta)
Table 2 = Square(theta)
Table 3 = Sawtooth(theta)
```

The End

Don't forget the following directive at the end of your program.

```
        .END
; end of program
```

AIO Port Programming

Setting the AIO conversion frequency

The AIO conversion frequency (sampling frequency) is set during the AIO configuration. There are two values that determine the conversion frequency, TA and TB. The conversion frequency (in Hertz) is:

$$\frac{10,000,000}{2 \cdot TA \cdot TB}$$

The values are most easily set using the macros CMDA_VAL and CMDB_VAL.

See "Linear Circuits; Data Conversion, DSP Analog Interface, and Video Interface; Data Book Volume 2" for more information on setting the conversion frequency. The AIO chip has a specified upper limit on the conversion frequency of 19.2 kHz, but the chip will operate considerably in excess of this. For example, the 9600 bps FSK modems use a conversion frequency 41666 Hz. A table of conversion frequencies is provided in the programming guide [1].

IO Port Programming

Which Port does What

The TMS320C25 has 16 IO ports, many of which are implemented in the DSP-93. Data is written to an I/O port with the OUT instruction and read with the IN instruction. For example:

```
OUT     CHARREAD,UART_CTRL
IN      CHARREAD,UART_READ
```

Debugging DSP-93 Programs

Debug functions in the Monitor

The Monitor ROM includes a debug routine developed by Tom McDermott, N5EG. This routine can be called as a development aid when you are generating new DSP code or if you are just studying existing code.

Debugging using LOC.ASM

The code in LOC.ASM was developed for finding problems. It may be used to determine when program execution stops. An author of code which seems to be stopping mysteriously should

integrate this code into his program for testing. Then one of the users with a DSP-93 which hangs may run the modified program and report back with the results. Results can be reported by dumping memory in the DSP-93 using the Monitor. The memory dump can be captured and posted for evaluation by the author of the code. If we can determine when the problem is occurring the solution may also appear.

Monitor IO Routines

A collection of Monitor routines which should help speed code development is available for use.

Refer to the file MONITOR.INC included with the release disks for the exact location of these routines.

GET4HEX and GETVAL16
These two routines are the same. They collect a 16 bit hex value from the serial port. The value should be presented as four ASCII characters (0 through F digits). The four hex digits are converted to a sixteen bit HEX word and stored in a single memory location for later use. Look at MONITOR.INC for the storage location and a suggested label. This memory storage location is for the current page of memory established by the LDPK instruction.. The LDPK is normally set to page 8 with the instruction LDPK 8.

GET2HEX
This routine collects an 8 bit hex value from the serial port. The value should be presented as two ASCII characters (0 through F digits). The two hex digits are converted to an eight bit HEX word and stored in a single memory location for later use. Look at MONITOR.INC for the storage location and a suggested label. This memory storage location is for the current page of memory established by the LDPK instruction.. The LDPK is normally set to page 8 with the instruction LDPK 8.

GETCHAR
This routine collects a 4 bit hex value from the serial port. The value should be presented as one ASCII character (0 through F digits). The hex digit is converted to a four bit HEX word and stored in a single memory location for later use. Look at MONITOR.INC for the storage location and a suggested label. This memory storage location is for the current page of memory established by the LDPK instruction.. The LDPK is normally set to page 8 with the instruction LDPK 8.

HEXOUT
This routine assumes a single HEX digit is stored in the accumulator. This digit is converted to ASCII and sent to the serial port.

INBIT
This routinue retrieves incoming data from the serial port. Data is placed in the indirect address location pointed at by AR(ARP).

OUTBIT
This sends the lower 8 bits of AR(ARP) to the serial port. This routine uses memory location 0060h of the current page for temporary storage. Location 0060h is used to store the UART register information while the routine is sending the data. The register information from the UART is used to determine if CTS is set or cleared and if the transmit data buffer is full.

OUTBIT2
Sends the lower 8 bits of location 0062h of the current page to the serial port. This routine uses memory location 0060h of the current page for temporary storage. Location 0060h is used to store the UART register information while the routine is sending the data. The register information from the UART is used to determine if CTS is set or cleared and if the transmit data buffer is full.

PRVAL08
The 8 bits in a defined memory location of the current page are converted to ASCII and sent to the serial port. MSB is sent first. See MONITOR.INC for the proper memory location and label to use for this routine. This routine uses HEXOUT.

PRVAL16
The 16 bits in a defined memory location of the current page are converted to ASCII and sent to the serial port. MSB is sent first. See MONITOR.INC for the proper memory location and label to use for this routine. This routine uses HEXOUT.

RESET
Jump to this location to restart the Monitor.

SD_CRLF
Sends a single carriage return and line feed to the serial port.

SD_STR
Calling this routine with a 16 bit address stored in the current AR(ARP) register will cause a string to be sent to the serial port. The C-style string should begin at the AR(ARP) memory pointer and end with 00. Only the lower 8 bits of the memory words will be sent. The string data must be in data memory space.

SP1 through SP10
These routines will send the indicated number of spaces (20 Hex) to the serial port.

MWAIT1 and MWAIT_A
The WAIT routines are shown here. You can enter the routine at MWAIT1 or MWAIT_A with your own value set for AR2. With a 40 MHz clock, the wait from MWAIT1 will be about 32 milliseconds while the wait from MWAIT_A will be about N mS where N is the value in AR2. Use MONITOR.INC for the entry locations for MWAIT1 or MWAIT_A.

MP_BLK_MV
This routine will move a block of data memory to program memory. You must provide pointers to the beginning and end of the block in program memory space and the beginning of the block in data memory space. This routine would be useful if you are dynamically creating program code in data memory and need to move it to program space.

PM_BLK_MV
This routine will move a block of program memory to data memory. You must provide pointers to the beginning and end of the block in program memory space and the beginning of the new block in data memory space. This routine would be useful if you want to include a sin table in your program. Your program would be loaded into the DSP-93 in what will become program memory. After starting your program you would use this routine to move the table to data memory. The routine may also be used to move string data from program memory to data memory for later use. The following example shows how the routine would be called.

Assembling a DSP-93 Program

How to assemble a file using TASM under DOS
If you are using DOS, the command line to assemble a TASM source file, say XXX.ASM, is: `TASM -3225 -la1 -g0 XXX.ASM` This will result in a listing file XXX.LST being generated and an object file XXX.OBJ. For further options when using TASM, see the TASM documentation.

Windows and Macintosh Assembly
See the Help files for information on using D93WE or DSP-93Control as a code development environment.

References:
1. Parsons, Ron, W5RKN. (1995). Programming Guide for the DSP-93. June, 1995. TAPR: Tucson, AZ.

2. Stricklin, Bob. (1994). TAPR/AMSAT Joint DSP Project: DSP-93. Proceedings of the TAPR 1994 Annual Meeting. Tucson Amateur Packet Radio Corp.

3. DSP-93: The TAPR/AMSAT Joint DSP Program. (1994). Issue #55, Summer 1994, Packet Status Register. pp. 1-4. Tucson Amateur Packet Radio Corp.

4. McDermott, Tom, N5EG. (1995). D93WE Windows Development Environment for the TAPR/AMSAT DSP-93. Proceedings of the 1995 TAPR Annual Meeting. St Louis, MO. March, 1995. TAPR: Tucson, AZ. p. 31.

5. Parsons, Ron, W5RKN. (1995). DSP-93 Control Macintosh Development Environment for the TAPR/AMSAT DSP-93. Proceedings of the 1995 TAPR Annual Meeting. St Louis, MO. March, 1995. TAPR: Tucson, AZ. p. 38.

Mechanical and Thermal Design

By Dick Jansson WD4FAB

Introduction:

Space satellites performing missions varying from (these days) the mundane to the exotic, all have one thing in common - the spaceframe structure. Despite all of the sophisticated technologies that may be involved in the payload packages contained in the spacecraft, the spaceframe technology is a well founded Mechanical Engineering practice based upon aircraft and airframe experiences. This does not mean that innovative designs and fabrications are not used, quite the contrary, they are essential. The designer is forced to employ methods that are sound, but less than conservative, as might be used for some terrestrial object.

The paramount consideration is, however, that of smoothly blending the mechanical design technology needs of the spaceframe with all of the other technologies that comprise the complete object, a successful satellite fulfilling its mission. While this presentation will deal mostly with the Mechanical Engineering aspects of the Phase 3D spacecraft, the observer must keep in mind that none of this is done out of the context of all of the technologies involved in the whole mission.

Spaceframe and Launch Adaptor:

The Phase 3D electronic equipment must be housed in something. That something is the spaceframe. In the case of Phase 3D, those designing and building the structure were continuously learning new techniques for such fabrications and getting quite an education in the process. Along the way a number of quite good lessons on light-weight aircraft structural construction methods were learned. While the end product is not as light as some would have liked (about 60kg), it has already demonstrated itself to be very strong. The spaceframes for OSCARs 10 and 13 weighed only 7kg,

The Phase 3D spaceframe is principally fabricated of thin-gauge sheet aluminum. Its formation, to rather unusually close tolerances for sheet metal structures, caused more than passing concerns by all who were involved in the effort. Typically these tolerances are in the range of 0.2mm (0.008in.). The secret to this type of construction is to place all of the load stresses into the shear plane of the sheet metal, where it is notably strong for its weight. An example of this are the six Divider Panels, one on each corner of the spaceframe. Three of these will be anchored to the launch vehicle which will get Phase 3D into space. Thus, during launch, these three points will be quite heavily loaded in all motions. The only machined parts in the spaceframe are the six Corner Posts at the outer ends of the Divider Panels. These must be robust enough to carry all of these launch thrust loads into the spaceframe, translating all of those forces into the plane of the 0.8mm thick sheet metal Divider Panels as sheer forces. It is difficult to completely convey these concepts in words and pictures, but those seeing the spaceframe in-person will be able to more readily grasp the concepts employed in the design.

Working with panels of this type is not all that easy when it comes to mounting massive single elements, such as an 11.5kg battery assembly. As such mountings are done to the flat surface of a Divider Panel, the panel will flex and bend at the slightest of influences, such as vibration. Such a mounting really needs to have its natural resonance frequency greater than 100 Hz, but without any modifications, such a panel resonance is less than 20 Hz. We found that by using light-weight aluminum stiffeners, formed into the shape of a hat, that we could bring the panel resonance up to 38 Hz. By placing a thin aluminum panel across the tops of the several stringers, we formed an aluminum sandwich, much like a honeycomb panel, and the resonance of the battery mass went up to 128 Hz. All of this added structure was done on the assembled spaceframe (not an easy way to so such a task) and joined with both rivets and epoxy bonding agents. Co-bonding structures like this is a very messy process.

Mention was made, above, of panel resonance frequencies. We did such tests in a manner that is one of the "flagstones" of AMSAT practice. The method, learned and 'borrowed' from our German compatriots, employs a high fidelity amplifier (a 45 year old Ultra Linear Williamson amplifier) and a speaker held inside of the spacecraft propellant bay. By driving the amplifier with a sine wave signal generator, the frequency was swept over the range of interest. On thin panels a light object, like a screw washer, will dance with panel resonance. Massive objects, such as the simulated battery, will not respond as well and required another method. This time we used an old ceramic microphone element attached to the 'battery' and to observe the output signal on an oscilloscope. Resonance frequencies are readily observable with such simple instrumentation. This is AMSAT.

SBS:

Since Phase 3D will be a secondary payload on an Ariane launch vehicle, it must conform to whatever space the European Space Agency (ESA) can make available.

ESA has the conical 1194V Adaptor which interfaces between the ϕ2624mm (ϕ103.3inches) diameter bolt circle on the Ariane upper stage to a ϕ1194mm clamp-band used for payloads. Although hollow, the conical adaptor does not provide sufficient space to house Phase 3D, or any other reasonably sized payload. Accordingly, ESA offered the amateur satellite community the opportunity to launch aboard the new Ariane 5 vehicle if we would provide a cylindrical "spacer" that could be mounted between the ϕ2624mm diameter bolt circles on the bottom and the conical section on the top. Phase 3D could then ride to orbit inside this cylinder while a prime payload satellite would attach to the conical adaptor with the ϕ1194mm clamp-band. Thus, they require that our cylindrical section must be able to support the launch loads of this prime payload fellow passenger. This means that this AMSAT provided ϕ2624mm diameter Specific Bearing Structure (SBS) must be able to withstand the load forces imposed by a 4.7 T (metric ton, 10,350 lb.) satellite load. In order to assure ourselves that our design is capable of handling such a load, extensive structural Finite Element Analysis (FEA) computer work has been performed (on the same home computer used to accomplish the thermal analysis).

Construction of two of these SBS units has been completed in Utah, mainly at Weber State University. Each of the $10k machined flange rings, or Frames, on each end of the SBS cylinder were done in Florida, obviously on a very large lathe. These were made from the highest quality of ring-forged aircraft aluminum. The Frames were mounted to a purpose-built precision steel table, holding flatness and roundness values to less than 0.05mm (0.002in.), far better than ESA requires. The 4mm thick sheet aluminum rolled shell sections are attached to the Frames with a total of 976 special fasteners. A total of 2600 additional rivet fasteners are also used in each assembly.

Tests have been conducted at Weber State University to verify the operation of the mechanism to separate the spacecraft from the SBS, and the launch vehicle. For this purpose, a 500kg Mass Mockup Unit (MMU) was constructed to take the place of the P3D satellite. The Separation Nut units were operated using Nitrogen gas, rather than the pyrotechnically generated gas sources that will be used in flight. In this manner, we could reuse the Nuts over a number of tests. After a little travail at the start of the tests, all went very well over quite a number of repeated tests, with concurrence of the three Nut separations being within 3ms (0.003 second) of each other. Witnessing the exiting of a 500kg object from the SBS was impressive, to say the least.

Thermal Control Subsystem:

Three axis stabilization satellite operation planned for Phase 3D drives the thermal design of the spacecraft. Most of the commercial communication satellites spin in order to keep any side from getting too hot and the opposite side too cold. Once in its desired orbit and orientation, Phase 3D will not spin, but will be oriented in three-dimensional space, with the antennas continually facing Earth. This continual attitude adjustment, with one side facing the sun, causes some interesting thermal design problems. The Phase 3D solution to overcome most of these problems is through the use of the four heat pipes. A heat pipe is a thermal linkage of very high conductivity consisting of a closed, evacuated tubular chamber with walls lined with a wick and partially filled with a pure fluid. The fluid used in Phase 3D is anhydrous ammonia. The fluid is vaporized at the hot end. The vapors then move through the hollow core of the tube, and condense at the cold end; from which the resulting liquid is returned through the wick to the hot end by capillary action. By this process, heat is transported from the hot to the cold end. Heat pipes typically offer heat transport characteristics that are many times greater than the heat transfer capability of the best heat conducting materials, while maintaining an essentially uniform temperature. The process requires no power and operates to its maximum performance in a zero-gravity environment.

In the case of the Phase 3D spacecraft, the internal ring-shaped heat pipes remove heat from one part of the spacecraft and re-distribute the energy to other parts where it is ultimately transported through the sides of the spacecraft and radiated to space - the ultimate "heat sink". What is felt to be a unique feature of this heat pipe system, as employed on Phase 3D, is that none of the pipes come in direct contact with space-facing panels. Instead they depend upon indirect re-radiation of the heat from internal equipment mounting panels to side panels that are deliberately allowed to become cold. All along, however, the electronic equipment modules maintain their desired temperatures because of the thermal influence of the heat pipe system, regardless of whether those modules are mounted on the solar heated side, or on the space-cold backside of the spacecraft. These design concepts put to practice the concepts of energy conservation, eliminating any need for active thermal control or supplemental heating.

The earlier Phase 3A, B and C satellites employed several multi-layer thermal insulation blankets to assist these spacecraft through the thermal rigors of spaceflight. Quite simply, such blankets are a first-class nuisance to fabricate, as the required assembly technology is *very* exacting. In the case of Phase 3D, the side panels of the spacecraft will be painted to provide the necessary radiative heat rejection. The top and bottom panels will be mostly solar energy absorbing metallic finishes of several different types, depending upon the location and desired temperatures of that section of the spacecraft. In general,

57

the thermal design calls for the mean spacecraft temperatures to be between -5° and +20°C for the expected range of sun angles (β) from -80° to +80°.

Extensive computer thermal analyses of the Phase 3D spacecraft have given us a very comfortable confidence that this design will provide the desired results, without the use of the kind of thermal blankets used on most other satellites. These thermal analytic computations were accomplished on a home computer to produce a series of temperature performance curves as functions of β angle.

More Power Needed:

One of the design features intended to make Phase 3D more accessible to smaller ground stations will be the use of higher power transmitters. This increased power carries with it another set of problems. First, the power must be generated. This means more solar array area. To achieve this, Phase 3D will employ four deployable solar panels in addition to the two mounted on the spaceframe. This will be the first use of deployable panels on an amateur satellite. Of course, deployable panels means mechanisms to initiate the unfolding plus appropriate hinges and latches to achieve the desired final configuration. This type of hinge is able to swing both ways but always return to the desired center position. One of the German members of the Phase 3D Design Team first suggested the use of this type of hinge, and actually obtained one at a hardware store to demonstrate the utility of the principle on the model of the former Phase 3D "Falcon" spacecraft design. As there is not the luxury of a lot of excess space around the current Phase 3D spacecraft when installed in the SBS, this hinge design had to go through several gestations in order to achieve the desired device in a compact manner. This effort included finding a spring wire able to withstand the metallurgical and thermal rigors of anticipated operation at temperatures as low as -100°C.

Power System :

Since satellites must get their primary power from a the sun, the only practical means of obtaining power is the use of semiconductor solar panels. Generating the power needed to support the transmitters aboard Phase 3D requires large solar panels. The design which evolved calls for a total solar panel area of 4.46 m^2 (48 ft^2) and BSFR Silicon solar cells of 14.3% efficiency. This array will produce about 620 Watts of power at the beginning-of-life (BOL) and at optimum sun angle (β=0°). After 10 years in orbit, this power number will still be about 350 Watts at a β=45°. This amount of power is still sufficient to operate at least two transmitters and the other necessary spacecraft systems. Like almost anything else, solar arrays deteriorate with age. This is why their performance after a specified number of years is an important design consideration. The cells for Phase 3D are being obtained through a very attractive agreement with DASA, the German Space

Agency. These cells are of US manufacture and were surplus inventory from a prior satellite program. While other sources and configurations of solar cells were considered, it was concluded that this one represents the best trade-off between performance and cost. Solar cells, and their assembled panels, represent one of the single highest cost items which go into building a spacecraft.

While solar panels are satisfactory as a sole source of power, some form of energy storage must also be provided. This is accomplished with a battery. Energy storage is necessary, not only to power the spacecraft during times that the sun is eclipsed by the earth, but also to operate the arc-jet thruster. It's power requirements exceed the capability of the solar arrays, even under the best of conditions. Actually the Phase 3D satellite will carry two batteries, a "main" and an "auxiliary". This is to provide redundancy in case of failure of the main battery. The Phase 3D design team evaluated several sources and types of batteries. A final decision was made to select a more or less conventional nickel-cadmium battery, albeit with a new plate design, as proposed by a German firm. Another contender was from a US firm which proposed the use of an assembly of Nickel-Metal Hydride cells for the main battery and a more conventional Nickel-Hydrogen stack for the auxiliary. As in the case of the solar cells, cost was an important factor in reaching this decision.

The Main Battery is composed of 20 cells of 40 Ahr capacity, for a 22-28 VDC supply. These rectangular cells are from a terrestrial application, but have been very well characterized for space service. They are contained in three subassemblies, two of seven cells and one of six cells. The seven cell assembly is 11.5kg mass and the respective assemblies will be mounted to reinforced Divider Panels, as previously discussed. The selection of the location of the lighter six cell subassembly will give us an option to use in achieving spacecraft balance.

For the Auxiliary Battery, a relatively new 10 Ahr cylindrical cell has been selected. A total of 40 of these cells will be mounted in two 20-cell parallel strings. The entire group is divided into four, ten cell subassemblies, mounted to the remaining three Divider Panels. As one panel will need to mount two of these subassemblies, we are again provided with a tool for spacecraft balancing.
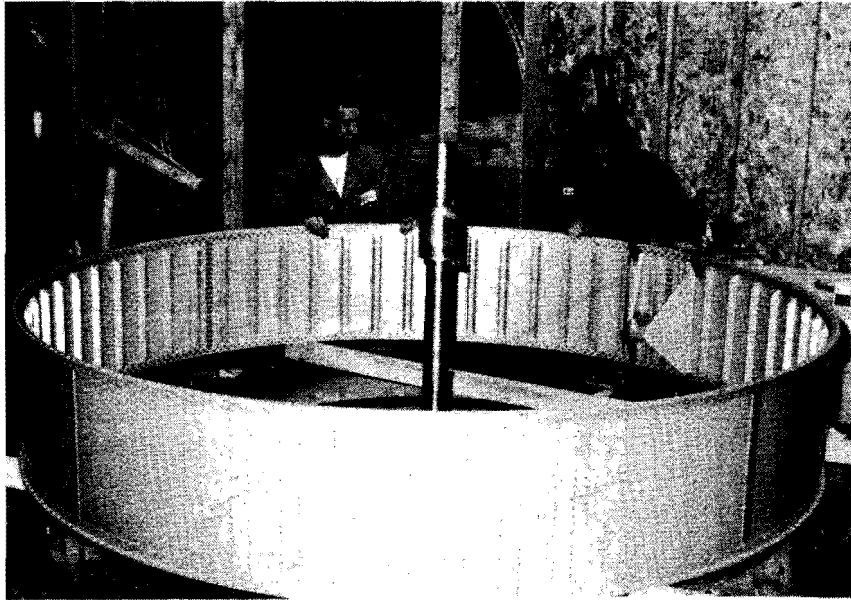
Summary:

Providing the 'containment' for all of the systems and experiments for the Phase 3D spacecraft has provided an interesting engineering experience for quite a number of us on the team. We are confident that this effort will translate into a very long lived mission for us to all enjoy in the communications afforded by Phase 3D.

58

P3D Arc Jet Motor

209
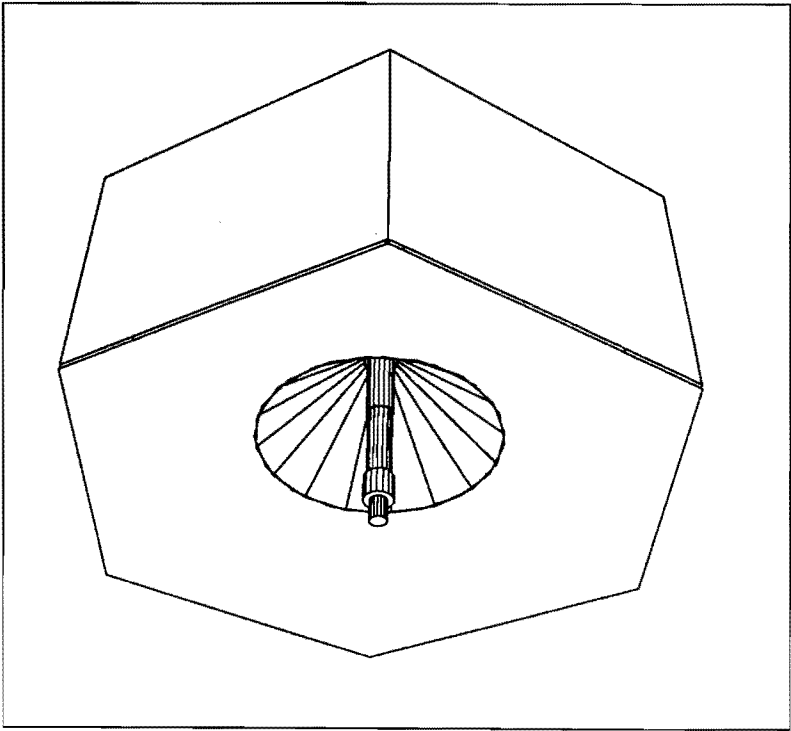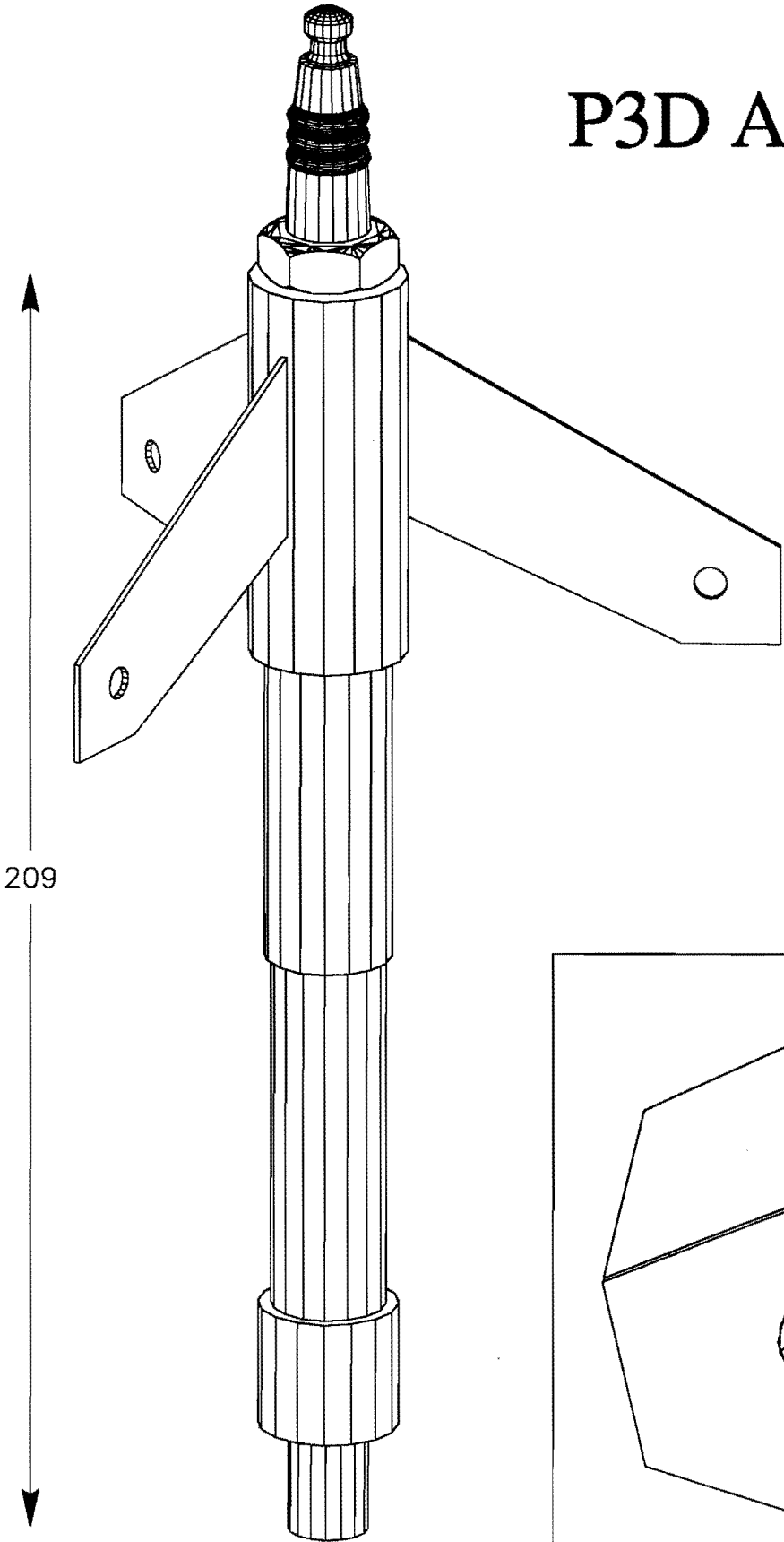
Student Project Co-Leaders Gene Hansen (L) and Richard Vanderford (R) inspect the completed Phase 3-D Specific Bearing Structure (SBS) in the Phase 3-D Lab at Weber State University in Ogden Utah. The SBS will be used to carry the Phase 3-D satellite to orbit aboard its Ariane launch vehicle.

(AMSAT-NA Photo by Dick Jansson, WD4FAB)
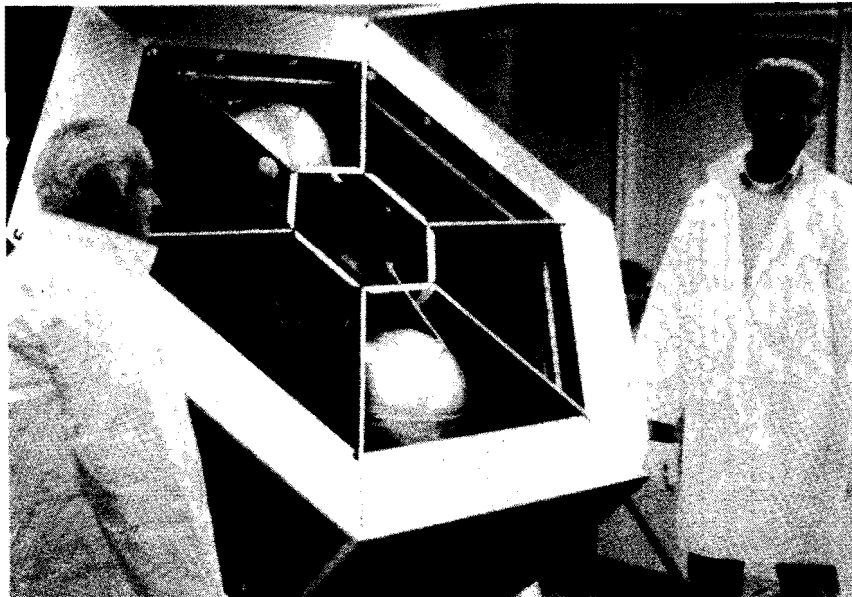
Phase 3-D Integration Team members Chuck Hennessey, W4AT, (L) and Stan Wood, WA4NFY, (R) work on the Phase 3-D flight spaceframe in the Phase 3-D Lab in Orlando, Florida.

(AMSAT-NA Photo by Keith Baker, KB1SF)

Phase 3D
Propulsion Systems

by Dick Daniels W4PUJ

Summary

Good progress has been made in bringing the two Phase 3D propulsion systems into being. Almost all major components are in hand. The Propellant Flow Assembly (PFA) is essentially complete. Propellant tanks have been mounted in the spaceframe and interconnections between the Propellant Flow Assembly (PFA), tanks, and the motors are also nearly complete. Pressurization tests and some propellant flow tests are planned to be conducted at the time of spacecraft environmental testing.

Two Propulsion Systems Needed

As has been stated in previous papers, two propulsion systems that will be used to move the Phase 3D spacecraft from the low-inclination initial orbit the 63 degree final orbit - and keep it there. The primary system utilizes a 400 Newton (95 pound) bipropellant liquid rocket motor with its associated tankage, plumbing and control circuitry. The secondary is a much lower thrust Ammonia Arcjet system developed at the University of Stuttgart in Germany.

The 400 N Propulsion System

The bipropellant propulsion system is a repackaged and updated version of those used successfully in the OSCAR 10 and 13 projects. It incorporates the 400 N motor, being provided by a German aerospace company, that utilizes monomethylhydrozine (MMH) for fuel and nitrogen tetroxide (N2O4) for oxidizer. The higher mass of the Phase 3D spacecraft, has required going to multiple propellant tanks to carry the larger amounts

required for the mission - over 60 kilograms of MMH and 130 kilograms of N2O4.

The plumbing required to transfer the propellants from the tanks to the motor has been designed for simplicity, but with sufficient redundancy to assure safety. Helium gas from a high pressure storage tank is regulated to a lower pressure the lower pressure required to operate the system by pulsing an electrically operated gas valve referenced to a pressure transducer. This gas is used both to pressurize the propellant tanks, through redundant check valves, feed the propellants to the motor and operate the motor valves. The pressure regulation system, includes a second electrically operated valve in series with the first, to take over regulating function should the firs fail. A relief valve provides additional safety.

The plumbing required for loading propellants, providing gas pressurization and propellant flow to both the 400 N and the arcjet systems has been consolidated on a 220 x 540 mm panel mounted in Equipment Bay 1, the Propellant Flow Assembly (PFA) The flight unit has been fabricated and pressure tested. The associated tubing connections to the propellant tanks and motors are nearly complete.

The Liquid Ignition Unit (LIU), the electronics module that supports the motor ignition and burn sequence is also mounted in Equipment Bay 1. This unit, responding to commands from the Integrated Housekeeping Unit (IHU), initiates the firing sequence by opening and pulsing the Helium isolation valves, control pressure in the propellant tanks, and open the motor valves. The sequence requires validation of coded firing commands, clocking, the

commanded motor burn time and safeing the system at the end of burn. Experience with OSCAR 13 has demonstrated the full capability of the 400 N system to support the multiple burns necessary to place the Phase 3D spacecraft in its final orbit.

The Arcjet Propulsion System

Developed at the Institute for Space Systems at the University of Stuttgart in Germany, the ammonia arcjet will provide for station-keeping and minor orbit adjustments after the Phase 3D spacecraft is in final orbit. Compared to the 400 Newton thrust of the primary propulsion system, this motor's puny 100 milliNewtons isn't much, however, its efficiency is much higher over long burn times. Thrust is accomplished by striking an electrical arc at the tip of the arcjet motor and then feeding a small quantity of gaseous ammonia fuel through the arc. The rapid heating expands the gas to generate highly efficient

thrust. Having the Arcjet motor on board the Phase 3D spacecraft for the first time provides a long-term capability to make minor orbit adjustments to correct for the kinds of instabilities introduced by lunar and solar perturbations that are predicted to cause reentry of the OSCAR 13 spacecraft in late 1996.

The flight unit arcjet motor has been fabricated and delivered. Full duration firing tests have been conducted at the University of Stuttgart with good results. The components for the plumbing system to convey ammonia from propellant tanks, heat it to a gaseous state and meter its flow to the motor have been incorporated into the PFA.

The Electric Propulsion Unit (EPU), the module that creates and controls the power required to initiate and maintain the electrical arc for the motor, has been designed, fabricated and AMSAT-DL in Marburg.
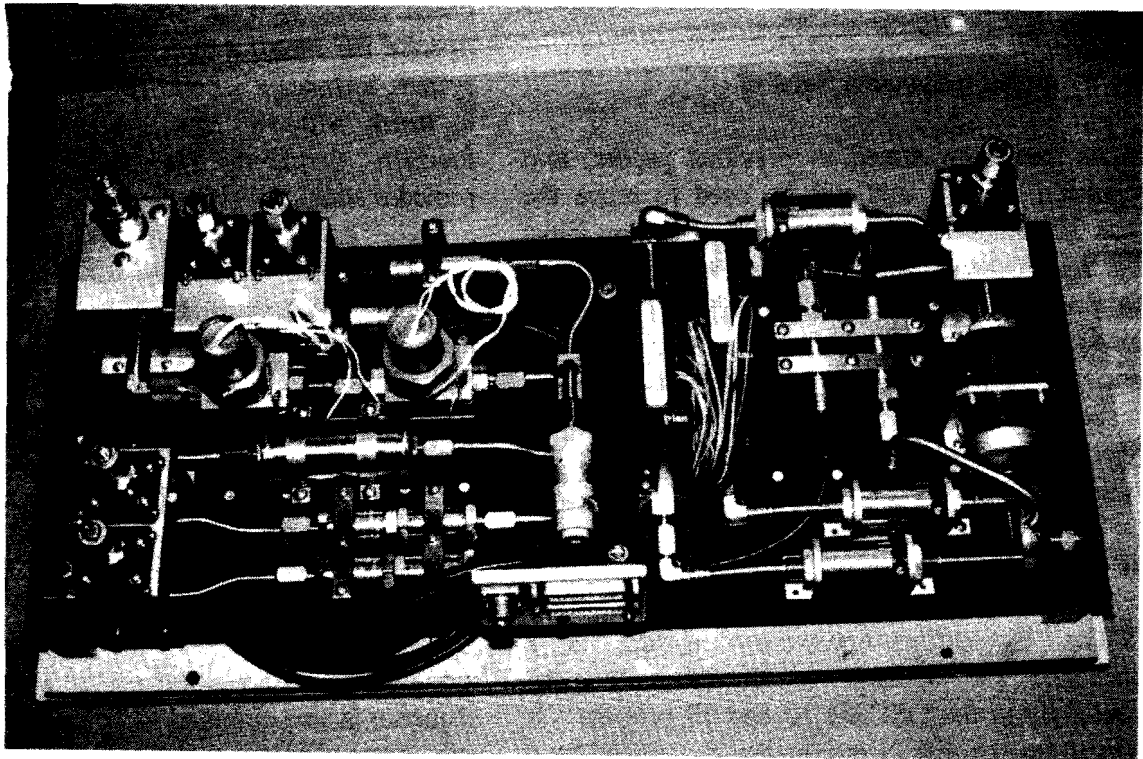

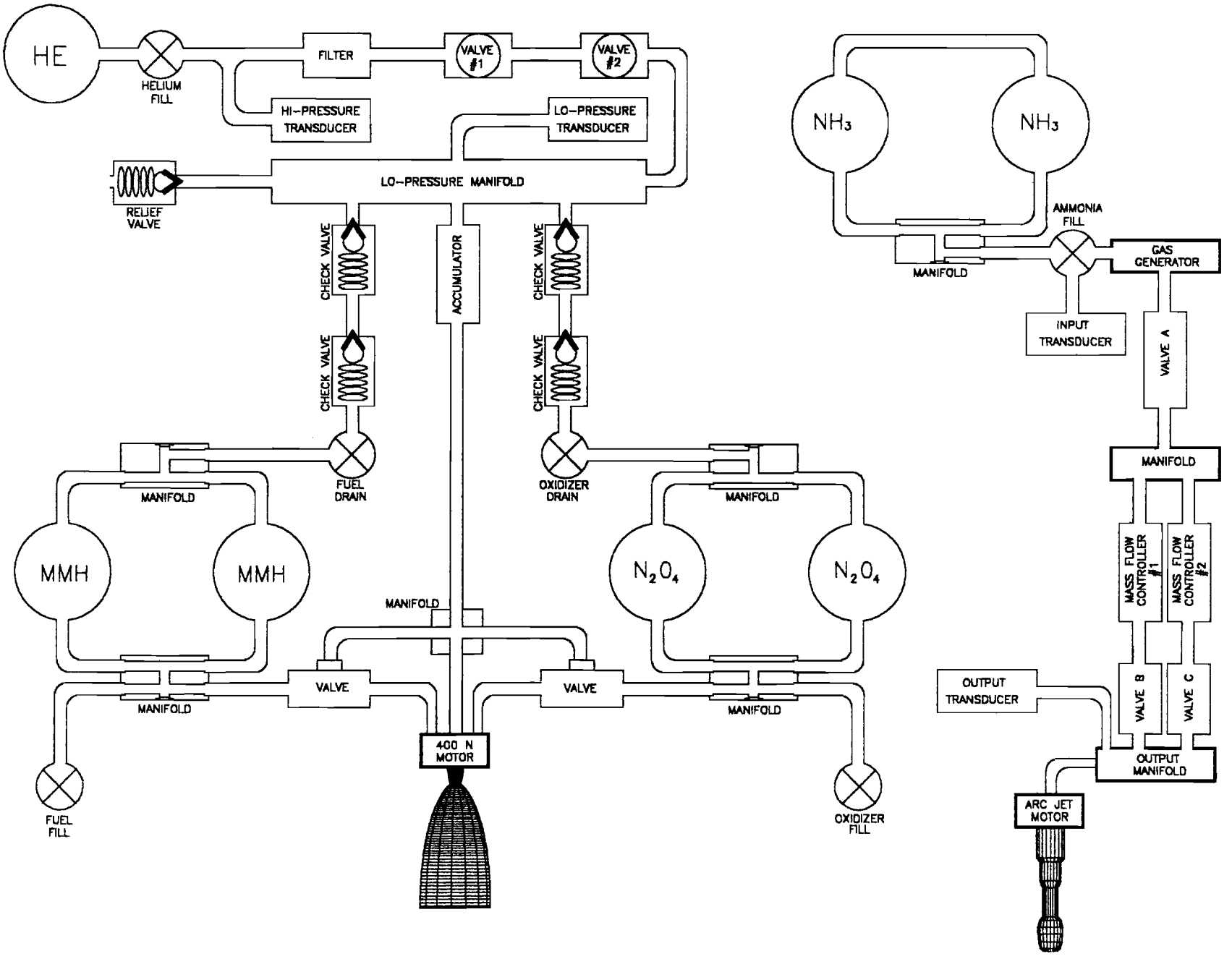Figure 1--The Propellant Flow Assembly (PFA)

Figure 2-- Block diagram of Phase 3D Propulsion system

WITHER THE HAMSATS?
(An Update)

by Keith Baker, KB1SF
Executive Vice President, AMSAT-NA

Many of you may recall my guest editorial in Bill Tynan's Apogee View a few months back, where I discussed some of the issues facing us as we move into the next century. Since that time, there's been a lot more discussion about the future of Hamsats in general and AMSAT in particular. I'd like to think that our editorial got some of you seriously thinking about the future of your organization. For example, a subject thread developed on AMSAT's Internet Bulletin Board in March, 1995 centered directly on the issues of future satellites beyond Phase 3-D, as well as the direction AMSAT should take to capitalize on the technology and launch opportunities of the future.

In addition, since this article first appeared in the May/June issue of the *AMSAT Journal*, the discussions have continued, and, as a result, new and innovative ways to launch amateur payloads have emerged. In this update, I'll include some of the new ideas gathered since my first article was published, as well as review some of the ideas discussed there.

For those who contributed to the original AMSAT-BB discussion, many were not aware that AMSAT-NA's leaders were also listening, albeit silently and in the background, so as not to bias the ongoing discussion. Many of them captured, read and then archived every word. The result was nothing short of a brilliant and far-reaching discussion on the central issues facing our organization in the future if we are to continue in the forefront of aerospace technology.

For those who may not have had access to those original discussions, I thought it appropriate here to again quote, summarize and consolidate many of the comments made, and I will again attempt to put them in perspective. I'll then go on to add some other key issues affecting our future that may not be generally known. My objective, as before, is to keep the discussion going, and to also look for ways to enlist your individual help in moving us into the future.

SHOULD WE BUILD MORE ANALOG FM BIRDS?

One central theme that played out early in the discussion examined the need for more analog FM birds like AO-21 and AO-27. Dan Schultz, N8FGV, even acted as consolidator for an informal poll of comments regarding this issue. His results seemed split between those who've had success with the FM birds and those who've had nothing but frustration getting into the transponders. The results of Dan's informal poll indicated that these satellites were wonderful tools to help get beginners interested in satellites. However, beyond this role, their effectiveness as a sustainable, high volume communications medium was sometimes offset by a handful of people who tended to monopolize the single transponder with high powered signals and/or long-winded ragchews. I also saw this same complaint recently aired on AMSAT-BB by frustrated users attempting contact with the MIR, SAREX and AO-27.

Walt Daniel, KE3HP, took a more technical look at the FM mode by examining the link calculations needed for a MICROSAT class FM transmitter in Low Earth Orbit. His calculations indicate that the link equations for the downlink budget were barely acceptable for FM voice and/or 1200 bps packet even without factoring in losses due to polarization, antenna nulls, atmospherics and feedlines. Walt then took the issue one step further by examining the link budget for a MICROSAT FM satellite in a Phase 3-D-type elliptical orbit. The results were even worse. Walt concluded his discussion by pointing out that AO-21 was not a Microsatellite, but, rather, was attached to a much larger satellite and benefited from the parent satellite's much larger power budget and pointing control.

Based on Dan's and Walt's analysis, it appears that unless lots of satellite power is available to support multi-channel FM operation, an FM-only satellite seems to have its best usage as an introductory bird. That is, a satellite for use by those who simply want a taste of satellite work. However, FM operation for anything more than brief greeting contacts is going to require a satellite with multiple

transponders. This translates into a lot bigger bird with a lot more available onboard power.

FM is a key-down, power hungry mode. That is, there is no time sharing of satellite power among several simultaneous users as with SSB and CW signals. An FM signal also occupies some 4 to 5 times the bandwidth of an equivalent SSB or CW signal. For comparison, I'm told the now silent AO-21 "FM" transmitter had an output power of about 10 watts. Add the laws of physics to this equation, and I think it should be obvious that even a 10 channel FM bird in low Earth orbit is going to be in the 100-watt-plus power category. That's some three times the power that's currently running everything now aboard Oscar 13 and over 20 times that of the MICROSATs! Still, even with all this available power, only 10 people will be able to work the new bird at any given time. Under this scenario, it's no wonder some might argue that instead of a single monopolized and unusable channel in orbit, we'd now have 10 of them!

Put such a satellite in an elliptical orbit similar to Phase 3-D, and the link budgets force even higher power requirements. Imagine if we were building Phase 3-D to have only 10, or even 20 available channels, vice the hundreds with SSB and CW now planned, not to mention P3-D's digital capabilities. Would YOU support its development and launch as generously as you have? I'm concerned such an approach might require far more financial resources than AMSAT can effectively muster. However, I still believe the FM concept needs to be explored further, lest we discard new, as yet undiscovered or innovative approaches to this age-old design dilemma before they've have a chance to mature.

OTHER FUTURE TRANSPONDERS

Another thread that wound its way through the recent discussions centered on a "if-not-an-FM-bird-then-what?" concept for future AMSAT satellite transponders. In this discussion, Phil Karn, KA9Q, ably pointed out that many of the cutting edge modulation schemes are digital, but that the technology is now staying on the ground vice being hard-wired into the satellite. Indeed, Phase 3-D's digital RUDAK transponder will be carrying both a 9600 baud FSK modem as well as some digital signal processing (DSP) equipment to take full advantage of some of these new technologies as they mature. Phil goes on to make the point that, "...for satellite users interested in communicating in real time with each other over a wide area, it's really hard to beat a dumb "bent pipe" in high orbit." This becomes especially true when users invent a modulation scheme that wasn't available when the satellite was launched.

WHAT'S A "BENT PIPE"?

My original article generated lots of questions about just what a "bent pipe" transponder is and what it does. As I understand it, a bent pipe is essentially a transponder that sends back whatever is sent up to it in exactly the same form. The transponder is transparent to the signals that it passes. Thus, it does not become dependent on the modulation type that is sent through it. AO-27's "FM" repeater is just such a device. Once launched, this type of transponder would give us wide flexibility. That's because as new modulation schemes are developed (and others fall out of favor) we don't have to keep launching new satellites to match the new modulation formats. This approach helps keep more of our experimentation on the ground vice in the bird. An added side benefit of this approach is that it helps reduce the feelings of "orphaning" sometimes expressed by our members. That is, current ground station equipment can still be used with the new bird, even while it's providing our experimenters with another platform to use while working on new modulation techniques and technology.

As I noted in our recent *Journal* editorial, we in AMSAT-NA are carefully watching the experimental development of just such a bent pipe transponder for possible use on a future, as yet unspecified, AMSAT satellite. As this article is being finalized, I understand hardware is being procured and terrestrial testing will soon begin. I'm told part of that testing program may also involve carrying a prototype transponder aboard an aircraft. Initial design results are encouraging, but only time will tell if theory can be successfully transformed into usable hardware. How such a wideband transponder might be used, and how we might get it to orbit, are challenges that still remain to be overcome.

SO HOW ABOUT A GEOSAT?

Many AMSAT groups from around the world are now working hard to make the Phase 3-D satellite an orbiting reality. However, as many of you well know, AMSAT was actively pursuing the construction and launch of a Geostationary satellite in the late 1980s under the Phase 4 program. Unfortunately, that project was shelved when it became increasingly apparent that financial support from its prime audience (Radio Amateurs in the Western Hemisphere) was not forthcoming. It was at this time AMSAT-NA combined forces with the team headed by AMSAT-DL to build and launch Phase 3-D. The rest, as they say, is history.

Now, nothing precludes us from again examining a Geostationary satellite project once Phase 3-D is safely in

orbit. Presumably, we are a bit farther down the road technologically than when the Phase 4 concept was shelved in favor of Phase 3-D. However, the funding issue still remains. Some have argued that AMSAT-NA now won't require the support of the rest of the world to build a geostationary satellite as we have with Phase 3-D. Some have also suggested that we seek to obtain funding from the Federal Government or from some other non-profit organization (Like the American Red Cross) or similar agency. In fact, even though government funds were actively sought for Phase 4, in the end it was the *lack* of US Federal Government interest in contributing to the building of an AMSAT Geosat that became one of the principal reasons why the Phase 4 concept was shelved!

In today's tight governmental fiscal climate, obtaining federal funding for a future Geosat satellite might prove even more elusive. In addition, the age-old adage that "along with government dollars goes government control" is something we'd have to seriously consider before we eagerly accepted government financial assistance. No doubt, if AMSAT were to accept federal monetary help, we'd probably also have to add paid staff in our Headquarters just to keep up with the steady stream of reports we'd now have to generate to help assure the taxpayers that we are spending their hard-earned tax dollars wisely. Experience from my 20 plus years working in the public sector have taught me that federal assistance is rarely (if ever) "free". The costs associated with changing AMSAT's management and business practices to accommodate such an approach would also have to be carefully considered and then realistically weighed against the potential benefits. These additional costs would then have to be factored into any requests we might make for federal assistance in future projects to see if the benefits truly outweighed their costs.

On the technical side, if we wish to capitalize on the "lessons learned" as outlined by Phil Karn in his discussions referenced above, a bent pipe transponder on an AMSAT satellite in Geostationary orbit offers us some VERY interesting potential as a follow-on project. On the other hand, one of the other big hurdles this concept is going to present to AMSAT in the near future will be assembling the team to build it, even if we *were* fortunate enough to secure a low-cost launch, and figure out ways to raise the necessary funding to make it all happen.

From my perspective on the Phase 3-D Development Team, I can tell you unequivocally that Phase 3-D will be the last AMSAT satellite to benefit from the talents of many of our dedicated experimenters. There are a variety of reasons for this, but most center on these outstanding people wanting to take a well-deserved break

after their near constant involvement in building a string of successful AMSAT satellites. Unfortunately, in far too many critical areas, our retiring experimenters are "one deep". For others, available spare time to work AMSAT projects has already, or soon will become, an ever-shrinking, scarce commodity. Unfortunately, the talents needed to build and launch a satellite are not available on every street corner, and are becoming more specialized, not less. Often, these skills are only honed after years of hands-on experience. They are also in great demand in the well-paid private sector.

This, then leads us to ask some other questions (and also leads to some other interesting approaches to launching satellites that we might consider). For example, must we *always* build our own dedicated spaceframes for our satellite projects? Could it be that we are still doing so because "we've always done it that way"? I suspect one of the main answers to that question is because that in years past, building our own bird was the *only* way we could effectively get the Amateur Radio payloads that we wanted into orbit. I believe it's important to again ask if those conditions...the major hurdles to some of our efforts back then.....are still in place today. As the popular song says...."the times they are a changin'". Maybe we don't need to continue going down the "build it all" road in today's space launch environment.

Those who are familiar with the Russian "Easy Sats" know that RS-10/11 and RS-12/13 are sharing space on much larger Russian navigation satellites and are benefiting from the larger satellite's power source. Maybe we could do the same thing for a Geosat.

So, assuming we could pull a design and construction team together, an inviting prospect is launching a "piggy-back" transponder on a Geostationary host satellite. The next big problem will be that of finding a host satellite owner who would be willing to carry us along. That's because every extra ounce of payload these satellites must carry to Geostationary orbit is usually offset by reduced station-keeping propellant to extend on-orbit lifetime. Contrary to popular belief, the leading cause of death for Geosats is that they run out of their stationkeeping propellant long before the electronic systems give out. Given a choice between carrying a "freebie" AMSAT payload and extending the commercial money-making lifetime of a Geosat, it doesn't take a rocket scientist to figure out which alternative's going to have the upper hand, at least initially.

Another "half-baked" variation on this same theme is somehow negotiating with a major spacecraft builder to incorporate an Amateur Radio transponder in some way

with another one already being developed and built for commercial purposes.

I'm convinced low cost launch opportunities for an organization such as ours are *still there,* even in today's highly competitive space environment. All we have to do is go find them, and then figure out ways to capitalize on them. Yes, there will be challenges. However, the over thirty satellites that AMSAT and its predecessor organizations have built and launched over the years are ample proof that we, as a group, have the knowledge, skills and abilities within our ranks to turn roadblocks and challenges into operational space hardware. In short, we've done it before and I'm confident we'll find ways to do it again.

LAUNCH OPPORTUNITIES FOR THE "FINANCIALLY CHALLENGED"

For example, I hope all of you read the excellent article by Phil Chien, KC4YER, in the March/April issue of the AMSAT Journal regarding launch opportunities beyond Phase 3-D. In it, Phil listed a number of potential launch opportunities that, had we been in the right place at the right time with the right equipment, AMSAT could have orbited a number of payloads into a variety of orbits (including some very attractive Geostationary ones) for next to nothing in financial outlay.

I think the key words here are "in the right place at the right time", because that's where each and every AMSAT member is going to have to lend us a hand in the future if we are to progress beyond Phase 3-D. In our recent *AMSAT Journal* editorial I was serious when I said that each of us is going to have to become a personal "Ambassador for AMSAT" in the future if we are to secure donations, obtain the needed design and construction labor, and then locate and exploit innovative launch opportunities. Had any one of us become aware of one or more of the launches Phil outlined in his Journal article in enough time for our leadership and experimenters to react, we might already *have* our Geosat (or any number of other attractive LEO satellites) in orbit.

Much to many people's surprise, the current leadership and core experimenter group of AMSAT amounts to little more than a handful of people. However, our active membership numbers some 7500. Many of our members are well-placed in the aerospace industry and have daily access to the kinds of information and influence that could enable us to successfully present our case for a substantial donation...or a launch opportunity. It is simply impossible for your AMSAT leaders to know about, let alone exploit, every potential donation of equipment,

materials, or test facility time that might come our way in the future. And, yes, the same logic applies to launch opportunities.

I'm glad to now report that as a *direct* result of this article first appearing in the *AMSAT Journal,* several of our members have already begun actively pursuing a number of potentially lucrative transponder and launch opportunities for us. These contacts are with a variety of satellite builders and launch agencies.

VISION

Many of our members have written well-intentioned letters about what "AMSAT should do ....". Believe me, their thoughts are always welcome, and will continue to be as AMSAT moves into the coming new century. Bill Tynan, our AMSAT-NA President, and I get a *lot* of mail from our members, much of it containing some innovative ideas regarding where AMSAT should go next. Each of those letters are read by one or the other of us (often both!) and we try our level best to at least *acknowledge* the excellent thoughts, concerns and suggestions they contain.

However, it also saddens me when I think about all the great ideas expressed in many of these letters that will remain just that....*great ideas on a piece of paper*....unless we also can find ways to muster the manpower and resources it's going to take to turn those innovative thoughts into flying space hardware and software.

Those who spent some time in the US military, or around the early main-frame computers, have no doubt heard about one the US Navy's finest officers, the late Commodore Grace Hopper. To those who knew her, Commodore Hopper was technically brilliant, as evidenced by her invention of the COBOL computer language for the early mainframe computers. In addition, she was *well* past the Navy's mandatory retirement age before they finally allowed her to retire! Commodore Hopper's basic approach to getting things done in large organizations was equally brilliant, and wonderfully simple. Briefly stated, she believed that, "...if it's good for the troops and the ships at sea, go ahead and *do it*, for it's always easier to apologize than to ask permission!"

From an AMSAT perspective, this means our members would be far more helpful to us if they were *also* willing to take those first exploratory steps needed to turn their "AMSAT should do....." ideas into reality. For example, what we *really* need are people who will, on their own, draw a group of volunteers together to explore and prototype an innovative transponder design, or begin

exploiting material donations, testing or launch opportunities when they first come along. Others might look at our current AMSAT software and publication lineup and see what might be added or improved upon for the future, and then will either write it themselves, or pull a team together to do it. Still others will compose an article for the *AMSAT Journal* without being asked to, or who will arrange to set up an AMSAT hamfest booth or forum talk where none has ever been done before. AMSAT people who routinely *find a need and then fill it* are going to be the ones who will keep our organization fresh and alive as we move into the late 1990s and beyond.

So, go ahead and start taking those first steps toward pursuing that half-baked idea you've been tossing around that might also help AMSAT achieve its objectives in space science and education. The *only* restriction we must place on your effort is that if AMSAT's monetary resources will ultimately be needed to support your new idea for a satellite project, the AMSAT-NA By-Laws require that the AMSAT Board of Directors (BOD) must also approve of the project before any AMSAT funds are committed and before AMSAT's corporate name is used in conjunction with your effort. Getting that approval involves a presentation to the AMSAT BOD sometime after you've completed your exploratory activities. If the AMSAT BOD approves of your approach and decides to embrace your idea, you are free to proceed with your project using the AMSAT corporate name and whatever financial backing AMSAT then allocates to your effort.

But, let me again emphasize, you certainly *don't* need our "permission" to take those first steps on our behalf to explore a possible AMSAT project for the future.

Each of us, individually, make up the collective whole we call AMSAT. Each of us brings something of unique value to the organization, be that engineering expertise, leadership skills, organizational and administrative talents, or contacts with people and organizations who can help us achieve our goals. I also believe each of us carries that same "can do" attitude as well as spirit of exploration and innovation that was present when our AMSAT charter members first met in that Washington apartment building back in 1969 to form our organization.

Your leaders don't have all the answers, and you certainly don't need to wait around for our permission to go exploring in the name of AMSAT. I thank each of you who took the time to create such a superb discussion on the critical issues regarding our future. You gave all of us a wealth of ideas to consider. Now, I encourage each of you to not only continue these discussions, but to also help us seek out and exploit those opportunities that will insure AMSAT continues to prosper as we head into the next century.

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Extending the lifetime of scientific satellites using AMSAT techniques

With early satellites the problem was keeping the satellite operational through its anticipated lifetime. But as experience was gained better spacecraft were built which consistently lasted well beyond their planned lifetimes. The concept of shutting off a working satellite which still contributed valuable scientific data was abhorrent, so additional funding was usually easy to obtain to keep the science coming in. In some extraordinary cases spacecraft lasted three times their planned lifetimes! The international Ultraviolet Explorer (IUE) was launched in 1978 with a three year planned lifetime and five year goal. It's still operating, sixteen years later, and its major problem is obtaining enough funding to keep it in operation. New spacecraft are specifically being designed to meet fixed budgets - without any plans to extend their missions. There is a clear understanding between the scientists and NASA that once the mission is completed the spacecraft will be shut off.

Scientists would like to continue to operate their spacecraft beyond what NASA will allow. Many spacecraft make their most significant discoveries well after when their missions were supposed to be completed. For example, IUE was the first spacecraft to observe Supernova 1987A, something which would not have been possible if its mission had been completed in 1983 as originally planned.

The current problem is NASA's constrained budget. With a 16% decrease in overall funds and high priority projects like the space station grabbing the lion's share of NASA's funding there is less money available to operate existing spacecraft beyond what's already budgeted. The alternative is almost as bad. If you continue to operate the existing spacecraft instead of building new spacecraft there will be less and less new spacecraft to launch in the future.

NASA does not have the funds to keep extending satellites just because they're built too well!

The solution:

AMSAT members have excellent home-built telemetry stations, capable of receiving data from our own spacecraft. These are relatively inexpensive ground stations, but in many cases just as reliable and capable as a government tracking station.

What I'm proposing is an arrangement where AMSAT builds ground stations for colleges and institutions to operate future spacecraft. In addition we will supply a standardized AMSAT-quality spacecraft transponder subsystem. The college will be responsible for the ground station's operation and the scientific data collected. NASA would still retain title to the spacecraft, and overall responsibility for its operation.

There are many potential benefits to AMSAT from this type of arrangement:
 We would obtain funds for each transponder and ground station we build. This income would go towards future dedicated AMSAT spacecraft.
 On a time and space-available basis these transponders could be used for amateur operations when they aren't returning scientific data.
 We would get more direct involvement with colleges and technical programs
 We would get additional exposure and membership through these programs
 More experimenting could be done with amateur radio hardware in space

The benefits for the scientific community include:
 extended lifetime for their spacecraft
 more involvement in spacecraft operations at the college level

For NASA the benefits include:
    additional educational opportunities
    more students - at all grade levels, getting involved in space activities
    More science for the buck

It should be noted that this is not a miracle solution. There are still many costs involved in operating a spacecraft. NASA will still retain control over the spacecraft's bus and must budget a small amount of money for its operations. The university must find funding for the ground station staff, typically undergraduate students, and funding for the scientific studies and investigations. Still, the overall costs will be far less than with current spacecraft operations.

Could NASA do this without AMSAT's participation?

Absolutely, but the government isn't geared for that sort of operation. In NASA terms a ground station is this extremely sophisticated facility with round-the-clock highly trained full-time professional personnel, a high bandwidth datalink back to the appropriate NASA center, and much more complicated (read: expensive) hardware than what I'm proposing. As examples visit the Space Telescope Institute at Johns Hopkins University in Baltimore Maryland or the Center for Extreme Ultraviolet Astronomy at the University of California in Berkeley. In many cases NASA is going towards university operated spacecraft - and that's all fine and good. But we're capable of driving down costs by an order of magnitude by using the same types of hardware we've been using for the past decade.

    strawman proposal:

A typical college setup would include a multi band transceiver, preamp, downverter, Az/El drive, L or S band dish for downlink, DSP modem, and 486 or equivalent computer. The system will include downverters to convert the incoming L-band or S-band scientific frequencies into the radio's input frequencies.

It's extremely important to note that while the transponder is being used for scientific data it will be transmitting on frequencies assigned to scientific spacecraft - not amateur radio frequencies. We will not be giving up any bandwidth for this proposal!

Unlike communications satellites, scientific satellites have much higher downlink requirements than uplinks. While a communications satellite is designed for two-way transmission of information a scientific spacecraft spends most of its time transmitting data back to a very small number of ground stations, and very little time receiving commands, or new programs.

As an estimate the system should have the capability to dump at least 10 Mbytes of data in a 7 minute pass. Most of the data gathering functions would be automated, but it's likely that an undergraduate student would be assigned the responsibility for verifying that the data has been received and cataloging it.

A first-order estimate on the weight of the spacecraft transponder and antenna would be about 7 kgs. (15 lbs). These numbers are just estimates and customized transponders could easily be developed for more specialized applications. The spacecraft would supply power, thermal control, and attitude control to our package. We would be responsible for transmitting the data to the ground station.

In a typical setup the spacecraft operates in an 300 km. polar orbit. It makes two passes each day over its ground station. For the early morning pass the satellite downlinks its data to the

ground. During the day the scientific community verifies the data, checks that the data set is valid and complete. During the evening pass a command is sent up to the spacecraft with any new science schedule, programs, etc., and a command to erase the memory which has been received. The system will be autonomous enough to handle ground station outages, incorrect commands, and failsafe modes. For cooperative projects multiple ground stations could be set up at different locations.

It's possible that while the spacecraft is not within range of its ground station the transponder could be used for amateur operations.

One of the more exciting possibilities for the amateur satellite community is the potential for a shared 50/50 scientific/amateur satellite. NASA's current policies call for commercial launch services procurements. Satellites are designed for a particular weight class, assuming that they'll be used with a particular launch vehicle. Most of the time this is true, but there are exceptions where a higher capacity launch vehicle is used because that company wanted the contract more badly. For example a particular satellite might be designed to fly on a Delta II launch vehicle. However Lockheed Martin decides that it wants to go after that particular contract, and offers an Atlas II launch vehicle at a substantial discount and wins the contract. The satellite is still just as capable, but well beneath the launch vehicle's capabilities. We could negotiate to obtain that excess capacity for our own spacecraft in exchange for an AMSAT-Scientific transponder. This actually happened in the commercial world a couple of years ago when the Atlas I won contracts to launch the Galaxy V and Galaxy IR spacecraft over the Delta II.

There are many types of spacecraft which are beyond our current capabilities. Anything beyond geosynchronous orbit, any planetary missions, or anything which requires constant interactive science is probably better served by NASA's existing Spacecraft Tracking and Data Network.

However there are dozens of spacecraft under construction which would benefit from this type of approach.

As an example, here are several current spacecraft in operation which could have benefited from the use of an AMSAT transponder:

    EUVE
    UARS
    TOPEX/Poseidon
    ROSAT
    CGRO
    IUE
    Radarsat

Here's several spacecraft under construction which could conceivably use our transponder:

    XTE
    Polar
    ACE
    FUSE
    Small Explorer
    Discovery
    New Millennium
    OSI
    EOS

Hypothetical invoice for our services

100 units   We supply a transponder and never see it again. AMSAT guarantees transponder's operation for at least 5 years of nominal operations. For a pure commercial deal like this AMSAT will have full-time paid personnel dedicated to the project, however all profits from the venture would go back into the funds for future satellites. This can be done while retaining our non-profit status.

90 units   While the spacecraft is not over its ground station and during weekends the transponder is available for amateur use (similar to the AO-27 spacecraft)

50 units   We get a portion of the spacecraft's resources for a dedicated amateur transponder, with the understanding that our payload will not interfere with the primary payload's operation

zero units   we get to share the spacecraft's resources (or launch vehicle) as an equal partner.

discounts:

Use of government or university furnished facilities and resources availability of an active AMSAT chapter at the school with school support

Potential AMSAT payloads for these transponders:

amateur scientific gathering (ozone hole information, CCD cameras, etc.)
6M beginner's bird
high speed packet spacecraft
payloads in geosynchronous orbit

Philip Chien, Earth News - space writer and consultant PCHIEN@IDS.NET

Phase-3D GPS Receiver Progress Report

Bdale Garbee, N3EUA

Overview of Project

A couple of years ago, Tom Clark W3IWI put a note out on one of the AMSAT electronic mailing lists proposing an experimental GPS payload module for the Phase-3D satellite. A small group of interested individuals agreed to work on the project, and met at the 1993 AMSAT annual meeting to officially get started. Our goal is to design and build a receiver that will use signals from the GPS satellite constellation to determine the orbital position and three-axis attitude of the Phase-3D space vehicle. As a side-effect, we will be able to provide precise timing information to other processors on the satellite.

The project has been forced to design a new receiver from scratch because of a mixture of unique requirements, regulatory issues in the commercial GPS sector, and proprietary technology used in most commercial receivers. The requirements imposed on a receiver for spacecraft use as a result of the environment and the dynamics of the vehicle are quite different from the terrestrial "appliance GPS" market. The desired outputs from the receiver are also different, for while time is a useful output in all environments, a space vehicle cares about orbital geometry while a terrestrial receiver cares about things like latitude, longitude, elevation, and velocities on each axis. Therefore, at a minimum, some work would need to be done to any commercial receiver's hardware and software to make it acceptable for flight on Phase-3D.

Manufacturers of commercial GPS receivers typically design custom application specific integrated circuits (ASICs), and write custom software to control those ASICs. They have legitimate competitive concerns about releasing documentation on the design details of their ASICs to groups such as ours, but that makes it really hard to modify their receivers for our needs. This was another significant motivator for undertaking a new receiver design as part of our project.

Finally, the US government imposes restrictions on commercial GPS receiver manufacturers in an attempt to prevent off-the-shelf receiver technology from being used by enemies of the US to target weapons. This usually manifests itself as limits on the velocity and/or maximum altitude at which the receiver will work without software modification. Even when a manufacturer is willing to work with a group such as ours to customize a receiver, there is a paperwork process involved in getting permission to buy a receiver that circumvents these limitations. This provided additional incentive to develop a receiver that would bypass those restrictions.

A paper describing our receiver design was presented by W3IWI at the 1994 annual GPS meeting of the Institute of Navigation, and was awarded "Best in Session". This has helped attract substantial interest in our receiver design from academic research groups, government-sponsored research labs, and several commercial satellite vendors.

Receiver Hardware Design

Fortunately for this project, the integrated circuit manufacturer GEC Plessey has chosen to produce ASICs for developers of GPS receivers. They sell building blocks that help downconvert the RF signals from L-band to a digital baseband, and then perform the core signal processing required to recover the GPS satellite transmissions. As a manufacturer of parts, and not of complete receivers, Plessey is motivated to assist in the development of receivers using their parts, and provide full documentation on their chips. They have also made a developer's kit available that includes a PC plug-in card using their chips and software written in ANSI C for a terrestrial 12-channel GPS receiver that they call "GPS Builder". W3IWI was able to cajole one of the beta GPS Builder cards from Plessey, and we have since purchased several additional units.

After some analysis of the software provided with GPS Builder, and experience with the Plessey parts, it became obvious that Plessey assumes a significant amount of processing performance will be available in conjunction with their chips to complete a receiver. We discussed CPU selection at great length, and after some false starts ended up picking the AMD 29200 embedded RISC processor. The chip has various I/O devices included, and is very fast. We operate the chip with a 16Mhz clock, and execute an instruction and a bus cycle every 60ns! Two of the attributes of the 29k family that shine for our application are the very large processor register set (192 general purpose registers), and the ability to process interrupts with very low overhead. Since the Plessey 1020 correlator chip needs to have an interrupt serviced about 2000 times per

second, interrupt performance is a crucial issue. The 29200 includes several peripheral devices integrated on the chip, reducing the complexity of our design.

Fig 2: AMSAT PHASE-3D
GPS EXPERIMENT
BLOCK DIAGRAM
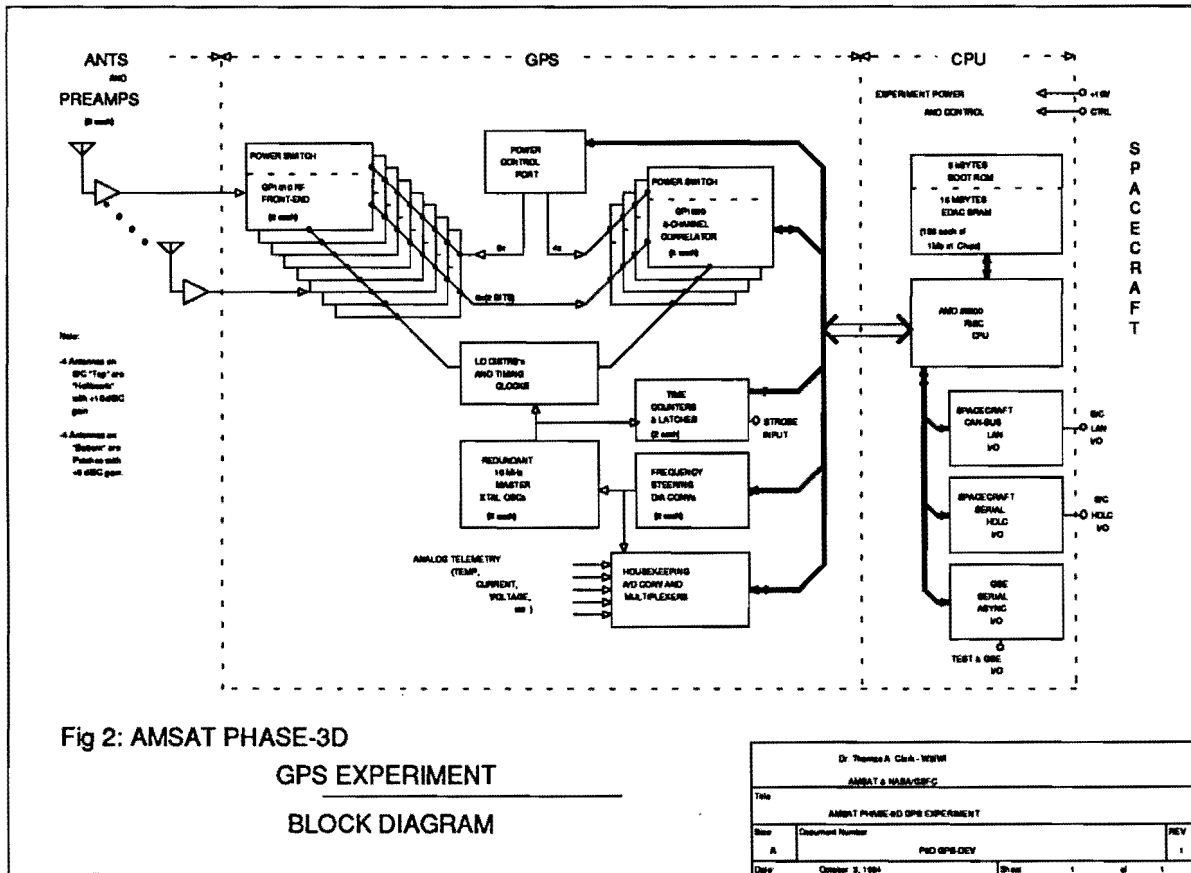
The above is a block diagram of the receiver we are building. We intend to fly 8 antennas, 4 each on the "top" and "bottom" surfaces of the satellite. Each antenna has a preamp, and feeds a Plessey 1010 downconverter and digitizer chip. For the orbit determination task, a single antenna would be adequate, but for the attitude determination task, we need to do interferometry with signals from antennas along different baselines to determine the orientation of our receiver relative to the GPS constellation. Since Phase-3D will be 3-axis stabilized, one surface will point "down", and one surface will point "up" at all times. During perigee passes, we will be below the GPS constellation, and have similar antenna gain needs to a terrestrial receiver. This, the "top" surface of the satellite will get low-gain patch antennas. During apogee passes, we will be above the GPS constellation, and perhaps acquiring signals only from GPS satellites that are essentially on the far side of their orbits, this higher gain antennas have been designed for the "bottom" surface.

The outputs of the 1010's feed the inputs of four Plessey 1020 6-channel correlator chips. The 1020's have input multiplexers designed for use with the Glonass system (the Russian equivalent of GPS) that we use to allow us to feed any antenna's signal to any or all of the 24 available correlator channels. The 1020's are peripherals for the 29200 processor with its associated memory and spacecraft I/O subsystems. In addition, we include two precision 10Mhz reference oscillators, and a counter/timer chain to allow calibration of the oscillators. Finally, we allow power control of each correlator and front-end channel to balance performance against power consumption, and reconfigure the receiver for various tasks.

Physically, the receiver is broken into two major circuit boards, and multiple copies of two minor circuit boards. One of the large boards hosts the CPU, memory, and spacecraft I/O interfaces. The second large board hosts the Plessey 1020

74

correlator chips, and associated oscillator chains and power control circuitry. The 1010 front-end chips reside on individual daughter cards for the 1020 board, and the preamps for the antennas reside on individual boards. The package will use a double-height box on the spacecraft, with the CPU in one half and the RF/correlator package in the other.

One of the neat aspects of the CPU design is that the RAM chips are organized onto modules (SIMMs) which are also used for the Rudak-U processors. The SIMMs are designed to support various memory array sizes for the different processors, and are a common sub-assembly manufactured "in volume" for the Phase-3D spacecraft.

Receiver Software Design

As mentioned previously, Plessey provides ANSI-C sourcecode for a reference GPS receiver design in their GPS Builder kit. In conjunction with the supplied 12-channel, single-antenna receiver hardware and a 33Mhz 486 or faster PC, this software implements a fairly full-featured terrestrial GPS receiver. This is incredibly useful to us as a starting point, but there is still a significant software effort involved in the project. The Builder software has to be ported to the 29k processor, support must be added for additional correlator and antenna channels and for management of the power control aspects of our design. Further, the code that produces navigation solutions from the raw data acquired must be re-written to "think in terms of" orbital elements, instead of three-axis position and velocity. And the attitude determination task requires entirely new software, using perhaps only the core data acquisition code from the Builder package. Finally, we need some way to command and monitor the receiver from the ground via the Rudak-U communications processor, which requires development of a suitable bootrom for the GPS receiver, a support task for the Rudak-U system, and protocol drivers for the operational software in the GPS receiver to communicate with the ground through Rudak-U.

There were two major choices for development tools for the 29200. AMD sells a DOS-hosted ANSI-C compiler and related assembler, linker, and target communication tools. We chose to adopt the GCC compiler and related tools from the Free Software Foundation's project GNU. The sourcecode for these tools is freely available, but runtime and library support for the 29k family was incomplete. By combining code fragments made available by AMD on their BBS, and discovering the freely-available library implementation from Cygnus, a company devoted to supporting the GNU tools, all the pieces came together. While we continue to improve our tools over time, everything required to generate software for the GPS project using ANSI-C and assembler has been working for several months.

The GPS Builder package includes a minimal multitasking kernel for the x86 family running DOS. We located a freely available multitasking kernel called uC/OS, which has been ported to the 29200. Work is underway to graft this kernel into GPS Builder, replacing Builder's kernel. Once the port of Builder to the 29k family is running, we will be able to verify our hardware can serve as a working terrestrial GPS receiver.

Before we can load and run GPS software on the receiver, a bootstrap program in ROM is needed to support the interfaces to Rudak-U. The bootrom is written entirely in hand-crafted 29k assembly language, and uses no RAM (all variables and buffers are in the register array). To date, the required "read", "write", and "run" commands are all implemented and working over the ground support (RS-232) interface. Work proceeds on adding support for booting over the HDLC serial link from Rudak-U, and the CAN bus.

For development and ground test purposes, the bootrom communicates with a program running on a PC using the ground support interface. The current ground test program supports simple commands like read, write, and run, but also supports complex commands for testing memory using lots of read and write commands, downloading code using lots of write commands, dumping memory contents to a file using lots of read commands, and so forth. In a sense, the bootrom and ground support program working together provide the functions that are often part of a "monitor ROM" on a microprocessor system.

After launch, the bootrom, and later the running receiver, will communicate with and via a task running on the Rudak-U communications processor(s). This task is under development using the same type of IBM RIC card to provide a simulated Rudak that was used in the Microsat development to simulate the spacecraft processor.

The task of converting the processing code in GPS Builder over from terrestrial to orbital GPS is deferred until after the software tasks that are critical-path for integration of the GPS receiver to the spacecraft have been completed, and Builder has been ported to the 29k sufficiently to demonstrate that our receiver can do terrestrial GPS. Since the flight software will not be loaded until after launch, there is no great sense of urgency to this task yet, but volunteers to start addressing the issues involved would be more than welcome!

Where We Stand

As of the time of this writing, in early August 1995, progress on the various pieces of the Phase-3D GPS receiver project are as follows:

The CPU board first cut has been turned on, and all subsystems checked out. A number of design changes were needed to get everything to work, so a second revision of the board has been designed and is currently in fabrication. We hope that this second revision of the board will be the flight version. Turn-on and testing should proceed fairly rapidly, since software test routines that were developed during the turn-on of the first revision will be used again.

The correlator board has been designed, and raw boards fabricated. Loading of parts on the first board is in process, and testing should begin soon. My understanding is that designs for the preamps and downconverter boards exist, but boards have not been fabricated yet.

The low-gain patch antennas were donated by Ball, and are in hand. The design of the higher-gain helibowl antennas looks good, but flight antennas have not been fabricated yet.

A bootrom exists that works over the ground support interface, and there is a working ground support program for it to talk to. Augmentation of the bootrom to support the HDLC and CAN interfaces on the CPU board is in process. The development environment for the Rudak-U task that will support the GPS receiver has been assembled, but the task has not been written yet. It is expected to borrow code from the ground support program, and from other, existing, Rudak tasks.

Conclusions

As you can see, the GPS project is an ambitious one, involving both a sophisticated hardware design, and a substantial software development effort. As is often the case with such projects, there have been a number of stumbling blocks, and related delays in our schedule. We remain confident of our ability to deliver flight hardware for integration, but there are substantial opportunities available for others to assist the project's software development effort before and after launch. If you are interested in working on the project, or would like more information on some aspect of what is being done, contact the overall project leader, Tom Clark, W3IWI, w3iwi@amsat.org, or the author, Bdale Garbee, N3EUA, n3eua@amsat.org.

Acknowledgments

W3IWI provided the receiver block diagram, which was also used in the paper "A Low Cost Spacecraft Receiver For Orbit and Attitude Determination" by Clark, Varney, and Bauer, all of NASA Goddard Space Flight Center, in the Proceedings of ION GPS-94, the 7th International Technical Meeting of The Satellite Division of The Institute of Navigation, Salt Lake City, Utah, September 1994.

Rob Savoye of Cygnus Support has made the use of the GNU tools possible by providing invaluable advice on configuration issues, by authoring the libgloss target support library, and by making N3EUA aware of the newlib C library available from Cygnus.

Many individuals have agreed to participate in the Phase-3D GPS project at various levels of commitment. I would like to identify a few key contributors, and what they are working on, in no particular order:

W3IWI	project instigator and leader, helibowl gain antenna design, liaison to P3D project leaders
N3EUA	GNU tool support, bootrom, Rudak-U task, testing of CPU board, test fixtures
KD9KX	early performance tests on Builder, porting Builder to the 29200
WA1UVP	design and testing of the RF/correlator board
VE6ATS	radiation testing
WA7GXD	design of the CPU board and memory SIMM modules
N0ADI	artwork for and fabrication of the CPU and SIMM boards
WD0FHG	test fixtures, software for radiation testing, ground support program

PICOSATS

A Proposed Method of Providing 24 hour per Day Satellite Service to Radio Amateurs Throughout the World

by

Peter Vekinis
ON9CGV/KC1QF

FORWARD

This paper deals with one approach that has been proposed under the general heading, "What do we do after the launch Phase 3D? The PICOSAT concept, as conceived by Peter Vekinis, certainly represents ONE interesting, and possibly viable, approach to defining the future of our organization in particular, and Amateur Radio satellites in general. It is one approach that will be studied by the AMSAT-NA Board of Directors, and possibly by the leadership of other groups active in building satellites for use by licensed amateurs throughout the world.

At present, however, a PICOSAT Project, as outlined in this paper, has not been approved or accepted by AMSAT-NA, nor any other satellite group of which I am aware. This specifically includes Stanford University, which is mentioned in this paper as a PICOSAT builder. However, I have been informed by a Stanford official that he has discussed the concept with the author of this paper, and expressed an interest in investigating the concept in greater detail.

As is the case with any proposed project, the opinions of those who hear or read this paper, are welcomed by the members of the AMSAT-NA Board of Directors. Please let them know your thoughts as to the viability of the PICOSAT approach so skillfully presented by Peter Vekinis. Is it THE project we should pursue after Phase 3D is successfully in orbit?

Is it only one of several? Or, is does it have limitations that would render it not worthy of further consideration?

Thanks for your attention and help.

73,

Bill Tynan W3XO

Disclaimer

The information presented herein is the sole responsibility of the author and does not necessarily constitute the views of any other parties.

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Table of Contents

1. Introduction

The world is changing. We all know that. From the early days of HF radio to these days of instantaneous satellite communication, our world is getting smaller and smaller. We can now pick up a phone and dial anyone, anywhere in the world, even on a boat anchored in one of those idyllic islands one sees only on postcards.

Radio amateurs have followed and sometimes led this explosion and have in the process identified many new areas of splendor. Myself, as a young man, I tried to also get in the field. At my parents home, I used wood, aluminium plates and a hell of a lot of screws to construct a rough parabolic antenna trying to capture the Apollo mission voice prints. Little did I know then about how complex these systems really are. I did however had an idea. And the idea over the years took form and became what is now known as Picosats.

I never went to college and have taught everything myself. I wanted to get into business and was not interested is 'wasting time' by going to college. I entered IBM in 1974 and made a good carrier in the computer business, being right in the beginning of the revolution. I helped Microsoft and Digital Research get into Europe in the late 70s and subsequently switched into Marketing where I took many small companies and made them successes (there is an interesting anecdote: in the late 70s, Microsoft was looking for a base in Europe together with Digital Research (it is now a Novell Company) . They approached a small company called Vector International. They explained to the owner that micros were the future and he would end up rich beyond the dreams of avarice if he helped them in the European market. When I heard this I got excited (after all I had been working with micros since the Intel 4004 came out) and my eyes must have been shining dollars. The owner told them No. He said that micros would get nowhere; they were not powerful enough and they would remain toys. I wonder if that is good enough reason to jump off the Empire state building!

I have been a radio ham since 1975. I was 18 back then and entered the hobby as a CW pirate. I did and dat, build my own transmitter and QSOed around the world. I was, naturally caught, and was given a week to pass the test, which, luckily for me and my folks, I did.

Over the years, I followed the hobby and became more interested in communicating than by experimenting. I bought one of the firsts TS50s and ended up having lots of fun, especially while mobiling. I made friends everywhere, K3SRO, KB1XN, W6LAS, KD2QC, W1BFA and many more.

I then became interested in satellites. Not only for me but because the best way to reach into a kid and excite him with ham radio is to tell him 'Hey, did you know you are talking to Jake over in San Francisco with YOUR OWN satellite?' Believe you me, that excites them every time.

However, using satellites is not easy; in fact it is a pain in the neck. I found out that I would need a big antenna, an amplifier, at least an SSB rig and a lot of patience waiting for the bird to 'turn the corner.' The commercial world, sees it differently. They have geostationary satellites; great huge dishes and

amplifiers and they sure dwarf our signals.

This commercial world, driven by the insatiable need for cash, has moved us one step further. Instead of taking us to the mountain, they are brining the mountain to us! They have created Iridium et al. And no ham has done anything about it. Until now.

Some of you in this room would like to 'play' with antennas and power amps and the kind. Others would just like to communicate. This Picosat project is for those of you that want to do the latter, easily, cheaply, and above all whenever and wherever you feel like it.

Picosats are very simple, small, efficient satellites that fly at Low Earth Orbits (otherwise known as LEOs). Their purpose is to offer easy-to-use communication anywhere. By being more than one and by flying low, a user would perceive continuous communications even though the actual satellite repeater would be changing all the time.

They are to be launched in LEO slots, should last about 4-5 years and should be powerful enough to be used by a little handheld radio, running ACSSB or FM (see later) in the 1.2GHZ/70cm bands.

Recent advances in telecommunications and the availability of cheap material as by-products of the cellular phone technology makes such a project a reality using block modules in both the transmitter and receiver circuits.

Picosats will be powered by solar cells that will extend from both sides and latch straight with the use of spring-loaded camed pivots. They will offer 10 x 13 cm x 13 cm solar collection area.

In order to face the sun all the time (to guarantee adequate power) Picosats will also have active stabilization with the use of compressed air bottles driving air vents. These vents will be controlled by an on-board computer. As Picosats are expected to be very light, the tiny compressed air bottles (similar to size to mini-gas weld guns) will offer active maintenance of 5 years.

Picosats will have two antennas, one 70 cm transmit and one 1.2GHz receive. The 1.2GHz antenna will be either a 5/8 or a small collinear with gain.

Picosats will be equal in all respects to one another, the idea being that we could have an easier process of building them. They will share frequencies, transponder and circuits. The only difference will be their identifiers.

Picosats will offer the ability to be used with an 2Watt HT using a simple antenna (rubber duck) - hey this is what Iridium is all about remember?). They will be launched in such a way as to be separated by a certain amount of minutes in polar orbits. The idea being that if you start using the first one, you should be able to continue to talk without interruption.

The initial launch calls for 16 Picosats plus 2 in-orbit spares.

Command of the picosats is to be via a normal 1200AFSK packet system with feedback provided in down link frequencies. Every picosat will have a beacon offering cw telemetry.

82

Picosats will offer at least 5 watt output power in the appropriate band. It is expected that with the availability of these easy-to-use birds and the expanded market they will create, manufacturers will build specific dual band USB/HTs(Kenwood has said yes to the idea).

1.1 What is a Picosat?

A picosat is a small (6 inch cube) satellite which offers simple circuits, active stabilization and low mass. It is a satellite that will be placed in a LEO orbit and be able to offer transponder use to the user.

The satellite is composed of the following elements:
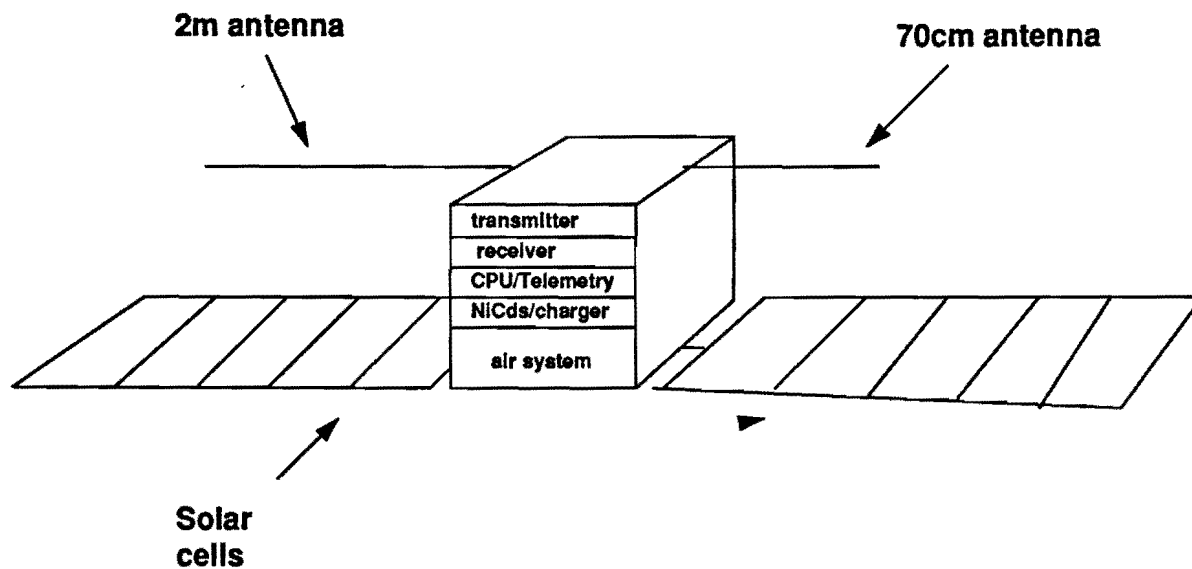
- It has two solar panel areas for gathering solar power
- It has 5 trays which hold the transmitter, receiver, control/control rx, battery and stabilization systems
- It has two antennas for receiving and transmitting
- In closed shape it is exactly 15cm by 15cm by 15cm

The satellite will use the 70cm and 1.2GHz bands. It will use a 100KHz/200KHz bandwidth to offer a minimum of 38/58 voice conversations in SSB or 9/19 conversations in FM.

The power output will be a maximum of 12 watts. The solar cells will produce a maximum of 14.4 watts of power. They will have the a of 5 x 13cm x 13 cm.

When the spacecraft is launched the configuration looks as follows:

spring loaded

70cm antenna

1.2GHz ant.

spring
loaded
pivot
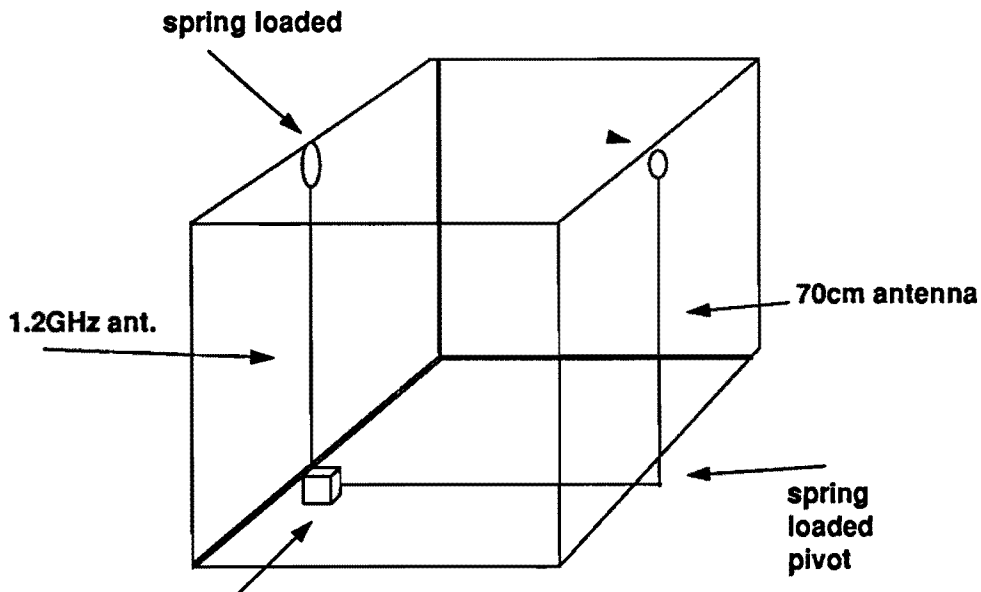
Upon ground command, the antennas will unfold and the solar cells will open.

1.2 The reason for Picosats

There is nothing like a picosat. All of the birds today are experimenter spacecraft. They need antennas, pointing systems, power and a good ear (or modem).

You can say that Picosats are to satellites, what HTs are to amateur radio.

They are extremely easy to use spacecraft. Pick up your HT, tune to the frequency and speak. That's all there is to it. You don't need to know when a bird will pass overhead. You don't need to have a special antenna. You don't need lots of power. You don't need complex systems. You communicate from anywhere on this planet; in the jungle; on the sea, on the poles, in the cities, in the fields and up the mountains. You can build gateway stations to repeat into satellite sub-bands from any other frequency (2 meters for example). You can use Picosats to call for help from anywhere. As long as someone is in the footprint, the world opens with Picosats. They offer what other amateur radio satellites don't offer: practicality.

The reasons are many:
- Cost: a Picosat costs little money. A maximum of $30,000 for the cost of the satellite.
- Launch: Real easy. How hard is it to launch a cube the size of a rubic's cube?
- Easy of use: cant say that often enough

1.3 Can it be done?

There is absolutely nothing difficult about building and launching a Picosat. After all it is a simple
84

'repeater' certified for space use. That's it.

Everything about these birds will be done for simplicity. From the design and circuits to the building; they will all be done from techniques used over and over again. This is not a spacecraft to see whether a new process works or not; it is a bird for continuous usage build with systems that have been certified over and over.

Thus, the guarantee of success will be high. And guarantees are what we are looking for in this program.

The picosats will be built and integrated at Stanford University's Satellite lab, overlooked by Professor Bob Twiggs. Stanford has the experience and knowledge to perform this task.

The funds required will be raised from the following sources:
- Corporate participation (see chapter 9)
- Individual funding
- Sales of posters and other items.

The program will raise the required funding within 1-2 years.

That's all fine with the details. But to know whether it can be done or not, you have to look within and ask yourselves this question: 'where do I want amateur radio satellites to go: should they go to a world offering easy of use where hamsats touch everyone, inspire the youth amongst us and offer an incredibly better communications medium or not.'

Myself and all of us involved in the Picosat program firmly believe this. Because if we didn't, Disneyworld, sounds so much better.

2. Mechanical specifications

A picosat satellite is a 15cm per side cube.

2m antenna

70cm antenna

| transmitter |
| receiver |
| CPU/Telemetry |
| NiCds/charger |
| air system |

Solar cells
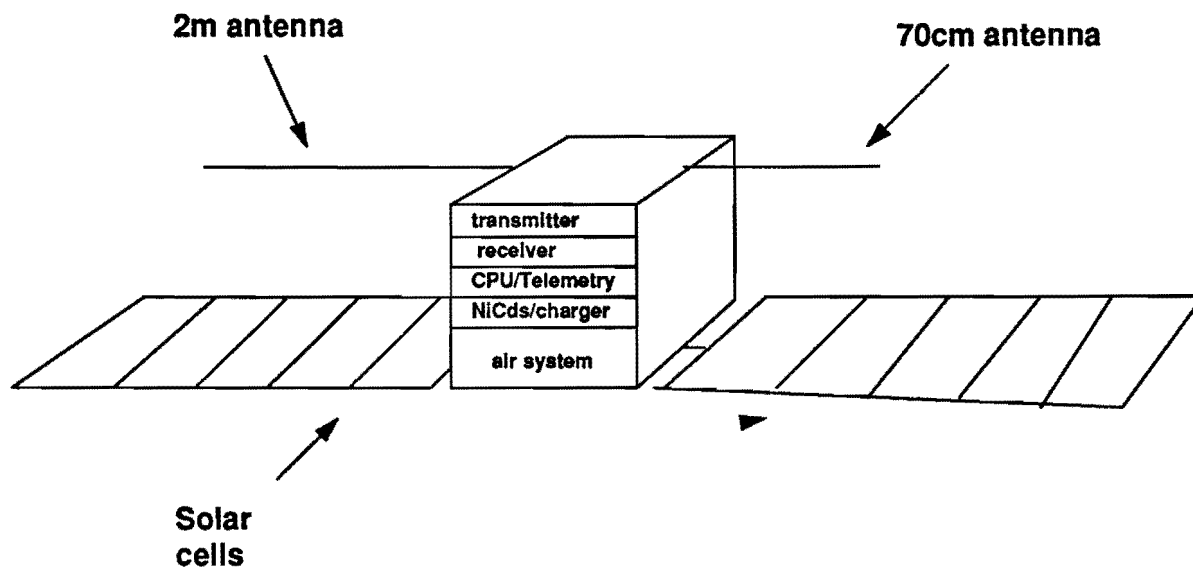
It is build around self standing layers. The top layer is the transmitter. Below is the receiver and then the cpu plus command receiver. Below is the charger/battery circuits and below is the attitude control system. Air distribution conduits are routed through the apex points to the required four vents.

Similar to microsats, each layer fits on the one below thus making a compact yet powerful unit. Dissimilar to Microsats, there is a frame that fits all. The frame also has space to store to solar cells during launch. As the layers fit, signals connect through headed connectors.

header

circuit area
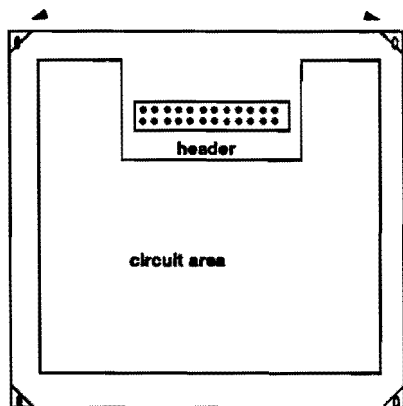
The solar cells are on 10, 13 cm x 13 cm panes that are hinged using spring loaded cammed hinges falling in position. Once they open they click into place. The solar cells are made 5 on a side offering an area of 1690 cm2. They always face the sun.

Measurements:

Picosats
- outside size of 15cm x 15cm x 15cm.
- area for PCBs is 14cm x 9cm (the rest is taken by the folded cells)

Picosats will be actively stabilized using a color system and compressed air in miniature 'small gas welder' size bottles. Due to the small mass of the satellite (less than 5kg) these are expected to last for at least 5 years. The air will be directed using positive stop-gas valves outputting through 4 vents. The entire air and valve mechanism will be placed in the bottom tray.

The air will be used for initial in-orbit rotation and for subsequent movement t replace faulty birds. After the initial orientation, the air will be turned off and the bird will be passively attitude controlled by painting the far side from the sun white and the side facing the sun black.

3. Electrical specifications

3.1 Solar Cells

A picosat satellite will take advantage of solar power and active stabilization.

Maximum electrical power output using 15% efficient solar cells is about 14.4Watts.
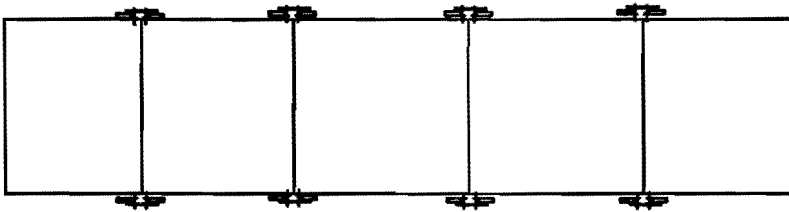
The solar cells will have worst case efficiency of 15%. They will have an area of 1690 cm2 providing 14.4 watts of power. As the birds will always face the sun, this power will be always available.

3.2 Battery support

Picosats will also use of NiCd batteries tried and tested. They will be one NiCd cells holding 8 A at 6V.

The power systems will operate at 6V. The transmitter module will use FET power modules rated at 6Volt. These are mainly used in cellular telephones and will work fine.

Solar cells will not pivot. The satellite will rotate along its long axis (the solar cell axis) so that the sun will always point at 90 degrees to the cells. This will not have a profound effect on the satellite except that the antennas, which will be mounted on the opposite edge to the cells, will slowly point away from the earth and near night time passes offer minimum signal strength (see figure 4).

Sun

Satellite
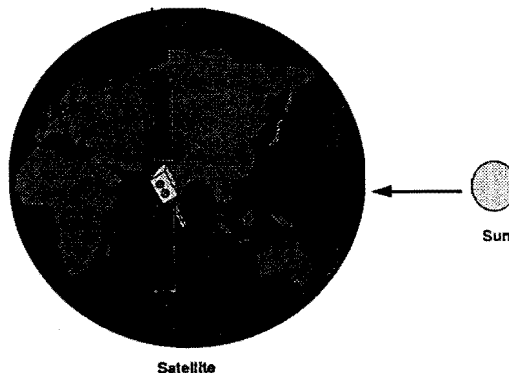
4. Electronic specifications

Picosats are designed to have simplified receive and transmit circuits. One receiver and one transmitter will be included. Picosat will receive on 1.2GHz and transmit on 70cm.

It is expected to use FET power output modules and simplified circuit design. Pass band is expected to be 100KHz/200KHz for Picosat.

Telemetry of the transmitter will be mixed to appear at a band limit area. Telemetry will be simple, CW code, providing only simple information.

A control receiver will receive commands via AFSK packet 1200 bps radio. Replies will via CW radio to the telemetry beacon. All picosats will be individually controllable

The CPU is expected to be a minimum single chip design using 8 bit word length and analogue interfaces.

Interfaces:	8 port D/A using 8 bit resolution
	8 port A/D using 8 bit resolution
	1 serial port for modem interfacing to the packet cmd receiver/ beacon tx
	8KB of RAM minimum
	1KB of RAM maximum
	8 bit of parallel port data I/O
	Watch dog timer

4.1 Transponder types

Picosats will carry passband transponders. These will provide a 100KHz/200KHz passband on the desired frequency. The frequency will be chosen so that it must be available 24 hours a day wherever. As Picosats offer communications at any time of day or night, the passband must be available all the time.

The transponders will be non-inverting, linear translators. This will ensure correct transmission of SSB waveforms. Depending on the users, FM will also be available. However the number of available channels will decrease. In SSB, the passband will be able to carry a maximum of 65 QSOs. In FM, it will carry a maximum of 18 QSOs. Both include guard bands. Please note however, that all of these channels will still have the same power available, ie 14.4 watts maximum, thus each channel will have decreased power. The worst case power calculation means each channel will have an output of 300mw for FM and an average of 250mw for SSB, although allowance must be given due to the fact that all the channels will not be using PEP power at any one time. ERP will take advantage of a 6db antenna gain to give a signal of 12watts worst case (FM) or 1watt SSB.

A spacing should of 4KHz for SSB and 10KHz for FM should in order to avoid splatter and interference.

4.2 FM vs ACSSB vs SSB

The choice of communications medium depends on the users. All of these have advantages and disadvantages.

FM is the best medium. Rigs are available today. However, there is still the problem of Doppler shifting which at the 1.2GHz area is in the order of about 30KHz. The HT will have to be retuned as the QSO progresses.

Amplitude Compandored SSB has been around for years, but no real use has come out of it. Well for this application, it will be necessary to offer ACSSB in order to automatically control the Doppler shift which may make SSB operation difficult.

ACSSB uses a pilot tone 10db down set at 3.1KHz above the carrier. For this use, the pilot carrier will decrease to 12db below the carrier but the frequency will remain the same(+3.1KHz). The carrier will be transmitted by the ground transmitter, and retransmitted by the satellite. The receiver will then lock onto to this carrier to offer automatic Doppler shifting. The pilot tone, which is 12db below will of course use power. This will decrease the amount of power available for the RF, but make Doppler adjustments automatic.

SSB is the final mode. This may require receivers that must automatically tune the birds. Such automatic tuning can easily be done by timed circuits linked to the DOWN and UP buttons on radios. They will still need manual adjustments.

4.3 Doppler shift

At the altitude Picosats will be flying, that is at LEOs, Doppler shifting of frequencies becomes a problem. Perhaps for experienced operators, Doppler shifting is old hat, but for newcomers and to fit the need of Picosats being easy to use, some sort of method must be found to compensate for Doppler shift.

In the Picosat LEO orbit, Doppler shift at 70cm would be about 10KHz and for 1.2GHz would be about 30KHz. This is both a problem for FM and SSB and this is where ACSSB comes into play. In FM mode the problem is not very serious (after al people can retune) but on SSB it is critical.

ACSSB has the pilot tone, which although uses power, can offer automatic adjustment of Doppler shifting.

In case where a setting satellite has a Doppler of say, -30KHz and the rising has +30KHz, some sort of procedure must be found to link the receivers. The best would be for the operator to have a handover time to switch satellites manually.

5. Use of Picosats

Picosats are designed to be really easy to use. Pick up your HT, tune to the right frequency and transmit. That's all!

5.1 Channel Capacity

There is a passband of 200KHz for the use of picosats. This may be commanded from the ground to decrease to 100KHz. The passband will offer linear amplification.

In FM mode:
Channels will be separated 10KHz. starting with +1/2 and ending with n-1/2. The first and last will be guard bands. These guardbands must not be used. Thus there will be 9 FM channels (becoming 19) for use.

In SSB mode:
Channels will be separated by 4KHz, starting at +1 and ending at n-1. This means that we will have either 23 channels or 46 channels. It would be advised that channels are created to use these satellites. The exact technique is difficult because with the Doppler shift, one would need to know where the satellite is to calculate which frequency to use for a specific channel..

Also the user must keep in mind that the receiving frequency will alter by the Doppler shift for the frequency in use.

5.2 Regulations

Similar to all the satellites, Picosats will have to comply with international regulations. Circuits will be on board to control each bird; transmitters will be turned off if necessary, and housekeeping will be done. Command information will thus have to remain classified. The onboard computers will have the possibility of turning the satellites off over specific areas of the Earth.

5.3 Emergency use

Due to their ease of use and 24 hour availability, a typical Picosat will have one or two channels allocated for emergency use when necessary. Such emergency use will be done with the use of PL tones (in FM) or other signalling arrangements in SSB, so that emergency messages will get through irrespective of the current users. This will ensure that emergencies will be handled by the best systems available.

5.4 Footprints

The footprint of the satellite depends on the orbit selected. As we don't have the means to actively select our orbits (apart from some small corrections) there are two footprints possible for Picosats.

SPACE SHUTTLE orbits(about 300 km)
These are low orbits. Disadvantages are extremely high Doppler due to the high speed; advantages are
ease of launch and high power signals. Space shuttle orbits will not allow us continuous coverage (we
would need more than 16 satellites to cover the earth's surface in this case).A typical footprint is shown
below:
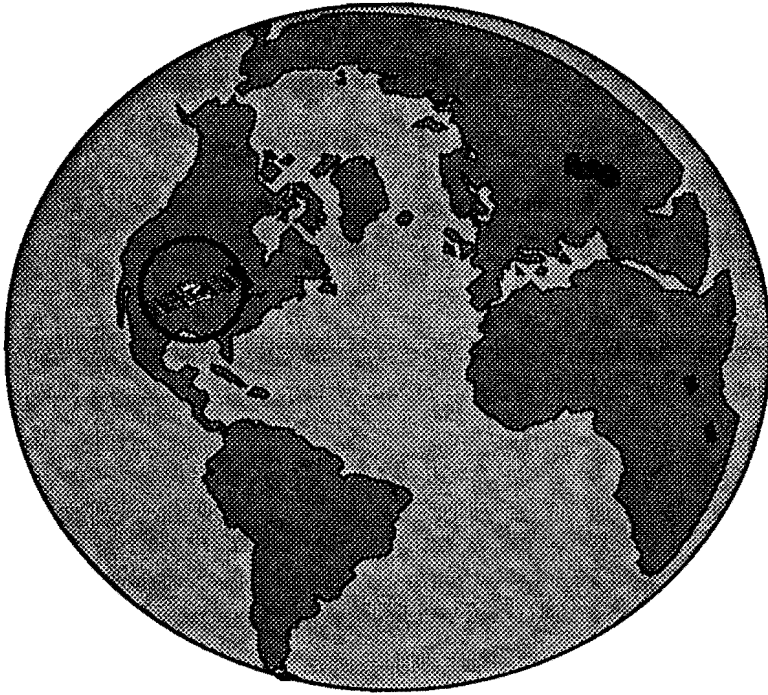
POLAR ORBITER orbits (about 1000km)

These are orbits made by weather satellites and resemble our own microsats. They look as follows:

6. Launch Requirements

Picosats are easy to launch being lightweight with an expected maximum weight of 5 kg.

The antennas and the solar cells are all tied back for launch. The spacecraft looks as follows:

spring loaded

1.2GHz ant.

70 cm antenna

spring
loaded
pivot

Launch configuration

space exaggerated
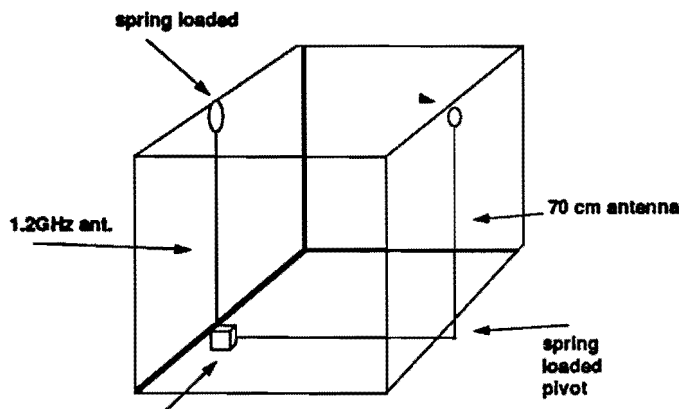
spring loaded pivot
joints
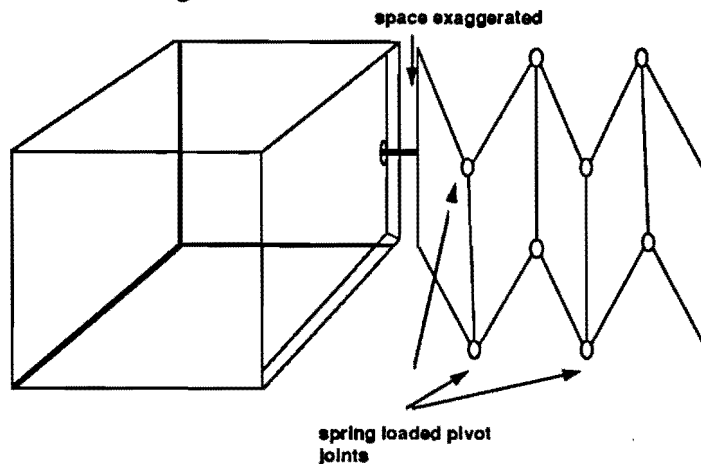
Solar panel detail launch configuration

The picosats will be held together in a spring loaded square contraption. As the lifting device reaches orbit, they will be commanded to eject. Two springs will be more powerful and longer that the other two and the fifth will be very weak (figure 7). They will be ejected so that the axis would point north-south thereby creating a separation of ten minutes between satellites. As soon as they reach correct location they would be stabilized using the onboard jets.
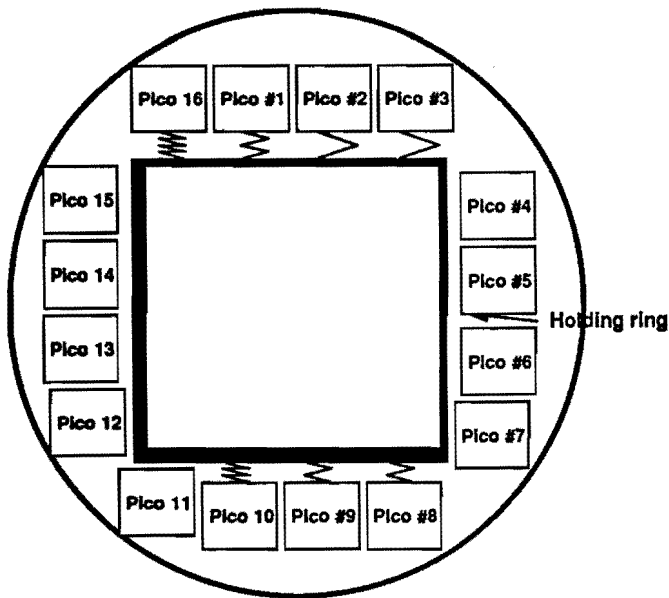
Rocket launch configuration (one possibility)

Launch vehicles include Arianne, the Space Shuttle (it is hoped to launch our first prototype bird in 1996) and the Russian Proton rockets.

7. Manufacture

7.1 Actual design
The actual design of Picosats is undertaken by the Picosat project team. The design includes RF receivers and transmitters, control circuits, battery and attitude systems. The design will use FET RF power transistors to operate at 6V, a simple single CPU chip design (parts donated by AMD), and solar panels similar to the ones used in Microsats.

7.2 Manufacture and integration

It is hoped that Professor Bob Twiggs and his Small satellite laboratory at Stanford University will undertake the integration and mechanical manufacture of these picosats.

It is in both of these areas where we need help. Again let me ask you to sign-up to the picosat mailing list.

8. Funding

As with every project, money is an important element. Most of the money will be for the actual satellite subsystems. Because Picosats are simple satellites, cost will be kept to a minimum. The expected cost of each Picosat will be about $30000.

8.1 Fund raising

There are three methods which will be used for fund raising:
- Individual donations to the Picosat program
- Individual participation to the picosat program
- Corporate participation will also be tax deductible
- Sales of posters, mugs and other paraphenalia.

Individual donations will be accepted graciously to help the program. In fact the only reason for Picosat's existence is Picosats and that's what the money will do. Nothing else. This is an assurance that funds will help the project.

Individual participation will mean that individuals who donate substantial amounts of money (a maximum of 3 people by $10000 each) will get an enscribed plaque on the particular satellite. In addition, the satellite will bear their name.

Corporate participation will mean that companies will donate funds to pay up for the entire satellite. This satellite then will be named after the participating company.

Sales of mugs, posters and other paraphernalia will also raise revenues from a world wide basis.

8.2 Marketing and press relations

Naturally a project such as Picosats deserves a lot of PR. Through a system in existence, press campaigns will be done, both for print and TV/RADIO media on a worldwide basis. This should provide the impetus required. Press campaigns will include interviews with key players, samples of the satellites available and proof (as if we need it) that amateurs can often beat the professionals at their own game.

9. Corporate Participation program

The following information is designed for companies and others who don't know what amateur radio is, or know very little about it.

9.1 Introduction

Have you heard of Intelsat? Or The Astra satellite system? Or Panamsat? I am sure you have heard of these, right? No? Oh well, just imaging the kind of satellite used when you make a phonecall across the Atlantic.

Intelsat, Astra, Panamsat are huge satellite systems, costing more than $200 MILLION each providing telecommunications facilities. They are huge, powerful and, as you have just seen, very expensive.
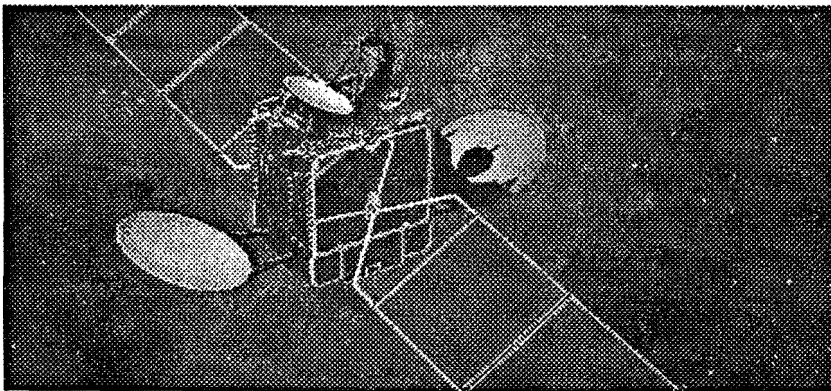
Photo 9.1. A typical Intelsat satellite

Well, just take one of the huge satellites, reduce in size by a factor of 1000, reduce it in cost by a factor of 5000 and you have a PICOSAT, part of the wonderful Picosat System.

Picosats are tiny satellites, 6 inch per side cubes (15 cm) with extendable solar panels, extremely simple, extremely small and very easy to launch and use. Anyone with a small hand held radio can use them. And they can be used anywhere. At any time. Under any conditions.

How? well just remember that 16 of these satellites will orbit the earth therefore there will always be one overhead.

PICOSATs are designed for two reasons:

for Radio Amateur use and

for Emergency communications.

All you need is a small hand held radio and that's it! (photo 9.2).

Photo 9.2. A typical walkie-talkie

PICOSATs are designed for the radio amateur service and as such are not permitted to carry business traffic (that's why it is called Amateur Service). However, their global implications are so great, that any company associated with the program is bound to have visibility from it.

The satellites will be called after the corporate sponsors, i.e. the companies who pay for them, and they will be called IBM-SAT, or BULL-SAT or SCITEX-SAT and so on. And the cost, is absolutely minimal. There is no better way to get visibility on a global scale than this; keeping the company name up in space for ever.

This document provides information on the PICOSATs, and offers possible contribution scenarios for your use. Read it and see what a wonderful opportunity PICOSATs are to your company.

9.2 What is a PICOSAT?

You have heard of what is a satellite. PICOSAT is a very small satellite, a maximum of 15 cm or 6 inches per side, weighs a maximum of 5 kilograms, has collapsible solar panels, and contains a receiver and a transmitter. Compare that to the usual satellites, that are about 5 meters long, weigh tons and cost millions.

Picosats contain the following elements:

A set of collapsible solar panels
An active gas stabilization system to keep the cells pointed to the sun
A transmitter and a receiver.
A controlling system.
A set of rechargeable batteries
Active stabilization based on compressed air

All in a small cube

The Picosat is designed to receive radio communications in the 1.2GHz band (1260-1300MHz) and transmit in the 70cm band (430MHz-440MHz). It will have a 5 watt power output, offering easy use from a small handheld radio.

Picosats will be constructed by the Stanford University's small satellite laboratory in California, USA.

9.3 How does it work

Well, just imagine that a Picosat is just flying overhead, just like the Space Shuttle. Well, as it flies, it moves over the area you are standing and then 'falls' below the horizon. While it flies overhead, you, a licensed radio amateur communicates with it, speaking to other radio amateurs. Then it sets. You would think that your communications would stop, right? Well no. And this is the beauty of the Picosat system. Because as one Picosat sets, another one rises, so that you will keep communicating continually. The amount of time you communicate will depend on how many there are (the more the better) and how high up they are (the higher, the greater coverage but the lower the signal).

Picosats will be launched by a launch vehicle so that many of them will be launched at the same time. Each one will precede the other by between 10 and 20 minutes.

This is a new way of communications, never achieved before at incredible value. Using resources of radio amateurs, their expert knowledge and techniques of radio communications, Picosats will cost a tiny fraction of the huge monsters. In fact this is the future for the space program.

9.4 What is Amateur Radio?

98

Amateur radio is a service that has been agreed by all the countries of the world and which allows individuals to communicate with each other, and selected third parties, under the auspices of radio experimentation, community communications or both.

Amateur radio is a hobby which is followed by about 6 million enthusiasts in the world. It follows seven principles:

1: Recognition and enhancement of the value of the amateur service to the public as a voluntary, non commercial communications service, particularly with respect to providing emergency communications.

Photo 9.3. Amateur radio helping earthquake victims

2: Continuation and extension of the amateur's proven ability to contribute to the advancement of radio communications.

3: Encouragement and improvement of the amateur service through rules which provide for skills in both the communications and the technical phases of the radio amateur's art.

4: Expansion of the existing skill base with the amateur radio service: trained operators, technicians, communicators and electronic experts.

5: Continuation and extension of international goodwill.

6: Improvement of education through amateur radio.

Photo 9.4. Amateur Radio in Schools

7: Making Amateur radio a hobby for the future

Amateur radio's important contribution to the world is the availability of emergency services irrespective whether communications infrastructure is in place or not. This has been demonstrated over and over again all over the world.

When these requirements are joined with the facilities of the Picosat system, you see how wonderful the result is.

Twenty-four hours per day, communication is available, irrespective of the infrastructure, conditions and local people. Using a small hand held walkie-talkie, people have access to the world.

9.5 What is Corporate participation of Picosats?

In amateur radio circles, there are currently about 27 satellites that have been launched. These are called various names, such OSCAR(Orbiting Satellite Carrying Amateur Radio), DOVE, LUSAT and so on. All amateur satellites have numeric designations so DOVE is also Oscar-17, Webersat is Oscar-18 and so on.

In the picosat era, we are changing the naming to reflect the contributor. They will called according to the individual contributor's wishes. If the contributor is IBM Corporation, the Picosat may be called

IBM-SAT, if the contributor is, say SCITEX Corporation, the Picosat will be called SCITEX-SAT and so on.

Great, right?

Well that's not all.

Because as part of the contribution program, the companies will additionally get:

Name recognition in the press for their satellites.
Recognition in TV interviews, the media, and printed press.

But that's not all.

They will also get their corporate name in space, and satellite nomenclature will also reflect the corporate name.

There is even more.

They will also get name recognition by the simple fact that satellites will be called by their names, i.e. IBM-SAT, SCITEX SAT etc., thereby creating a multiplier effect in the world's radio amateur community.

Don't you think this is incredible value?

And finally, companies will also contribute to a project that offers emergency communications anywhere on this globe, using simple walkie-talkie equipment to help people in need, using radio amateurs. Now this is a good cause.

But the best news is yet to come!

9.6 The Cost of contributing to a Picosat.

Picosats costs millions, or billions, <u>less</u> than full size satellites. They give incredible 'bang' for the 'buck.' And this is where the power of corporate contribution comes into play.

If a company had to pay for the kind of coverage envisaged, the amount would easily run into millions. Just add the targeted coverage, the cost of air time, the cost of sponsoring major events and soon and you see how quickly millions add up.

However the cost of contribution for a single picosat is in the region of about $30000- $35,000 ! This is excellent value for money.

But we have kept the best for last: *All contributions towards the Picosat Program are tax deductible*

under (in the US) IRS 501(c)(3) company rules. You would never get such an opportunity anywhere else!

Just think. Your company has some money left over. They can pay it towards taxes or they can do the noble thing and contribute a Picosat Satellite, with their name on it, that could save lives!

A once-in-a lifetime opportunity!

9.7 Summary

The facts have been presented. Please help us start a satellite project that gives your company name power in conjunction with tax deductible contribution and with a good cause behind it.

All the funds will go towards the satellites and none will be used to pay salaries. In fact there is no salaries.

Both these companies are composed of dedicated volunteers with one aim; the successful creation and launch of these 16 satellites.

We are asking for contribution and we provide much more: name, a good cause, and all, tax deductible.

Please note: Picosat includes a group of volunteer radio amateur operators with many years of combined satellite expertise. Some of us are satellite designers, others are politicians, others are business experts. We come from the four corners of the world. We are putting our expertise and knowledge to good use with this program.

We do not run a flashy marketing operation; our apologies in advance.

10. Project participants (from the picosat mailing list in no particular order)

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<center>AMSAT NET VIA COMMERCIAL SATELLITE</center>

by Bruce Paige, KK5DO
AMSAT Life Member 2117

Internet: KK5DO@AMSAT.ORG

Voice: 713-933-8385 x201

The Houston AMSAT Net originates in Houston every Tuesday at 10 p.m.
local time on the 147.10 repeater and is heard coast-to-coast and in
Canada over local repeaters.

How did this small group of 4 people pull off such a feat? It all began
in January, 1994 when Craig Davidson, WD5BDX, the owner and trustee of
the repeater decided to try something new. He made arrangments with the
Omega Radio Network to donate the time for our local net to be
retransmitted over Galaxy 3, Transponder 17 on a 5.8Mhz Audio
Subcarrier. This also happens to be one of the secondary audio
subcarriers of the Shop At Home Channel.

It turned out that a few repeater operators in Alaska and New England
recievied the transmission and retransmitted our net over their local
repeaters. That was the beginning of something new, something different,
a way to communicate over a wide area and bridge two communication
arenas that of amateur satellite radio with that of commercial satellite
communications.

In February 1, 1995, Craig no longer could provide the link to the
satellite due to a family move to an area with antenna restrictions.
Bruce, KK5DO and Andy, WA5ZIB quickly moved to provide the link and that
week we set up a phone patch and tested our equipment. In three days, we
were up and running ready to continue the link.

Omega Radio Network moved to Telstar 302, Transponder 21, 5.8Mhz Audio
and we were once again on the air. April 25, 1995 was our last link with
Omega Radio Network as they were ceasing operation. During the next
three weeks, we provided our net by phone to the Netarc Net with KK5DO
and George, K1MON and also to Vern, WA0RCR (1.860 Mhz).

On May 23, 1995 Bruce, KK5DO, secured permission on the new Tech Talk
Network to continue providing our net over Telstar 302. The word went
out and most of the repeaters carrying our net were back on line.

Here is the technical aspect of the net. Andy, WA5ZIB acts as net
control in Houston. He transmits on the 147.10 repeater. Bruce, KK5DO
receives the net from the repeater and through a phone patch, has the
call go to the uplinking station and then to the satellite. The
commercial satellite using a geo-stationary orbit transmits over North
America where hams and non-hams with TVRO dishes can receive the net.
Hams with TVRO dishes and receivers then link to their 2m or 70cm radio
and retransmit the net over their local repeaters.

Over the second phone line special guests such as Bill Tynan, W3XO and
Keith Pugh, W5IU have been able to speak about AMSAT and Phase 3D. I
also use the second phone line for access to internet.

Part of our experimenting has been taking check-ins live on internet in
two places. We can be found on the IRC (Internet Relay Chat),
manhattan.ks.us.undernet.org in the 'amsat' channel. Also via Telnet at
hydra.carleton.ca 3600 in channel '302'. This has proven to be very
popular places to be during our net. Those with internet access check in

and pass the names of others in their area that are listening to the net. We can then announce those check-ins over the net.

Another experiment that has been tried successfully is the use of IPHONE (Internet Phone). This is the ability to actually talk over the internet as if you were on a phone. Both parties must be running IPHONE software and have sound cards and mics on their computers. I then hook the output from my computer to the input of the radio and everyone on the net can listen to the person talking to me over internet.

Our net is now carried live on such bizarre modes as a 1.2Gig ATV repeater, 1.860 Mhz and over many simplex frequencies where no repeater is available. We also have a cable company in Tulsa, Oklahoma that retransmits the net in their area. There are some 35 repeater operators that spend the time to retransmit the net. We provide a call in phone number for those that would like to check into the net or ask questions.

What makes this net so valuable is that we provide the AMSAT News Service Bulletins, Space News and 'How to' segments. The bulletins are presented by our Net Control, Andy MacAllister, WA5ZIB. The 'How to' segments are done by Bruce Paige, KK5DO as well as the link to the satellite and to the internet.

Check-in and questions are handled by Marty Smith, WD5DZC. Ed, N5EM, our first Net Control checks in and brings ATV information.

To defray the cost of the long distance call which lasts one hour each week, we enlisted the help of Oklahoma Comm Center.

There have been check-ins from Hawaii, Montreal, Toronto, Alaska, Florida, and Maine to name a distant few. As a result of the net, there have been many new Technician's to the hobby that have got on a satellite and made their first contact. There is a lot of excitement and that is evident when the number of repeaters that carry the net continue to grow.

Dana, AJ1R in Tampa, FL has even taken our net one step further. He carries it live and then retransmits it on Wednesday and Thursdays at 7 p.m. He also has taken the segments that I do on 'How to work the Shuttle Missions' and digitizes it on his Macintosh computer. He uses the computer to interrupt his live transmissions during each shuttle mission of NASA Select to interject every 15 minutes the 'How to' segment. There is no way every ham in Tampa would not know on what frequencies to look for the shuttle and how to make either a voice or packet contact.

Craig Davidson started something back in January, 1994 with his initial vision to try something new. Craig and Ed have since become inactive in our regular production. We have now done 70 weeks of our local net for North America. If you say 'It can't be done', someone will find a way to do it. If you say 'Why do it?' We'll say 'cuz'.

So, what's next? .... 73 de Bruce, KK5DO

This is a current list of the repeaters carrying our net.

Houston AMSAT Net --- North America Schedule
Data updated 4/24/95

Originates Live from Houston Tuesdays at 10:00 PM Central Time on 147.100
Carried Live on Telstar 302, Transponder 21, 5.8Mhz Audio Subcarrier
    Video is the Skyvision Channel

Repeater Trustee & Net Concept: Craig Davidson, WD5BDX
Long Distance Call Sponsor to Telstar 302: Oklahoma Comm Center
Net Control Operator : Andy MacAllister, WA5ZIB
Bridge to Telstar 302: Bruce Paige, KK5DO
Contributing Reports : Bruce Paige, KK5DO - "How To" segment
                Andy MacAllister, WA5ZIB - "Balloons, ATV,& NASA"
                Marty Smith, WD5DZC - Check-In's & Questions

****
Anyone receiving this net has blanket permission to our net over any HAM
frequency they see fit. This net is of a technical nature for those
interested in Satellite, ATV
and balloon launch communications.
****
Satellite Enthusiasts - Want more up to date info on neat stuff???
AMSAT News Bulletins, Space News, NASA news, Hints & Tips on working
satellites and much more. Available every week on the Houston AMSAT
Net.

These repeater operators carry the net live or rebroadcast it at a more
convienent time. If you like the net, let your repeater trustee know.

They go through a lot of trouble to bring you our net so thank them. If
your local repeater does not carry our net, ask the trustee if they
would.

NETARC - New England
WA1PBJ   448.225 - 88.5   Sargents Pur, NH (White Mountains Area)
WA1PBJ   446.575 - 88.5   Boston, MA
KC1HF   448.225 - 88.5   Framingham, MA
WA1PBJ   442.000 + 88.5   Fitchburg, MA
K1MON   442.600 + 88.5   Portland, ME

Southern Wisconsin Repeater Group
AA9AD   53.090   Fort Atkinson, WI
N9KAN   443.400   Madison, WI
KD9UU   443.675   North Freedom, WI

The AJ1R Repeater Network
AJ1R   51.840   Largo, FL
AJ1R   145.230   Largo, FL
AJ1R   147.285   St. Petersburg, FL
AJ1R   442.075   Clearwater Beach, FL
AJ1R   443.625   St. Petersburg, FL

The AJ1R system carries the net live at 11:00 PM eastern time. It is
taped and re-transmitted in its entirety on Wednesday and Thursday
evenings beginning at 7:00 PM eastern time.

Other Repeaters and Frequencies (Alphabetized by State then City)
NL7H   147.000   Anchorage, AK
KL7FZ   444.950   Anchorage, AK
WL7AML   439.250   Kodiak, AK Audio on ATV Repeater
W6VIO   224.080   Pasadena, CA (Pasadena, Los Angeles, North
Orange County Areas)
NO6B   445.450   Sunset Ridge, CA (Pasadena, Los Angeles,
San Bernardino & Orange County Areas)
KM4OP   444.950   Hollywood, Ft. Lauderdale, Miami, FL
KE4TP   145.750   Simplex Ft. Lauderdale, FL
WA4HXZ   146.670   Lakeworth, FL (West Palm Beach Area)
KE4GJC   146.910   Sarasota, FL
WB9YCZ   147.390   Noblesville, IN (N. Indianapolis Area)

107

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KB9BNR    146.550   Simplex        Moline, IL (40 Mile range)
WB9YCZ    444.125                  Noblesville, IN (N. Indianapolis Area)
N0PMZ     146.570   Simplex        Garden City, KS
KA0PQW    223.940                  Chaska, MN  (Minneapolis/St. Paul Area)
WB0BWL    145.210                  Columbia Heights, MN (Minneapolis Area)
WA0RCR      1.860   160 Mtrs       Wentzville, MO
WA0ZOK    146.715                  Horace, ND
WA0ZOK    443.750                  Horace, ND
KB7BY     1.2G ATV  Repeater       Las Vegas, NV
N7ZEV     146.480   Simplex        Las Vegas, NV
N2JEU     146.670                  Canastota, NY
KD8XB     146.805                  Lisbon, OH
W0KIE      88.5 FM                 Tulsa, OK  (Tulsa Cablevision)
WA5YVC    146.760                  Ft. Worth, TX
WD5BDX    147.100                  Houston, TX (Origination Site of Net)
KJ7AZ     449.400                  Rawlins, WY
KB7PLA    147.900                  Riverton, WY
N7ZEF     147.530                  Sinclair, WY
VE6GPS    444.400                  Edmonton, Alberta  Canada
VE3RCK    146.865                  Kitchener, Ontario  Canada
VE3XIX    145.230                  Toronto, Ontario  Canada
VE3XTX    146.730                  Owen Sound, Ontario  Canada
VE3XUU    145.230                  Toronto, Ontario  Canada
```

Compiled by: Marty Smith - WD5DZC & Bruce Paige - KK5DO
Check-in, questions, queries, comments during the net? Call us:
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During the Net you can find us at the following internet locations.

To connect on internet relay chat:
     irc
     /server manhattan.ks.us.undernet.org
     /channel #amsat

To connect on internet telnet:
     telnet hydra.carleton.ca 3600
     at login request   /n CALLSIGN 302

To connect on internet phone:
     use irc vocaltec.com
     look for nickname KK5DO

Please let us know if you are repeating our net so we can add your
repeater to this list.

73's de Marty & Bruce   See ya on the birds.
===
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ARRL OBS, VE & AM   Voice: 713-933-8385 x201

Listen to my EZSATS segment on 'This Week In Amateur Radio' and to the
Houston AMSAT Net - Tuesday Evenings, 10PM CDT on Telstar 302, T21,
5.8MHZ.
===

108

Developing and Utilizing Satellite Gateway Nodes:
A Sysop's Perspective
by
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Abstract

There are a number of significant advantages for developing alternative methods for users to access digital satellites. WA0PTV developed an outstanding means for integrating a PBBS with a satellite station several years ago. This paper explains the benefits and describes what is required to create a Satellite Gateway Node.

Introduction

The increasing interest in digital satellites coincides with the growing numbers of users who have joined the amateur ranks as 'no code' techs. Many of these people came to amateur radio with a digital background and are very interested in packet radio and other forms of digital communications. A natural result is the migration towards digital satellites which offers a number of features that cannot be easily met by 'land line' means--such as downloading satellite imagery and the ability to interact with amateurs outside their borders. Demand for satellite services is increasing.

Technology has also advanced to the point whereby new users can enter the 9600 baud satellite arena more easily than in the past. Manufacturers are starting to provide 9600 capability in their transceivers; high speed modems are cheaper in price than in the past (such as PacComm's NB-9600); and the development of DSP (Digital Signal Processing) modems provides more flexibility (such as the AMSAT-TAPR DSP modem). Additional changes include wide spread dissemination of relatively easy 'mods' for radios such as the FT-736R; the introduction of automatic satellite tracking and Doppler shift tracking devices (such as TAPR's Trakbox, Kiron's SATTRAK IV, and AEA's ST-1); and the ability to track and operate through multiple satellites utilizing software such as WISP, developed by ZL2TPO .

The establishment of a 'base' of expertise has also reduced the risk that new users face when attempting to establish a digital satellite station. The wider use of this technology means that amateurs can more easily gain advice and technical support. Publications such as "The AMSAT-NA Digital Satellite Guide" have been invaluable in getting new stations established.

Future satellites are being developed which will incorporate high speed digital satellite capability. These new satellites include Phase 3D, Sunsat, JAS-2, SEDSAT-1, and Techsat. The shift towards 9600 (and higher) data rates is due in part to technological advancement as well as being more affordable to the user.

The result of lower risk, relatively lower cost, and increasing number of digital satellites is a significant increase in the number of amateurs who daily compete for satellite time. The rapid growth in the number of satellite stations accessing the high speed digital satellites (KO-23, KO-25, and UO-22) has been phenomenal. The demand for such services can be seen by the increasing difficulty in getting into the 'Que'; the number of new call signs that are attempting to upload and download files, and the high volume of file transactions that occur. Even when additional capacity is launched, these resources are quickly saturated. The use of automated ground stations means that every user is attempting to transact with the satellite on every pass.

Despite the lower costs and technological risks of building digital satellite stations, there are still some compelling factors that must be recognized. First, the total cost of building a satellite station is still not 'cheap.' A user must essentially have a 'phase 3' analog station in order to operate effectively into the digital satellites on a consistent basis. This includes the ability to uplink on 2 meters and download on 70 CM; the ability to automatically track the satellite and compensate for Doppler shift (if unattended operation is desired); and steerable antennas (with preamps). While users have used 'fixed' antennas such as a j-pole, given the amount of competition to get into the Que, steerable arrays are almost a necessity.

Along with the complexity of the radio portion of the digital satellite station, the satellite operator must also develop the computer portion of his station as well. This means installing and configuring software used to store files to/from the satellite, specifying his station characteristics, and conforming to the satellites of interest. Users may utilize various DOS programs (such as PB/PG and WA2N's SATSKED) or Windows based programs (such as WISP). Tracking processes must also be dealt with, whether as separate tracking device (such as SATRAK IV) or PC-Card (such as KC Tracker/Tuner). The user must have sufficient computer power to store files, operate at higher data rates between the TNC and computer, and process files for uploading/downloading.

Why a Satellite Gateway Node?

From a users perspective the decision to 'go into digital satellites' is clearly one which still suggests significant investment in capital, time, and learning to get everything working properly.

From a systems perspective, there are also some significant implications as well. As more digital satellite stations are placed in service, there are corresponding impacts. For example, as more stations attempt to get into the Que, other users find a degrading result as it makes it more difficult to get into the system themselves. More stations are asking for files. More stations are requesting directories. More stations are attempting to uplink data. The satellites can become overloaded despite the efficient 'broadcast protocol' that these satellites are utilizing.

110

The bottom line is that both users and 'The System' can benefit from a process that will allow users to access a given satellite without creating additional ground stations. A Satellite Gateway Node is one mechanism that is capable of offering almost all the advantages of owning a satellite station without the corresponding costs/headaches and reduces potential satellite congestion.

What is a Satellite Gateway Node?

John Hansen, WA0PTV, wrote an article in the May 1993 issue of '73 Magazine which described how a Satellite Gateway Node allows a user with just a basic packet radio connection to a packet bulletin board system (pbbs) to gain access to a high speed digital satellite. The key is to have the pbbs contain a link to a satellite station. John wrote software that provides the necessary automatic interface between these two systems. The system is designed to:

> a) Allow a pbbs user to get a listing of current files on a particular satellite (such as KO-23);
> b) Request specific files from the satellite (Those files addressed to 'ALL' and less than 5K in length are automatically downloaded and placed on the pbbs); and
> c) Upload ASCII (not binary) files to the satellite. Files can be addressed to ALL or to a specific station.

In the case of the WD4ASW Satellite Gateway Node, a KO-23 directory is created twice each day and placed on the pbbs at 1200 and 0001. The directory is addressed to KO23DR (DR for directory) from WD4ASW and lists the current files on the satellite. The directory lists for each file on KO-23 the file number, size of the file, the to/from address, type of file (ASCII or binary), the date when the file was placed on the satellite, the filename and subject of the file. A portion of a KO23DR directory listing is shown in Exhibit 1.

Once the user decides which messages should be downloaded, a message is sent by the user to KO23MK@KO23MK (MK for 'mark for downloading') with each satellite file number requested listed on a separate line. The system then checks to see if that file was downloaded previously (but not placed on the pbbs) and retrieves it immediately if available. Otherwise, it is designated for downloading on the next pass. Once downloaded, it is passed to the pbbs where it is placed as a message addressed to the individual requesting that particular file. If the file is ASCII, the message is placed on the PBBS and the text contains information pertaining to the message such as originator (YV6BHP), Destination (WD4ASW),and File Number (16b91) as well as actual content. If the file is binary, it is placed in the \F6FBB\USERS\YAPP subdirectory and a message is placed on the pbbs alerting the recipient that the binary file is available for downloading from the pbbs utilizing YAPP protocol.

A reprint of a message placed on the WD4ASW PBBS is shown in Exhibit 2.

The user can upload a ASCII file by addressing the message to the addressee @ KO23UP (UP for uplink). Thus, a message to N1PXB could be sent by a satellite gateway node user by addressing it to N1PXB @ KO23UP. ('All' is also an acceptable address for disseminating to all satellite users.) The user then enters a subject and finally his message content just as would be done for a

terrestrial message.

From the satellite's perspective, the uploading station is the originator, not the satellite gateway node. Consequently, the file listing on KO-23 will contain the callsign of the user, not WD4ASW. For example, a message to N1PXB from N1NFC (a 'regular' on the WD4ASW Satellite Gateway Node) will list N1NFC in the 'from' column of the satellite directory (though WD4ASW will be shown in the Que as the uploading station).

Once a user uploads a message, the satellite gateway node now recognizes that individual as a satellite user. Consequently, any future message that is sent via KO-23 to that person will be automatically downloaded and placed on the pbbs for review. The user does not have to scan the KO23DR file listing to find messages addressed to him/her. The system will maintain a base of 24 users whose mail will be downloaded automatically. In the event of additional users who upload, the oldest user listed will be bumped. My experience is that 24 is more than adequate to support regular users.

Because standard pbbs software is utilized, users will be familiar with the standard commands that they've encountered with 'landlocked' bulletin boards. For example, to respond to a message addressed to 'ALL', the user can use the 'SR' command (send response) and the routing back to the originator via KO-23 will be automatically plugged into the message. The use of pbbs software also allows linking of the gateway node to other systems. For example, there is a rose connection to WD4ASW so that users can easily connect to the gateway over existing paths. Users in Gainesville, FL can connect to the gateway by using the command 'C WD4ASW via KD4SR-5 904026.' While not implemented at WD4ASW, sysops could also automatically transfer requested files or messages back to the user's home pbbs.

Comparing Satellite Gateway Nodes to N7HPR's Web Site

Steve Bible, N7HPR, has done a marvelous job of creating a world wide web site which allows users to connect to his system via Internet. His system allows users to view directories and review files of three satellites (UO-22, KO-23, and KO-25). The web site offers an opportunity for people curious about digital satellites to get a taste of digital satellites. The key differences that I see between a Satellite Gateway Node and a Web Site function are these:

a) The Web Site allows review of directories and files from three satellites; the WD4ASW Satellite Gateway Node handles only one satellite automatically.

b) The Web Site allows users to review downloaded files only; it doesn't allow users to request files not already downloaded. The Gateway Node does allow users to request specific files.

c) The Web Site currently handles ASCII files only (not binary). The Gateway Node can handle both ASCII and binary files.

d) The Web Site does not allow users to upload files; The Gateway node allows

uploading of ASCII files.

e) The Web Site allows anyone with Web capability to review the files; The Gateway Node requires an amateur license since connection is through packet radio or via a modem with password protection (non-registered users via modem have read privileges only).

f) The web site has the capability of handling images easily; the gateway node doesn't normally download images automatically.

g) The Web Site typically has telemetry files; Satellite Gateways do not.

h) Use of a web site requires knowledge of web procedures, installation of a web browser, have Internet access, and have associated equipment (such as a high speed modem). Depending upon circumstance, Web access may not be cheap (particularly if a major service provider is utilized). Satellite Gateway access is 'free' via packet radio or relatively low cost via long distance telephone. Standard modem communication software (such as Procomm or HyperACCESS) can be used. I often connect using a HP-200 Palmtop utilizing the built-in communications program.

I) From a user's perspective, the Web Site provides a 'glass window' view of digital satellites--one can take advantage of what is available, but cannot manipulate the system to get items not currently available nor respond via the web site. The Satellite Gateway Node offers almost as much flexibility as owning a satellite station (The exception being that binary files cannot be uploaded--and that is because the sysop is still responsible for what passes through his gateway).

Benefits of Operating a Gateway Node

One of the reasons for writing this article is to encourage existing satellite users to consider modifying their existing systems to include the Gateway Node capability so that others can take advantage of satellites. Fully automated stations are operating 24 hours per day for essentially one user (the owner). I have found great satisfaction in making available to others what my system is providing to me. It means providing a 'public service' with relatively little effort and increases both the availability and publicity of satellites to the amateur radio community of the 'Florida First Coast.' For new amateurs or those just starting to develop an interest in satellites, it provides a low risk method for seeing for themselves what digital satellites are all about without the frustration and cost of developing their own satellite stations.

Amateur awareness of AMSAT and the satellite program can also result from providing a local satellite gateway node. The availability of a gateway node increases support for the satellite program by making it easy for people to see what is happening in the satellite arena and improves our chances of gaining further enthusiasts.

An additional benefit from a sysop perspective is that I have found it much easier to use KO-23 via the pbbs process than attempting to deal with PB/PG and associated files directly. I simply switch to the pbbs window and retrieve messages, request files, and upload as any user would do. Of course, being the sysop means quicker response and I can scan the PB directory if I want to review the satellite side of the system.

From a utilization perspective, it makes more sense to have one full time dedicated satellite station serving multiple users than having multiple users each having their own satellite capability. When uploading for example, files from several originators are handled sequentially without competing for satellite time. Downloads are done only once and are accessible to all users (as the term 'Node' suggests). Only one station is dedicated full-time; other satellite stations no longer have to be running simultaneously which reduces equipment wear and tear and allows equipment to used for other purposes (such as analog satellites).

How to Construct a Satellite Gateway Node

Assuming that a digital satellite station is currently operational, the following additional requirements are necessary for construction of a gateway node:

a) Terrestrial PBBS software. I use F6FBB version 5.15b; WA0PTV's software will also work with AA4RE.

b) Multitasking software. I use DESQVIEW. I run the pbbs software in one window and satellite software in another window.

c) Gateway node software: WA0PTV has made available in the past this software from him. By the time this paper is published, it should be available on the FTP.AMSAT.ORG site along with documentation.

d) Satellite Software: WA0PTV's software interfaces with PB, PG, and associated files. As far as I know, it is not compatible with WISP. Consequently, it is normally used with a single satellite (I use KO-23). The loss of automatic multiple satellite capability is not that significant since it appears that most files are uploaded to both KO-25 and KO-23. One can also manually switch satellites if desired.

f) Terrestrial PBBS communications equipment: VHF and/or UHF radio, antenna, and associated equipment. A modem for telephone connection may also be used.

The most challenging part to me in developing my Satellite Gateway Node was to configure the pbbs software and become proficient as a Sysop. I was fortunate in having a local packet 'guru' assist me with the pbbs installation and get the packet bulletin board functioning properly. I then installed the WA0PTV software, modified various 'system' files in F6FBB, and started the Gateway Node. Later I added a modem (at 2400 baud and later upgraded to 14400).

Being a Sysop also means working with individuals who are interested in using your system as well as working with others to create appropriate links. In the case of WD4ASW, I have worked with local ROSE Network personnel (such as N4KOX) so that stations can easily connect to the satellite gateway node via existing systems. This allows N1NFC, in Brunswick, GA to send messages via KO-23 and allows me to remote connect to the BBS when I'm near Gainesville, FL (about 70 miles away).

Gateway Usage

The number of active users of satellite gateways has remained fairly small. There about 8 amateurs who are regular users of WD4ASW, though a much higher number have logged onto the system and explored what is available. Users typically browse the directory, read the ALL files that are automatically placed on the pbbs, request files for review, and do limited uploading. Indeed, the biggest surprise to me is that most users are more interested in 'reading the mail' than sending files. Those that do send files usually send relatively small files in response to an ALL message. My experience suggests that the addition of a satellite gateway to an existing digital station provides two benefits: 1) It reduces the need for individual satellite station sites which means a reduction in the amount of linking to the satellite; and 2) It increases the number of users who can benefit from access to the digital satellites without materially increasing the amount of traffic to the satellite. The net result is increased utilization of both the satellite station that is configured as a satellite gateway node and the satellite itself.

I do not forward any traffic to any other pbbs. This policy ensures that messages on KO-23 addressed to ALL that are meant for the satellite community are not forwarded to terrestrial systems. It also avoids inadvertent duplication of files that are sent via normal channels, such as AMSAT News Service, Keplerian Data, Space News, etc. Finally, it keeps a clean distinction between getting on a satellite in order to interface with the satellite users versus attempting to forward messages via satellite to those who are not satellite users themselves. I explain to users that getting on KO-23 is a means of communicating only with those who get on the 'orbiting BBS' themselves.

The WD4ASW Satellite Gateway Node Configuration

The WD4ASW Satellite Gateway Node has been in operation since early 1993. Users are encouraged to 'connect' one of two ways: a) If in North Florida, connect via the Rose Network (C WD4ASW via XXXXXX 904026, where xxxxx is the local rose switch and 904026 is the WD4ASW Rose Address); or b)via Modem. The phone number is 904-396-7114. Standard protocol (N-8-1) and baud rates up to 14400 are supported. Non-registered users have read capability and can leave a message to the Sysop. Registered users have full access once a password arrangement is made.

New users are encouraged to get the 'information' file by typing 'I' at the prompt. This file provides complete instructions on how to read directories, access files, and upload files.

The WD4ASW satellite gateway computer system consists of a 486/33 DX machine with 8 MB

RAM, 180 MB hard drive, 14400 internal modem, Pac-Comm NB-9600 TNC for satellite work, a Pac-Comm TNC-200 for the PBBS, MSDOS 6.2 (no Windows), DESQview V2.3 Multitasking Software, F6FBB V5.15b PBBS software, WA0PTV Satellite Gateway Node Software v2.0, and PB/PG satellite software (and associated files such as PKZIP, LHA, etc.). A Yaesu FT-4700 dual band radio is used to provide PBBS access. Local amateurs can connect directly on 145.61 MHZ and the system is also setup for duplex operation to the Rose Switch using two meters on transmit and 70 CM on receive.

Other Satellite Gateways

I placed a message on KO-23 and AMSAT-BB in mid-July asking for information pertaining to existing Satellite Gateway Nodes. Based upon that survey and other input, it appears that the only other Satellite Gateway Nodes in North America are W1GQR near Portland, ME and VE3GKG in Kenora, Ontario. David Finn, W1GQR, had his Gateway in operation for over a year prior to developing some problems in April 1995. He expects to be back in operation by October 1995. Contact Dave at 207-926-4590 for more information. Gary Kern, VE3GKG, provides a gateway service in Northwestern Ontario. His system provides coverage for two additional BBS's: VE3JJV and VE3EEX.

The only other Gateway response I've received is from XQ2FOD in La Serena, Chile. His Gateway has seen very limited use by other Amateurs. Manfred, XQ2FOD utilizes the system primarily for his own benefit (he accesses the satgate remotely) just as I have found it convenient to check with my system when out-of-town.

Several stations in Wales, Venezuela, and Oman forwarded messages to me via KO-23 expressing interest in Satellite Gateway Nodes as well. These amateurs have all indicated the desire to develop a means so that their local packet friends can also learn about satellite operations.

Summary

The utilization of a Satellite Gateway Node offers significant advantages to both the existing satellite user community as well as individuals who have yet to invest in digital satellite stations. The rapid increase in demand for digital satellite services suggests that an infrastructure of satellite gateway nodes provides an effective alternative to having each potential user install their own digital satellite station. The ability to support a user base provides an opportunity to serve a local community without a corresponding increase in satellite usage. The use of a 'Node' concept improves productivity. Utilization of existing digital station assets is increased by distributing available files without additional satellite time. Interest in AMSAT is increased as amateurs are made aware of digital satellites.

Existing digital satellite stations are encouraged to consider whether they would like to support gateway operations in their area. Amateurs are invited to give the gateway node a try by dialing 904-396-7114 and setting their modems to No parity, 8 data bits, and 1 stop bit (N-8-1). Persons who are interested in further information on satellite gateway nodes should contact the author.

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Exhibit 1
Portion of a KO23DR Satellite Directory

KitSat 23 Directory

Msg#	Size	To	From	T	Date	Filename	Subject
17351	539	VE3BDR	GI0IJB	A	08/26	GI0IJB53.MSG	Re: Over run errors
1734a	394	EA1IW	EB3DXD	A	08/26	EB3DXD27.MSG	Ya la tengo
17346	1519	EA5XE	EA5DOM	A	08/26	jose26.lzh RIG	etc
17354	964	DL1CR	DL1MAC	A	08/26	DL1MAC17.MSG	icsdoa
17357	470	NS1Z	AA1AQ	A	08/26	AA1AQ68.MSG	QSL
17358	1306	W0TUP	N0IYN	A	08/26	N0IYN87.MSG	sleep
1735c	751	XQ2FOD	DL3DA	A	08/26	181430.msg	Your question about u
17355	1259	EA1IW	EA5DOM	A	08/26	ealiw26.ago	U-tomatizacion
17366	489	VE4LU	7J1ALV	A	08/26	7J1ALV10.MSG	No reply
17347	1164	F1SMV	F5NSF	A	08/26	F5NSF44.MSG	RE/WIN 95
17356	2738	ZP6XD	G4STA	A	08/26	G4STA48.ZIP	Re: Dark Frames
1735d	1051	N1PXB	G4STA	A	08/26	G4STA49.ZIP	Re: Logitech Scanner
17331	25703	LX1BBO	N1AIG	B	08/26	ON1AIG26.ZIP	Wisp Driv
1735e	39281	N1PXB	G4STA	B	08/26	G4STA51.ZIP	Scanner soft image

Exhibit 2

Message Request Downloaded to the WD4ASW PBBS

*This satellite file was not addressed to the pbbs user (WD4ASW). It was
downloaded to the pbbs after a message addressed to KO23MK@KO23MK was
sent requesting satellite file 175a5. After processing, the message was placed on
the pbbs addressed to WD4ASW. Note that original routing information and
satellite file number is embedded in the message so that the reader knows which
satellite file was downloaded.*

From   :WA1OMM
To   :WD4ASW
Type/status   :PY
Date/time   :01-SEP 07:14
Bid   :157_KO23
Title   :Re: WISP-WIN95?
Path: !KO23UP!

===
This file was received from KitSat 23
Originator: WA1OMM
Destination: G7UPN VE3AHJ
File Number: 175A5
===

To : G7UPN VE3AHJ
From: WA1OMM
Time: 032451UTC
Date: 31 Aug 1995

Hi Chris,

I've been running WiSP with the KCT Windows driver under Windows 95 for several
months quite successfully. True, you must do your calibration and so on under
Windows 3.1, but once that is accomplished it is only a matter of copying the kctdrv.ini
file to the C:\WINDOWS directory and the kctt.drv file to the C:\WINDOWS\SYSTEM
directory.

****
| 73 de Paul, WA1OMM KO-23<->KO-25 Nashua, New Hampshire USA |
| Internet: paulm@ultranet.com Packet: WA1OMM@KB4N.NH.USA.NOAM |
****

APRtrack, A Program for Determining the Locations of Ground Stations and Spacecraft

by Bob Bruninga WB4APR

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Glen Burnie, MD 21031

APRtrak provides a mechanism for plotting the positions of stations and objects world wide based on both lat/long and gridsquare. It evolved from the APRS (Automatic Packet Reporting System) software which is a packet program for tracking mobiles using GPS units interfaced to standard AX.25 packet radios. The objective of APRtrak is to provide this same tracking and plotting capability for Spacecraft and satellite ground stations. Not only does APRtrak satisfy the inherent curiosity that all amateur radio operators have about the locations of other stations, but it also helps newcomers to radio visualize the three dimensional and geographic aspects of satellite communications.

Figure 1

APRS display of simulated track of Space Shuttle across U.S. sending its GPS position every two minutes. All stations, beaconing their LAT/LON that were digipeated by the Shuttle SAREX equipment, show up in real time. Callsigns have been suppressed to keep picture uncluttered.

APRtrak is designed to extract the most useful information for the largest number of users from the minimum number of packets. In this respect, it is unlike other packet programs, because it does not concentrate on the exchange of message text, but on position data. APRtrak avoids the overhead and complexity of a connected link by using the AX.25 unnumbered information (UI) packets. This mode is called UNPROTO for un-protocol packets. These packets are like beacons to everyone on frequency, instead of being addressed to individual stations. APRS scans these UI packets looking for position data or other useful information in every packet, and only needs one valid packet to plot a position.

THE SHUTTLE AMATEUR RADIO EXPERIMENT (SAREX):

The original SAREX packet robot was designed in the mid 1980's when most stations were still using dumb terminals with their TNC's. The robot provided unique serial numbers to each station that connected with the shuttle, but five successful and successive packets were required for
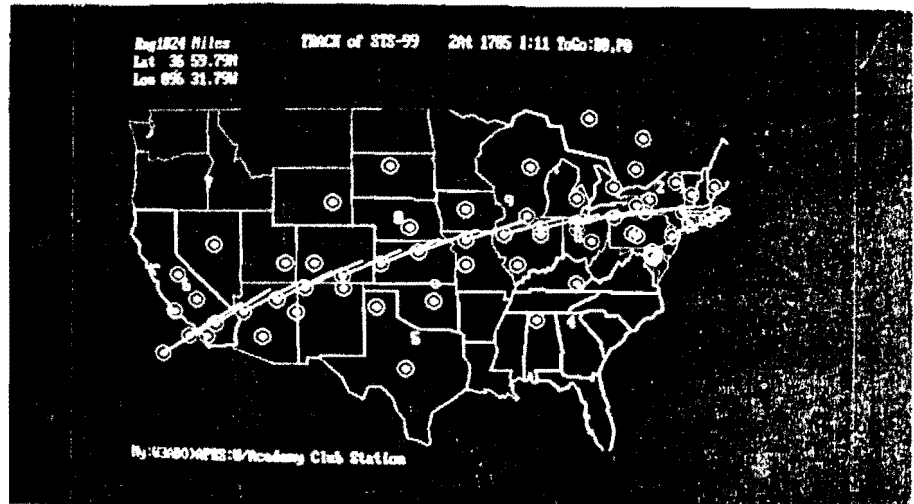
success. Although hundreds of stations were successful, more than three times as many showed up in the HEARD log as having at least gotten one CONNECT-REQUEST packet through. Thousands more had probably tried.

APRtrak was designed to take advantage of single packets to not only permit a greater success rate, but also to provide a more visually rewarding image of the spacecraft, orbit, and ground station geometry. Since shorter packets result in success of more stations, the complete position report is compressed into the TO address of all uplinked packets using the Maidenhead Grid Square system. These grid squares are only 6 characters but provide a location anywhere on earth to about the nearest 2 miles. These position reports then are just as short as a CONNECT-REQUESTs, provide much more information, and only require one packet for success!

To demonstrate the effect of having SAREX digipeat these position reports, use the FILE-REPLAY command to replay the SHUTTLE.HST file and watch the contacts appear as the shuttle moves across the country. You may

119

enhance the demonstration by selecting to see only the Shuttle, STS-99, or by turning off CALLS to reduce the clutter of callsigns on the display. Obviously, in this SHUTTLE.hst file, we simulated the Shuttle having its TNC connected to a GPS navigation receiver so that it was also beaconing its position once per minute.

APRtrak DISPLAYS:

Obviously the map is the most important display screen, but APRtrak has several other screens for presenting other information about all packets that it hears as follows:

HELP	- Help screen, lists all commands
LATEST	- Displays the latest UI frame from each station.
POSITIONS	- Displays positions of each station.
MESSAGES	- Shows your incoming and outgoing messages. rate.
BULLETINS	- This screen captures all BULLETINS.
TRAFFIC	- Shows the last 23 lines of messages heard.
ALL LOG	- Time sequenced log of all new beacons/messages.
HEARD LOG	- Number of packets from each station per hour.
DIGIPEATERS	- Displays raw packet headers of other stations.
VIEW	- Displays all packets on a scrolling screen.

STATION TRACKING.

Although APRtrak was designed to track spacecraft and ground station position reports, it can also track any station, fixed or mobile that is transmitting its position via packet using the APRS protocols. Further provision is made for transmitting the location of objects on one station's screen to every one else's screen. This feature can be used by one station to uplink the position of an Arctic polar expedition, or ships at sea for example.

GRID SQUARES: Because of the ambiguity of a grid-square position report, APRS will not display a 4 or 6

digit gridsquare report on map ranges less than 128 and 8 miles respectively. Stations reported in the same grid square are randomly offset to avoid cluttering of callsigns on top of each other in the same gridsquare. The P-list is annotated to indicate that the position is approximate. The big advantage of grid squares is their short length of 6 characters vice seventeen for lat/long.

PROTOCOL - Since the objective of the APRS protocols are the rapid dissemination of real-time information using packet UI frames, a fundamental precept is that old information is less important than new information. All NEW beacons, position reports, messages and display graphics are redundantly transmitted but at a longer and longer repetition rate. Each new beacon is transmitted immediately, then 20 seconds later. After every transmission, the period is doubled. After ten minutes only six packets have been transmitted. From then on, only 1 packet every 10 minutes is transmitted. All transmissions can be turned off using the CONTROLS-XMT command. But a transmission can be forced at any time by hitting the X key. For details on the APRS raw packet formats see the PROTOCOL.txt file.

COMMANDS: In most cases the keyboard is always active awaiting any of the many single key commands. Many commands bring up additional menus on the bottom of the screen. Note that processing of packets on the air is continuous EXCEPT while waiting for the user response to a BOXED prompt. Commands fall in to 3 categories:

SCREENS:

The Space Bar draws the map and the letters; A, B, D, H, L, R, T and V bring up the other 10 displays noted above.

MESSAGES:

R - READ	-	Displays your incoming and outgoing messages
S - Send	-	Sends traffic to a station
E - Erase	-	Erases outgoing traffic lines
K - Kill	-	Kills incoming traffic lines
T - Traffic	-	Message traffic between other stations

DEMONSTRATION FILE: To see how APRtrak can display meaningful packet position reports in a number of different applications, use FILES-LOAD to load the file called 2METERS.BK. This file contains all the local stations on the local APRS frequency in the Washington DC area. To see the tracking of the GPS equipped Army/Navy game football run, load the file named FBALL.BK and

replay the file named FBALL.HST and select to see only FBALL, or CHASE1. To see the Marine Corps marathon event, load MARATHON.BK and replay the MARTHON.HST file. See Details in README.1st.

HOOKING STATIONS: The cursor can be moved to select any station on the map screens using the arrow keys. When near any station symbol, the ENTER key will "hook" the station. Detail information on that station will be displayed on the bottom of the screen. Alternatively, use the + and -keys to step through each station one by one. You may also use the cursor on the P or L-list to hook a station or object. Once hooked, several functions may be performed:

ALL	- A list all beacons from that station.
MOVE	- Move cursor, hit INSert key to move station
DELETE	- Using the D key.
UPLINK	- Uplink the station/object to all other stations
KILL	- kill the object from all displays in the network
ALARM	- You will be alerted if that station ever moves.
TRACK	- Keeps display centered on selected station
#MARK	- Mark stations for individual display.

Pressing the # or * key instead of the SPACE BAR displays only the marked stations.

The hook function also works on the LATEST and POSITION display lists by using the up/down arrow keys. If a position exists, hitting the HOME key will display the map screen with that station centered on the display.

REPLAY: The positions of any moving station can be replayed either from memory or from a file. Tracks are kept in on-line memory until 150 have been saved, and then are saved to a HISTORY file. During REPLAY, use the Calls command to toggle on and off the display of callsigns, and use the HOME and page keys to center and zoom the map display if the mobile station moves off the screen. During replay, use these commands:

C	- ALLsigns on/off
HOME	- Homes map to presently displayed station
SPACE	- Redraws the present map to remove track clutter
F	- Faster. Speeds up playback

G	- Overlays the Civil Air Patrol Search and Rescue grids
M	- Medium replay speed
P	- Pause
S	- Slow. Slows down playback
Q	- Quit playback.
PgUp/PgDn	- Zoom in and out

FILES: All APRtrak files are retained in five different sub-directories of BAKS, LOGS, HSTS, MAPS, SYSTEM and

README. There are several other files used by the system:

MAPLIST.sat - The directory of all map files. APRS uses this file to know what map to use for a given cursor location.

BACKUP .BK - Automatic backup of system every time program is quit. This file is overwritten every time the program is quit. It can be reloaded by simply indicating the letter B for a filename.

MAPFIX .EXE - A program for finding and making maps!

SYSTEM (DIR) - Contains the following required files:

IintTAPR.TNC - Setup cmds for your TNC

InitAEA.TNC - For AEA TNCs

RESTORE.TNC - Commands to restore your TNC

CAPGRIDS.DAT - A file of the Civil Air Patrol Sectional Aeronautical charts

DXCALLS.DAT - Callsign posits database

XXXX.SYS - Numerous brief files for APRS internal screens

APRtrak OPERATIONS:

There are two operating modes for APRtrack. The first mode, or passive mode only transmits your position about once every 10 minutes. This position report is your exact LAT/LONG location and position comments. It allows all stations on frequency within range of each other, to see who else is nearby. The other mode is SPACE mode specifically designed to transmit a minimum length grid-square report via a spacecraft transponder.

In SPACE mode, APRtrak places your GridSquare in the TO address of your TNC by using the UNPROTO command of UNPROTO ATRAK via XXXXX. Where XXXXX is the callsign of the satellite or spacecraft digipeater. If APRtrak sees your packet digipeated by the spacecraft, it will beep several times and display a CONGRATULATIONS message. To improve your chances for getting a packet through the spacecraft, you may force a transmission of your GridSquare BEACON each time your press the XMT-BEACON command. A timer prevents you from sending any more than one packet every 8 seconds. Also in SPACE mode, APRtrak will automatically increase its beacon rate when ever it hears packets from the designated spacecraft digipeater. It does this by resetting the normal decaying BEACON period timers to minimum. This results in several packets over the next few minutes, but, as usual, the period between each packet doubles.

To minimize QRM, any APRtrak station that sees its own BEACON digipeated by the spacecraft will immediately reset its beacon timer to 4 minutes, since there is no need for that station to continue to transmit again until later in the pass to cover a different geographical footprint.

OPERATING TIPS VIA DIGIPEATING SPACECRAFT:

First, be sure that APRS position reporting is being authorized via the particular spacecraft. To have a good chance of being seen via the SPACE digipeater and to minimize unnecessary QRM, use the following procedures. Even under worst case scenarios, APRS stations will still generate fewer packets than other stations attempting to CONNECT to the spacecraft!

* Use OPS-UNPROTO to set the Space DIgipeater callsign.
* Use alt-SETUP-MODES-SPACE to activate the SPACE mode.
* Make your BCN text as short as possible, or none at all.
* Use X command to force a transmission as desired - OR -

* Use alt-SETUP-POSRATE to reset your POSIT period decay timer. APRS will send an immediate packet and then double the period to the next one and so forth. This prevents unattended stations from accidentally cluttering the frequency.

* Use the APRS VIEW screen to VIEW all packets on a full screen

* Use your lowest 2m antenna (preferably on the ground). This minimizes any QRM to your receiver from other local uplink stations, and also minimizes your QRM to them. A ground level antenna should work perfectly well, since it can still see the sky, and the SPACECRAFT is so far away on the horizon and has such high Doppler that you will NOT make it anyway at elevations below 20 degrees or so.

UNATTENDED OPERATION: If you use a low antenna as described above and leave APRS unattended, you will be transmitting only one BCN and POSIT about once every 10 minutes. This is less than one-half of one percent (0.5%) of the number of packets generated by other stations trying to connect to the spacecraft. Of course your chances are similarly diminished, but its only fair for unattended stations not to QRM manned stations. If this idea catches on, then maybe all of those other stations will STOP trying to CONNECT to the spacecraft and join us! That would be a net REDUCTION in MIR/SAREX QRM!

Imagine the fun that the cosmonauts and astronauts will have if they carry a lap-top computer so they can see everyone on their maps!

MicroSat Ground Station Software
For
Linux and X-Windows

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Introduction

The typical radio amateur likes to experiment, making changes to their radio equipment as a means of learning and as a means to improve their station. Obtaining technical information about the equipment is usually fairly easy, even if the equipment is black box commercial gear, as the circuit diagrams and component layouts are readily available. With this kind of information it is fairly easy to locate and make changes to experiment with the equipment. A good example are the changes required to work with 9600 baud digital data.

As more amateur radio modes require computers to operate, or to provide some form of control, it is only natural that the radio amateur would want to experiment with the software. Unfortunately, most software is only released in its object form, making it very difficult for the experimenter to learn about how it works and/or try to improve it without starting from scratch.

From the first launch of the digital satellites, I have only used my own software. Originally this was written for MS-DOS and then Windows (version 2). What I really wanted, was to be able to provide a software environment that would be ideal to experiment with, not only for myself, but to make the source available to others.

Linux provides an ideal environment for the experimenter. It is very cheap, comes with a complete development environment, includes all the source code, and now includes the AX.25 protocols as part of the core operating system.

The satellites provide an ideal opportunity for the software experimenter. Besides the message store and forward capability of the satellites there is also a wealth of information about the health of the satellites, images of the earth taken from the satellites, and other experiments.

This paper gives an introduction to Linux, and to the software that I have developed to communicate with the PacSats[1] and some other software packages that are available.

Hopefully, this will encourage others to participate in this side of amateur radio.

What is Linux?

Linux is a **FREE** Unix clone operating system for Intel 386/486/Pentium PC's. It has been developed by Linus Torvalds, plus a few hundred programmers on the Internet.

It is a full multitasking, multi-user operating system that provides real memory management and pre-emptive scheduling. It includes a complete development system (C, C++, Pascal, Fortran, etc), networking (TCP/IP and AX.25), X-Windows, a DOS emulator, with a Windows emulator under development, plus a lot more.

The software is released under the GNU[2] license. This means that it includes the full source of the operating system and utilities, and is **FREELY** distributable. This means that it is perfectly legal to install the software on as many systems as you want.

How can you get Linux?

If you have Internet access, it is available via anonymous ftp from several archive sites[3]. Some Bulletin Boards have copies for downloading, and several companies sell CDROMS or disk sets containing the archive dumps and complete distributions with installation scripts[4].

What kind of system do you need to run Linux?

Linux has been developed to run on a standard Intel 386/486 PC. It can support DOS file systems, IDE and SCSI disk drives, CDROMS and many network cards. A 387 co-processor can be emulated in the kernel if you do not have a math co-processor.

A minimum system could be installed using 15 MBytes of disk and run in 2 MBytes of ram. Expanding to 4 MBytes of ram would support compiling, and 8 MBytes of ram would support X-Windows. A complete system requires about 100 MBytes of disk storage.

A typical MS-DOS/Windows systems can support Linux very well. You can partition a disk and have both DOS/Windows and Linux on the same machine.

How can it be used in Ham Radio?

Most software that is used in ham radio could be developed to run on Linux. This could include engineering software for circuit analysis, simulation, antenna design and terminal programs for packet radio.

There is already a satellite tracking program (SatTrack) available written by DL5KR (see Figure 9 for a screen dump of this program).

One big advantage of Linux is that the AX.25 protocols have been developed as part of the kernel. This is due to the efforts of Alan Cox (GW4PTS)[5]. The package is available as an addition to the standard kernel, and provides a socket interface for the programmer.

A TNC running in KISS mode is connected via a serial port to the PC to provide the interface to the outside world. Several communications programs exist that would allow communication with the TNC in its standard mode.

Also included with the AX.25 package are a set of user applications to provide standard AX.25 connect support for access to BBS's, an application to monitor all received packets, an application to transmit a beacon message, and a Personal Message System. (Note: that all the source is released for both the kernel and the user applications).

It can also be used to run TCP/IP over AX.25 using the standard Unix TCP/IP applications (TELNET, FTP, etc).

MicroSat Ground Station Software

I have developed a set of programs to provide access to the MicroSats. All the programs are written in C and use the Motif Graphical User Interface for X-Windows. The source of all the applications has been made available. Earlier versions have been release that used the OpenLook and the XAW GUI libraries.

The programs are:

     xpb
     xpg
     directory
     downloaded
     message
     viewtext
     xweber
     xloadimage

The current version of the software does not provide any automation other than collecting all messages and directory entries received on the downlink by **xpb**. Downloading, directory filling and message uploading require manual intervention by the operator. However, this is no more than pointing and clicking with the mouse.

The next area of development is to add a level of automation so that the software will request files, directory fills and file uploads without the user having to click the mouse on buttons.

Anyone that would like to help with the development of this software is most welcome. I only ask that I be informed of any work that is going on so that we can co-ordinate releases.

Most of the code is fairly straight forward. The most complicated being the hole list management for downloaded files and directories.

xpb

This program is the main work horse for the broadcast protocols. It performs all the work of collecting files and directories, maintaining hole lists, and sending requests to have files sent, holes filled in files, and holes filled in the directory.

The program window has a scrolling window that displays status information as it is received from the satellite (PB Queue List, shortened directory entries, and other status messages).

There are buttons to click on to request the directory holes to be filled (**Fill Directory**), and to manually enter a file id to be filled or sent (**Fill File**). There are also buttons to turn KISS logging on or off and also Telemetry logging on or off.

There is also an additional interface (currently using tcp/ip loopback) that allows other applications to send requests for the directory to be filled or for files to be sent or filled.

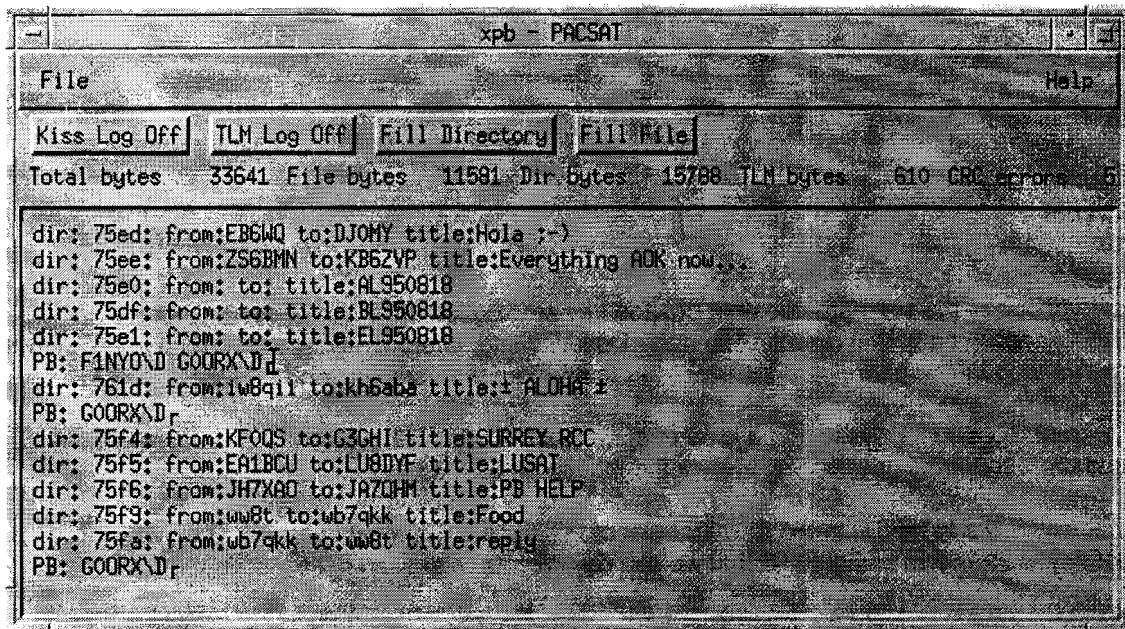This is the only program that needs to be running to collect directory entries and files.

Figure 1 - xpb display window

126

xpg

This program displays the list of messages that have been prepared for uploading and handles the FTL0 connected mode protocols for uploading messages.
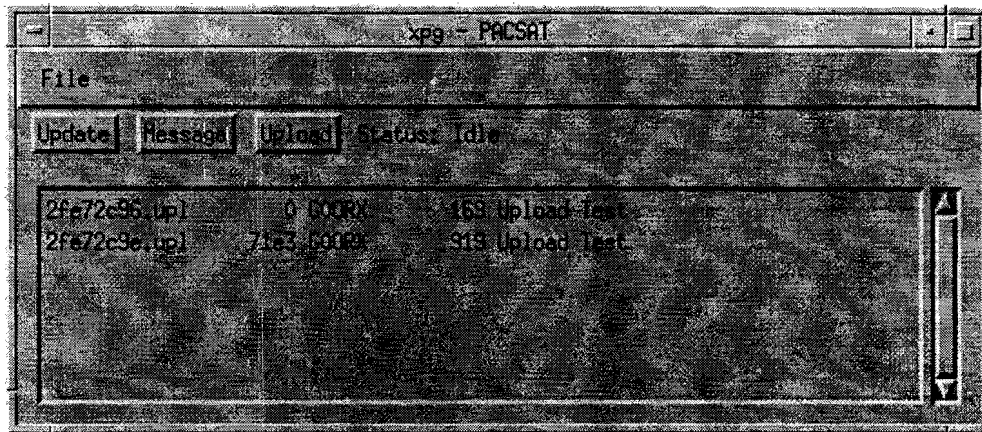

Figure 2 - The xpg display window

Clicking on the **Message** button will start a copy of message so that you can prepare a new message for uploading (see also the **Reply** buttons in **downloaded** and **viewtext**).

To upload a message, you select the message to upload from the listbox, and click on the **Upload** button. During an upload session, the Status message will be updated with useful information.

If an attempt has been made to upload a file, but the connection is lost without completing the upload, the file Id will be updated for future attempts.

Note that currently each connect session only uploads the one message selected.

directory

This programs displays the current directory listing that has been collected by **xpb** in a scrollable list box. As new entries are received by **xpb**, the directory file(s) will be updated, but the list will only be updated when the **Update** button is clicked on, or the **View** selection is changed.
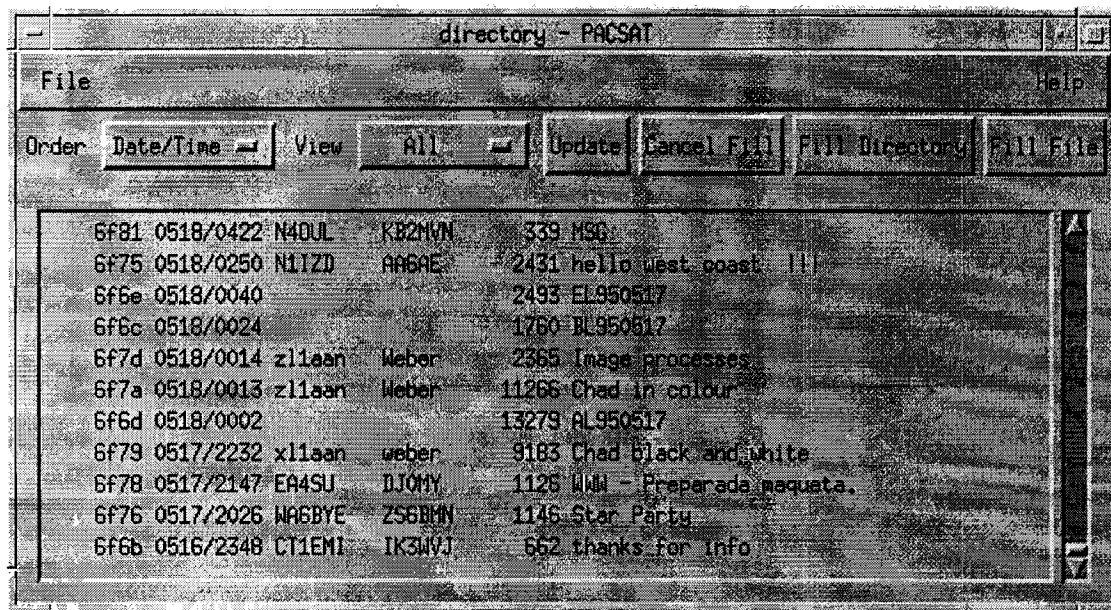

Figure 3 - The Directory Display Window.

The list can be scrolled by clicking the mouse on the elevator control on the right hand side.

Clicking on **Update** will get the list refreshed by rereading the directory file(s).

Clicking on the **Fill Directory** button will send a request to **xpb** to send a hole fill request to the satellite for the directory.

Clicking on **Fill File** will send a request to **xpb** to send either a hole list request or a file send request to the satellite for the selected file in the listbox.

The **View** button is a pull down menu to select which directory entries are displayed. Currently this supports displaying **All** the messages, **Mail** to/from your own call sign, **Broadcast** messages (addressed to all) and Image files **(EIS)**.

The **Order** button lets you select different ways to order the list of messages. Currently you can select Date/Time, Message Id, From Callsign, To Callsign, size, Title.

downloaded

This programs displays the current list of messages that has been downloaded by **xpb** in a scrollable list box. As new messages are downloaded by **xpb**, the files will be updated, but the list will only be updated when the **Update** button is clicked on, or the **View** selection is changed.
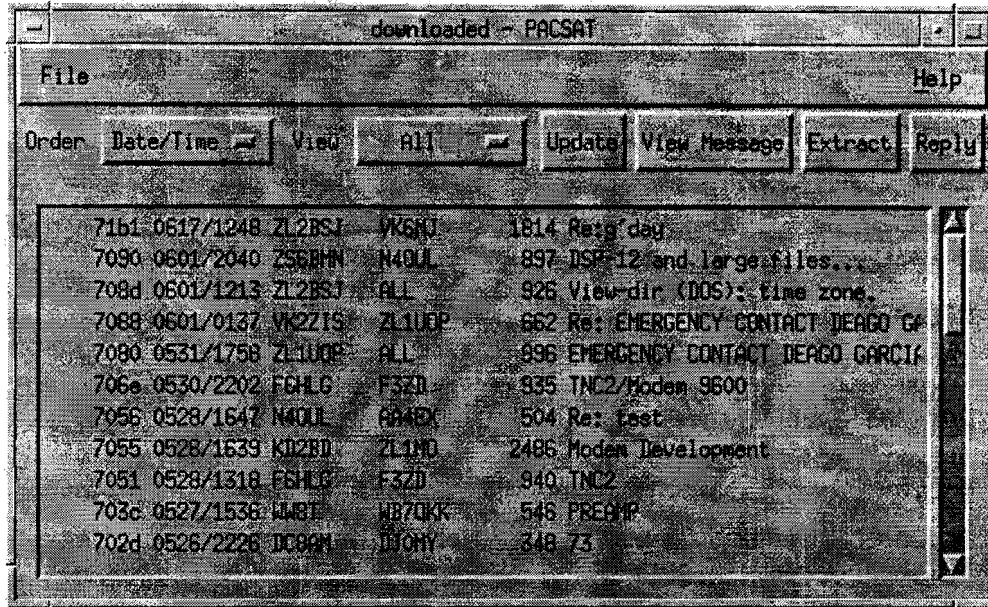

Figure 4 - The Downloaded Message Display Window

Clicking on **Update** will get the list refreshed.

Clicking on **Extract** will extract the file from the currently selected message and store it in a subdirectory named **msgs**.

Clicking on **View Message** will display either a plain ASCII text message or a EIS image file without having to extract them to a file. If the file is compressed an attempt is made to uncompress the file and then display the uncompressed message.

Clicking on **Reply** will bring up the message preparation window and will fill in the destination and title with the source of the current message and the title with Re: inserted in front.

The **View** button is a pull down menu to select which downloaded messages are displayed. Currently this supports displaying **All** the messages, **Mail** to/from your own call sign, **Broadcast** messages (addressed to all) and image files (**EIS**).

129

viewtext

This program is used to view text messages. It is usually started by selecting a file in the **downloaded** list box, and then clicking on the **View** button.
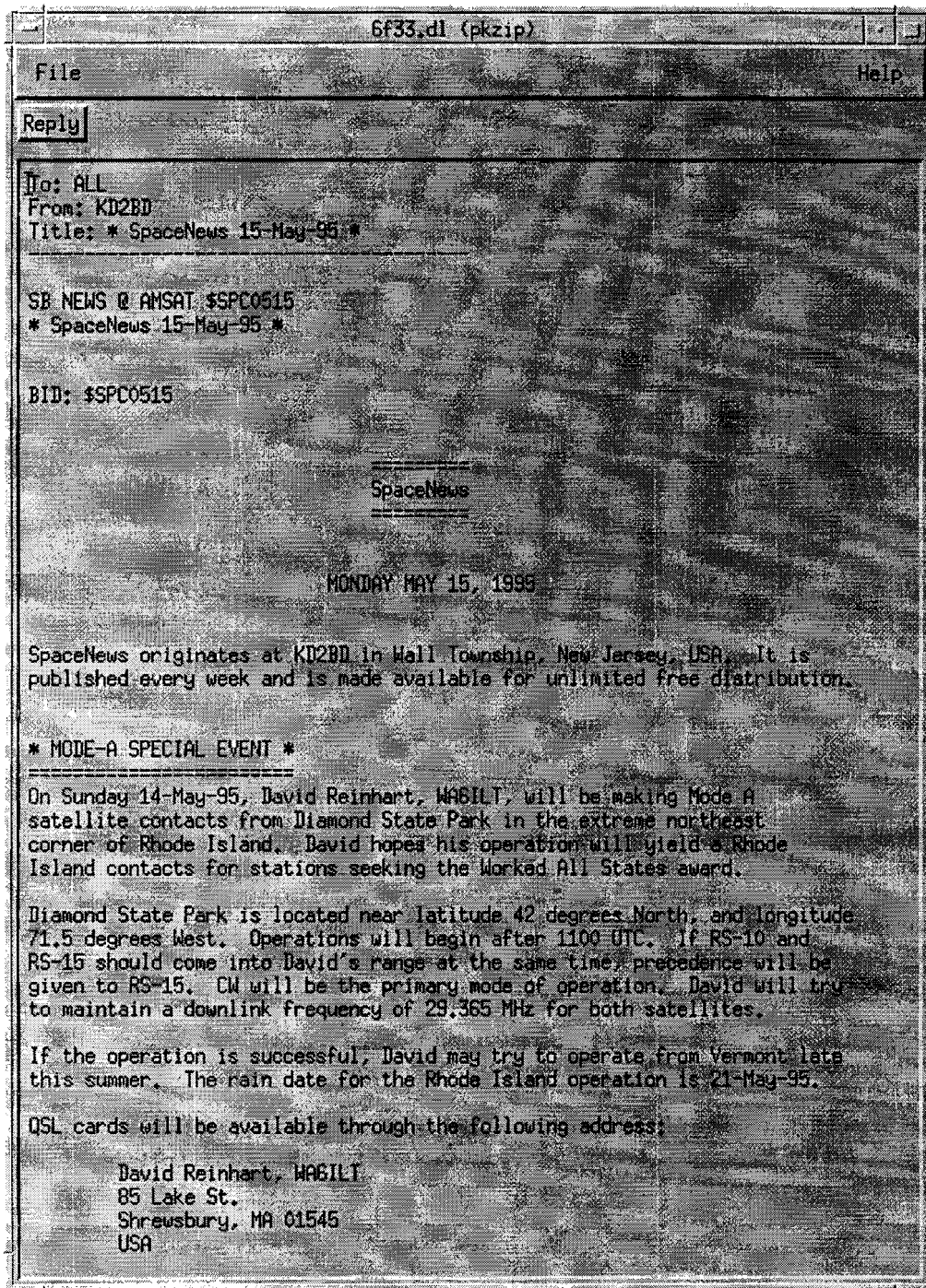

Figure 5 - The ASCII Text Viewer Window

The **Reply** button will start up a copy of **message** with the destination and title filled in.

message

This program is used to prepare messages for uploading. Simple ASCII text messages can be created from within the program, or a file can be specified.
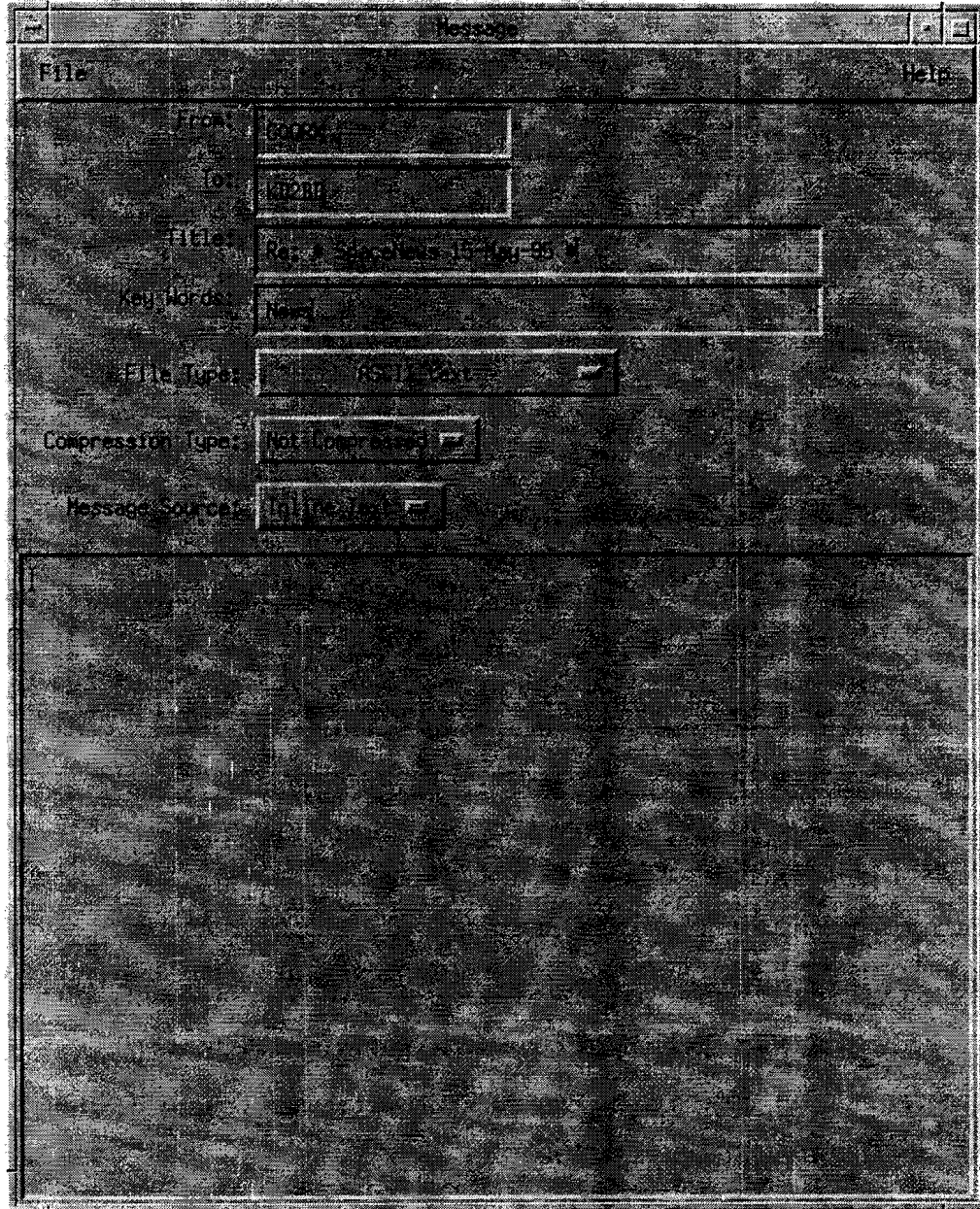

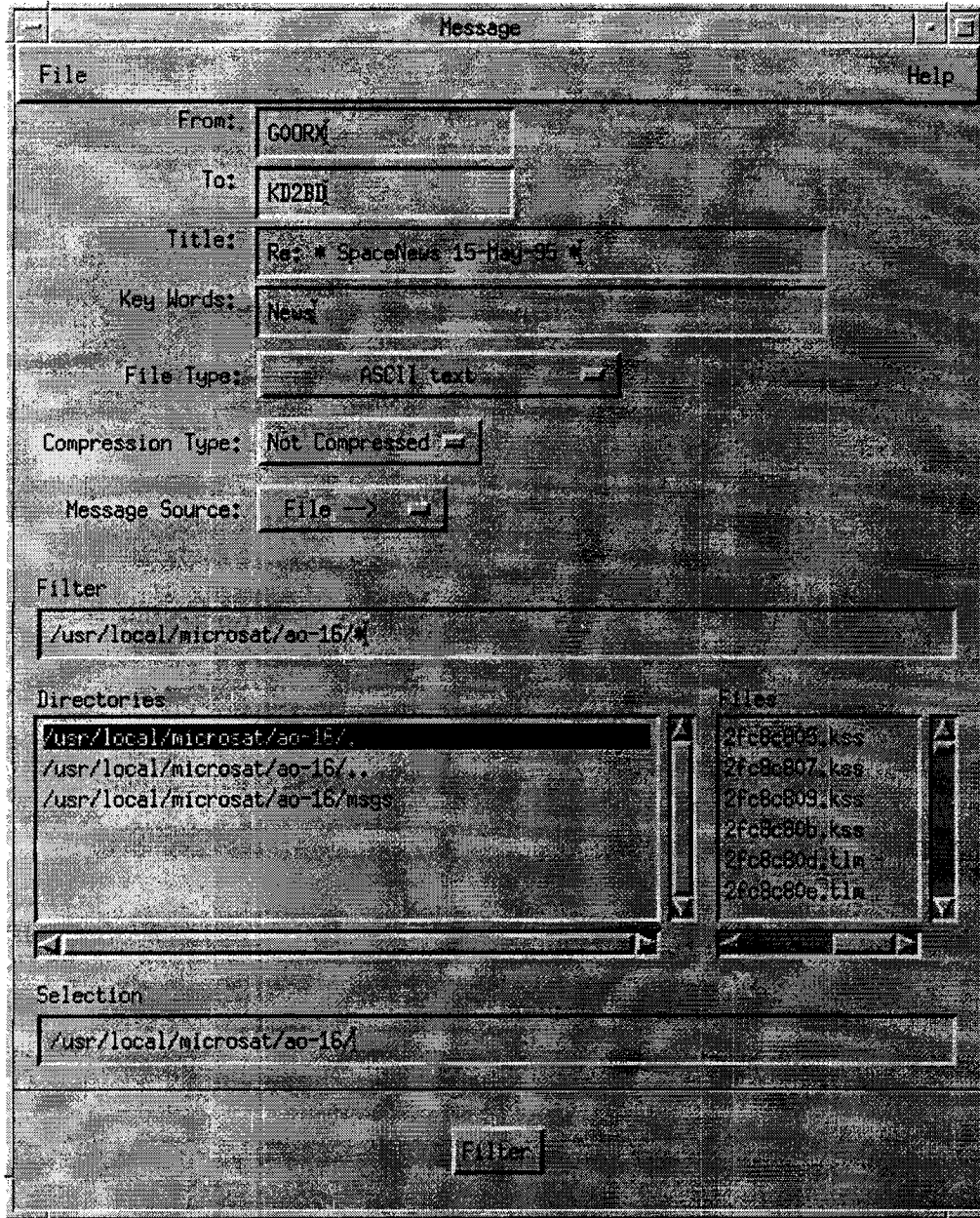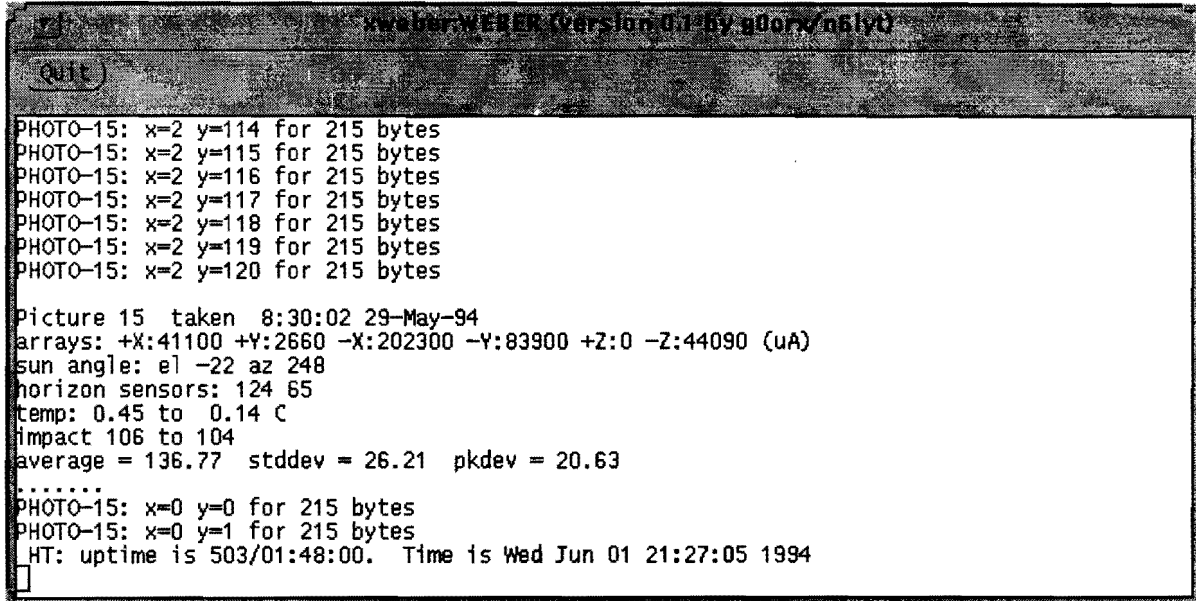Figure 6 - The Message Preparation Window (simple text)

Figure 7 - The Message Preparation Window (file selection)

When the message is completed, clicking on the **Prepare** button will generate a message for **upload** with the PFH header on the front.

xweber

This program is used to collect PHOTO data from WeberSat. The image data is written to a file using the image name (i.e. PHOTO-15). At any time the image can be viewed using a modified version of xloadimage.

```
xweber WEBER (Version 0.1 by g0ory/n6lyt)

Quit

PHOTO-15: x=2 y=114 for 215 bytes
PHOTO-15: x=2 y=115 for 215 bytes
PHOTO-15: x=2 y=116 for 215 bytes
PHOTO-15: x=2 y=117 for 215 bytes
PHOTO-15: x=2 y=118 for 215 bytes
PHOTO-15: x=2 y=119 for 215 bytes
PHOTO-15: x=2 y=120 for 215 bytes

Picture 15  taken  8:30:02 29-May-94
arrays: +X:41100 +Y:2660 -X:202300 -Y:83900 +Z:0 -Z:44090 (uA)
sun angle: el -22 az 248
horizon sensors: 124 65
temp: 0.45 to  0.14 C
impact 106 to 104
average = 136.77   stddev = 26.21   pkdev = 20.63
.......
PHOTO-15: x=0 y=0 for 215 bytes
PHOTO-15: x=0 y=1 for 215 bytes
HT: uptime is 503/01:48:00.  Time is Wed Jun 01 21:27:05 1994
```

Figure 8 - The xweber Window

133

Other Software for Linux

xloadimage

This program is released with Linux and again includes the source code. It will decode many image file formats and display the image in a window under X-Windows. I have added the functions to decode and load EIS images and Weber PHOTO images.
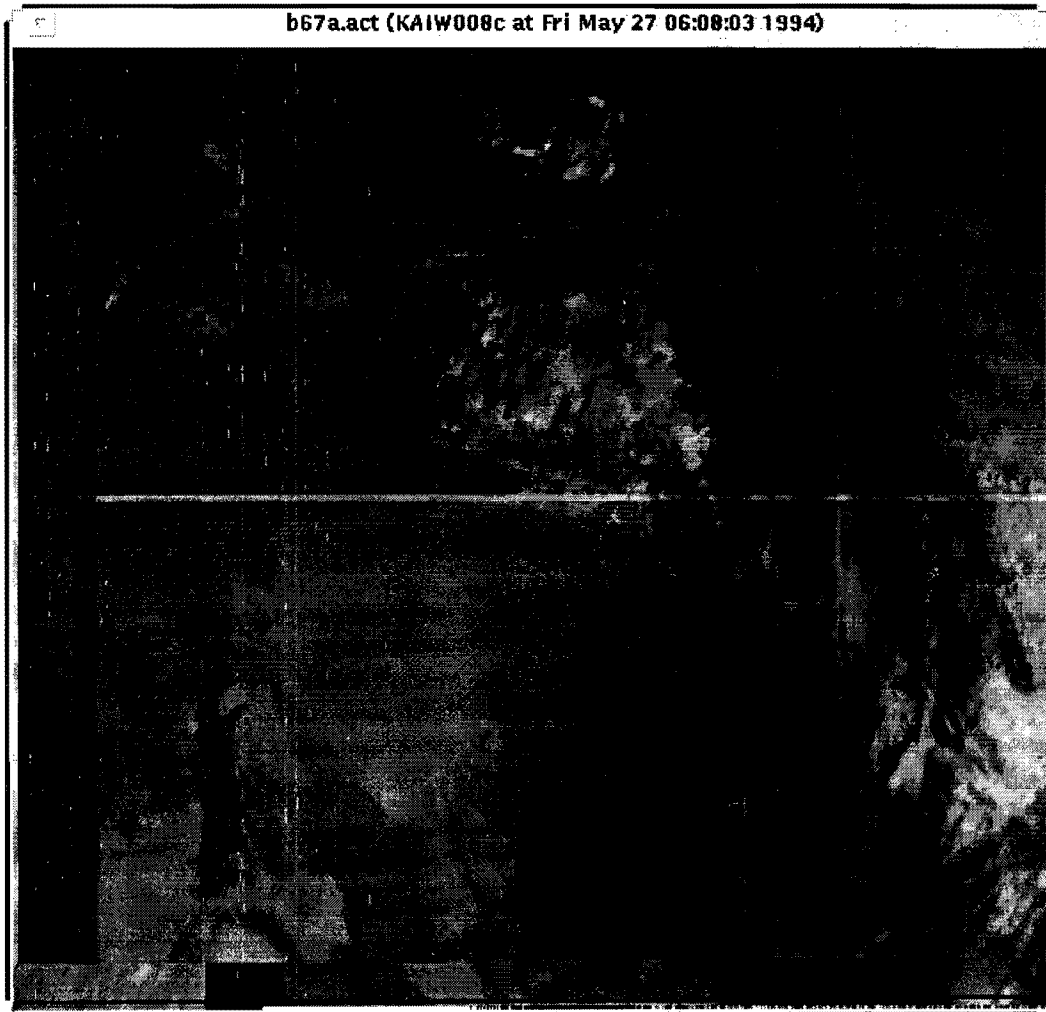
Figure 9 - The xloadimage window

It is possible to display an image before it has been completely downloaded, provided that the PFH header has been received.

The program can be run from a command line specifying a .act file rather than a .dl file (i.e. xloadimage b355.act). Missing packets of data will appear as black segments in the image.

The current structure of an EIS image file contains all the even numbered lines at the front of the file, followed by all the odd numbered lines. A command line option is available to only display the even numbered lines, and to generate the odd numbered lines by duplicating the even numbered lines.
This will generate quite a good image when only half of the file has been downloaded.
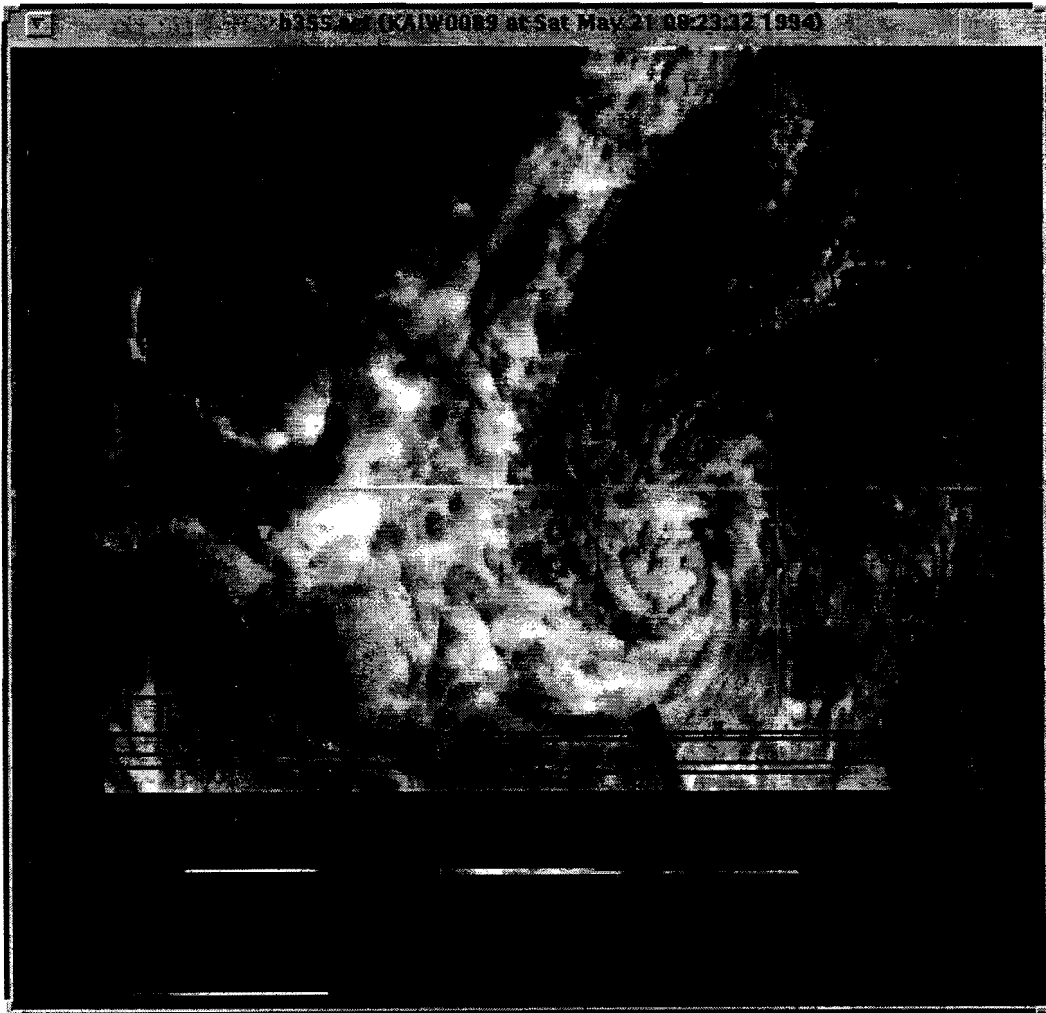
Figure 10 - A partialially downloaded image

SatTrack

SatTrack is a satellite tracking program written by Manfred Bester (DL5KR) [6]. This program has been written to run on a simple ASCII terminal, but also includes the ability to show the satellite track in a graphic window under X-Windows. Again, this program is released along with the source code.
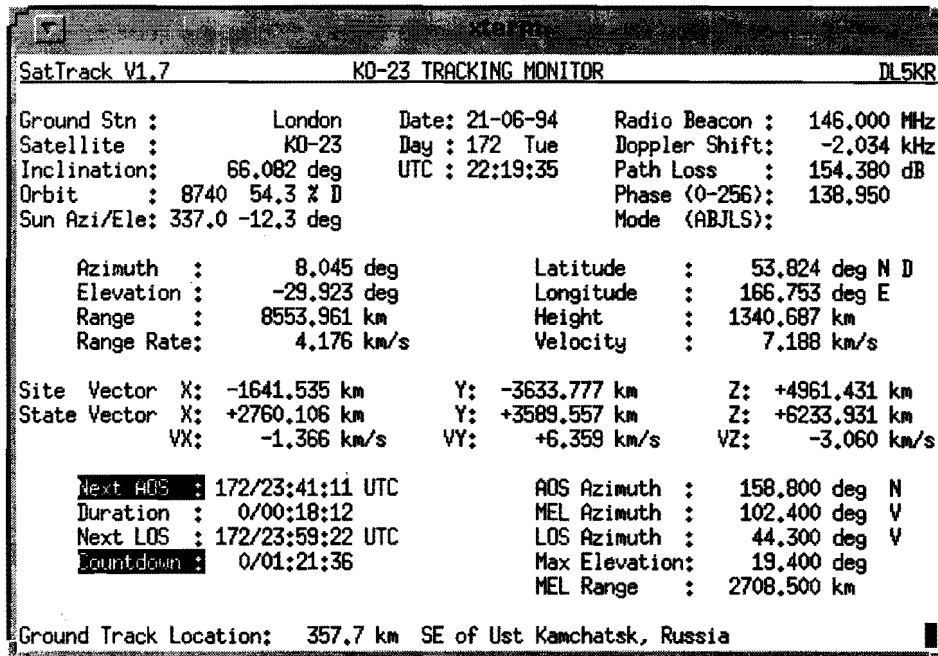
Figure 11 - The SatTrack window
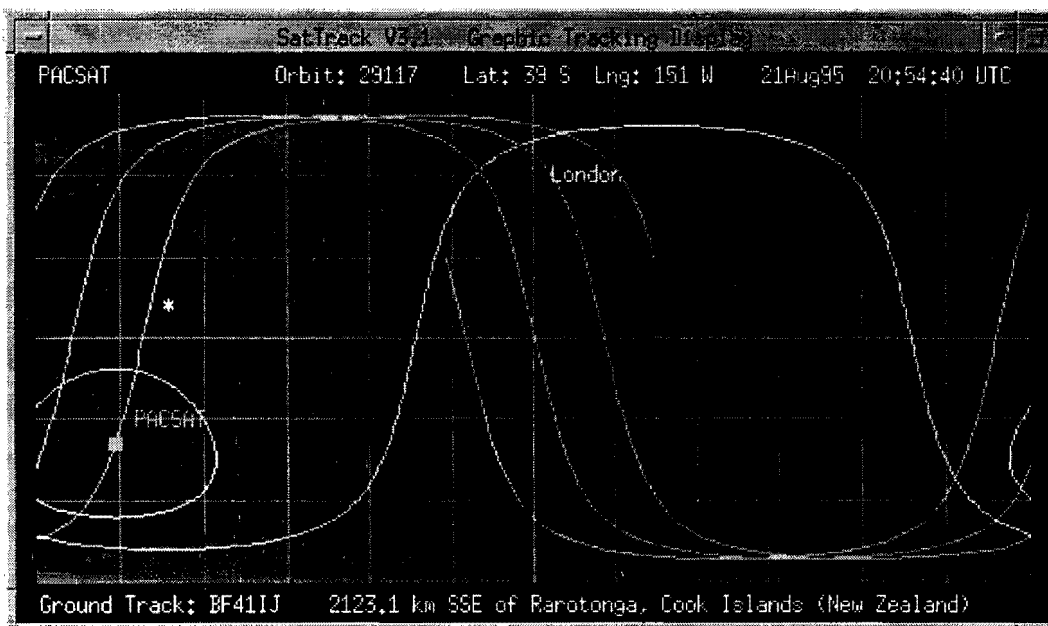
Figure 12 - The SatTrack graphic window

References

1. MicroSat Ground Station Software is available by anonymous ftp from ftp.amsat.org.

2. GNU General Public License, Version 2, June 1991 - Free Software foundation, Inc. 625 Massachusetts Ave, Cambridge, MA 02139, USA

3. FTP sites that archive Linux: sunsite.unc.edu, tsx-11.mit.edu, ftp.funet.fi

4. One source of Linux on CDROM is InfoMagic. Telephone (609) 683-5501, FAX (609) 683-5502.

5. Alan Cox (GW4PTS) Internet: A.Cox@swansea.ac.uk

6. Manfred Bester (DL5KR) Internet: manfred@isi5.ssl.berkeley.edu

Iowa Satellite Project's
Spacecraft Systems and Operations Laboratory's
Involvement with
BREM-SAT

Mark A. McKeown
February 1995

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Rockwell International
Yaesu
Federal Communications Commission
Spectrum International Inc.

Abstract

During February 1995, personnel and students of the Iowa Satellite Project established a secondary command station at the Spacecraft Systems and Operations Laboratory for the small satellite BREM-SAT operated by the University of Bremen. This command station provided a secondary data collection and command site during BREM-SAT's reentry phase. Though the final trajectory of BREM-SAT did not permit the SSOL to collect the last experiments' data, the lab did function as a last ditch effort to turn on the second to last experiment.

This paper focuses on the Iowa Satellite Project's involvement in BREM-SAT's last phase of operations with emphasis in the setup, initial tests and operations done by the Spacecraft Systems and Operations Laboratory (SSOL) and Boone Aviation and Space Education (BASE) ground stations. The initial modification, purchasing and integration of the receiving and transmitting systems is discussed as well as tracking methodology and hardware. The paper describes the as of date capabilities of the SSOL and concludes with recommendations for modifications to the facility.

Nomenclature

SSOL	Spacecraft Systems and Operations Laboratory
ISAT	Iowa Satellite [Project]
AOS	Acquisition of Signal
LOS	Line of Sight
RHCH	Right Handed Circular Polarized
BREMSAT	Bremen Satellte project
BREM-SAT	Bremen Satellite [-1]
CARC	Cyclone Amateur Radio Club

Introduction

The BREMSAT project is lead by the University of Bremen with the University of Brunswick in charge of orbital tracking. BREM-SAT, a small satellite dedicated to science, was launched on February 3, 1994 by the space shuttle Discovery. The spacecraft orbited the earth for just over a year and reentered Earth's atmosphere February 15, 1995. The satellite carried 6 experiments, two operating in each of the three phases: microgravity, orbital and reentry.

The Iowa Satellite Project (ISAT) is a multi disiplinary student led project at Iowa State University in Ames, Iowa. The project is funded by the Iowa Space Grant Consortium (ISGC), Institute for Physical Research and Technology and the Aerospace Engineering and Engineering Mechanics department of the College of engineering at ISU and operates from it's laboratory, the Spacecraft Systems and Operations Laboratory (SSOL). This lab has educated students of ISU in developing spacecraft hardware and satellite operations. The Iowa Satellite Project's goal is to design, develop and operate it's own satellite using the resources gathered over the years at the SSOL.

Boone Aviation and Space Education (BASE) is a program initiate by Sylvia Tiala at Boone High School that exposes students to the array of opportunities in the aerospace discipline.

Timeline

Initial contact with the BREMSAT project was made at the 8th Annual AIAA USU Small Satellite Conference in Logan, Utah September 1994. Hans Königsmann and Hartmut Renken, BREMSAT personnel, presented a paper, "BREM-SAT - First Flight Results" in which they emphasized the reentry date of BREM-SAT. Knowing data downlink limits due to experience[1], dialog was initiated with Hans Königsmann concerning the use of the SSOL as a secondary downlink/telecommand site. After the conference a follow on letter was sent to Mr. Königsmann and upon reception interaction was done vial e-mail. Initial e-mails concerned the SSOL's ground coordinates and communication equipment design, modifications and integration. Final e-mails coordinated the reentry phase of BREM-SAT.

The integration of the BREM-SAT communications system to the SSOL began first with existing gear and later in modifications to this gear and purchase of additional equipment. BREM-SAT transmitted at 137.8 MHz and received at 149.24 MHz. The SSOL's receiving system was initially based around an existing weather imaging system[2] and first tests were conducted 20Nov94 10:21:00 UT. This test proved unsuccessful and was attributed to the receiver's optimization to the polar satellites audio output. A new receiver was ordered and modified. Additional reception tests were conducted through the 18Jan95 pass using sound clarity, audio recording and data collection as criteria. Also at this time, the initial push for providing an uplink to BREM-SAT was initiated. This involved the modification to the existing OSCAR ground station and acquiring a license to transmit at BREMSAT's uplink frequency.

As integration continued at the SSOL and BASE, BREM-SAT personnel planned their final operations phase. This phase included a representative from the BREM-SAT team to work at the SSOL/BASE facilities. Reiner Heyen arrived at Des Moines airport on 5Feb95 and immediately began working at the SSOL. After initial tests perform by Mr. Heyen, the final receiving system was decided on and additional modifications to the SSOL's receiver were performed. Due to the orbital motion of BREM-SAT, Mr. Heyen remained at the SSOL in order to provide the secondary telecommand site. Some difficulty was experience during Reiner's visit with the receiving system, however the uplink capability of the SSOL worked exemplary.

ISAT Facilities

Spacecraft Systems and Operations Laboratory (SSOL)

The SSOL's BREM-SAT communications system was based on existing systems with additional gear added. The receiving system consisted of an ISU built directional antenna, preamp from the Timestep Remote Sensing system, and a R137 weather satellite receiver from Hamtronics specifically tuned to BREM-SAT's downlink frequency. The directional antenna was a 8 element cross yagi RHCH antenna built by a senior in the Electrical Engineering department of ISU and member of the Cyclone Amateur Radio Club (CARC). The design and development of the antenna was done due to the lack of any capable directional antenna at 137.8 MHz. The preamp is a low noise GaAs-FET receive preamp that is located at the antenna feed line connection point.

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[1] Iowa Satellite Project's designs for the ISAT-1 and IOWA spacecraft.

[2] This system is the TimeStep Remote Sensing System, produced by Spectrum International, receives weather images from polar orbiting weather satellites.

141

The preamp has a passband allowing reception of most polar orbiting weather satellites (NOAA, Meteor, etc.) and is powered by a simplex method via the feed line. A circuit was made to provide the simplex power since the Timestep system powers the preamp via it's receiver whereas a R137 receiver did not have the capability.

The Timestep system's receiver, PROSCAN, was originally used for the first signal test. Though the signal was discernible it was not satisfactory to attempt decoding. This is due to the fact that this receiver is optimized for the 2400 Hz audio signal inherent with the polar orbiting weather satellites. It was necessary to physically modify the receiver, however this was forgone due to its priority for receiving weather imagery. The R137 Weather Satellite Receiver (Hamtronics) was selected and modified. A capacitor was removed from the board to allow the reception of BREM-SAT's audio signal (~11 kHz).

The audio output of the receiver was inputted to the BREM-SAT bitsync provided by the BREMSAT project. The bitsync (encoder/decoder) was connected serially to a computer where a specific program decoded the data, BREMSAT.EXE.
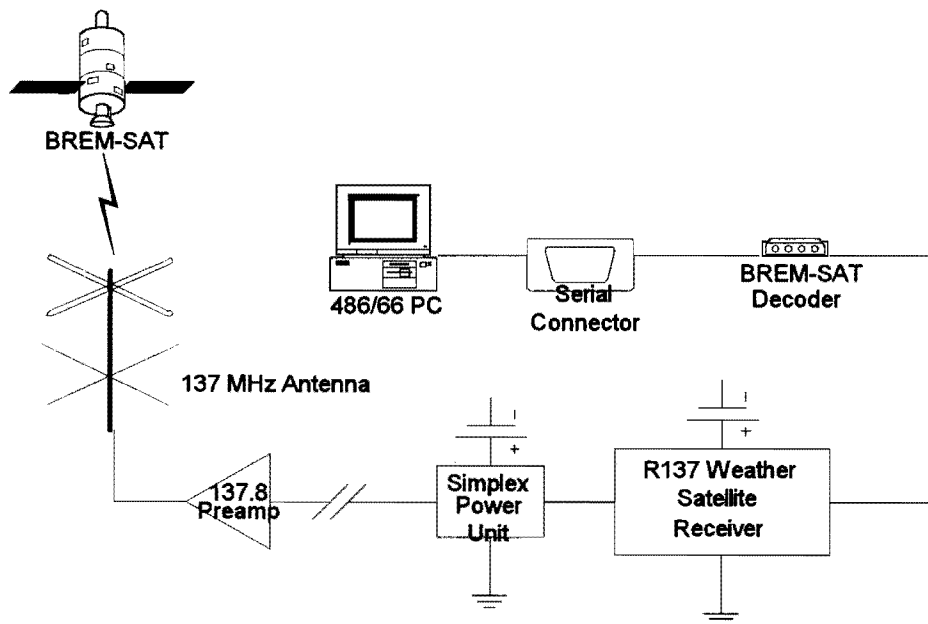
Figure 1 SSOL's BREM-SAT receiving system. Note, this
figure shows the early system. The later system used a
directional antenna instead of the hemispherical.
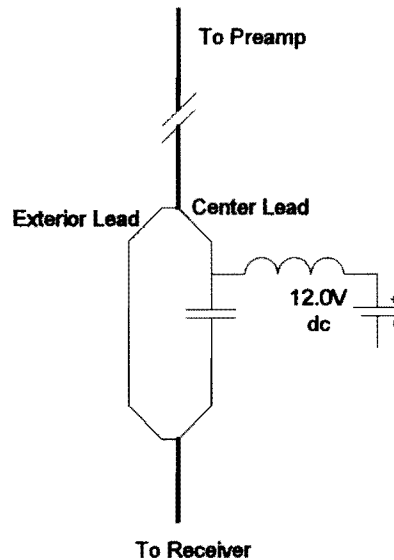
Figure 2 Simplex Power to preamp. This was integrated
onto a PC board and enclosed in a metal casing.

The BREM-SAT uplink presented problems outside of physical integration of a communications system. The uplink frequency lies outside the US amateur band in which personnel at the SSOL have been licensed. Initial dialog had been initiated with the FCC in attaining a temporary license for transmission from 15Jan95 to 15Mar95. The license was approved for 24Jan95 to 16Mar95 with the call sign KS2XAN[3]. The actual hardware used is the existing FT736R transceiver with a directional 2 meter antenna, both of which were from the existing OSCAR ground station. This transceiver has the capability of transmitting at the required frequency however the SSOL's version (US) was not equipped to do so. This required a simple addition of a diode to the 2 meter board. A hemispherical antenna was originally planned to be designed and constructed, however on further review and the timely arrival of an antenna rotating system the existing 2 meter directional antenna was chosen.

Boone Aviation and Space Education (BASE) Facility
In addition to the SSOL's BREM-SAT communications system, a backup facility was selected in case of system failure at the SSOL. BASE is run from the Boone High School and also possessed an OSCAR ground station. The BREM-SAT specific gear (receiver, preamp, directional receive antenna and bitsync) would be ferried back and forth between the SSOL and BASE facilities. A problem occurred during reception tests; the BASE facility's transceiver FT-736R did not function properly. Thus the SSOL's transceiver was also slated to be ferried until the BASE's transceiver returned from repairs.

Originally the 137.8 MHz directional receiving antenna was used at BASE, however it was integrated to the SSOL facility. This is due to the timely arrival of the SSOL's antenna rotating system (G-5400). The SSOL's rotating system included a computer controller (GS232) whereas the BASE's system did not and thus made it feasible to perform computer control tracks.

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[3] Ken Daigh is credited with dealing with the FCC. With his thoroughness and speedy response the license was approved in a considerable short time.

Tracking

The tracking of BREM-SAT was done using the TrakSat program using updated NASA Two Line element sets. The element sets were downloaded from an USAF server site (129.92.1.66) periodically (appendix A). Problems arose latter during Reiner Heyen's visit when the above server was not updating BREMSAT's orbital elements frequently enough. A six day difference in orbital elements lead to roughly 7 and 13 degrees longitude and latitude differences respectively[4]. Ralph Wallio[5] supplied additional orbital element sets for BREMSAT.

Additional orbital element sets were supplied by the University of Brunswick. These element sets were based on a prediction method determined from Doppler shift measurements done at BREM-SAT's ground station at Bremen. An attempt to do similar calculations was done at the SSOL. Doppler shift measurements were attempted in mid January. The initial system includes the use of a digital multimeter connected to the discriminator within the R137 Weather Satellite receiver. The Doppler shift would be determined from the measured voltage across the discriminator and compared to a predetermined calibration curve of frequency vs. voltage. In order to develop this calibration, the receiver was subjected to a range of frequencies produced from a signal generator (Boonton Electronics 102D FM-AM Signal Generator, donated by Rockwell).
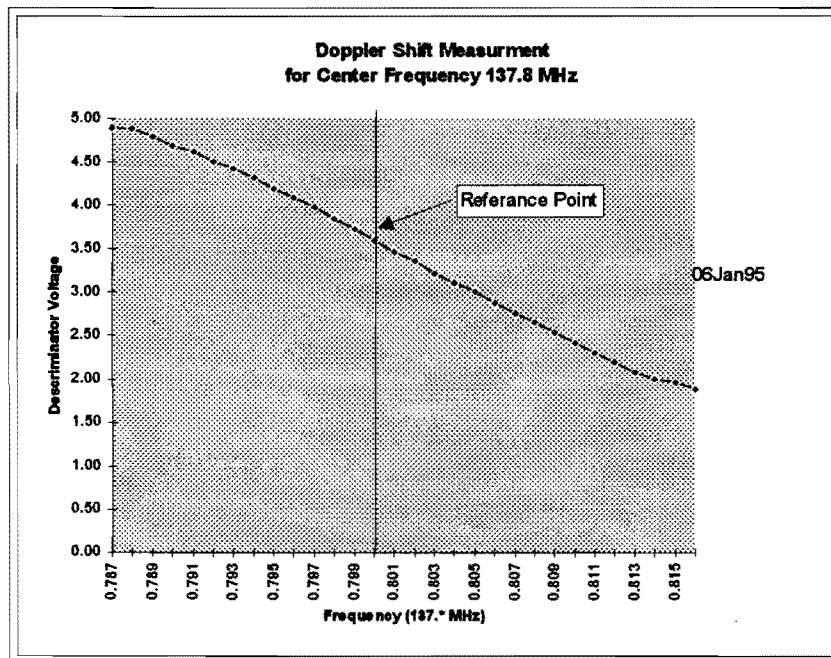
Graph #1 Doppler Shift measurement calibration.

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[4] One example of how satellites under 210 km altitude orbits are effected.

[5] Former Vice President of Operations for AMSAT, now coordinator for HABET.
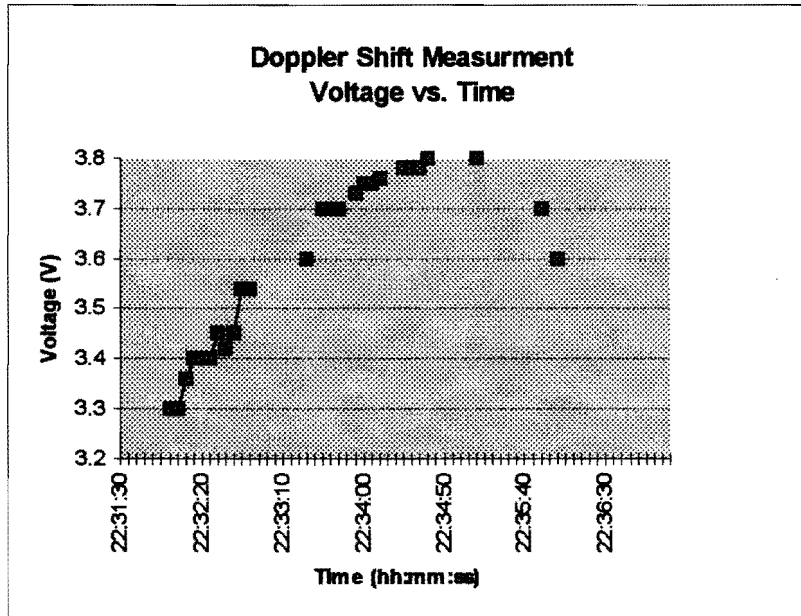
Graph #2 Doppler Shift measurement

A test was performed and the results are plotted in graph 2. As seen in the graph, the Doppler shift is apparent. However the measurements were not steady due to three reasons. First, the discriminator voltage exhibited a slight unsteady behavior. Second, the transmissions of BREM-SAT are done in bursts. In between bursts the discriminator voltage would tend towards the reference and at the beginning of a burst the voltage would jump. Third, the measurements were recorded by hand. During Mr. Heyen's visit, a second system was integrated into the SSOL. This consisted of a spectrum analyzer which sent data to a printer via a HP-IL line. The system would monitor an intermediate frequency within Mr. Heyen's receiver[6]. However, the system proved not sensitive enough, thus Doppler measurements ceased at the SSOL.

The element sets were used by the TrakSat program to produce a path of elevation and azimuth angular pairs with a specified time interval between each pair. This data was sent to the GS232 which would rotate the antennas to the point of suspected AOS[7]. The path was initiated at the time of AOS or the predicted rise time. The GS232 would control the elevation and azimuth rotors of the Yaesu G-5400 to step through the path of LOS angle pairs in a timed sequence.

Reception Tests

Signal tests prior to Reiner's visit were scheduled for passes that attained an elevation higher than 45 degrees relative to the SSOL's geographic coordinates.

Latitude	42.0650	North
Longitude	93.8813	West
Altitude	600	ft

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[6] Reiner Heyen brought a standard BREM-SAT receive/transmit system.

[7] Reiner Heyen developed a computer program to convert the TrakSat data to data useable by the GS232.

145

Transmission Time	Confirmation	Reception
20Nov94 10:21:00	Yes	Yes* (minimal recp)
04Dec94 21:26:00	Yes	Yes (Full four minutes)
12Dec94 18:38:00	Yes	Yes
15Dec94 00:58:00	No	No
15Dec94 17:09:00	Yes	Yes
16Dec94 17:10:00	No	No
18Dec94 23:27:00	No	No
20Dec94 15:38:00	Yes	Yes
22Dec94 21:53:00	Yes	Yes
24Dec94 14:01:00	No	No
27Dec94 20:13:00		
28Dec94 12:22:00		
29Dec94 12:20:00		
11Jan95 14:41:00	No	
12Jan95 06:47:00	Yes	Yes (one 5 sec. burst)
13Jan95 06:41:00	No	
18Jan95 04:32:00	Yes	Yes Full Transmission
19Jan95 04:25:00		

Table #1 List of scheduled transmit
times and results

These tests were used by ISAT personnel to integrated the SSOL's receiving system.

Sound Records

The later signal tests included the recording of the audio output of the receiver. The audio output was connected to a Sound Blaster 16 (Creative Labs). The resultant *.wav files were compared to one that was downloaded from the BREMSAT personnel through their server (wowbagger.zfn.uni-bremen.de or 134.102.228.9, /public/ftp/pub/Uni-Bremen/Institutes/Zarm/BremSat with anonymous ftp). Later the sound files were played into the BREM-SAT Bitsync which fed signals into the computer. Some success was obtained, however only a portion of the collected data sets were error free. This was attributed two both the quality of the recording and the hemispherical antenna receiving system used at that time.

File	Pass	
bs1.wav	12Dec94	12:42:18 CST
bs2.wav	15Dec94	11:11:52 CST
bs3.wav	06Jan95	10:43:02 CST
bs4.wav	12Jan95	06:46:00 UT
bs5.wav	17Jan95	22:37:00 UT
bs6.wav	18Jan95	22:29:00 UT

Table #2 List of sound files captured

BREM-SAT Final Phase

Upon Reiner Heyen's arrival, 05Feb95, the SSOL's BREMSAT systems were modified again to work properly. The R137 receiver was modified additionally to stop an induced oscillation probably due to the removal of the capacitor allowing BREMSAT's audio frequency. The

directional 137.8 MHz antenna was removed from BASE and integrated to the SSOL facility. There were many alterations to the receiving system to determine problems in the downlink, however the above arrangement was determined to be the most successful.

Originally, Reiner Heyen was to arrive at the SSOL to conduct some additional tests and then fly out to Canada to receive data from BREMSAT's last orbit[8]. During Mr. Heyen's absence, the SSOL would operate as a backup station if it was required to uplink any necessary commands. However, the orbital motion of BREMSAT made this inadequate. Mr. Heyen remained at the SSOL to provide the secondary uplink capability[9]. In fact the SSOL facility was the last effort to turn on experiment 4 (see appendix B).

Conclusion and Recommendations

During the reentry phase of BREMSAT the Iowa Satellite Project's Spacecraft Systems and Operations Laboratory played a key role in the ground operations. The SSOL personnel swiftly and effectively established a BREMSAT communications system with the available resources at hand. Students of both university and high school levels have gained experience in actual hands on work with the BREMSAT project. In addition the SSOL gained additional capabilities and insight due to the push to accomplish the BREMSAT ground operations.

Although some success was achieved during this project, it is apparent the SSOL requires additional equipment to make it a fully operating ground station. The following are suggested improvements the SSOL.

- Build or Purchase a new mast for the rotators. It must be easy to take down and put back up to facilitate quick change of antennas.
- A component box should lie at the base of the antenna mast to house preamp, amps and filters. This box should have a degree of temperature control, passive or active.
- An array of band pass filters (designs and parts or fully functional units) should be available and be easily integrated into the communication's system.
- A visual system should be installed to observe the actual pointing direction of the antennas.

Acknowledgments

Thanks is deserving to many organizations and people. The Iowa Space Grant Consortium is the most deserving, since without this organization none of the existing organizations and the SSOL facility would be founded. AMSAT also contributed much to this report since much of our experience is attributed to the SSOL's OSCAR ground station and information that is readily available now on the World Wide Web.

Ralph Wallio (W0RPK) and Bob McCaffrey helped immensely both directly and much of my knowledge of AMSAT and communications is derived from their teachings. Thanks to Sylvia Tiala and the Boone High School for the use of their facilities.

References

[8] BREM-SAT's inclination (57 degrees) made it more probable that a final reentry would occur North of the SSOL's position.
[9] BREMSAT personnel were stationed around the world: Japan, South America, Italy, Iowa and Bremen.

1   Witry, Timothy C., "Obtaining Orbital Elements", Iowa State University of Science and Technology, Fourth Annual Iowa Space Conference 1994.

2   Schwendinger, Eric, "Design, Construction and Tuning of a 137.8 MHz Directional Antenna"

3   Lephart, Mike B., "The Iowa Satellite Project", Iowa State University of Science and Technology. Creative component Dec. 1994.

4   Königsmann, Hans J., Oelze, Holger W. and Rath, Hans J., "BREM-SAT - First Flight Results", ZARM, Center of Applied Space Technology and Microgravity University Bremen, Germany -- 8th Annual AIAA/USU Small Satellite Conference, September 1994.

Appendix A.
BREM-SAT Two Line Element Sets

Data for satellite consists of three lines in the following format:

```
AAAAAAAAAAAAAAAAAAAAAAAA
1 NNNNNU NNNNNAAA NNNNN.NNNNNNNN S.NNNNNNNN SNNNNN-N SNNNNN-N N NNNNN
2 NNNNN NNN.NNNN NNN.NNNN NNNNNNN NNN.NNNN NNN.NNNN NN.NNNNNNNNNNNNNNN
```

Line 1
01-01 Line Number of Element Data
03-07 Satellite Number
10-11 International Designator (Last two digits of launch year)
12-14 International Designator (Launch number of the year)
15-17 International Designator (Piece of launch)
19-20 Epoch Year (Last two digits of year)
21-32 Epoch (Day of year and fractional portion of the day)
34-43 First Time Derivative of the Mean Motion
45-52 Second Time Derivative of the Mean Motion (decimal pt. assumed; blank if N/A)
54-61 BSTAR drag term if SGP4 general perturbation theory was used. Otherwise, radiation pressure coefficient(Decimal pt assumed)
63-63 Ephemeris type
65-68 Element number
69-69 Check Sum (Modulo 10, Letters, blanks, periods, plus signs = 0; minus signs = 1)

Line 2
01-01 Line Number of Element Data
03-07 Satellite Number
09-16 Inclination [Degrees]
18-25 Right Ascension of the Ascending Node [Degrees]
27-33 Eccentricity (decimal pt. assumed)
35-42 Argument of Perigee [Degrees]
44-51 Mean Anomaly [Degrees]
53-63 Mean Motion [Revs per day]
64-68 Revolution number at epoch [Revs]
69-69 Check Sum (Modulo 10)

```
BREMSAT
1 22998U 94006H   94277.90152748  .00063672  00000-0  23904-3 0  1777
2 22998   56.9882 189.7987 0014537  69.7324 290.5312 15.87188383 21333
BREMSAT
1 22998U 94006H   94307.71939455  .00083949  13029-4  26296-3 0  2044
2 22998   56.9874  52.3468 0012864  97.8110 262.4459 15.91467311 26071
BREMSAT
1 22998U 94006H   94337.88348300  .00108479  15193-4  25384-3 0  2416
2 22998   56.9838 272.2804 0011720 123.5424 236.6799 15.96799570 30887
BREMSAT
1 22998U 94006H   94338.88507055  .00096074  14209-4  22340-3 0  2425
2 22998   56.9862 267.6084 0011248 122.3419 237.8697 15.96993410 31046
BREMSAT
```

```
1 22998U 94006H   94342.82756265  .00107641  15209-4  23830-3 0  2477
2 22998  56.9820 249.2102 0010286 127.8318 232.3690 15.97834221 31673
BREMSAT
1 22998U 94006H   94349.70626396  .00103963  15018-4  21225-3 0  2547
2 22998  56.9835 217.0568 0009728 138.0683 222.0788 15.99304229 32774
BREMSAT
1 22998U 94006H   94351.01874036  .00113774  15916-4  22789-3 0  2555
2 22998  56.9829 210.9132 0008290 127.9346 232.2479 15.99618659 32980
BREMSAT
1 22998U 94006H   94355.95393420  .00116537  16289-4  21909-3 0  2596
2 22998  56.9775 187.7826 0006272 141.0562 219.0915 16.00741820 33772
BREMSAT
1 22998U 94006H   94361.88384858  .00129429  17785-4  22244-3 0  2656
2 22998  56.9813 159.9439 0003496 149.7770 210.3473 16.02260941 34728
BREMSAT
1 22998U 94006H   95003.49365466  .00127920  17829-4  19903-3 0  2720
2 22998  56.9811 128.8436 0001573  97.8598 262.2745 16.03946751 35789
```

Appendix B
Organizations

BREM-SAT

BREM-SAT is a small university satellite which was originally scheduled to be launched with the German D-2 mission. Due to a NASA hardware failure on an earlier mission (ODERACS), the Get-Away-Special ejection system was not available on time and the launch is now scheduled for February 3, 1993.

The desired orbit is 160 by 190 nm (296 x 350 km), where the lifetime is estimated to be 3-4 months. The main ground station is located at ZARM, University of Bremen.

The small satellite (63kg, 520 mm by 480 mm diameter) is completely dedicated to science. Six experiments of different scientific areas are integrated in the satellite:

- Exp #1: Measurements of heat conductivity of fluid mixtures with a thin platin wire stretched in the measurement cell.
- Exp #2: Residual acceleration, measured as support for E-1 and E-4.
- Exp #3: Micrometeorite Dust Detector, detects particles from 10E-8 to 10E-18 kg with relative velocities up to 45 km/s.
- Exp #4: Measurements of gas/surface interaction. One of the solar panels is fixed to a scale, which can measure tangential and normal deflections caused by aerodynamic forces. This experiment is activated below 160 km, because the forces must exceed a certain threshold.
- Exp #5: Measurements of pressure and temperature during the first phase of the re-entry. Extendable sensors measure this parameter in front of the satellite's shock wave, while reference measurements are made at the surface.
- Exp#6: Determination of the atomic oxygen flux. The eigenfrequency of a carbon-coated piezo crystal is determined every 10 minutes to measure erosion by atomic oxygen.

The satellite itself is controlled by a Transputer T800. The power is supplied by SI-solar cells on twelf panels around the satellite and stored in two batteries for eclipse times. Attitude is maintained with a momentum wheel and a magnetic torquer. The satellite transmits data with 9600 bit/s and BPSK deomdulation at VHF. Shortly after launch, the telemetry frequency can be published if interest is indicated.

Since BREM-SAT is not a re-entry capsule, a frequently-asked-question is how do you get your experiment-5 data down to ground? First, we have three additional ground stations distributed around the world. Second, we do analyse drag coefficients and all other parameters relevant for re-entry prediction during the preceding 3 month, so we expect the prediction to be fairly correct. However, there is a chance that we might miss the data. Solar flares and magnetic storms could change the orbit in a different way than estimated and our team can not correct its position fast enough. As you do not necessarily need a BPSK demodulator to receiver the satellite's data, catching the satellite could also be done by a radio amateurs. We strongly appreciate any help, especially from southern latitudes and or from Europe. As the launch date comes closer, we will publish more data about BREM-SAT and how to listen to its telemetry data. BREM-SAT has been build by OHB-System, Bremen, HTG-Goettingen and ZARM and is

funded by the German Space Agency DARA (50 QV 9819). For additional information, the BREM-SAT office can be contacted via phone, fax or ordinary mail:

Hans Koenigsmann or Holger Oelze
ZARM/Unversitaet Bremen
Hochschulring/Am Fallturm
28359 Bremen

The Iowa Satellite Project (ISAT)
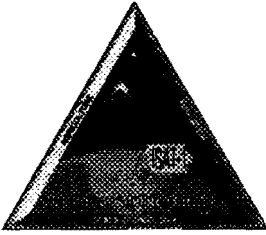
The primary objective of the Iowa Satellite Project is to design, construct, test, deliver for launch, and operate a small relatively inexpensive satellite. To date four different projects have been created to accomplish these goals. The first project was the design of the Iowas Satellite One or ISAT-1 spacecraft. ISAT-1 is being developed as an educational satellite meant to educate the citizens of Iowa in space sciences. The second project was the design of the Iowa Joint Experiment in Microgravity Solidification or IJEMS spacecraft. IJEMS is being developed to investigate the solidification process of a model alloy solution in a microgravity environment. The third project was the design of the Iowa Orbiting Wave Analyzer or IOWA spacecraft. IOWA will investigate the radio environment of the Earth and determine the effect of the ionosphere on Earth-space radio propagation. The fourth project was the development of the Spacecraft Systems and Operations Laboratory or SSOL. The SSOL will give students at Iowa State University an opportunity to obtain hands-on experience with spacecraft. This experience will take two forms. First, students will have an opportunity to interact with orbiting spacecraft. Secondly, students will have opportunities to do experiments with actual space flight hardware. It is hoped that these projects will lead to an opportunity for Iowa State University to design, build, test, launch, and operate its own satellites.

Boone Aviation and Space Education (BASE)

Boone Aviation and Space Exploration began in 1993 when the Iowa Space Grant Consortium funded the development and construction of an interactive space capsule simulator. The project was designed to interest students in math, science and technology using Aerospace as the main theme. The interactive space capsule simulator became part of a larger program as students interest and community support made it viable to add Aviation and Aerospace classes to Boone High School's Curriculum. Approximately seventy students enroll in Boone's Aviation and Aerospace programs each year. Computers, models, simulations and engineering projects give high school students the opportunity to use math, science and technical skills to solve reall problems. Exploring space suit designs, rocket designs, and space food preparation using Iowa's interative fiber-optic system tests students' communication and teamwork abilities. Individuals also participate in NASA teleconferences via satellite dish and telephone.

Developing partnerships with educational, government and business institutions is a key element which makes this program unique. Boone High School students formed an educational partnership with ISAT in December of 1993. Physics and Industrial Techonology students at Boone High School participated in designing a micrometeoroid detection system for ISAT-1. A tenth grader who volunteers at the ISAT facility is conducting further tests on this micrometeoroid system. Students using radio transceivers and tracking antennas are able to communicate with a variety of orbiting satellites. The amateur radio station at Boone High will help ISAT conduct tracking and downlinking experiments with the German (BREMSAT) satellite.

Shuttle Amateur Radio Experiment (SAREX)
Status 1995

Frank H. Bauer, KA3HDO
AMSAT V.P. for Manned Space Programs
and
Matt Bordelon, KC5BTL
SAREX Principal Investigator

Abstract

The Shuttle Amateur Radio Experiment (SAREX) is sponsored by the American Radio Relay League (ARRL), the Radio Amateur Satellite Corporation (AMSAT) and the National Aeronautics and Space Administration (NASA). In 1995 SAREX has maintained its outstanding, multifaceted program of education, experimentation and amateur radio communication between astronauts on the Space Shuttle and ham radio operators and students on the ground. The SAREX Working Group and its hundreds of volunteers have worked hard to develop a robust, comprehensive SAREX program. Despite several challenges which have threatened the program in the past, this team has developed a well rounded, fully operational program on the Shuttle and are working with the NASA engineers, managers and astronauts in an effort to develop a permanent capability on the International Space Station. While not a guarantee, the SAREX team is "cautiously optimistic" that a permanent amateur radio station on the International Space Station will become a reality.

As of this writing, the SAREX team has successfully completed three Shuttle missions in 1995. A fourth mission is planned for the fall and several more are being planned for 1996, including the potential for some long duration SAREX activities. The following represents some detailed highlights from 1995, some of the changes in the program and our visions for the future.
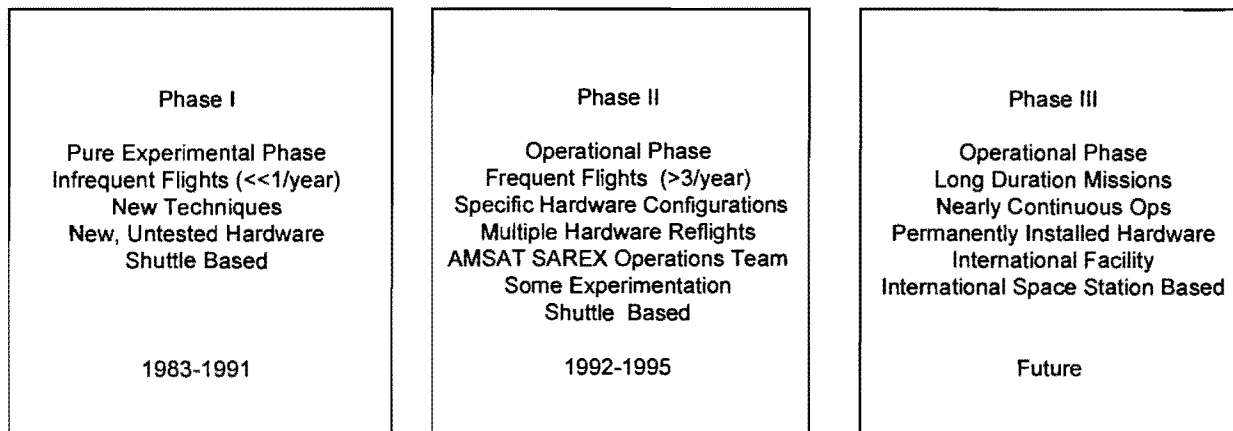
Introduction

The year 1995 will most likely be noted as a year of transition for the Shuttle Amateur Radio EXperiment (SAREX) program. Over the past 11 years, SAREX has flown 18 times as a secondary payload on all 5 U.S. Space Shuttles. Tables 1 and 2 depict all the SAREX flights flown to date. NASA is currently shifting its manned space activity from short duration missions on U.S. Space Shuttles to long duration continuous presence experimentation on the International Space Station (ISS). As NASA transitions, SAREX is striving to stay in lock-step with NASA's manned space plans. Through these efforts and international coordination with amateur space activities in other countries, the SAREX team hopes to provide a permanent amateur radio presence on human-tended space vehicles.

As was stated in reference 1, the SAREX program has evolved through two major phases in its development cycle. See figure 1. The first phase, the pure experimental phase, introduced new amateur radio hardware and techniques to the Space Shuttle program and accomplished several firsts in manned space history. These include the first communications between astronauts and people on the ground outside of the "official" channels (usually reserved for presidents and heads of state). This occurred on STS-9. Other firsts included the first uplink and downlink of pictures on STS-51F, the first packet computer-to-computer radio link on STS-35 and the first video uplink on STS-37.

SAREX Phase II, which started in 1992, represents the operational frequent-flyer phase. During this phase of SAREX, the paperwork, tools and operational techniques have been honed to allow SAREX to fly up to 4-5 times a year on the Space Shuttle. This could only be accomplished through careful development of several specific SAREX configurations which allowed the generation of generic SAREX paperwork to meet Shuttle payload integration requirements. The Crew Training Plan was formalized and made more efficient; generic lessons were developed that could be used for every flight. In addition, a concerted effort was initiated to license the Space Shuttle astronauts. To date, almost half of the U.S. astronauts currently have ham radio licenses. ARRL developed SAREX

Phase I	Phase II	Phase III
Pure Experimental Phase Infrequent Flights (<<1/year) New Techniques New, Untested Hardware Shuttle Based 1983-1991	Operational Phase Frequent Flights (>3/year) Specific Hardware Configurations Multiple Hardware Reflights AMSAT SAREX Operations Team Some Experimentation Shuttle Based 1992-1995	Operational Phase Long Duration Missions Nearly Continuous Ops Permanently Installed Hardware International Facility International Space Station Based Future

SAREX Development Phases
Figure 1

educational materials to be distributed to the schools. To support SAREX Phase II, AMSAT set up a network of volunteers who prepare the schools for their SAREX contacts. These volunteers, who comprise the AMSAT SAREX Operations Team, provide real-time information bulletins to hams around the world and provide critical mission control support to the SAREX team at the Johnson Space Center.

The beginning of SAREX Phase III is represented by the current transition from short duration, intense, Space Shuttle flights to long duration U.S. presence on the Russian Space Station MIR and finally permanently tended human operations on the ISS. As was required when SAREX transitioned from Phase I to SAREX Phase II, the SAREX team will need to evolve its hardware development, its documentation and its operations techniques to better serve the long duration activities in space during the Phase III era. Since both MIR and ISS represent international facilities, a much closer relationship with our international amateur radio partners is required. School group contact, personal contact and experimental contact scheduling and preparation will also require new techniques and procedures. New hardware and new operating bands will naturally occur with a new facility. While this permanent amateur station will provide some new challenges to the SAREX team, it also promises to open the doors to some very exciting, new capabilities which will significantly enhance the SAREX educational outreach program. In addition, it will also provide hams on the ground more frequent, comprehensive access to space.

SAREX Working Group Changes

The SAREX Working Group consists of a core group of "board of directors" that manage the day-to-day SAREX activities and provide guidance and direction to the program. Figure 2 depicts the SAREX Working Group organization. The group consists of members from the ARRL, AMSAT and the Johnson Space Center Amateur Radio Club with Roy Neal, K6DUE, as the working group lead.

As shown in figure 2, the new SAREX Principal investigator is Matt Bordelon, KC5BTL. Matt has stepped in to assume the responsibilities of Lou McFadin, W5DID, who retired from the Johnson Space Center this past spring. Lou is a charter member of the SAREX team. His untiring support as the Principal Investigator of SAREX included the oversight in the development and integration of all SAREX hardware and oversight of SAREX operations at the Johnson Space Center. Matt has assumed these roles as well as supports our recent endeavor to incorporate SAREX on the ISS.

Guidelines

In 1993 the SAREX working group initiated the development of a set of written guidelines. This document has provided a written backbone to help the SAREX team develop a more comprehensive program. These guidelines have been reviewed and approved by
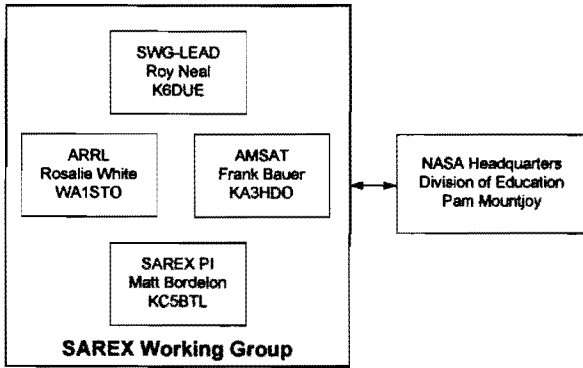
SAREX Working Group Organization
Figure 2

the SAREX team, the Shuttle Program Office and the Astronaut Office. They define the mission planning requirements, particularly the deadlines for SAREX contact inputs to and from the mission timeliners and they aid in the selection of school groups. They define school group selection deadlines, requirements for school group applications, and also define specifics such as the number of contacts per mission and the number of SAREX missions per year. The most recent version of the guidelines is documented in Appendix A. These guidelines have resulted in solidifying SAREX as a frequent flyer payload on the Shuttle. Since our requirements are defined explicitly in this document, they have strengthened our relationship with the NASA team at the Johnson Space Center. As a result, we have significantly improved our chances to become a permanent payload on the ISS.

AMSAT SAREX Operations Team

AMSAT's primary role in the SAREX program is to provide technical support to the team and to foster interest in amateur space activities. In 1992 the AMSAT V.P. for Manned Space developed the AMSAT SAREX Operations Team. This team is comprised of a contingent of AMSAT volunteers from around the world. The primary goal of this team is to provide coordinated technical support for SAREX over the large spectrum of operations and coordination activities.

The breakdown of responsibility of AMSAT's SAREX Operations Team is shown in figure 3. The team provides mentors who technically coordinate the SAREX selected schools, and provides a representative who supports the SAREX flight operations at the Johnson Space Center during each SAREX mission. In addition to these activities, the team staffs the worldwide network of telebridge stations; they disseminate SAREX-related information before, during, and after the flight; and they are responsible for the distribution of the QSL cards. As shown, John Nickel, WD5EEV, is Frank Bauer's assistant. As such, he coordinates some of these activities and acts on Frank's behalf in his absence. In particular, John manages the telebridge support and QSL distribution. Also, and John and Karen Nickel, WD5EEU, provide critical flight operations support for various SAREX missions. The following paragraphs highlight some of these activities and describe some of the changes since reference 4 was published.
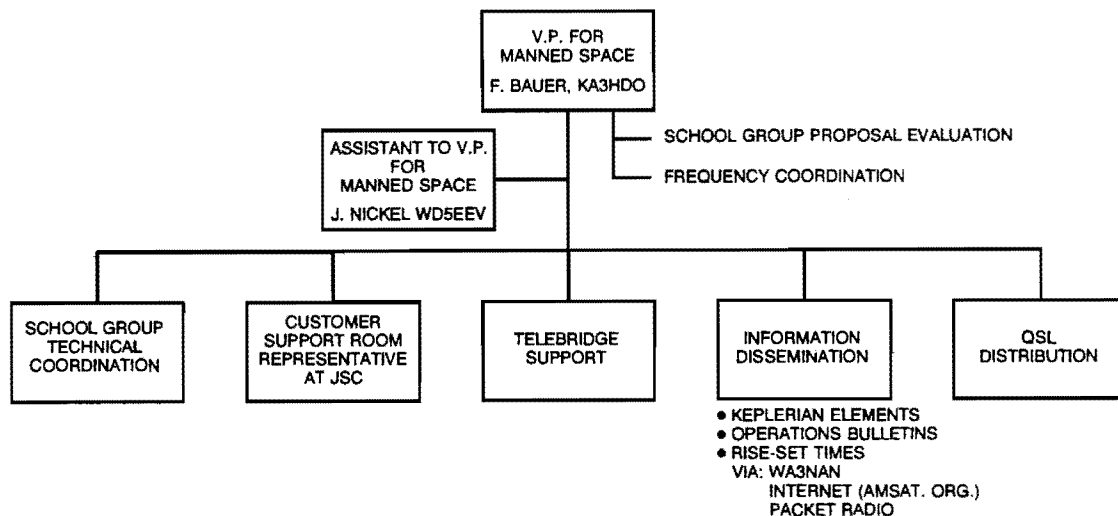
AMSAT SAREX Operations Team
Figure 3

Timely, accurate information is critical during short duration Space Shuttle missions with SAREX onboard. Stale Keplerian elements means that OSCAR antennas will be incorrectly pointed. This leads to missed contacts. Also, primary payload issues can result in a significant shift in the secondary payload mission timeline. General QSO voice and packet operations will be impacted as a result. Backup school group contacts sometimes are cleared for general QSO operations with less than 24 hours notice. The SAREX team relies on several information dissemination methods to get timely information to the users. In particular, the AMSAT.ORG mail exploders "sarex" and "ans" are used during the flight to post up-to-the-minute bulletins on SAREX, to provide the latest orbital elements and to provide Rise and Set times for those without orbital prediction programs. The above information can also be obtained via internet on the Spacelink BBS: spacelink.msfc.nasa.gov or via the GSFC ARC BBS: wa3nan.gsfc.nasa.gov.

The SAREX World-Wide-Web home page is another excellent source of information. This home page, which is currently being restructured, will include information on upcoming SAREX missions and it includes several SAREX-related photos. Currently, there are photos depicting the SAREX flight hardware,

a typical SAREX school group station and some photos of school students talking to Jerry Linenger on STS-64. There are also some audio clips of a school group contact. The URL for the SAREX home page is: http://www.nasa.gov/sarex/sarex_mainpage.html.

Another key information dissemination source is the Goddard ARC shuttle retransmission station WA3NAN. In addition to the latest orbital elements, WA3NAN transmits SAREX bulletins and telebridge school group contacts while they are in progress.

Telebridge Enhancements

The telebridge system consists of an international network of Shuttle ground stations which can be linked to school groups using a telephone conferencing system. See figures 4 and 5. The telebridge system is used when direct Shuttle communications is impractical; possibly due to a low inclination orbit, lack of satellite operations experience at the school, or due to rise/set time scheduling conflicts between the school group and the Shuttle crew. As part of this activity DAROME Telecommunications in Chicago provides the vital telebridge communications link between the astronauts and the school. DAROME has provided this service to the SAREX team since the inception of the telebridge concept on STS-35 in 1990.
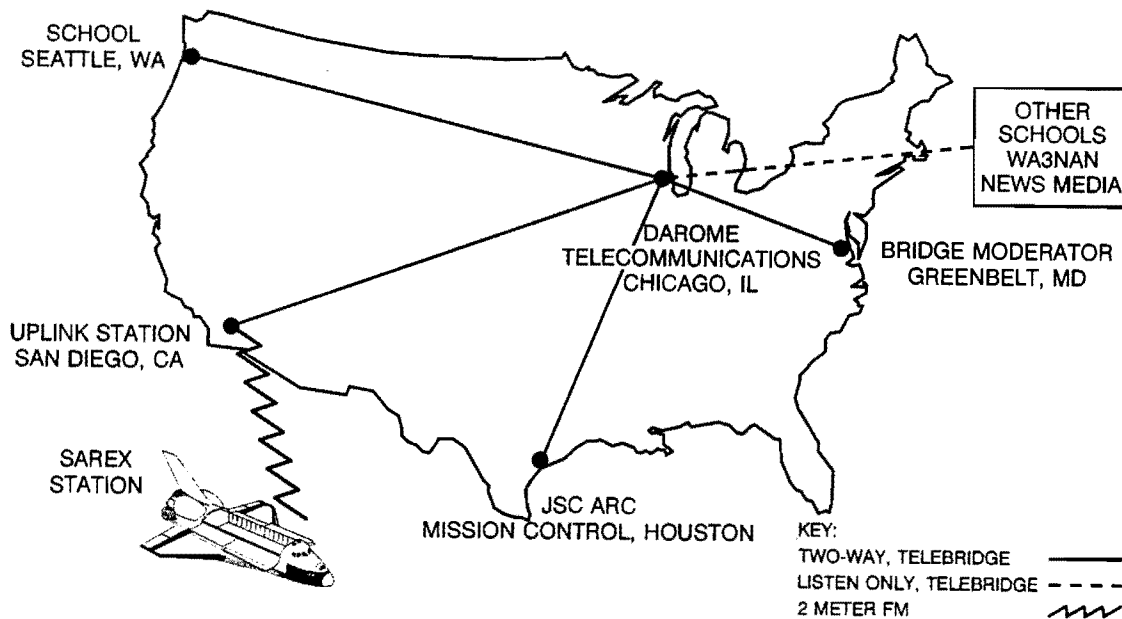
Telebridge Communications Links
Figure 4
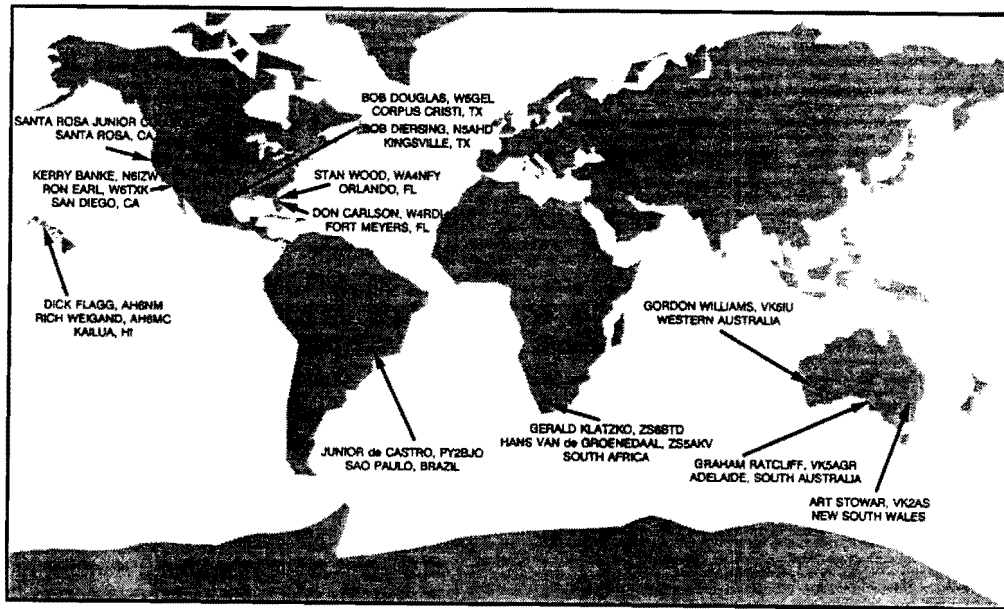
Telebridge Ground Stations
Figure 5

Several enhancements have been made to the telebridge system in the past two years. In particular, two new areas that have been added to augment the telebridge capabilities--South Africa and one high latitude area in the U.S. See figure 5. Hans van de Groenedaal, ZS5AKV, and Gerald Klatzko, ZS6BTD, have graciously donated their services to the SAREX cause in South Africa. In California, several ham enthusiasts, including Tim Bosma, AB6FL, and Steve Teegarden, WH6IC, had a vision to develop a premier telebridge station in a high latitude region of the U.S. They convinced the staff at the Santa Rosa Junior College, Santa Rosa, California, particularly Randy McNally, the assistant dean of instruction, that the bridge station could become a significant educational resource to the school. They were then able to raise over $30,000 in donations to install the telebridge station at the school. The facility includes a state of the art bridging system and an OSCAR satellite station. It also retransmits the Space Shuttle air-to-ground communications on Voice and ATV and provides amateur satellite demonstrations to middle and elementary school students. This premier facility is currently operational and available for all future SAREX missions. Their recent ribbon cutting ceremony attracted a great deal of media coverage from the San Francisco Bay Area.

Over a period of several years, one would expect some changes in telebridge ground stations and ground station support resulting from relocations, career changes, and lifestyle changes. As such, there have been several changes in our bridging support. Steve Teegarden's relocation from Hawaii to California resulted in the enlistment of Rich Weigand, AH6MC, to support Dick Flagg, AH6NM, in Hawaii. In addition, Ralph Warner started school in Los Angeles and could not support future SAREX missions in Southern California. Ron Earl, W6TXK, and Kerry Banke, N6IZW, were, therefore, recruited as bridge stations in San Diego. Another addition to the SAREX telebridge team is Bob Diersing, N5AHD, who has supported several missions from the Texas A&M facility in Kingsville, Texas. All these changes and additions are reflected in figure 5.

School Group Mentoring

AMSAT's international team of operations volunteers, initially formed in October 1992, have done a superb job in making sure the schools are technically ready for their contacts. Each school group is now assigned a technical mentor, who is familiar with satellite communications. The primary responsibility of this mentor is to provide guidance in the school technical setup, to be on-hand for any questions or problems, and to be a conduit for vital information before, during and after the contact. In addition, technical guides, similar to the educational guideline material provided to the schools by the ARRL are distributed to the

159

school contact coordinator. Frequent (weekly or biweekly) meetings/telecons are held with the operations team to ensure they have the latest information and are progressing with their schools. As a result of these efforts, the technical support to all school groups has been considerably enhanced. Since its inception, the success rate with the schools has soared from 66-75% in 1992 to over 90% in 1994. On the most recent SAREX flight (STS-70) the team achieved its first mission with 100% success. A higher success rate provides the general ham community additional opportunities to have QSOs with the astronauts because backup contacts, not required due to a successful prime contact, are usually cleared for general voice and packet QSOs. The AMSAT-NA would like to thank its SAREX Operations Team for their outstanding support and dedication in making these school contacts such a huge success.

The AMSAT team is also developing several SAREX resource guides including a 35mm slide set and a written publication. The written guide will include a compilation of information on past SAREX flights and will help School Group Coordinators prepare for their SAREX contacts.

QSL Cards

A unique QSL card is developed for each SAREX mission. Members of the ARRL Educational Activities Department (EAD), particularly Bob Inderbitzen, NQ1R, works with the astronauts to obtain mission photos and layout the cards. Next, the QSL cards are printed through an ARRL printing service. Hams who make contact with the astronauts or hear their downlink are requested to send their cards directly to the ARRL EAD with the mission number on the front of the envelope. These cards as well as the blank QSL cards are sent to the volunteer organization that distributes the cards. It is AMSAT's job to ensure a timely distribution the QSL cards. John Nickel, WD5EEV, coordinates the distribution of the cards. A specific volunteer group is selected for each mission to distribute the cards. These volunteers provide a valuable service to ham radio operators, to the astronauts and to the SAREX team and their support is extremely appreciated. The cards are usually completely distributed within 2 months after receipt of the cards. To date, all the QSL cards for missions up to STS-67 have been distributed. Figure 6 represents a sample QSL card from the STS-64 mission. Table 3 lists the groups that have volunteered to distribute the QSL cards since 1993.

Frequency Coordination

AMSAT has worked with the ARRL and members of the IARU to help coordinate the SAREX frequencies at the International level. The SAREX frequencies

STS-64 QSL Card
Figure 6

chosen at the beginning of 1993 have had some success. See table 4. However, it has become increasingly difficult to find clear frequencies to use during the school group contacts. The lack of national-level frequency coordination for packet radio has made SAREX operation quite challenging to near impossible in some areas of the U.S. On every SAREX flight, the AMSAT technical mentors have to go to great lengths to research where potential clear frequencies exist at EACH school area and feed this information to the working group. From our extensive worldwide experience, we have found that packet operation is splattered throughout the two-meter band with no coherent bandplan. It, therefore, becomes difficult to impossible for the SAREX team to pick specific school group frequencies which can be used over much of the U.S.

In addition to the above, the Working Group has received post-flight complaints from the Astronauts regarding packet interference on the SAREX voice uplink frequencies. The astronaut concerns and some concerns raised by the European ham community regarding the 145.55 downlink frequency have resulted in an extensive review of the 2 meter bandplan and recommendations for new frequencies. Some of these frequencies were used for the first time on STS-71. In the near future it is hoped that these will be used by all manned spacecraft (Space Shuttle, ISS, and MIR) on 2 meters. Note that these new frequencies do not help the school group frequency problems. Only a coordination of packet radio frequencies at the **national** level will alleviate this problem. A concerted effort should be initiated to develop a nationally recognized coordinated bandplan for packet, similar to the successful repeater bandplan that is now in place.

The following new manned spaceflight frequency bandplan has been presented to the AMSAT/ARRL team as well as several IARU consultants in the US and Europe.

Manned Space Frequency Recommendations:

1)   Worldwide Voice Operation on MIR
        and ISS:
                Downlink   145.80
                Uplinks   144.47 & 144.45

2)   Worldwide Packet Operation on MIR and
        ISS:
                Downlink   145.80
                Uplink   144.49

3)   A secondary downlink frequency of 145.84 is suggested to augment 145.80. This downlink will be used for Shuttle-type vehicles (such as the U.S. Space Shuttle) and for SAREX operations.

4)   If a 600 kHz split pair is desired for Region 1 (Europe and Africa), the following is suggested:
                Downlink   145.80
                Uplink   145.20

5)   The AMSAT V.P. for Manned Space Programs will work with the IARU, the ARRL and the U.S. Digital community in an effort to globally coordinate the above frequencies for manned space operations. Global coordination of all non confidential manned space frequencies for 15 meters, 10 meters and 70 cm is highly recommended and should be initiated.

Note that the above split mode frequency recommendations do not preclude simplex operations, if required. For simplex operations, the team will use frequencies which will minimize frequency contention such as 144.49 and 144.47, and 144.45.

1995 Mission Status

To date, the SAREX team was completed three highly successful missions in 1995 with another planned for later this fall. See table 2 and 5. The following represents highlights of the first three SAREX missions for 1995.

STS-67

The STS-67 mission in March represented the longest space shuttle mission in history, 18 days. Six of the seven crew members on this flight were ham radio operators. These included Steve Oswald, KB5YSR, Bill Gregory, KC5MGA, Tammy Jernigan, KC5MGF, Wendy Lawrence, KC5KII, Sam Durrance, N3TQA and Ron Parise, WA4SIR. See figure 7. The flight included a record 26 schools which stretched the limits of all the volunteers who supported this flight; particularly the AMSAT school group mentors. Despite this heavy workload, this mission, from a SAREX perspective, was nearly flawless.
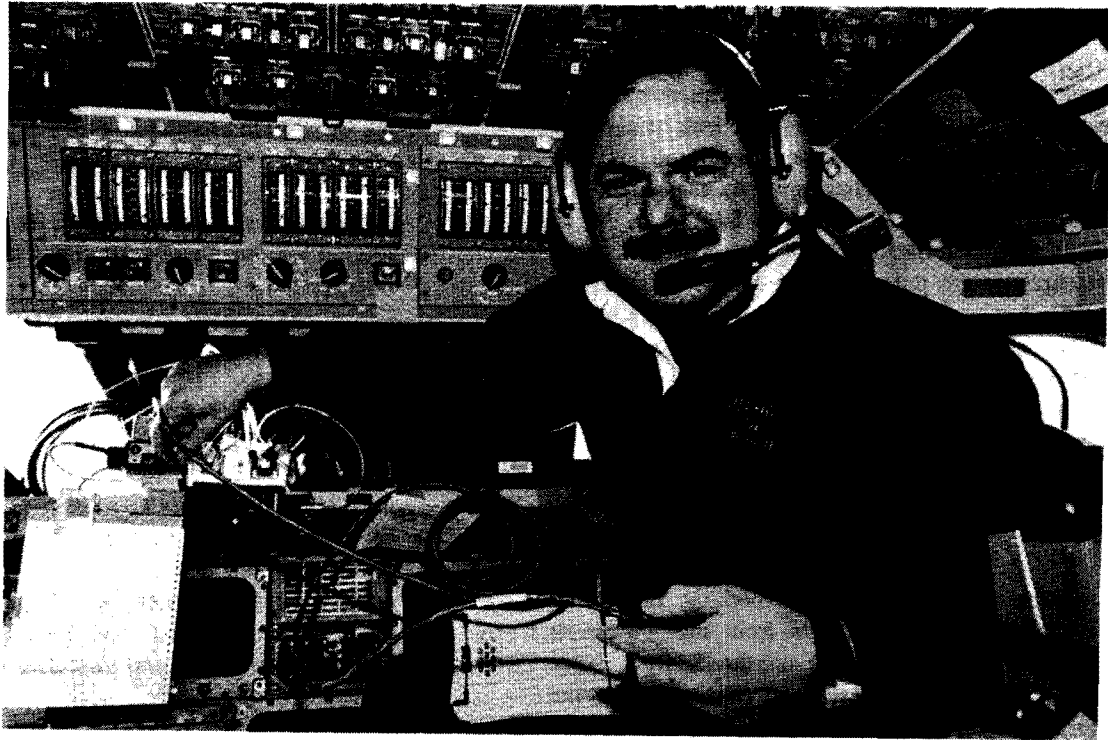
Ron Parise, WA4SIR, with the SAREX Hardware on STS-67

Figure 7

SAREX was well balanced activity on this flight. It included packet radio operations, general voice QSOs, primarily by Ron Parise, school group contacts and personal communications between the crew their families. A total of over 2100 students were present during the shuttle radio linkups. Two noteworthy schools were the JJ Fray Elementary School in Rustburg, Virginia and the Little Lillies English School in Bangalore India. Both schools had outstanding educational programs with significant coverage by the press. The JJ Fray School got letters of congratulation for their SAREX accomplishments from the President and Vice President of the United States and all the federal and state congressional delegates from their area. They also received coverage in many magazines and papers including the Virginia Journal of Education, for example. The Little Lillies School received (and continues to receive) significant television and printed media coverage by all the major networks and papers in India. The students studied amateur radio and astronomy and posed some pretty challenging astrophysics questions to Astronaut Tammy Jernigan.

STS-71

The STS-71 mission in June was the first Shuttle-MIR docking flight. The Russian-American flavor of this mission extended beyond the docking flight. Since there was an amateur radio station on MIR and SAREX on the Space Shuttle, amateur contacts on both vehicles were contemplated and successfully accomplished. Ham astronauts Charlie Precourt, KB5YSQ and Ellen Baker, KB5SIX, were an integral part of this historic flight. Precourt, in fact, piloted the Space Shuttle during the rendezvous and docking activity. (Another first for ham radio operators). Five schools had an opportunity to talk to the shuttle crew during this flight including the Benbrook Elementary School in Benbrook, Texas, with Donna McKinney, N5WOE, at the helm and the Yessentuki School Number 3 in Yessentuki, Russia which was coordinated by Valery Agabekov, UA6HZ.

The astronauts and cosmonauts used both the SAREX equipment and the MIR equipment during this flight. A new SAREX configuration was developed for this and subsequent Shuttle-MIR missions--Configuration M. Configuration M consists of the 10 watt Motorola

wide-band radio used by NASA to communicate with MIR and either a window mounted antenna or a payload bay antenna which were developed for MIR operations. As part of the experimentation on this flight, the performance of each antenna was tested through SAREX ground stations. Doug Loughmiller, G0SYX, in Surrey England; Gordon Williams, VK6IU, in Australia; and Stan Wood, W4NFY, and Lou McFadin, W5DID, in Orlando Florida supported these tests.

STS-70

Just a few days after the STS-71 landing, the STS-70 mission commenced despite its one month delay due to woodpeckers that poked holes in the external tank. Ham astronauts Don Thomas, KC5FVF, and Nancy Sherlock Curie, KC5OZX provided the SAREX team with a truly outstanding mission. The following bulletin, uplinked to the crew for the SAREX team on the last day of the flight, truly sums up this mission.

STS-70 Uplink on Flight Day 8:

The SAREX team wishes to congratulate the 18th SAREX crew for an outstanding job. We hope you enjoyed the eight school contacts. By our calculations, you have talked to 291 students (1523 people in attendance) and answered 91 of their questions. You have conversed with over 400 hams by voice and 771 by packet.

It is an incredible feeling to see all the hard work come together and perform flawlessly on this mission. The amateur radio community, the school groups, ARRL, and AMSAT express their deep gratitude to you for all you have done. The schools send a Buckeye thanks (Note: all but one crew member had roots in Ohio). Your new friends in Argentina (one of the school groups) send their regards. Your ham contacts have already started sending in their QSL cards and are asking when you might fly again.

Your efforts allow us to ride along side you. Your superb answers to school childrens questions provide the inspiration for the future astronauts of our small blue planet. You have made this a truly educational experience for all of us.

Thank you for a job well done. 73 de SAREX.

Hardware Enhancements

There are several hardware upgrades in progress at this time. Lou McFadin is modifying pico-packet TNC to include several SAREX enhancements over the current SAREX TNC. In particular, the SAREX software is being installed in the TNC. Adequate RAM has been incorporated to store all the SAREX robot contacts without requiring a download on the Shuttle laptop, and battery operation will allow the TNC to be powered up during Shuttle power conservation measures. It is expected that this hardware will be available for flight in the middle of 1996.

The ROBOT 1200C SSTV module was qualified and initially flown on STS-51F in 1985. Since that time, there have been substantial reductions in the size and weight of SSTV electronics. The Robot SSTV hardware is not flown very often due to its size and weight. The potential for a significant size and weight reduction, coupled with the fact that today's PC computers can send and receive SSTV signals with a minimal, low cost hardware make SAREX SSTV an attractive operational mode. The SAREX team is currently working with several SSTV hardware experts to develop a small, low power, lightweight module for the Shuttle. Its size and weight should be comparable to today's packet module. It is hoped that this module will be available by the end of 1996 or early 1997.

Future SAREX Flights on the Space Shuttle

There is one more SAREX flight planned for 1995 and at least five more scheduled for 1996. See table 5. Four of these missions will be Shuttle-MIR docking missions--STS-74, STS-76, STS-79 and STS-81. On two of these flights, STS-76 and STS-79, crew members Shannon Lucid and Jerry Linenger, KC5HBR, will leave the Shuttle for a long duration stay on MIR. During a recent meeting in Houston, a request was made by the SAREX Working Group which would allow the astronauts to make SAREX contacts (school group, general QSO and personal contacts) using the MIR radio. While there are several hurdles that need to be overcome to make this feasible, it could provide the SAREX Working Group a unique opportunity to validate some of the new operations techniques that we will need to put into practice on the ISS. The Working Group will continue its dialog with NASA and its Russian partners to support this unique opportunity.

International Space Station Plans

NASA will reach a continuous human presence in space in three discrete steps. The first is through joint U.S. Russian missions where U.S. Astronauts will spend extended periods of time (on the order of 90 days) on the Russian Space Station MIR. This activity was initiated in 1995 with Norm Thaggard's visit to MIR and the STS-71 MIR docking mission. This activity will continue until 1997. As the ISS is being assembled, from 1997 to 2002, "human-tended" operations represent the second discrete step in the NASA program. During this phase of the ISS development several week duration operations in the ISS laboratory module with a docked Space Shuttle will become the norm. Finally in 2002 the habitation module will be installed an permanent crew presence on the ISS will begin.

After reviewing the future shuttle flights, it becomes increasingly apparent to focus future SAREX activities toward a permanent presence in space. If one were to ponder the probability of amateur activities in space, one would quickly realize that "permanent presence" is the International Space Station.

The SAREX team picks flights based on many criteria, but the major variables in the SAREX manifest are the attitude timeline and primary mission of each shuttle flight:

Shuttle/Mir docking missions have a busy timeline, many flight manuevers, minimal school activity (<5 schools), and some random QSO activity. The same goes for "early assembly flights," which will look very similar.

Laboratory flights use a stable shuttle attitude and consistent activity level. These are ideal SAREX conditions. These flights can have more school contacts, more random QSO's, packet operations, and even time for experimentation.

Midway through the assembly flights (at the human tended operations milestone) there will be packet, regularly scheduled school contacts, and random QSO's because of less restrictive timelines. These flights are similar in activity levels with the MIR station.

After the habitation module is launched, our permanent presence will facilitate more school contacts, random

QSO's, experiments, demonstrations, earth observation downlinks, etc.

SAREX will (1) SERVE as an educational tool, (2) BE an outreach to the general public, (3) ALLOW a method for crews to maintain contact with family and friends while on orbit (to improve psychological factors), (4) PROVIDE an experimental communications testbed, (5) OFFER a back up communiations link for emergencies, and (6) PROVIDE public information to the grass-roots public.

SAREX Equipment Strategy

While focusing on the new home for SAREX, we must not forget what got us where we are today. The plan is to gradually phase SAREX operations to a permanent station inside the ISS Habitation module in the year 2002.

The first step SAREX will take is to update/upgrade the equipment currently used onboard shuttle missions (some of the upgrades were mentioned previously). SAREX currently has six different configurations (including the non-SAREX hardware config) which provide us with 2m frequencies at 2.5 watts, a 1200 baud TNC which counts "connects," a slow scan module, a fast scan (ATV) module, a 2m/70cm cavity antenna, a 70cm loop antenna, and numerous interface cables. Upgrades would include a dual bander (2m, 70cm) radio; an expanded TNC (pico packet with more memory and BBS); a better, smaller slow scan module; and a battery charger.

At the same time, SAREX will the utilize the unique opportunity of having US hams onboard the Russian space station Mir to develop and refine procedures & equipment that will also be used aboard the ISS. Mir already has a 2m station onboard, but has plans to add new capabilities to the station in the near future (see Euromir ANS bulletin).

Next, SAREX will utilize the upgraded, portable equipment during the early "ISS assembly flights," which start in late 1997. Current, tenative plans include SAREX operations and permanent stowage as early as the second assembly flight. SAREX equipment during this time period has the distinct possibility of operating on both vehicles. Changes in the cavity antenna's adapter plate will be sought to use nadir windows on the partially assembled space station. The equipment will be upgraded to include a radio and TNC capable of higher baud rates.

During later assembly flights (1998), SAREX will explore opportunities to mount a steerable antenna on the ISS truss to provide the capability to work other space craft and satellites (i.e., Phase 3D). SAREX will attempt to upgrade the portable equipment one last time before the permanent station is delivered in its module.

Finally in 2002, the habitation module will be delivered with a external nadir antenna; and a rack mounted tranceiver capable of many new modes, frequencies, and future expansion.

SAREX Development Strategy

When do we start? The answer is NOW. The working group has prepared paperwork to become "officially manifested." The ISS design and its outfitting are maturing at a rapid rate. We must ramp up our effort on the habitation module station design. Work has begun on the scarring requirements for the permanent station. We must explore the real estate for our steerable antenna. We must design for future expansion. We must make the portable equipment usable on both vehicles. We must use the lessons learned from our past flights.

Lastly, SAREX will seek to combine efforts with the International Partners who are helping forge the ISS. We must keep SAREX an international venture. We must coordinate amateur activities in European, Japanese, and Russian modules on the ISS. This will enhance the overall ISS amateur "presence" and capability.

Third Party Restrictions

As the U.S. space program merges its activities with the international community, particularly Russia, the SAREX program is quickly doing the same. Amateur radio has always shared an international camaraderie with our neighbors across the waters. This camaraderie has resulted in international partnerships which have extended to new heights...outer space. The most recent international space station collaboration is resulting in a quick blurring of the separate U.S. and Russian amateur radio activities on the U.S. Space Shuttle and the Russian space station MIR into a single Manned Space activity. These changes have brought new challenges to the SAREX team; that of ensuring a strong, well balanced program on an evolving manned platform while maintaining and adapting the international regulations regarding international

amateur communications. The 3rd party restrictions between Russia, the U.S. and other countries have been a problem for the SAREX and MIR teams this past year. As more countries become active partners in the international space station, this issue will get worse. Unfortunately, these restrictions curtail the amateur community's ability to spark student's interest in amateur radio by not allowing some astronauts (on international space carriers) and some foreign space participants to talk to students while in space.

The SAREX team is actively working with our international partners, particularly Russia in an attempt to get a permanent waiver of third party traffic restrictions to manned space vehicles. This would go a long way in improving international participation in amateur radio.

Conclusions

Human operated ham radio in space appears to be transitioning from short, intense bursts of activity (analogous to a DXpedition) to permanent (nearly continuous) operations. Multiband, multi-mode operation and regularly scheduled school group contacts will be the norm in this scenario. While "cautiously optimistic" in an era of government budget cuts, the SAREX team will put forth its best efforts to ensure these dreams will become a reality for terrestrial based radio amateurs and ham radio operators in space.

While it continually maintains an eye towards the future, the SAREX team strives to improve the on-going Shuttle-based SAREX activities. SAREX is an outstanding, low cost outreach program for amateur radio, NASA and science and technology. It could only be accomplished through the superb support from the hundreds of volunteers from around the world and the support, interest and encouragement from NASA, particularly the Astronaut Office and Division of Education at NASA Headquarters. The authors extend their deepest thanks to all these volunteers and especially to outgoing Principal Investigator Lou McFadin, W5DID, for their tremendous support to bring space-borne Shuttle astronauts literally into the schools and living rooms of the general public.

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STS-9 Columbia	November, 1983	Owen Garriott, W5LFL	Voice
STS-51F Challenger	July, 1985	Tony England, W0ORE John-David Bartoe, W4NYZ	Voice, SSTV
STS-35 Columbia	December 1990	Ron Parise, WA4SIR	Voice, Packet
STS-37 Atlantis	April 1991	Ken Cameron, KB5AWP Jay Apt, N5QWL Linda Godwin, N5RAX Steve Nagel, N5RAW Jerry Ross, N5SCW	Voice, Packet, SSTV, ATV Uplink
STS-45 Atlantis	March 1992	Dave Leestma, N5WQC Brian Duffy, N5WQW Dirk Frimout, ON1AFD Kathy Sullivan, N5YYV	Voice
STS-50 Columbia	June 1992	Dick Richards, KB5SIW Ellen Baker, KB5SIX	Voice, Packet SSTV, ATV Uplink
STS-47 Endeavour	September 1992	Jay Apt, N5QWL Mamoru Mohri, 7L2NJY	Voice, Packet
STS-56 Discovery	April 1993	Ken Cameron, KB5AWP Ken Cockrell, KB5UAH Mike Foale, KB5UAC Ellen Ochoa, KB5TZZ Steve Oswald, KB5YSR	Voice, Packet SSTV, ATV Uplink
STS-55 Columbia	April 1993	Steve Nagel, N5RAW Jerry Ross, N5SCW Charlie Precourt, KB5YSQ Hans Schlegel, DG1KIH Ulrich Walter, DG1KIM	Voice, Packet
STS-57 Endeavour	June 1993	Brian Duffy, N5WQW Janice Voss, KC5BTK	Voice, Packet
STS-58 Columbia	October 1993	Bill McArthur, KC5ACR Marty Fettman, KC5AXA Rick Searfoss, KC5CKM	Voice, Packet

SAREX Missions Flown to Date 1983-1993
Table 1

Flight	Date	Ham Crew	Modes
STS-60 Discovery	February, 1994	Charlie Bolden, KE4IQB Ron Sega, KC5ETH Sergei Krikalev, U5MIR	Voice, Packet
STS-59 Endeavour	April, 1994	Jay Apt, N5QWL Linda Godwin, N5RAX	Voice, Packet
STS-65 Columbia	July 1994	Don Thomas, KC5FVF Bob Cabana, KC5HBV	Voice, Packet
STS-64 Discovery	September 1994	Dick Richards, KB5SIW Blaine Hammond, KC5HBS Jerry Linenger, KC5HBR	Voice, Packet,
STS-67 Endeavour	March 1995	Steve Oswald, KB5YSR Bill Gregory, KC5MGA Wendy Lawrence, KC5KII Tammy Jernigan, KC5MGF Sam Durance, N3TQA Ron Parise, WA4SIR	Voice, Packet
STS-71 Atlantis	June-July 1995	Charlie Precourt, KB5YSQ Ellen Baker, KB5SIX	Voice
STS-70 Discovery	July 1995	Don Thomas, KC5FVF, MS Nancy Curie, KC5OZX, MS	Voice, Packet

SAREX Missions Flown to Date 1994-1995
Table 2

Mission	Date	Organization	Coordinator
STS-56	4/93	Vienna Wireless Society	Chris Bayus
STS-55	4/93	IBM Amateur Radio Club	Neal Osborn, N4PYB
STS-57	6/93	Miami County ARC	Marvin Force, KB8MUV
STS-58	10/93	ARRL/Connecticut DX Association	Peter Budnick, KB1HY
STS-60	2/94	Cowley County Amateur Radio Club	Karen Nickel, WD5EEU
STS-59	4/94	Orange Park Amateur Radio Club	Dave Kalahar, KD4HXT
STS-65	7/94	Lake County Amateur Radio Club	Charlie Sufana, AJ9N
STS-64	9/94	Nashua Area Radio Club	Joel Levin, KD1ON
STS-67	3/95	Edison Radio Amateur Association	Brian Westphal, KB8QXA
STS-71	6/95	Sacred Hearts Academy Radio Club	Dick Flagg, AH6NM
STS-70	7/95	Sterling Park ARC	Dick Maylot, W4LMJ
STS-74	10/95	Greater Norwalk ARC	Ray Hilson, WB1U

SAREX QSL Volunteer Organizations
Table 3

		Europe	Rest of World
Voice	Downlink	145.55 MHz	145.55 MHz
	Uplinks	144.80 MHz	144.99 MHz
		144.75 MHz	144.97 MHz
		144.80 MHz	144.95 MHz
			144.93 MHz
			144.91 MHz
Packet	Downlink	145.55 MHz	145.55 MHz
	Uplink	144.49 MHz	144.49 MHz

SAREX Frequencies Chosen in 1993
Table 4

Mission	Launch	Length	Ham Crew	Inclination	Config.	Op. Modes
STS-74 MIR Docking Flt-2 Atlantis	10/26/95	8 days	Ken Cameron, KB5AWP, CDR Bill McArthur, KC5ACR, MS Jerry Ross, N5SCW, MS	51.6	M	FM Voice
STS-76 MIR Docking Flt-3 Atlantis	3/21/96	9 days	Richard Searfoss, KC5CKM, PLT Shannon Lucid, TBD, MS Linda Godwin, N5RAX, MS Ron Sega, KC5ETH, MS	51.6	M	FM Voice
STS-78/LMS Columbia	6/27/96	16 days	Susan Helms, TBD, MS Charles Brady, N4BQW, MS Robert Thirsk, VA3CSA, MS Jean-Jacques Favier, TBD, MS	39	C	FM Voice Packet
STS-79 MIR Docking Flt-4 Atlantis	8/1/96	9 days	Jay Apt, N5QWL, MS Jerry Linenger, KC5HBR, MS	51.6	M	FM Voice
STS-80 Columbia	11/7/96	16 days	TBD	28.5	C	FM Voice Packet
STS-81 MIR Docking Flt-5 Atlantis	12/5/96	9 days	TBD	51.6	M	FM Voice

Notes: CDR=Commander, PLT=Pilot,
MS#=Mission Specialist, PS#=Payload Specialist

Future SAREX Flights
Table 5

Appendix A
SAREX Contact Guidelines

1. The deadline for school group applications for a particular mission will be set at launch minus seven and a half months (L-7.5). Final school selection will be made at L-7.

2. No school groups will be considered for a SAREX contact unless a fully completed application is received by the ARRL (American Radio Relay League) before the deadline set for that particular mission. Proposals are also encouraged but do not take the place of an official application.

3. In an effort to geographically diversify the SAREX contacts, there will be no more than two school contacts from the same state on one specific mission.

4. To maintain fairness to those schools seeking a SAREX contact, repeat contacts with school groups/school districts should be discouraged whenever possible. (ARRL does have a waiting list already)

5. The selection of schools should be based on the application/proposal submitted by the school group. The following criteria should be used to evaluate the schools:
    a) Educational program including the school's ability/knowledge to carry out such a plan.
       (Note, this criteria carries the most weight in the selection process)
    b) Amateur radio activities initiated prior to the SAREX contact and planned after the completion of the SAREX contact.
    c) Technical ability of the group to set up an adequate station and successfully complete the SAREX contact.

6. The SAREX configuration for a specific mission will be discussed and decided with the crew at the Flight Planning and Storage Review (L-8). A list of the number and type of all planned crew selected activities (personal, school and experimental) shall be provided by the crew at the start of crew training. SAREX will provide the preliminary requirements to the Flight Activities Officer (FAO) at approximately L-7. An initial pass list (from FAO) shall be provided to SAREX at L-6. SAREX shall provide the final requirements by L-5. The final pass list shall be supplied to SAREX at L-4.

    The total number of contacts that can be accommodated on a specific mission shall be determined based on negotiations with the ARRL, the Radio Amateur Satellite Corporation (AMSAT), the Space Shuttle Program (SSP), NASA Headquarters Education Division (Office of Human Resources and Education), and the flight crew. There will be one SAREX radio check scheduled as the first SAREX contact. In addition, the total number of scheduled SAREX school and experimental activities, excluding personal flight crew contacts, shall not exceed an average of 2 per day for the duration of the mission. Crew recommendations will be carefully considered for final selection of schools to be contacted but should not exceed one-fourth of the total. Personal flight crew scheduled contacts will be limited to one per crew member. An adequate backup schedule shall be developed and included in the mission timeline.

7. The SAREX team will make every effort to minimize personal contacts over the mainland U.S.

8. General contacts with the amateur fraternity are a vital facet of SAREX. The crew is highly encouraged to make voice or packet contacts with hams on the ground whenever possible.

9. When SAREX is left unattended during a flight, it is desired that the packet system shall be kept in robot mode as much as possible.

10. Backup contacts which are pre-scheduled into the timeline but not needed due to successful prime contacts may be used for general voice contacts with the amateur radio fraternity, if crew activities permit.

11. Mission Development and the SAREX program have established that nominally four SAREX flights should be manifested per year. This number is a SAREX target which can be increased or decreased from year to year based primarily on SAREX budgetary and resource constraints.

Benbrook Elementary's Experience
With The Shuttle Amateur Radio EXperiment

Donna McKinney, N5WOE

On July 4th, 1995 at least 250 people in Benbrook Texas had an experience they will never forget. They were present as students from Benbrook Elementary School got their chance to interview an astronaut while he was orbiting the earth in the space shuttle "Atlantis". None of us could think of a more exciting and patriotic way to spend our holiday.

It all began a year and a half earlier at the 11th Annual AMSAT Space Symposium in Arlington Texas in October 1993. Amateur Radio Operators Randy McKinney, N5SVW, and Donna McKinney, N5WOE attended the symposium and, among other things, learned how to request a SAREX radio contact with the school that their 2 sons attend. Frank Bauer, KA3HDO, of AMSAT and Rosalie White, WA1STO, of ARRL filled them in on the details. Both are members of the SAREX Working Group comprised of representatives from NASA, the ARRL and AMSAT.

Next Donna approached the Principal of Benbrook Elementary School Mrs. Jonna Murray, who agreed that SAREX would be a great project for our students. In the 1993 - 94 School year SAREX was introduced to the students of all grade levels (Kindergarten to 5th Grade) through presentations by Donna McKinney about SAREX and the science onboard the missions that carried this special amateur radio payload. Lesson Plans provided by the ARRL were used for these presentations. The students were very excited by all this space talk and wanted to learn more.

Early in 1994 the McKinney's worked along with several teachers, administrators and ham radio operators to draw up a SAREX proposal. Included were many educational activities that we hoped to do at Benbrook Elementary to take full advantage of the SAREX experience. These activities were not only limited to classwork, but also included guest speakers from the community, field trips to space related exhibits, an involvement with the cites government, the formation of a science club, a "Space Camp", "Star Parties" with the local astronomical group, a "Good Luck Banner" which we hoped could fly on the shuttle, and several contest. This very optimistic proposal was sent to the SAREX Working Group along with our schools SAREX School Application on February 14, 1994.

In March of 1994 Rosalie White of ARRL Educational Activities Department asked Donna McKinney to speak at ARRL National Convention Educational Workshop on "Introducing SAREX at an Elementary School". This was conveniently being held at Ham-Com in Arlington Texas. We at Benbrook Elementary felt that our SAREX proposal had been well received.

In May of 1994 Frank Bauer of AMSAT let us know that Richland Elementary School in nearby North Richland Hills was having a SAREX Radio Contact with STS-65. He suggested we see if Sandra Hines, KB5CXR, 5th Grade teacher at Richland Elementary would like some help planning for the event. Mrs. Jimmie Haygood, 5th Grade teacher from Benbrook helped with their Space Camp. Doug Howard, KG5OA, and Ray Hoad, WA5QGD, helped with setting up the equipment prior to the event.

Randy and Donna McKinney and several teachers and administrators from Benbrook Elementary were present at Richland Elementary's SAREX Contact with STS-65 in July 1994. The exposure to this SAREX event provided us with very valuable lessons in how to prepare and rehearse the students to ask their questions, how to set up our auditorium during the contact and what to include in a program leading up to the contact. We used all of this information about a year later.


**Jimmie Haygood, 5th Grade teacher with
Donna McKinney, N5WOE and Randy McKinney, N5SVW**

The 1994 - 1995 school year started in August. We had to determine which educational activities in the proposal could begin right away. Others had to wait until we were selected for a SAREX contact with a certain mission. We also gained video support from Polly High Schools Communications department and are still working with them on a documentary we hope to complete by Fall 1995.

Here are details of the educational activities we completed during the 1994 - 1995 school year leading up to our SAREX Radio contact:

Science Club: 35 students joined. We met after school two Mondays each month. We heard speakers from the Ft. Worth Astronomical Society, the North Texas Balloon Projects, and the Dallas Area Rocket Society. Students built model rockets and launched them 2 times at the school. Students also

helped support the "Space Camp" by making 30 paper mache globes (one for each class) and giving tours through the space camp activities.
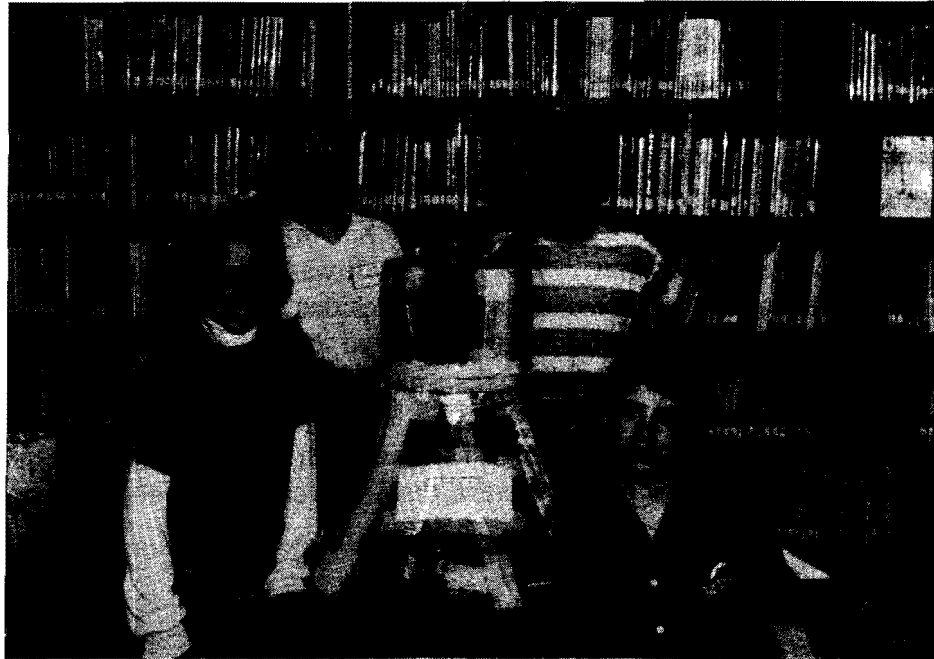
Donna McKinney, N5WOE, discussing the North Texas Balloon Project payload with Science Club students Kandice Marburger, David Smith and Robert McKinney.

Space Cafe: Science Club students decorated cardboard walls with pictures and information about the NASA shuttle program. All 635 students at the school had an opportunity to eat lunch in the Space Cafe and watch a NASA video about living and working in space.

Star Party: On the shores of Lake Benbrook. Members of the Fort Worth Astronomical Society brought telescopes ranging from 16 inch to 3 inch mirrors. Fun was had by all who attended.

Space Camp Month in January 1995:

Week 1 - Solar System Week. Students looked at an astro-photography display, watched a NASA Video on the planets, and preformed a gravity activity which compared their own weight on earth and on different planets.

Week 2 - Geography. Classes looked at a book called "Seeing Earth from Space" by Patricia Lauber. It gives an astronaut's view of the earth. We compared globes to flat maps. Each class added the features to the paper mache' globes made by the science club.

Week 3 - Living & Working in Space. We performed hands-on experiments included in two NASA Books called "Living & Working in Space" Book 1 and Book 2. These experiments focused on interesting things like gravity, satellite communications, the bulkiness of space suits, and sleeping and eating in space. The students loved this week!

Week 4 - Art Week. We made a space collage' that was 82 feet long and 4 1/2 feet high. Every class participated. All of the students placed a space man with their own face on the collage along with pictures, photographs, poems, and stories about space. It was displayed in a school hallway for Public School Week and for the rest of the school year.

In January 1995 we were informed by the SAREX Working Group that Benbrook Elementary was selected for a SAREX Radio Contact with STS-71. It was scheduled for launch in May 1995. STS-71 was going to be a very historic mission which included the first docking of an American space shuttle with the Russian Mir space station. We were elated to be picked for this particular mission! Now we could begin the other educational activities included in our SAREX proposal.

In February 1995 we held a Logo Contest. It was won by Jeff Meredith in the 5th Grade. His logo was used on invitations to our SAREX event, thank you cards and 640 T-Shirts.

Jeffery Meredith, 5th Grade, holding up a T-Shirt with his winning SAREX Logo.

Our focus on city government began in March 1995 when Mrs. Joy Lott's 1st and 2nd grade students held a school wide election to pick a new name for the street in front of the school. These students appeared before the Benbrook City Council and asked them to change the name of street to "Astronaut Ave" during the duration of the STS-71 mission. The Council agreed to do so and worked with the Benbrook Firefighter's Association to have the signs made. They were great with the words "Astronaut Avenue" in large letters and "SAREX 1995" appearing under a silhouette of a space shuttle.

The community of Benbrook became very involved in this project. The 2 local newspapers ran almost weekly articles about our SAREX events at the school. Many businesses and organizations within Benbrook donated money to fund the project and to buy space related educational items for the school.

In April we placed a local photographer on the school roof to take a class picture of all teachers and students as well as representatives from many of the community groups that had helped us with the project. There were about 680 people in the picture. We surrounded the picture with signatures of key people at the school, one student from each grade level, the Benbrook City Council members, Benbrook Police Department, Benbrook Fire Department, Benbrook Water Authority, Congressman Joe Barton and his assistant Christy Townsend, and the core of Amateur Radio Operators. We left an area blank for the STS-71 astronauts to sign. Our space picture had to be examined and receive proper approval. It could not be very big (4 inches by 6 inches weighing 0.5 ounces). We were very happy when we received word that it was going to be allowed to fly on the "Atlantis". When it is returned to us it will be displayed at the school.

During the Spring many of our students made field trips to the local OMNImax Theater to see "Destiny in Space" about the repair of the Hubble Space Telescope on STS-61. Some classes also went to the Pate Museum Of Transportation which has on display 2 space Capsules and a Chimp Coach.

Several local collectors loaned us items for a Space Memorabilia display which included priceless stamps, collectors coins, space photographs, SAREX QSL Cards, Crew Insignia Patches, and the Space Shuttle Model from the Fort Worth Museum of Science and History. This display gave us an opportunity to speak with all of the students about the history of space program.

At a PTA Meeting in May we showed the ARRL video "Ham Radio In Space" which is an excellent way to describe SAREX to newcomers. At this meeting we announced the winners of the SAREX Student Question Contest. These 14 students would ask their winning questions to the astronaut during our SAREX contact with STS-71.

Also in May Astronaut Dr. Bernard Harris, Jr. visited our school. He flew on STS-63 the mission that performed a rendezvous with Mir space station in Feb. 1995. During this mission Dr. Harris became the first African American to walk in space on an EVA to test new space suit designs. He is a very inspirational speaker who emphasized to the students following their dreams, and the importance of science, math, and technology to their futures.

Our school year ended before the launch of STS-71. We used the time between May 25th and July 4th to meet with, rehearse and study the mission with the 14 students who would talk during our

SAREX Contact. We held a launch party on June 27. The two weeks prior to launch we were busy setting up the SAREX radio station on top of and inside the school.

**Keith Pugh, W5IU, with Randy McKinney, N5SVW, and
Mark Felton, N5UWM with the antenna's on the schools roof.**
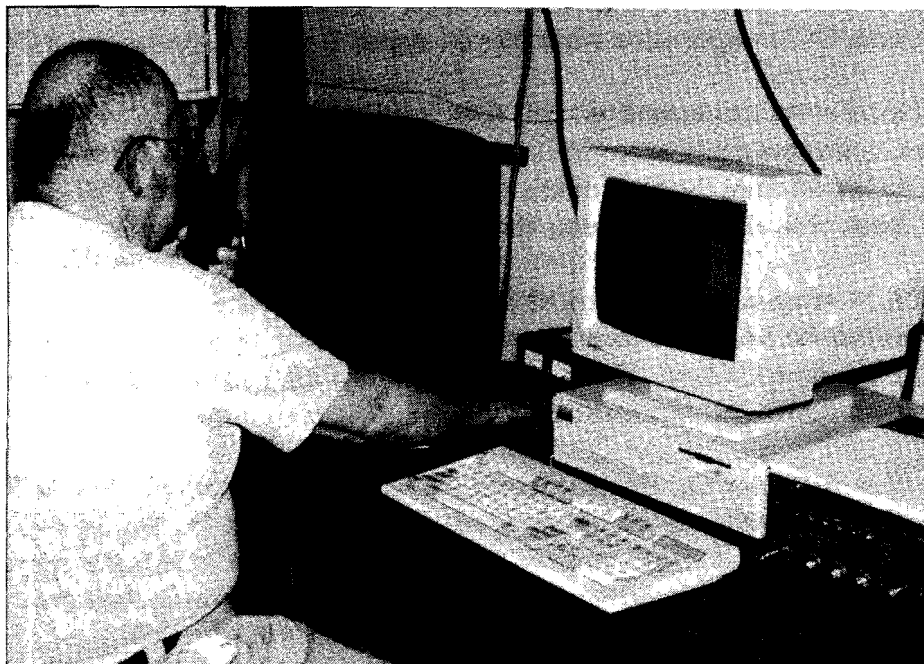
Keith Pugh, W5IU at the station during testing.

176

The culmination of all of these activities took place on July 4th, 1995 when Benbrook Elementary was placed in the STS-71 timeline for a SAREX contact just before 2:00 pm CDT. Benbrook Elementary was the first school scheduled for a SAREX school contact with the shuttle using the new Mir radio configuration of a Motorola Radio and Helix antenna in the cargo bay. All of the Ham Radio operators involved were very anxious about the signal strength coming from Atlantis.

We started hearing Atlantis/Astronaut Greg Harbaugh about 1 1/2 minutes into the pass, but had to wait until almost 2 minutes to hear him over the local power line noise (which had never been there during any of our evening rehearsals). His signal was 5/9 during the middle of the pass. We were pleased at how well he heard our students. He did not ask for any of them to repeat! We had 11 questions answered and 3 students disappointed.

**Student Brandon Moore asking his question to
Astronaut Greg Harbaugh with Donna McKinney, N5WOE.**

There were about 250 people (mostly non-hams) present during the contact. They were spellbound by what they were witnessing. It was very rewarding for everyone, especially the 11 successful students.

We had excellent media coverage for our SAREX radio contact with STS-71. The week before our event 4 local radio stations played interviews and announcements about the upcoming event. One local NBC station did a story on our dress rehearsal, which was on the day the Atlantis and Mir actually docked. On July 4th during our SAREX radio contact the media showed up in force: 3 local TV stations (NBC, CBS, and FOX), 2 local radio stations and 4 local newspapers. The coverage they gave

us was great with every story mentioning both the Shuttle Amateur Radio EXperiment and Ham radio's role in the project. This coverage reached throughout much of the state of Texas.

The SAREX contact was played real time over a system of repeaters covering much of North Texas. Many hams who were not able to attend were still able to share in the experience in this way. Special thanks to Harold Reasoner, K5SXK, and Gary Higgs, N5XED for their help with this.

The hams involved in the set up of the station were: Randy McKinney, N5SVW, Donna McKinney, N5WOE, Keith Pugh, W5IU, Harold Reasoner, K5SXK, Mark Felton, N5UWM, Doug Howard, KG5OA, and Ralph Ward, KB5UAA. Many others assisted during the contact. Included is a block diagram of the setup of the station at the school.

SAREX at Benbrook Elementary was a lot of work with many, many hours and months involved. The project educated the students, school staff and community about Amateur Radio and the space program. It emphasized the importance of education to reach future goals. We think we will see the rewards in the lives of many of the students at the school. Their hugs in the hallway are the real reward!

We wish to thank everyone in the SAREX Working Group and the crew of STS-71 for selecting our school to speak with them. We feel very honored to have been involved with STS-71 and its historic first docking with the Russian Mir space station. None of us will every forget where we were on the 4th of July in 1995.

ADDRESSES AND PHONE NUMBERS

TO RECEIVE SAREX INFORMATION, LESSON PLANS, SCHOOL APPLICATION CONTACT:

The American Radio Relay League
Glenn Swanson, KB1GW, ARRL Educational Activities Department
225 Main Street
Newington, CT 06111
e-mail gswanson@arrl.org
(860) 594-0200   FAX: (860) 594-0259

TO REQUEST EDUCATIONAL MATERIALS AND VIDEOS FROM NASA INCLUDING THE ONES MENTIONED PREVIOUSLY CONTACT:

Either of the NASA addresses below to find out where the nearest NASA Teacher Resource Center is to where you live:

NASA Central Operation of Resources for Educators:
NASA CORE
Lorain County Joint Vocational School
15181 Route 58 South
Oberlin, OH 44074
(216) 774-1051, Ext. 293 or 294

NASA Johnson Space Center
Teacher Resource Room
Mail Code AP-4
Houston, TX 77058
(713) 483-8696

NASA Spacelink: is a computer-based information service that allows individuals to receive news about current NASA programs and activities and space related information. Anyone with a personal computer, a modem, communications software and a long- distance telephone line can gain access to the network. The Spacelink computer access number is (205) 895-0028.

NASA Television: is the Agency's distribution system for live Space Shuttle mission coverage, press briefings and educational programming. It is available without cost to cable operators. Many cable companies throughout the entire country broadcast NASA Select TV. Call your local cable company and ask if they show it. If they don't encourage them to start showing it. It is free of charge to them.

You can also receive NASA Select TV directly from the Spacenet-2 satellite, transponder 5. It is located at 69 degrees west longitude and has horizontal polorization. Its frequency is 3880.0 megahertz with audio at 6.8 megahertz.

BLOCK DIAGRAM OF THE SAREX STATION AT BENBROOK ELEMENTARY APPEARS ON THE NEXT PAGE.

BENBROOK ELEMENTARY SCHOOL SAREX STATION CONFIGURATION

KLM
22C
22 el. Cir. Yagi

AZ/EL ROTOR

J-Pole 2 mtr Ant.

KANSAS CITY TRACKER ROTOR CONTROL CABLE

120 VAC

AZ/EL ROTOR CONTROL UNIT A/R-1

120V AC

ROTOR CABLE

RG-8U

TANDY PC WITH KANSAS CITY TRACKER AZ/EL ROTOR INTERFACE & INSTANT TRACK SOFTWARE

L/R CIR. POL SIGNAL

ANT POLARITY & PREAMP POWER SWITCHES

12V DC

ANT ANTENNA PREAMPLIFIER

R/A-1

A/B SW

AC POWER SOURCE

MAIN LINE

BACK-UP GENERATOR

120 VAC	120 VAC	170 W
12V P/S	2 METER TRANCEIVER	2 METER AMPLIFIER
PS-1	R/T-1	P/A-1
12V DC 90 A		12V DC

RF

42' 1/2 HELIAX

A/B SW A/B SW   RF

42' 9913

120 VAC	120 VAC		170 W
12V P/S	12V P/S	2 METER TRANCEIVER	2 METER AMPLIFIER
PS-2	PS-2	R/T-2	P/A-2
12V DC 30 A	12V DC 20 A	12V DC	12V DC

RF

ROOF TOP

OPERATING POSITION

RCMSAREX B
28 MAY 1995